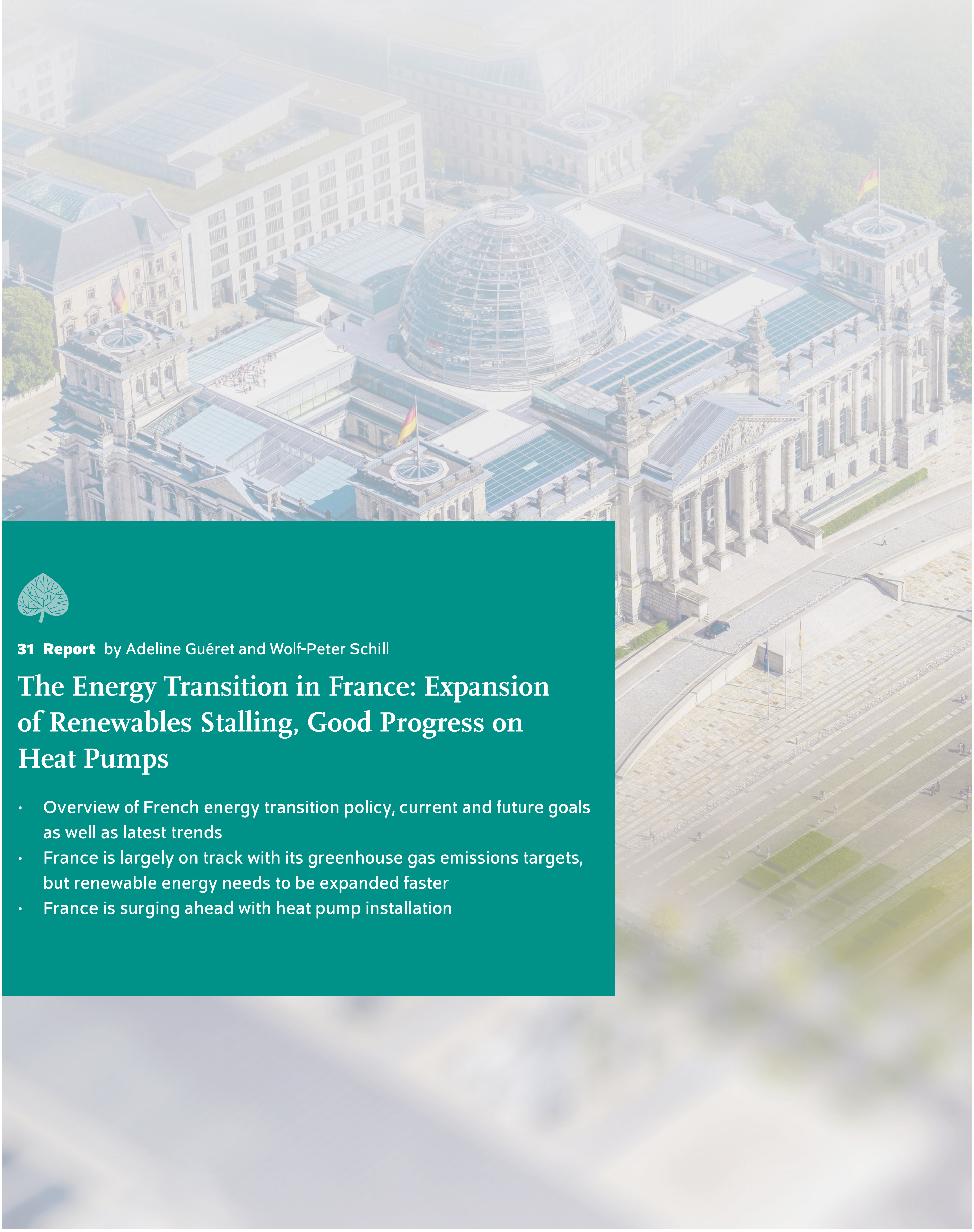
DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

4+5 2024



31 **Report** by Adeline Guéret and Wolf-Peter Schill

The Energy Transition in France: Expansion of Renewables Stalling, Good Progress on Heat Pumps

- Overview of French energy transition policy, current and future goals as well as latest trends
- France is largely on track with its greenhouse gas emissions targets, but renewable energy needs to be expanded faster
- France is surging ahead with heat pump installation

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89 – 0 Fax: – 200
Volume 14 February 6, 2024

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 4+5 2024

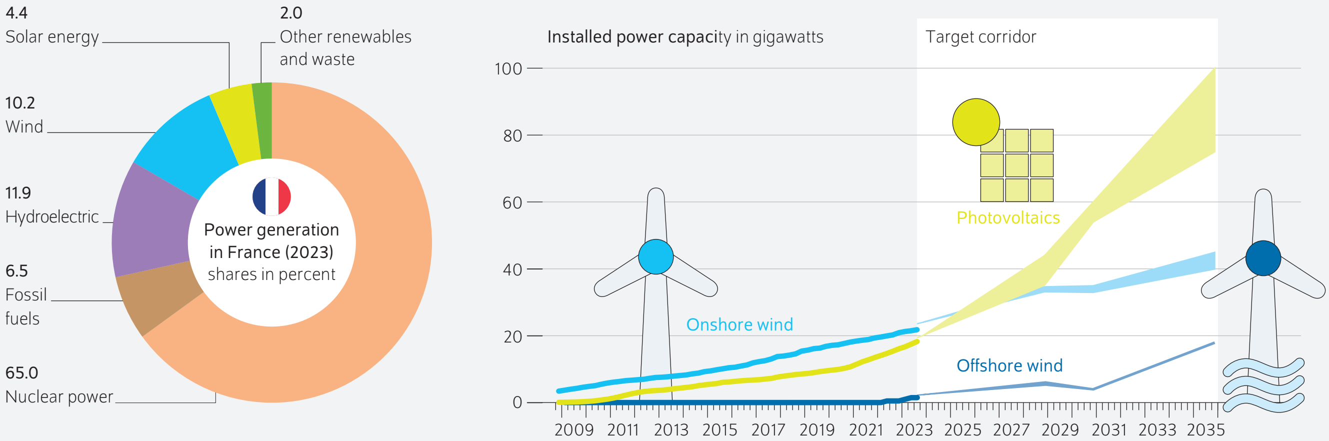
AT A GLANCE

The Energy Transition in France: Expansion of Renewables Stalling, Good Progress on Heat Pumps

By Adeline Guéret and Wolf-Peter Schill

- Overview of French energy transition policy, current and future goals as well as latest trends
- France is largely on track with its greenhouse gas emissions targets, but renewable energy needs to be expanded faster
- France is surging ahead with heat pump installation
- Stark differences between Germany and France on energy transition in the power sector
- Similar challenges for both countries on heating and transport

France relies heavily on nuclear power, needs to expand renewable energy capacities faster to achieve its targets



Source: own diagram based on Réseau de Transport d'Électricité.

FROM THE AUTHORS

"The results of the energy transition in France have been mixed so far. Even though France is relying on nuclear power, both now and in the future, it still needs to expand renewable energy capacities faster in order to achieve its climate goals."

— Adeline Guéret —

MEDIA

Audio Interview with Adeline Guéret (in German)
www.diw.de/mediathek

The Energy Transition in France: Expansion of Renewables Stalling, Good Progress on Heat Pumps

By Adeline Guéret and Wolf-Peter Schill

ABSTRACT

The energy transition is a major challenge for both Germany and France. This Weekly Report provides an overview of the short- and long-term goals as well as current developments and trends in France's energy and climate policy. It reveals that France is largely on track with its greenhouse gases targets and is also making good progress on installing heat pumps. However, its expansion of renewable energy capacities is falling short. Differences in the energy policies of France and Germany are most apparent in the power sector: While France is prioritizing nuclear power, Germany is relying heavily on renewable energy. For France to achieve its climate goals, it will have to expand renewable energy faster. One challenge faced by both countries is their planned electrification of mobility and space heating.

France's energy policy is currently undergoing an update process. A new climate bill for the next five years is to be adopted in the coming months. A strategy paper, relevant for future planning in the energy sector, was published at the end of November 2023 and opened to public consultation (Box). This Weekly Report outlines the energy policy goals and measures of the French government and compares them with progress made so far using selected indicators. It also highlights the individual similarities and differences with the energy transition in Germany.[1]

Mixed results for overarching goals so far

As with Germany, France's energy and climate policy goals are geared to European requirements. Implementation of the European Fit for 55 package[2] is particularly important here. It includes more ambitious targets for reducing greenhouse gas emissions and increasing the share of renewable energy in Europe.[3]

Greenhouse gas emissions targets are currently being mostly met

At the European level, the goal is to make the EU climate neutral by 2050. In addition, according to the latest revised targets, net greenhouse gas emissions[4] must now be reduced to 55 percent of 1990 levels by 2030.[5] In France, the goal of becoming climate neutral by 2050 has been enshrined in

1 On the German energy transition, see Wolf-Peter Schill, Alexander Roth, and Adeline Guéret, "*Ampel-Monitor Energiewende* shows the pace of the energy transition must be accelerated significantly," *DIW Weekly Report*, no. 27 (2022): 371–379 (available online; accessed on January 8, 2024. This applies to all other online sources in this report unless stated otherwise); up-to-date figures and diagrams are available on the *Ampel-Monitor Energiewende* website at any time (in German; available online).

2 European Commission, "Fit for 55: Delivering on the proposals," (2023) (available online).

3 The following charts and further analyses, including those relating to energy efficiency targets and other aspects, such as green hydrogen, are provided in the Open Energy Tracker (available online). Parts of the Open Energy Tracker and this Weekly Report were developed as part of the research projects "Ariadne" 1&2 (03SFKSN0 & 03SFKSN0-2) and "Distribution effects and incentive effects of coordinated climate and social policy" (FIS. 03.00016.21).

4 Including carbon sinks, i.e., after taking land use, land-use change, and forestry into account.

5 European Commission, *Stepping up Europe's 2030 climate ambition* (2020) (available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-4-1

Box

Legislative framework for the energy transition in France

A cornerstone of the legislative framework for the energy transition in France is the act on the energy transition for green growth (*Loi relative à la transition énergétique pour la croissance verte*[1]) from August 17, 2015. This law was passed in the run-up to the UN Climate Change Conference (COP21) that took place in Paris in December 2015. This act made it mandatory among other things, for the French government to develop a national decarbonization strategy (*Stratégie* Nationale *Bas Carbone*,[2] SNBC) for the first time as well as a multi-annual energy program (*Programmation Pluriannuelle* de l'Énergie,[3] PPE). Both programs contain quantitative targets for a series of subsectors. They are intended to help France reduce its greenhouse gas emissions, become more energy efficient, and increase its share of renewable energy.

The decarbonization strategy (SNBC) sets out a long-term goal for greenhouse gas emissions and short-term emissions budgets for three successive five-year periods. These budgets set upper limits for total greenhouse gas emissions that may not be exceeded in the respective period. The strategy must be revised every five years, whereby one part of the upper limit set in the previous strategy must be amended and a new upper limit proposed for the next five-year period. The first SNBC set an emissions limit for the periods from 2015 to 2018,[4] from 2019 to 2023, and from 2024 to 2028. The second SNBC revised the upper limit set for the period from 2019 to 2023 and from 2024 to 2028, and introduced a new upper limit for the period from 2029 to 2033. The third SNBC should currently being drafted by the government.

The multi-annual energy program (PPE) is based on a similar principle. It sets out plans for two five-year periods and is reviewed every five years. It sets targets specifically for the energy sector, with a lower and an upper target value being defined in each case.

Some provisions of the act from 2015 were amended by the Energy and Climate Act[5] of November 8, 2019.[6] Since then, it has represented another cornerstone of France's energy and environmental policy. In particular, it led to the government being mandated to pass a law every five years (*Loi de programmation quinquennale sur l'économie et le climat*), which sets out in detail the targets and priorities of its energy and climate policy for the next five years. The first five-year law should have been adopted by July 1, 2023,[7] but the government did not meet this deadline. The new French energy and climate strategy (SFEC)[8] was published only on November 22, 2023. This strategy contains, among other things, quantitative targets that are likely to be included in the next multi-annual energy program (PPE3). At the end of December, the first draft version of the energy sovereignty act was published, which is intended to serve as the energy block of the previously mentioned first five-year law.[9]

After President Emmanuel Macron was re-elected in May 2022, two different ministries were responsible for energy and environmental issues: The Ministry for the Energy Transition and the Ministry of Ecological Transition and Territorial Cohesion. In addition, a General Secretariat for Ecological Planning was set up, which reports directly to the Prime Minister. After the government reshuffle on January 9, 2024, the Ministry for the Energy Transition was suppressed , and the energy portfolio was transferred to the Ministry of Economy and Finance.

1 *Légifrance, Loi nº 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte*, 2022 (available online).

2 Ministère de la Transition écologique et solidaire, *Stratégie Nationale Bas Carbone* (2020) (available online).

3 Ministère de la Transition écologique et solidaire, *Programmation Pluriannuelle de l'Energie* (2020) (available online).

4 The first SNBC was revised from 2018 to 2019 due to the adoption of the Energy and Climate Act and the new climate neutrality target. As a result, the first budget only covers four years instead of five.

5 Légifrance, *Loi nº 2019-1147 du 8 novembre 2019 relative à l'énergie et au climat* (2019) (available online).

6 The objectives and provisions provided for in the various energy-related laws are summarised in the French Energy Code. If a law amends certain objectives that were provided for in a previous law, the corresponding article of the Energy Code is amended (available online).

7 Légifrance, *Article L100-1 A of the French Energy Code* (2023) (available online)

8 Ministère de la Transition Énergétique, *Stratégie Française pour l'Energie et le Climat* (2023) (available online)

9 Thomas Chemel, "Comment l'avant-projet de loi de souveraineté énergétique détricote les objectifs climatiques," *Contexte*, January 4, 2024 (available online).

energy law code.[6] In comparison, Germany intends to be climate neutral by as early as 2045. The new EU target for 2030 has not yet been implemented in France. For 2030, it still plans to cut gross emissions by 40 percent over 1990 levels. This target also forms the basis of the current emissions budget. For the period 2015 to 2018, the target was 442 million tons of CO_2 equivalent ($MtCO_2$-eq) per year. At an average of 456 million tons of CO_2 equivalent per year, this target was not met during the four years in question (Figure 1).[7]

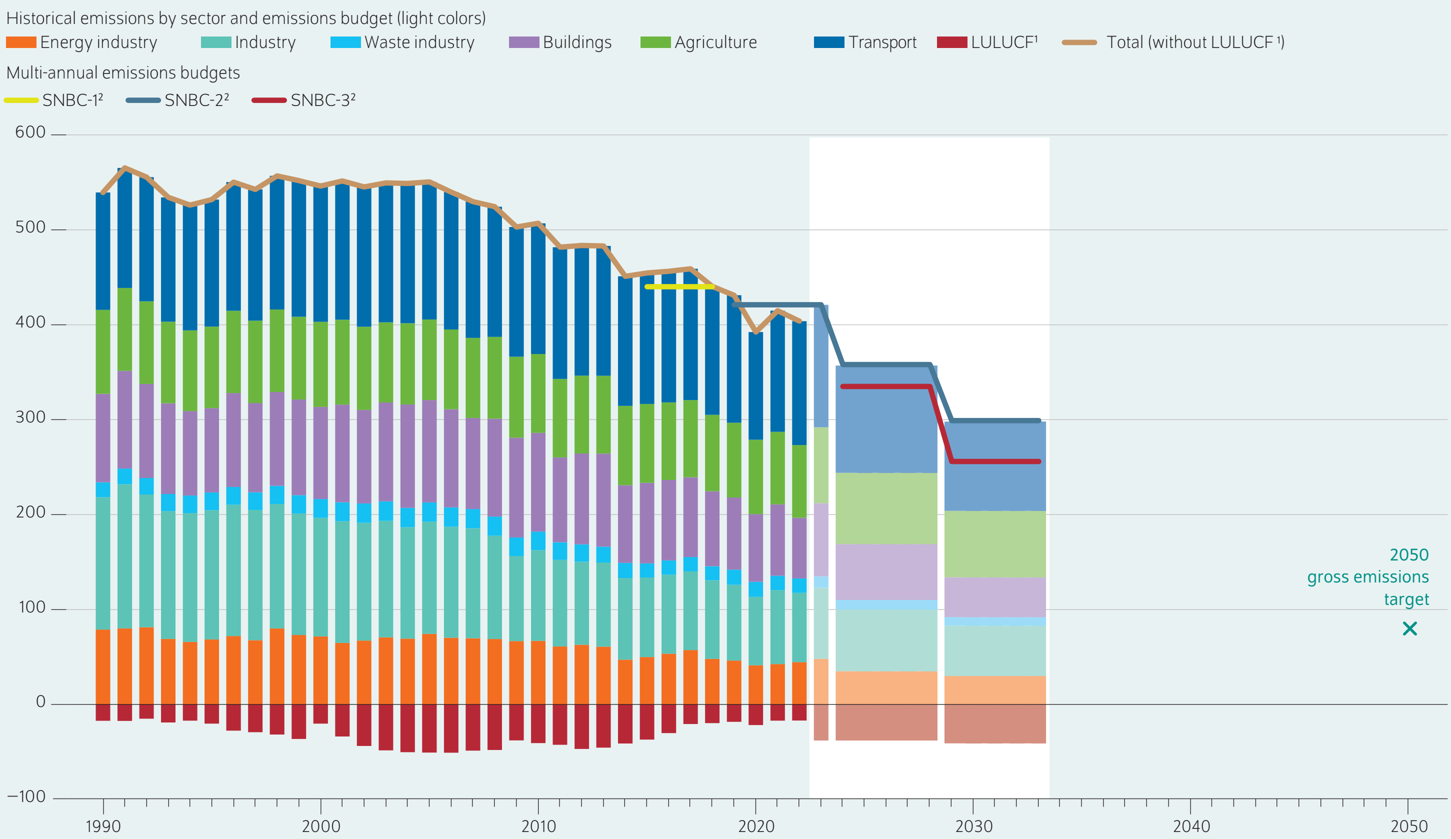
The second emissions budget, which relates to the five-year period from 2019 to 2023, sets an upper limit on gross greenhouse gas emissions of 421 million tons of CO_2 equivalent

6 Légifrance, Article L100-4 of the French Energy Code (2023) (available online).

7 Centre interprofessionnel technique d'études de la pollution atmosphérique (CITEPA), Tableau de bord des engagements climat, (2024) (available online). See also Haut Conseil pour le Climat (HCC), *Rapport annuel* (2023): 65 (available online).

Figure 1

France's greenhouse gas emissions and emissions budgets by sector
In millions of tons of CO_2 equivalent



1 LULUCF: Land use, land-use change, and forestry
2 SNBC: National decarbonization strategy

Source: CITEPA (Secten) (available online), PNEC2023 (available online), Ministère de la Transition Énergétique (available online). Here, the emissions budgets presented in the Integrated National Energy and Climate Plan are considered to be those of the SNBC-3.

France sets its emissions reduction targets in five-year budgets.

per year.[8] This corresponds to around 6.5 tons per person. This is considerably less than in Germany, whose emissions amounted to around nine tons per capita in 2022. Between 2020 and 2022, gross emissions in France remained below the emissions budget. However, these findings should be interpreted with caution since both the COVID-19 pandemic and the energy price crisis occurred in this period, which led to a significant reduction in energy consumption and therefore emissions. Furthermore, net greenhouse gas emissions in 2019 and 2021 were above the indicative yearly limits set. This is due to, among other things, the fact that the reduction in greenhouse gases from forestry was less than planned. Overall, net emissions in France were therefore slightly above the target in the period from 2015 to 2021 (more recent data is not yet available).[9]

The decarbonization strategy (SNBC) also contains an estimate of emissions budgets by sector, which are consistent with the overall five-year budget. However, this breakdown is only indicative. One sector can emit more if this is offset by a greater reduction in emissions in another sector, as long as the overall budget is respected. In contrast, Germany has so far had targets for each sector. However, the current draft amendment to the Climate Protection Act will allow only one overall target to apply in future, similar to France.[10]

With around 129 million tons of CO_2 equivalent per year for the period from 2019 to 2023, the transport sector has the largest emissions budget. It is historically also the sector that has produced the most emissions. It is followed by the budget for agriculture (80 million tons CO_2 equivalent

8 Ministère de la Transition Énergétique, *Ajustement technique des budgets carbone* (2022) (available online).

9 Haut Conseil pour le Climat (HCC), *Rapport annuel* (2023): 65 (available online).

10 German Bundestag, "Homepage on the amendment to the Climate Protection Act," (2023) (in German; available online).

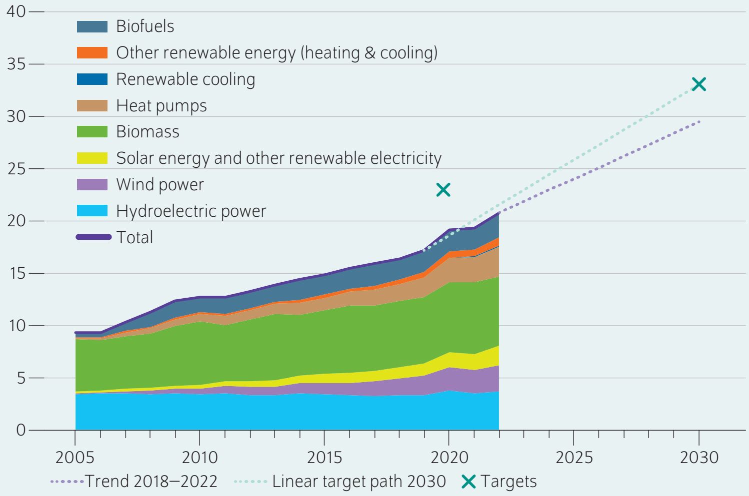
per annum), buildings (77 million tons CO_2 equivalent) and industry (75 million tons CO_2 equivalent). The energy sector is the sector with the second-lowest emissions budget after waste.[11] The buildings and transport sectors will have to reduce their emissions the most: by around 45 and 30 percent respectively when comparing 2019 levels to the 2029–2033 period.

Sectoral emissions and sectoral targets in France differ greatly from those in Germany. In Germany, energy has traditionally accounted for the highest share of total emissions, which is primarily due to the high level of coal-fired power generation. It is followed by industry, as Germany has a particularly large amount of energy-intensive industry, and then by the transport and buildings sectors.

The implementation of new European targets for reducing net greenhouse gas emissions of at least 55 percent by 2030 will lead to a downward correction of France's emissions budgets for the years 2024 to 2028 and for 2029 to 2034. The Integrated National Energy and Climate Plan for France,[12] which was submitted to the European Commission for review in October 2023, sets out an average emissions budget for the period from 2024 to 2028 (2029 to 2034), which is six percent (14 percent) lower than in the current decarbonization strategy.

Figure 2

Share of renewable energy in gross final energy consumption in France
In percent



Source: Ministère de la Transition Écologique et de la Cohésion des Territoires (available online); French Energy Code (available online); authors' calculations.

The share of renewable energy in gross final energy consumption falls short of the targets.

Renewable energy share too low

The European Renewable Energy Directive from 2009 contained binding targets for the share of renewable energy in gross final energy consumption for all Member States for the year 2020. The target for France was 23 percent, while for Germany it was 18 percent. However, France only achieved 19.2 percent and, as a result, was the only country in the EU to miss its target for 2020 (Figure 2).[13]

The most important renewable energy sources in France are renewable solid biomass and residential waste used for heat generation (32 percent of renewable gross final energy consumption in 2022), followed by hydroelectric power (18 percent). Heat pumps, wind power, and biofuels each account for around ten to 14 percent of gross final energy consumption from renewable energy sources.[14] In Germany, biomass for heat generation has a similar share of energy supply from renewable energy sources as it does in France; in contrast, the share of wind and solar energy in Germany is much higher and the share of hydroelectric power is significantly lower.[15]

To implement current EU requirements, the French Energy and Climate Act of 2019 sets a target of at least 33 percent of renewable energy in gross final energy consumption by 2030.[16] In 2022, this share was 20.7 percent;[17] in Germany it was 20.8 percent. After the EU target was increased from 32 to 42.5 or even 45 percent,[18] France is also expected to adjust its targets for 2030 accordingly. However, its recently submitted plan contains no adjustment of its targets so far. Instead, it sets a target for the share of carbon-free energy sources, which include nuclear power as well as renewable energy.[19]

Reducing fossil fuel consumption

In contrast to Germany, France has set explicit targets for reducing the consumption of primary fossil fuels. By 2030, it aims to have reduced its consumption by 40 percent over 2012 levels. This will require a considerable reduction in current consumption trends.[20]

11 Ministère de la Transition Énergétique, *Ajustement technique des budgets carbone* (2022) (available online).

12 European Commission, *France – Draft Updated NECP 2021–2030* (2023) (available online).

13 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Les énergies renouvelables en France en 2022 – Suivi de la directive (UE) 2018/2001 relative à la promotion de l'utilisation des énergies renouvelables," (2023) (available online); and European Commission, "Assessment of the draft updated National Energy and Climate Plan of France," 3 (2023) (available online).

14 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Les énergies renouvelables en France en 2022 – Suivi de la directive (UE) 2018/2001 relative à la promotion de l'utilisation des énergies renouvelables," (2023) (available online).

15 Umweltbundesamt, "Erneuerbare Energien in Zahlen," (2023) (in German; available online).

16 *Légifrance, Article L100-4 of the French Energy Code* (available online).

17 The data for 2022 are preliminary. In 2021, the share was 19.4 percent.

18 EU Directive 2023/2413, October 2023.

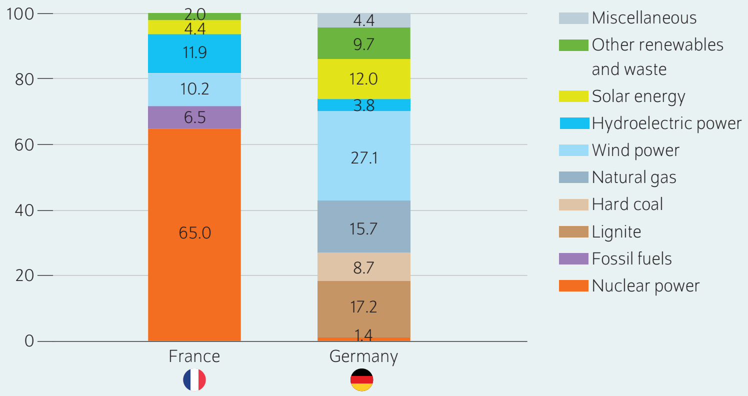
19 Paul Messad, "France sticks to its guns, refuses to table 2030 renewable energy target," *Euractiv*, December 19, 2023 (available online).

20 Open Energy Tracker (available online).

Figure 3

Power generation in France and Germany in 2023

In percent



Note: Natural gas, hard coal, and lignite are fossil fuels; the data for France does not differentiate between them. For Germany, gross electricity generation is shown without pumped storage. The data for both countries are preliminary.

Source: RTE (available online); AGEB (available online).

In France, nuclear power plants generated around two thirds of electricity; in Germany renewable energy generated a good half.

Targets in the power sector

In 2023, nuclear power generated around 65 percent of France's electricity, followed by hydropower with 12 percent (Figure 3). Wind power and solar energy recently grew to ten and four percent of power generation, respectively. The total share of renewable energy in overall power generation was 18 percent. Coal- and gas-fired power plants continued on a downward trend and accounted for just under seven percent of power generation in 2023 (compared to ten percent in 2007).[21] In 2023, only just over one percent of electricity generation in Germany came from nuclear power plants, while over half came from renewable energy sources. Coal- and gas-fired power plants together accounted for just under 42 percent.[22]

Annual power generation in France (527 to 550 terawatt hours (TWh) in the period from 2000 to 2021) is usually well above annual consumption (425 to 499 TWh),[23] which makes it a net exporter of electricity.[24] The only exception was in 2022 when France became a net importer due to a temporary outage of a large portion of its nuclear power plants. Due to its high share of nuclear power, France's carbon intensity of the power mix is relatively small. Generated electricity emitted less than 50 grams of CO_2 per kilowatt hour. In Germany, the figure in 2022 was more than six times higher due to the high level of coal-fired power generation.[25]

In the French electricity sector, the current goal is to achieve a 40-percent share of renewable energy in electricity generation by no later than 2030. This share has risen steadily since 2015, from just under 19 percent in 2015 to 28 percent in 2022.[26] However, the trend for the years from 2020 to 2022 should be interpreted with caution, as 2022 was in many respects an exceptional year for the French electricity system because generation from nuclear and hydroelectric power plants was historically low. In Germany, the targets for renewable energy are significantly higher. The aim is to achieve a share of at least 80 percent of renewable energy in gross electricity consumption by 2030.

Growth in photovoltaics

For the photovoltaics sector, France's multi-annual energy program (PPE) sets a target of 20.1 gigawatts (GW) of installed capacity for 2023 and between 35.1 and 44 GW for 2028. By the end of September 2023, there were 18.3 GW of installed capacity, and no new data has been available since. This means that 1.8 GW would have to have been added between September and December 2023 for this target to have been achieved, which is the equivalent of more than what has been installed in the first three quarters of 2023. It can be assumed that this target will not be achieved. Nevertheless, expansion of the photovoltaics industry since the beginning of 2021 has accelerated significantly and the trend over the past 12 months is significantly above that of the past five years (Figure 4). The first draft of the third multi-annual energy program contains even higher targets of 54 to 60 GW in 2030 and 75 to 100 GW in 2035.

In comparison, Germany has an installed capacity of over 80 GW from photovoltaics. It plans to increase this figure to 215 GW by 2030 and to 309 GW by 2035. Relative to current population, the targets for 2035 in France correspond to around 1.1 to 1.5 kilowatt (kW) per capita. At around 3.7 kW per person, Germany's target for 2035 is around three times higher.

Slow expansion of onshore wind power

For onshore wind power plants, the current plans sets capacity targets of 24.1 GW for 2023 and 33.2 to 34.7 GW by 2028. At the end of September 2023, installed capacity amounted to 21.9 GW and was therefore 2.2 GW below the target that should have been achieved three months later. As a result, the target is likely to be missed. In contrast to photovoltaics, growth in onshore wind energy has not accelerated recently,

21 RTE, "Generation," (2024) (available online). Data for 2023 are preliminary.

22 AGEB, *Bruttostromerzeugung in Deutschland nach Energieträgern* (2023) (in German, available online).

23 RTE, "Consumption," (2024) (available online).

24 RTE, "Markets," (2024) (available online).

25 RTE, "Annual Electricity Review 2022," (2024) (available online); cf. also Umweltbundesamt, *Entwicklung der spezifischen Treibhausgas-Emissionen des deutschen Strommix in den Jahren 1990–2022*, (2023) (in German, available online).

26 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Chiffres des des énergies renouvelables – Edition 2023," (2023) (available online).

as the trend over the past twelve months is roughly the same as the trend over the past five years. It is therefore essential to speed up the pace of expansion to achieve targets for 2028. This applies all the more if the increased targets from 33 to 35 GW of installed capacity by 2030 (and 40 to 45 GW by 2035) set out in the latest French energy and climate strategy (SFEC) are to be achieved.

In comparison, Germany currently has an installed capacity of around 61 GW from onshore wind power. This figure should rise to 115 GW by 2030 and to 157 GW by 2035. The French target for 2035 corresponds to around 0.6 to 0.7 kW per capita; Germany's target is around 1.9 kW per capita.

France's foray into offshore wind power

The expansion of offshore wind power in France began in the second quarter of 2022 with the commissioning of its first offshore wind farm off the coast of Saint-Nazaire with a capacity of 480 MW. Two further farms were connected to the grid by the end of 2023, increasing installed capacity to around 1.5 GW. However, this development will not be sufficient to achieve the target of 2.4 GW of installed capacity set for 2023. Hence, France first needs to make up a shortfall of around one GW; it must then install a further 2.8 GW within five years in order to achieve the lower target of 5.2 GW by 2028. To reach the upper target of 6.2 GW, around three times as much capacity as what has been installed to date would need to be added by the end of 2028. The new target recently proposed for 2030 of four GW is actually slightly below the lower target of the current multi-annual program plan; however, it is aiming to achieve much stronger growth up to 18 GW by 2035.

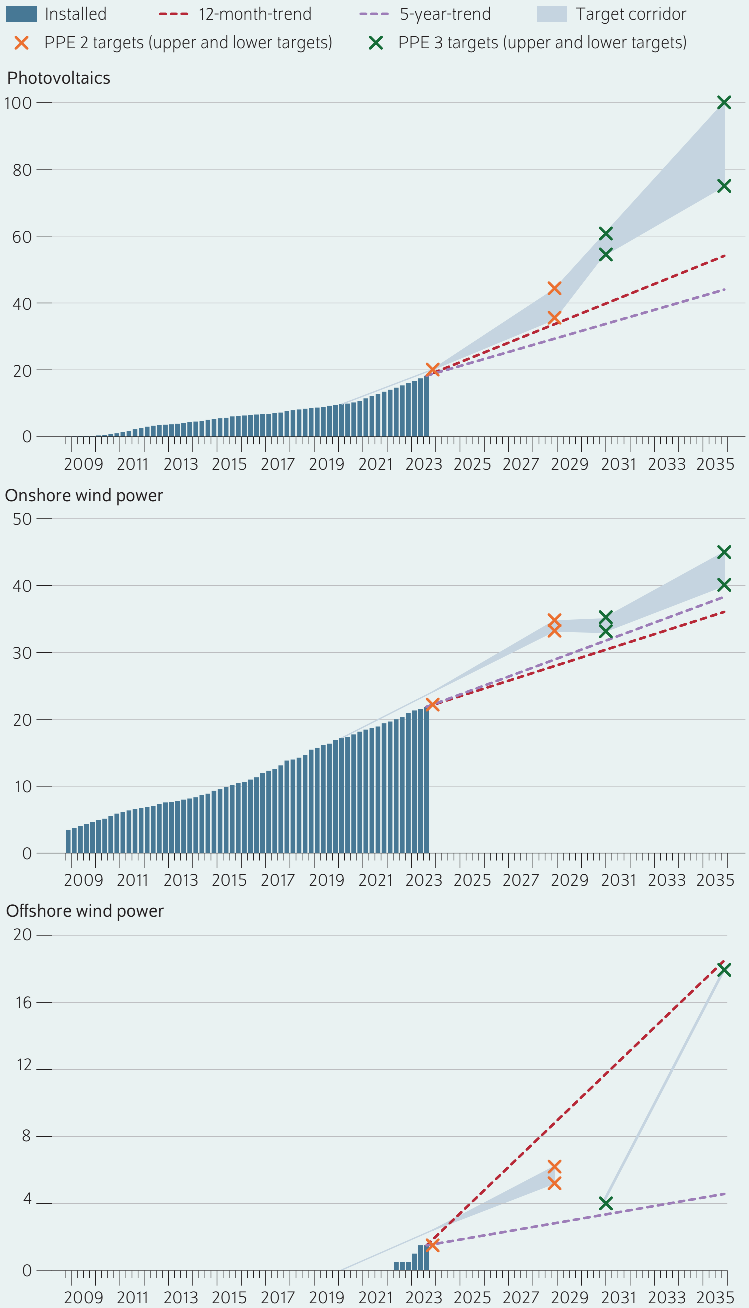
In comparison, Germany currently has an installed capacity of a good eight GW from offshore wind power. The plan is to reach 30 GW by 2030 and 40 GW just five years after that. In terms of targets per capita, France's new goal for 2035 is equivalent to 0.3 kW per capita, while in Germany this figure is nearly 0.5 kW.

Changing course on nuclear power

The 2015 legislation set a target for reducing the nuclear power share in total electricity generation for the first time. It was to be gradually reduced from 76 percent in 2015 to 50 percent by 2025. This target was then amended by the Energy and Climate Act of 2019, which pushed the target year back to 2035. In the end, this target was abandoned completely.[27] The upper limit of 63.2 GW for total nuclear power generation capacity was also abandoned. This legislative amendment reflects the vision of French President Emmanuel Macron and his government of an energy transition[28] in

Figure 4

Installed renewable energy capacity in France
In gigawatts



Note: PPE2: second multi-annual energy program. PPE3: Here, the targets set out in the SFEC of November 2023 are considered to be those of PPE3. Quarterly figures are shown; no data is yet available for the last quarter of 2023.

Source: Ministère de la Transition Écologie et de la Cohésion des Territoires (available online); Ministère de la Transition Écologie et de la Cohésion des Territoires (available online); Ministère de la Transition Énergétique (available online); authors' calculations.

The speed at which renewables are being expanded needs to increase significantly for France to meet its targets.

27 Légifrance, "Loi n°2023-491 du 22 juin 2023 relative à l'accélération des procédures liées à la construction de nouvelles installations nucléaires à proximité de sites nucléaires existants et au fonctionnement des installations existantes," (2023) (available online).

28 Emmanuel Macron outlined this vision, in particular, in his speech in Belfort on February 10, 2022 (available online).

which nuclear power is the cornerstone, which includes both extending the lifetime of existing reactors and constructing new reactors. In contrast, Germany completely phased out nuclear power in April 2023.

Transport sector: different trends in biofuels and electromobility

Due to the transport sector's high share in total GHG emissions, measures in this area are key to France's climate policy. Passenger vehicles, which account for more than half of greenhouse gas emissions in this sector, are particularly important.[29]

In France there are around 39 million passenger vehicles[30] compared to around 49 million in Germany. The per capita figure is almost the same for both countries, with around 590 cars for France and 580 cars for Germany per 1,000 inhabitants.

Stagnation in biofuels

France aims to achieve a 15-percent share of renewable energy in transport fuel consumption by no later than 2030. In 2022, it achieved a share of nearly nine percent.[31] Biodiesel made up around 72 percent of that figure followed by bioethanol with 27 percent.[32] Compared along a linear target path between 2015 and 2030, the share recently achieved was 2.5 percentage points too low.[33] In addition, the trend in recent years has been stagnant or even downward. The use of biofuels has also been stagnating for years in Germany. Instead, both countries intend to rely heavily on electromobility in the future.

Electromobility: modest targets achieved

The multi-annual energy program also includes specific targets for the number of all-electric vehicles and plug-in hybrid passenger cars as well as for the number of publicly accessible charging points between 2023 and 2028. The plan is to have 660,000 all-electric vehicles and 500,000 plug-in hybrid passenger cars by the end of 2030;[34] these numbers are supposed to grow to three million vehicles and 1.8 million passenger vehicles, respectively, by 2028. The total number of all-electric vehicles exceeded one million at the end of 2023, so France has achieved this target by far.[35] With around 575,000 vehicles, the target for plug-in hybrids has also been comfortably achieved.[36]

There are various support measures available to achieve these goals. One of these measures was the "ecological bonus" for purchasing a new or used electric vehicle (up to 7,000 euros) and a "conversion bonus" for purchasing a low emission vehicle if a less environmentally friendly vehicle is taken out of service (up to 6,000 euros).[37] In addition, a tax must be paid when a vehicle is first registered if the vehicle is classified as environmentally harmful (known as the "ecological penalty").[38] The level of the tax depends on how environmentally harmful the purchased vehicle is. Since January 2024, there has also been a social leasing offer for households under a certain income threshold and who have a sufficiently long commute. It allows them to lease an electric vehicle for 100 euros per month.[39]

Germany has a target of 15 million all-electric battery powered passenger vehicles by 2030. Currently, there are only 1.4 million such vehicles on the road in Germany. Using a logistic progression path, indicative intermediary targets for 2023 and 2028 are around 1.8 million and then 10.1 million electric cars, respectively. These targets are significantly higher than those in France, but the actual growth in numbers is currently lagging behind the target path.[40] In terms of current passenger vehicle numbers, the French target for 2028 corresponds to a share of just under eight percent for all-electric vehicles. In Germany, the derived target for 2028 produces a corresponding share of just under 21 percent, and the 15 million electric cars envisaged by 2030 correspond to a share of just under 31 percent.

The target for publicly accessible charging points was set at 100,000 by 2023[41] and 400,000 by 2030 (including 50,000 fast-charging points).[42] This target for 2023 was already achieved in May of 2023. By the end of 2023, there were already 118,000 publicly accessible charging points in France, of which around 20,000 were fast-charging points with an power rating of more than 22 kW.[43]

29 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Chiffres clés des transports – Edition 2023," (2023) (available online).

30 The most recent data are from January 1, 2023 (available online).

31 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques 1, "Chiffres clés des transports – Edition 2023„" (2023) (available online). More recent data are not yet available.

32 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Les énergies renouvelables en France en 2022 – Suivi de la directive (UE) 2018/2001 relative à la promotion de l'utilisation des énergies renouvelables," (2023) (available online).

33 The corresponding visualization can be found on the Open Energy Tracker (available online).

34 Légifrance, "Décret n° 2020-456 du 21 avril 2020 relatif à la programmation pluriannuelle de l'énergie," (2020) (available online).

35 Avère France, "[Baromètre] Décembre 2023: le cap du millionième véhicule électrique est franchi!" (2024) (available online).

36 This figure may also include plug-in hybrids that are not passenger vehicles.

37 Ministère de la Transition Énergétique, "Prime à la conversion des véhicules et Bonus écologique 2023," (2024) (available online).

38 Passenger vehicles with CO_2 emissions of more than 117 grammes per kilometre (available online).

39 Ministère de la Transition Énergétique, "Prime à la conversion des véhicules et Bonus écologique 2023," (2024) (available online)

40 Cf. Wolf-Peter Schill et al., "Mixed Mid-Term Review for German Traffic Light Coalition in the Energy Transition; Significant Effort Needed to Achieve Targets," *DIW focus*, no. 10 (2023) (available online).

41 Légifrance, "Décret no 2020-456 du 21 avril 2020 relatif à la programmation pluriannuelle de l'énergie," (2020) (available online).

42 Gouvernement français, *Dossier de presse (27.10.2023) – Déploiement des bornes de recharge, En route pour 2030! (2023)* (available online).

43 Avère France, "[Baromètre] 118 009 points de recharge ouverts au public fin décembre 2023," (2024) (available online).

Germany plans to have one million publicly accessible charging points by 2030. According to the most recently available data, it has nearly 100,000 charging points.[44] That is fewer than in France, despite it having a larger number of electric cars on the road.

Buildings: high energy consumption, but comparatively low emissions

Buildings in France are responsible for almost half of final energy consumption,[45] almost two thirds of which is from residential buildings. However, the buildings sector only accounted for around 18 percent of greenhouse gas emissions in 2021 due to a high proportion of electric heating.[46] In 2021, more than a third of main residential buildings that year used electricity as their main source of energy for heating (including just under eight percent with heat pumps).[47] In Germany, space heating accounts for a slightly smaller share of final energy consumption than in France, at just under one third.[48] However, in 2022, heat pumps and storage heaters accounted for a significantly lower share of all domestic heating systems in Germany at just under six and two percent respectively.[49]

France's strategy for reducing emissions in the buildings sector is based on further electrifying its heating systems and banning technologies with high emissions. In addition, energy consumption is to be reduced through improved building insulation. Since January 2023, new rental contracts for apartments in existing buildings can only be concluded if they meet a certain energy efficiency level.[50] Furthermore, the installation of heating systems that emit more than 300 grams of CO_2 equivalent per kilowatt hour has been prohibited since July 1, 2022, which means a de facto ban on the installation of new oil-fired boilers.[51] Besides, the installation of natural gas heating systems in new single-family homes has been prohibited since 2022. They will also be banned in new apartment buildings from 2025. France was considering reducing the emissions ceiling from 300 to 150 grams of CO_2 equivalent per kilowatt hour. This would have resulted in a ban on the installation of new gas boilers.[52] However, the idea was abandoned in summer 2023.

Germany's coalition government (SPD/FDP/Greens) had originally set out plans in its coalition agreement that, from 2025, it would only allow new heating systems that are powered by at least 65 percent renewable energy. This start date was to be brought forward by one year, but after lengthy discussions relating to the Buildings Energy Act, it is now being postponed. Gas or oil heating systems may now continue to be installed in existing buildings until a heating plan is available in the respective municipality, which may take until June 2028 depending on the municipality.[53]

Strong growth of renewable energy in the heating sector

By 2030, France aims to achieve a 38 percent share of renewable energy in gross final energy consumption for heating and cooling. In 2022, that share was 27.2 percent. The largest contribution was made by heating with wood in households (40 percent of energy consumption for heating and cooling from renewable energy sources), followed by heat pumps (27 percent), and biomass excluding wood (23 percent).[54] The share achieved was therefore slightly below the figure expected from a linear target path between 2015 and 2030.[55] However, the recent trend has been dynamic with the share of renewable energy rising from 21.4 percent in 2018 to 27.2 percent in 2022. If France can keep this pace up until 2030, it will achieve its target of 38 percent for that year. The increase was largely due to the expansion of heat pump installation, which progressed much faster in France than in Germany. One reason for the lower uptake of heat pumps in Germany is likely its higher household electricity prices. Furthermore, natural gas was long regarded as a "bridge fuel" in Germany, and the installation of new natural gas heating systems was even subsidized there until recently. In France, heat pumps have been subsidized for some time now.

The multi-annual energy program sets out specific goals for annual heat generation from heat pumps. The target for 2023 is just under 40 TWh per year, of which 35 TWh is to be provided by air-source heat pumps and just under five TWh by geothermal heat pumps.[56] In 2022, total heat generation from heat pumps amounted to 42.7 TWh (weather-adjusted to 47.6 TWh), which is well above the target. The main reason for this development was the recent significant increase

44 Bundesnetzagentur, "Elektromobilität: Öffentliche Ladeinfrastruktur," (2023) (in German, available online).

45 Ministère de la Transition EÉologique et de la Cohésion des Territoires, Service des données et études statistiques, "Chiffres clés de l'énergie – Edition 2023," (2023) (available online).

46 Centre interprofessionnel technique d'études de la pollution atmosphérique (CITEPA), *Rapport Secten* (2023) (available online). Data for 2022 are preliminary and amount to 16 percent.

47 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Tableau de suivi de la rénovation énergétique dans le secteur résidentiel," (2023) (available online).

48 Umweltbundesamt, "Indikator: Energieverbrauch für Gebäude," (2023) (in German; available online).

49 BDEW, "Wie heizt Deutschland 2023?" (2023) (available online).

50 This refers to residential buildings with a final energy consumption for heating purposes of less than 450 kWh/m². Cf. Légifrance, "Décret n°2021–19 du 11 janvier 2021 relatif au critère de performance énergétique dans la définition du logement décent en France métropolitaine," (2021) (available online).

51 Légifrance, "Décret n°2022-8 du 5 janvier 2022 relatif au résultat minimal de performance environnementale concernant l'installation d'un équipement de chauffage ou de production d'eau chaude sanitaire dans un bâtiment," (2022) (available online).

52 Gouvernement français, *Dossier de concertation – Accélérer la décarbonation du secteur du bâtiment* (2023): 29 (available online).

53 For a more in-depth discussion on heat pumps and the Buildings Energy Act, cf. episodes 7 to 9 of the *fossilfrei* podcast (in German; available online).

54 Ministère de la Transition Écologique et de la Cohésion des Territoires, Service des données et études statistiques, "Les énergies renouvelables en France en 2022 – Suivi de la directive (UE) 2018/2001 relative à la promotion de l'utilisation des énergies renouvelables," (2023) (available online).

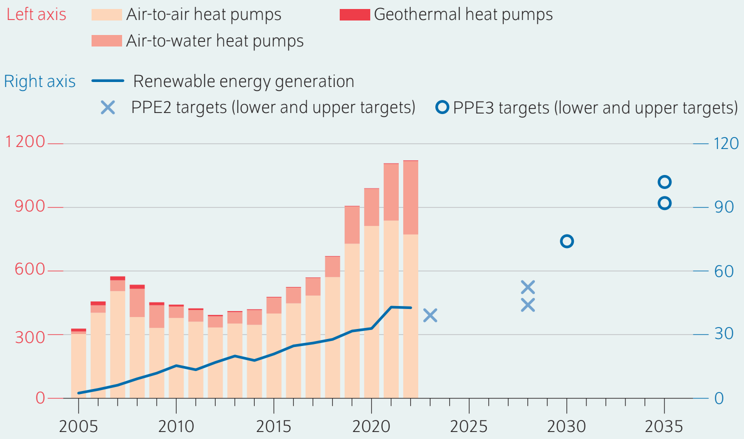
55 The corresponding visualization can be found on the Open Energy Tracker (available online).

56 Article 4 of Decree No. 2020-456 dated April 21, 2020, on multi-annual energy planning (available online).

Figure 5

Annual sales of heat pumps and renewable heat generation in France

In thousands of units (left axis) and terawatt hours (right axis)



Note: PPE2: second multi-annual energy program. PPE3: Here, the targets set out in the SFEC of November 2023 are considered to be those of PPE3.

Source: Ministère de la Transition Écologique et de la Cohésion des Territoires (available online); PPE2 (available online); Stratégie Française pour l'Energie et le Climat (available online).

France is surging ahead with heat pump installation.

in sales of heat pumps in France, which saw over 1.1 million units sold in 2022, 770,000 of which were air-to-air heat pumps. If the trend from the past five years continues, the 2028 target (between 44 and 52 TWh) will be achieved early (Figure 5). In Germany, the annual increase in heat pumps is considerably lower. In 2022, only 236,000 heat pumps were installed;[57] half a million new heat pumps are expected to be installed each year from 2024.

Conclusion: Positive and negative developments in the French energy transition

France's energy and climate policy comprises a large number of short-, medium-, and long-term targets that are revised in five-year, structured planning processes. However, the French government is now behind schedule: France's new five-year law on energy and climate strategy should have been adopted at latest on July 1, 2023. An initial draft bill was submitted at the end of 2023 but was immediately criticized for its lack of specific targets for renewable energy.[58]

France currently appears to be largely on track to reduce its gross greenhouse gas emissions, although this is certainly also due to the unique effects of the COVID-19 pandemic and the energy price crisis. In the buildings sector, France appears to be meeting its targets, mainly due to the strong expansion of heat pumps.

It has not, however, met its renewable energy targets and progress over the last five years, particularly in the transport sector, is not very encouraging. In general, France is behind on all its targets to expand photovoltaics and onshore and offshore wind power. It is instead relying on nuclear power. This is a political decision, which clearly underlines the "écologie à la française" under Macron's presidency.[59,60] However, if its targets for renewable energy are to be achieved, it will need to expand its wind and solar power plants significantly.

Although there are differences in the energy policy goals of France and Germany, there are also similarities. Greenhouse gas emissions are already significantly lower in France, but Germany is aiming to go climate neutral five years before France. In terms of mobility and space heating, both countries are focusing on electrification. While Germany's targets for electromobility are more ambitious, the number of electric cars and charging infrastructure clearly needs to grow faster in both countries. France is currently making faster progress than Germany on expanding heat pumps.

The differences are greatest in the electricity sector: While France is prioritizing nuclear power,[61] Germany is relying heavily on renewable energy. France is also aiming to use more wind power and solar energy over the long term, but at a considerably lower level.

It would make sense for France to expand renewable energy faster. This would not only allow it to achieve its targets for renewable energy, which it has not met, but it would also help the country meet its climate goals and safeguard against the risks of using nuclear power. If there are further problems with existing power plants in the future or delays in constructing new reactors, an additional, increased expansion of renewable energy would be helpful. The risk that France would generate "too much" emission-free power as a result, appears to be low considering the strong growth in demand for renewable electricity expected in Europe.

57 Cf. Bundesverband Wärmepumpe e.V., "Wärmepumpenabsatz 2022: Wachstum von 53 Prozent gegenüber dem Vorjahr," press release from January 17, 2023 (in German; available online).

58 Perrine Mauterde, "Le projet de loi sur la souveraineté énergétique critiqué pour l'absence d'objectif chiffré sur les renouvelables," *Le Monde*, January 8, 2024 (available online).

59 Which can be translated in English as a kind of "made in France ecology."

60 Cf. Adeline Guéret, "Ecologie à la Macron": Handeln darf nicht nur ein Wort sein: Kommentar," *DIW Wochenbericht*, no. 40 (2023): 558 (in German, available online).

61 On the role of nuclear power in international energy scenarios, cf. Christian von Hirschhausen et al., "Energy and Climate Scenarios Paradoxically Assume Considerable Nuclear Energy Growth," *DIW Weekly Report*, no. 45 (2023): 294-301 (available online).

Adeline Guéret is a Research Associate in the Energy, Transportation, Environment Department at DIW Berlin | agueret@diw.de

Wolf-Peter Schill is Head of the Transformation of the Energy Economy Research Area in the Energy, Transportation, Environment Department at DIW Berlin | wschill@diw.de

JEL: Q40, Q42, Q48

Keywords: France; energy policy; energy transition

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

13+14 2024

109 Report by Isabell Braunger, Philipp Herpich, Franziska Holz, Julia Rechlitz, and Claudia Kemfert

Heat transition: Municipalities need federal support in decommissioning natural gas networks

- Decline in natural gas demand will successively lead to decommissioning of the natural gas network
- Study investigates if re-municipalization and heat planning can accelerate the German heat transition
- Municipalities require assistance in organizing the decommissioning of gas networks

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89 – 0 Fax: – 200
Volume 14 April 2, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Sophie Behr

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Ulrike Fokken; Petra Jasper; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 13+14 2024

AT A GLANCE

Heat transition: Municipalities need federal support in decommissioning natural gas networks

By Isabell Braunger, Philipp Herpich, Franziska Holz, Julia Rechlitz, and Claudia Kemfert

- Decline for natural gas demand will successively lead to the large-scale decommissioning of the natural gas distribution network
- Study investigates if re-municipalization of the natural gas distribution networks can speed up the natural gas phase-out
- Case study of Baden-Württemberg shows that there is uncertainty in municipalities; their heat plans do not address the decommissioning of natural gas networks
- Regulatory framework and the municipalities' financial dependency on the natural gas sector prevent decommissioning of natural gas infrastructure
- Municipalities and public utilities need support in organizing the decommissioning of the natural gas networks and to ensure public services can be financed

Natural gas demand will decline over the course of the heat transition, but municipalities must still ensure the heat supply

Source: Authors' depiction.

FROM THE AUTHORS

*"The transition to a climate-friendly heat supply is a challenge for the municipalities. With low natural gas demand, the gas distribution networks will become superfluous in some cases. Even if municipalities buy these networks back, cost efficiency takes precedence over climate action. At the same time, network operators also have the obligation to connect." — **Franziska Holz** —*

MEDIA

Audio Interview with Franziska Holz (in German)
www.diw.de/mediathek

Heat transition: Municipalities need federal support in decommissioning natural gas networks

By Isabell Braunger, Philipp Herpich, Franziska Holz, Julia Rechlitz, and Claudia Kemfert

ABSTRACT

Large parts of the existing natural gas distribution networks must be decommissioned due to the decarbonization of the heat supply. However, there are neither regulatory nor economic incentives for the gas network operators to do so and delaying the decommissioning could be expensive for the remaining customers. This Weekly Report analyzes to what extent municipalities can partially decommission the natural gas infrastructure with the help of municipal heat planning and by re-municipalizing the gas industry. This study also outlines the challenges associated with these instruments. Accordingly, re-municipalization does not necessarily result in the gas networks being decommissioned faster, a fact that remains unconsidered in the existing heat plans. Furthermore, the current regulatory framework, which is based on cost efficiency and the obligation to connect, makes decommissioning more difficult. In addition, the municipalities have a financial incentive to continue generating revenue from gas, partially because alternative income sources for funding public services are unavailable. Thus, the regulation must be adjusted and the federal and state governments must provide more support for the municipalities in organizing the partial decommissioning of the natural gas infrastructure.

Germany has long relied on natural gas for residential heating. In 2020, the share of natural gas heating was 45 percent, with around 522,000 kilometers of natural gas distribution networks in operation.[1] Large amounts are invested into network expansion and maintenance every year: In 2019, the around 700 gas distribution network operators in Germany[2] invested 1.5 billion euros in the networks.[3]

The Act on Heat Planning and the Decarbonization of the Heat Networks (*Gesetz für die Wärmeplanung und die Dekarbonisierung der Wärmenetze*), which came into force on January 1, 2024, is meant to accelerate the heat transition. Its aim is a gradual decline in the use of natural gas through renovations, increasing electrification, and the expansion of district heating. Even in scenarios with a high share of synthetic gases such as hydrogen, long-term scenarios for the energy transition in Germany predict a decline in use of the gas distribution networks (Figure 1).[4] Thus, parts of the networks will no longer be able to be operated economically.[5] Organizing the decommissioning[6] of the natural gas networks and coordinating it with the development of other energy networks, such as electricity and district heating, will be central to the municipal heat transition.

In this Weekly Report, different possibilities for dealing with the challenges of the heat transition are considered, such as the buy-back of natural gas networks or the municipal heat plans that are now required; to do so, we analyze the heat plans already in place in some municipalities in Baden-Württemberg. This analysis also includes interviews with

1 Bundesnetzagentur and Bundeskartellamt, *Monitoringbericht 2020. Report* (2021) (in German; available online. Accessed on March 5, 2024. This applies to all other online sources in this report).

2 Bundesnetzagentur, *Eckpunktepapier Netze. Effizient. Sicher. Transformiert.* (2024) (in German; available online).

3 Bundesnetzagentur and Bundeskartellamt, *Monitoringbericht 2020*.

4 Bundesministerium für Wirtschaft und Energie, *Langfristszenarien für die Transformation des Energiesystems in Deutschland 3* (2021) (in German; available online).

5 Daniel Then et al., "Impact of Natural Gas Distribution Network Structure and Operator Strategies on Grid Economy in Face of Decreasing Demand," *Energies* 13, no. 3 (2020): 664 (available online); Conor Hickey et al., "Is There a Future for the Gas Network in a Low Carbon Energy System?" *Energy Policy* 126 (2019): 480-493 (available online).

6 Decommissioning refers to shutting down parts of or the entire network. This is considered separately from a possible dismantling, in which the pipes are removed from the ground.

DOI: https://doi.org/10.18723/diw_dwr:2024-13-1

actors in the heat transition and considers the economic and regulatory barriers to the heat transition.

Municipalities want to influence natural gas distribution networks via re-municipalization

One way for local authorities to handle the heat transition is to buy back the natural gas networks. However, this is not an uncontroversial undertaking. Recently, Hamburg bought back the energy networks and Berlin is also considering purchasing its local gas utility.[7]

Municipalities have various expectations related to re-municipalization that may not materialize in practice. On the one hand, they want to accelerate the energy transition and influence the gas utilities accordingly. However, this objective conflicts with the regulatory framework, which stipulates an obligation to connect households and, thus, restricts any network downsizing (Box 1). In addition, the municipalities will have to amortize their investments and municipal companies will operate under a profit-oriented approach. The more and the longer they sell natural gas, the higher the profits. Thus, the financial prospects often get in the way of taking climate action.

Two paths to re-municipalization

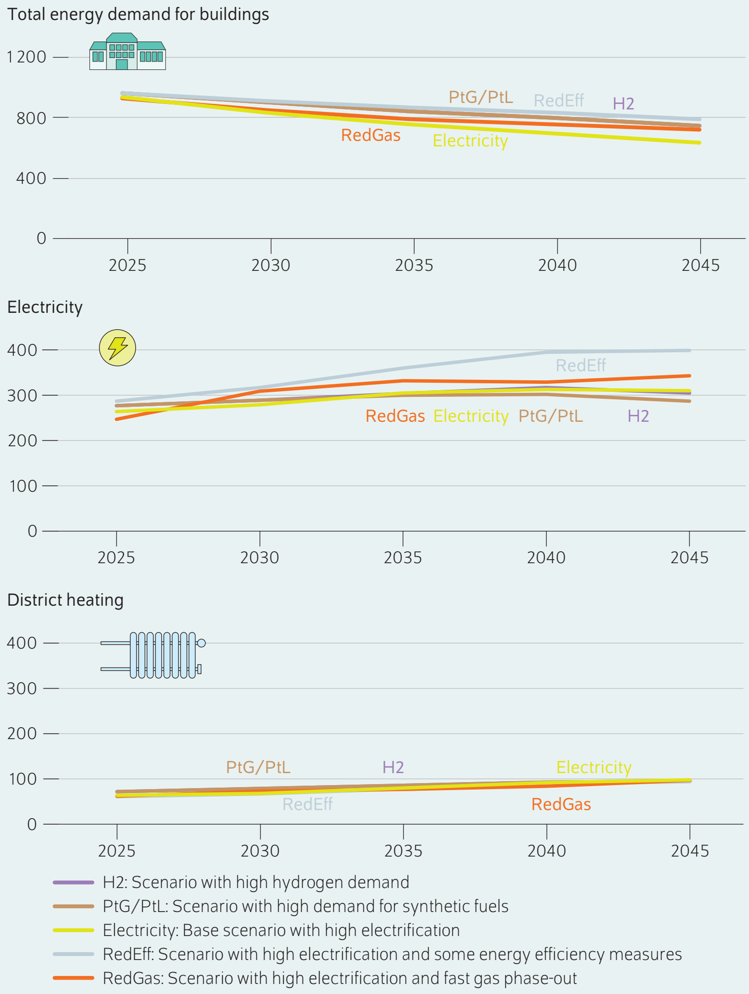
Municipalities have two options for re-municipalizing the energy networks. First, a municipality can apply with a municipal company when a new concession is awarded. The Energy Industry Act (*Energiewirtschaftsgesetz*, EnWG) applies to the selection of the future concession holder when awarding a new concession (Box 1). The tendering procedure must be non-discriminatory. The municipal company is not guaranteed to be awarded the concession rights in the tender procedure. If the concession rights are transferred to another company, the former concession holder is entitled to appropriate remuneration for the network, which can be based on future revenue.

Alternatively, municipalities can purchase the gas network operator that holds the concession rights. The State of Berlin, for example, is considering purchasing shares of the gas utility Gasag.[8] The advantage of this is the continuity of operations, as the gas utility would remain intact and the knowledge required to operate the network would be retained. However, such a purchase involves risks, as the municipality would take on the company's obligations while future profits are difficult to predict in the transition phase of the heating and energy markets. To determine the purchase price, municipalities must evaluate the energy sector conditions, such as future gas demand, the amount of hydrogen available regionally, and the expected fuel and carbon prices.

Figure 1

Long-term forecast of the energy demand for buildings, including electricity and district heating demand in the building sector in Germany

In terawatt hours



Sources: Federal Ministry for Economic Affairs and Energy (2021); authors' depiction.

Residential heat demand will decline as a result of renovations and other energy efficiency measures. In contrast, the demand for electricity and district heating will increase.

The key assumptions on which a purchase is based should be published because such a purchase involves public funds that will then be unavailable for the energy transition. It must be taken into account that in the future, hydrogen will only replace a fraction of the amount of natural gas that is currently being consumed (Figure 2). There is a broad scientific consensus that hydrogen is not suitable for use in residential heating because it will be scarce, expensive, and inefficient.[9] The political recognition of these problems is reflected in the National Hydrogen Strategy, which does not

7 Philipp Herpich, Franziska Holz, and Konstantin Löffler, "Wärmewende in Berlin: Versorgungssicherheit nach dem Erdgas mit erneuerbaren Energien gewährleisten," *DIW Wochenbericht* no. 49 (2023) (in German; available online).

8 CDU and SPD, *Koalitionsvertrag 2023-2026* (2023). *Das Beste für Berlin* (in German; available online).

9 Jan Rosenow, "Is heating homes with hydrogen all but a pipe dream? An evidence review," *Joule* 10, no. 6 (2022): 2225-2228 (available online).

Box 1

Regulatory framework for natural gas distribution networks

From an economic viewpoint, natural gas networks, like all pipeline-based infrastructure, are natural monopolies. This means that the construction and operation of one network is more efficient than the construction of multiple networks due to the high fixed costs and relatively low operating costs. Natural gas networks in the European Union are subject to regulation to ensure that natural monopolies do not exploit their advantage at the expense of consumers with high prices and low investments.[1]

The regulation of the natural gas networks adheres to three basic principles: non-discriminatory access for natural gas sellers to the pipeline network, the unbundling of the network companies from the natural gas sellers, and the regulation of network charges and profits. A regulatory authority monitors the compliance with these principles; for the distribution network operators, this body is either the Federal Network Agency or the state regulatory authority. Network fee regulation is mandated in Germany as an incentive regulation, meaning it aims to provide an incentive for network operators to operate efficiently.[2] To this end, efficiency comparisons are performed between similar companies.[3] The similarity is determined using structural parameters such as the number of connections.

The concession contracts for gas distribution networks are awarded as an easement contract for an entire municipal area for up to 20 years.[4] Concession holders must ensure that gas networks are safely operated and expanded, provided this can be done economically. In particular, there is an obligation to fulfill all connection requests within the municipality, i.e., to build new pipelines and connections if necessary (general obligation to connect).[5] The municipalities can also take additional local community matters into account in the tenders for the concession contracts. However, the federal objectives of the obligation to connect and cost efficiency take priority over municipal-specific targets such as climate action.

1 Implementation in Germany is regulated in the EnWG.

2 Cf. Regulation on the incentive regulation of the energy supply networks (ARegV) (in German; available online); Astrid Cullmann et al., "No Barriers to Investment in Electricity and Gas Distribution Grids through Incentive Regulation," *DIW Weekly Report* no. 6 (2015) (available online).

3 In contrast to incentive regulation, pure cost-based regulation (cost-plus regulation) would stipulate for all costs to be offset and thus provide an incentive for unnecessary investments.

4 Section 46 of the EnWG.

5 Section 18 of the EnWG.

clearly repudiate the use of hydrogen in residential heating but recognizes that the use of hydrogen in buildings has largely been rejected and will only be considered in a few individual cases.[10]

Re-municipalization: Conflict of interest between climate action and profit generation

The mere political will for re-municipalization is insufficient. If municipalities are considering re-municipalization, the sum they must pay to the former concession holder significantly influences the purchase decision. The purchase price determines how much natural gas must be sold in the future in order to amortize the investments. In Hamburg, it took ten years following the purchase to recover one third of the costs.[11]

In the future, however, there will be no time for municipalities to amortize the investments. According to climate targets, carbon emissions must decrease. Thus, natural gas can only be delivered until 2045 at the latest and consumption will decline well before then. This fact must be reflected in the purchase decision and price; otherwise, municipalities will be paying high sums for fossil infrastructure and will lack funds in other areas for the energy transition.

In any case, the decision to re-municipalize should be included in a municipal heat plan that clearly sets out the remaining gas volumes and provides a framework for the operation of the remaining network. The heat plan should also consider the foreseeable lack of hydrogen and the decline in heat demand overall (Figure 3).

The municipalities are experiencing a conflict of interest, as they must choose between climate action and natural gas profits following re-municipalization. In addition, the regulatory framework prescribing a general obligation to connect ensures that decommissioning of parts of the gas network is hardly possible. This prevents more climate action even if a municipal company is operating the gas network. These requirements are laid out in the EnWG (Box 1) and thus cannot be influenced by the municipalities.

Municipal heat planning should be used to plan the decommissioning of natural gas distribution networks

The Act on Heat Planning and the Decarbonization of the Heat Networks came into effect on January 1, 2024.[12] Its

10 Bundesregierung, *Fortschreibung der Nationalen Wasserstoffstrategie* (2023) (in German; available online).

11 Andreas Dassel, *Zehn Jahre Rückkauf der Energienetze. Ein Gewinn für Hamburg und das Klima* (2023) (in German; available online).

12 Heat Planning Act (*Wärmeplanungsgesetz*), (in German; available online).

aim is to make the heat supply greenhouse gas neutral and to provide support in achieving climate targets by 2045. It requires all municipalities in Germany with more than 100,000 inhabitants to develop a heat plan by mid-2026. All municipalities with fewer than 100,000 inhabitants have until mid-2028 to carry out their heat planning and municipalities with fewer than 10,000 inhabitants are subject to simplified planning requirements. The planning process contains seven steps, and the plan must be reviewed or continued every five years (Figure 4). Various stakeholders, such as natural gas or heat network operators and representatives of public interests, are to be involved in the process.

The Heat Planning Act provides access to previously unavailable data, for example data from energy companies and the associations of the craftsman and chimney sweeps, about connections to the natural gas network, heating systems, or consumption. This new data makes it possible for municipalities to take a leading role in heat planning and its coordination.

Heat planning can contribute to overcoming the insufficient planning for the heat transition, to creating investment security for renewable energy infrastructure and to adjusting consumers' expectations. Ideally, heat plans would contain clear statements on the medium and long-term natural gas coverage of a neighborhood. Natural gas customers would then know by when they would have to replace their gas heating and natural gas network operators would be able to make their investments with foresight and make targeted investments in maintenance where the networks are in operation for longer.[13] Such a planned approach to the decommissioning of the gas distribution networks is recommended but not required in the Heat Planning Act. The following analysis of municipal heat planning in some municipalities in Baden-Württemberg shows that the municipalities cannot be expected to directly address natural gas grids and their decommissioning in their heat planning.

Baden-Württemberg has already implemented municipal heat planning

The first state in Germany to implement heat planning was Baden-Württemberg, where it has been mandatory for large municipalities since December 2020. Its municipalities must present their heat plans by the end of 2023. An evaluation of these initial experiences in Baden-Württemberg provides insights into implementation that is relevant for the rest of Germany. The data for this analysis are from interviews with 20 representatives of the most important interest groups of the heat transition in Baden-Württemberg as well as five scientific experts.[14] Representatives of public utilities, network

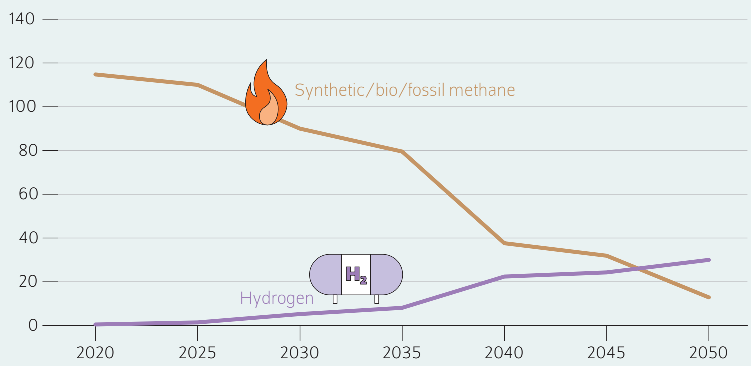
13 When planning the gradual decommissioning, risk-determining factors should be taken into account, such as the age of the network, high upcoming maintenance investments, the expected decline in gas consumption due to district modernization, the advanced age of the gas boilers, anchor customers for district heating, and upcoming civil engineering measures that could favor the relocation of heating networks.

14 The detailed evaluation of the interviews is available in Isabell Branger, "Communal heat planning: Overcoming the path-dependency of natural gas in residential heating?" *Environmental Innovation and Societal Transitions,* Vol. 48 (2023): 100768 (available online).

Figure 2

Long-term forecast of natural gas and hydrogen demand in Berlin's climate neutrality strategy

In petajoules



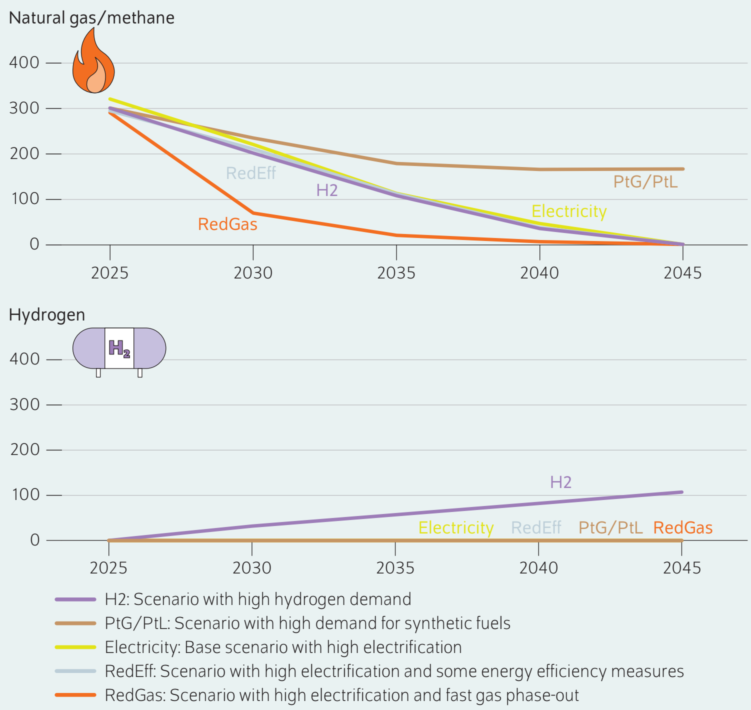
Sources: The Institute for Ecological Economy Research (IÖW) on behalf of the Berlin Senate Department for Urban Mobility, Transport, Climate Action and the Environment; authors' depiction.

Renewable hydrogen will only be available in limited amounts in the future and will barely replace natural gas in the pipelines.

Figure 3

Long-term forecast of demand for natural gas and hydrogen in the building sector in Germany

In terawatt hours



Sources: Federal Ministry for Economic Affairs and Energy (2021); authors' depiction.

Except in an extreme scenario, gas demand will decline considerably by 2045. Hydrogen will not play a role in the building sector.

Box 2

Analysis of actors in Baden-Württemberg

The data for this analysis come from interviews with 20 representatives of the most important interest groups of the heat transition in Baden-Württemberg as well as five scientific experts. Among those interviewed were representatives of public utilities, network operators, energy agencies, municipal actors, and the State Ministry of Food, Rural Affairs and Consumer Protection. The semi-structured interviews were conducted between October and December 2021 and evaluated using a qualitative content analysis.[1]

In addition, six heat plans from Baden-Württemberg were analyzed from the municipalities of Lörrach, Freiburg, Giengen, Baden-Baden, Obersontheim, and Kirchheim-Unterteck. The municipal heat plans for these municipalities were completed and available online by the end of 2023. The analysis is based on a matrix that focuses on the future development of the gas network in the heat plan and investigates different qualitative dimensions. These dimensions include defining areas with declining gas demand, identifying and explaining the risk factors involved in decommissioning the gas network, and developing concrete measures for decommissioning. In addition, where available, the more general discussion of the issue was evaluated.

1 Jochen Gläser and Grit Laudel, *Experteninterviews und qualitative Inhaltsanalyse: als Instrumente rekonstruierender Untersuchungen*, 4th ed. (2010: VS Verlag für Sozialwissenschaften) (in German; available online).

operators, energy agencies, and the State Ministry of Food, Rural Affairs and Consumer Protection were interviewed (Box 2). In addition, six published heat plans from municipalities in Baden-Württemberg were analyzed.

Heat plans do not sufficiently consider the decline of natural gas consumption

The evaluation of heat plans from Baden-Württemberg shows that they have not sufficiently taken into account the need to decommission natural gas distribution networks. Concrete decommissioning plans, for example by classifying priority areas, are not included in the heat plans. The plans do not explicitly state when the natural gas distribution networks are likely to be decommissioned, even for areas designated as priority areas for district heating supply. The actors ascribe this to a high level of uncertainty regarding the future availability of renewable gases such as hydrogen.[15] As a result, natural gas customers remain unsure as to how long they will be able to continue to operate their gas heating despite the existing heat plans.

Uncertainty is only one reason why municipalities in Baden-Württemberg are not sufficiently taking into account the decommissioning of the natural gas distribution networks. Municipalities also face economic and regulatory barriers during planning and implementation. While the results are from interviews conducted in Baden-Württemberg, they provide insights into the framework conditions that apply nationwide and are thus formulated generally and relevant for municipalities in other German states.

Decommissioning natural gas networks reduces municipal revenues

So far, the business models of municipal energy and heat utilities have been significantly based on the sales of natural gas.[16] In 2017, public utilities employed three times more employees in natural gas operations than in district heating operations;[17] it can be assumed that this ratio has not changed much over the past years. Utilities must develop new competencies, strategies, and business models for the heat transition. The interviews show that adjusting business models can lead to conflicting objectives, especially when it comes to expanding district heating in areas with an existing natural gas network.

Indeed, in many municipalities, the profits of the public gas utilities have been used to cross-finance other public services.[18] A decline in profits from a municipal gas utility could lead to financial challenges for the municipalities.[19]

If the natural gas network belongs to a private operator, the municipal budget loses out on income from concession fees.[20] Concession fees are an important source of revenue, especially for smaller municipalities. Many municipalities, therefore, have little interest in the end of the natural gas sector, as one of the interviewees pointed out. At the same time, the municipalities have the opportunity to take an active role in designing municipal heat planning.

Partial decommissioning of natural gas infrastructure is limited by existing regulation

The existing (incentive) regulation of natural gas distribution networks is designed to expand and maintain the networks, while reducing the size of the networks has not been possible to date. As long as there are even isolated connections, existing networks must remain in operation.[21]

15 See, for example, the municipal heat plan of the Landkreis Lörrach (in German; available online).

16 Isabel Schrems and Lorena Eulgem, *Die Rolle des Erdgasgeschäfts von Stadtwerken für die kommunale Daseinsvorsorge – Eine Fallstudienanalyse* (2022) (in German; available online).

17 Thomas Bruckner et al., "Kommunale Energieversorger: Gewinner oder Verlierer der Energiewende?" *Wiso Diskurs* 04 (2017) (in German; available online).

18 Cf. Bruckner et al., "Kommunale Energieversorger."

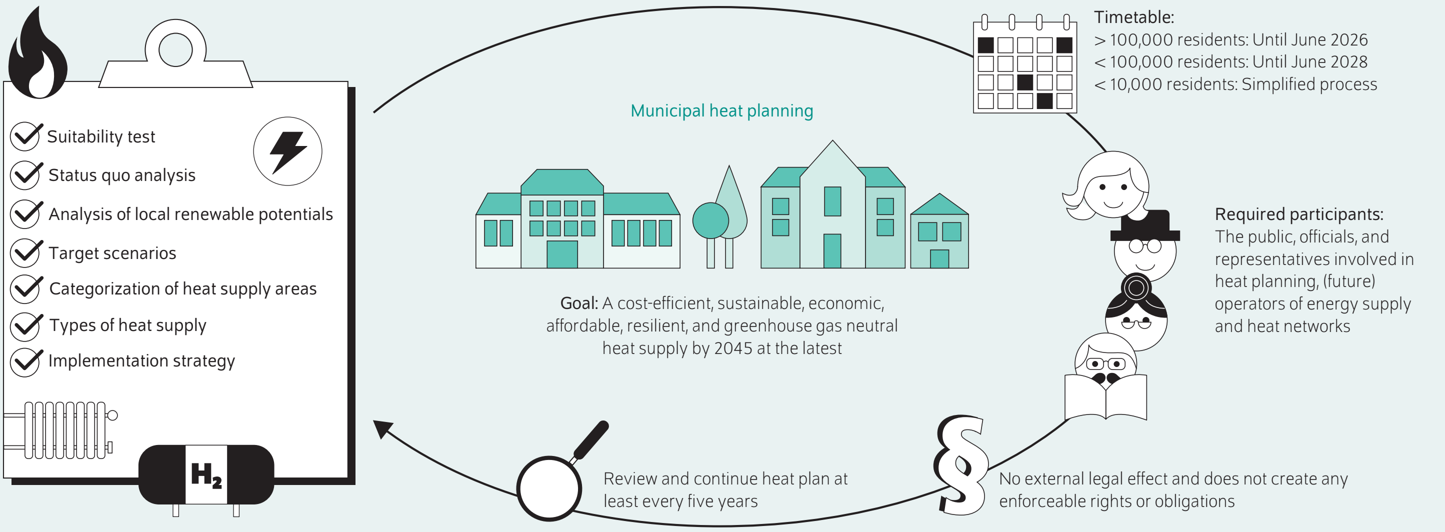
19 Schrems and Eulgem, *Die Rolle des Erdgasgeschäfts von Stadtwerken für die kommunale Daseinsvorsorge*.

20 Municipal network operators pay concession fees too. However, they are deducted from the profits of the municipal company and reduce the amount of revenue that can be used to finance public services.

21 Energiewirtschaftsgesetz, EnWG, sections 11, 17, 18, and 20 (in German; available online).

Figure 4

Central elements of municipal heat planning



Source: Heat Planning Act; authors' depiction.

The Heat Planning Act requires municipalities to prepare a heat plan by either 2026 or 2028.

The maintenance and operation costs of the networks are passed on to the connected gas customers. If customers successively switch to a renewable heat supply in the future, the network charges will increase for the ever-fewer remaining gas customers.[22] This could reduce the acceptance of the heat transition, for example among renters who do not have a choice in their heating system and are forced to assume the rising network charges.

The concession contracts between municipalities and gas network operators set the framework for developments in the network. However, municipalities have very little influence on large parts of the content of the concession contracts. The concession area always covers the entire municipal area by law and reducing it, for example due to the municipal heat plan, is not possible. Concessions are awarded exclusively according to legally defined economic criteria, while criteria such as climate action have previously not been permitted.[23]

According to the EnWG, gas distribution network operators must amortize the networks over 45 to 55 years.[24] Premature decommissioning leads to uncovered investment costs and requires value adjustments, leaving companies with stranded assets on their balance sheets.[25] In Germany, 55 percent of the pipelines were built or renewed between 1990 and 2020; they would be only partially depreciated by 2045.[26] The Federal Network Agency (*Bundesnetzagentur*) has recognized the need to adjust the expected operating life and depreciation procedures and has begun a consultation process to do so.[27] This is an important step in advancing the decommissioning of the natural gas distribution network.

Heat planning process must be improved

The statutory obligation of heat planning creates a responsibility in the municipalities to coordinate the heat transition. In the interviews, however, various stakeholders pointed out that staffing levels are low in most municipalities and that the development of additional capacities is not sufficiently guaranteed due to low compensation funding for the heat planning. This can lead to a lack of continuity in heat planning and implementation as well as to knowledge asymmetries vis-a-vis non-municipal actors, thus leading to municipal interests being insufficiently represented.

In addition, in the planning process in Baden-Württemberg it is not mandatory to include key actors and the public;

22 Agora Energiewende, *Ein neuer Ordnungsrahmen für die Erdgasverteilnetze* (2023) (in German; available online).

23 Julian Senders, "Wärmeplanung und Gaskonzessionen: Eine Untersuchung der bestehenden kommunalen Spielräume in der Wärmeplanung unter besonderer Berücksichtigung von Wärmenetzen," *Würzburger Studien zum Umweltenergierecht*, no. 27 (2022) (in German; available online).

24 Section 46 of the EnWG.

25 Veit Bürger et al., *Agenda Wärmewende 202. Studie im Auftrag der Stiftung Klimaneutralität und Agora Energiewende* (2021) (in German; available online).

26 Ronny Lange, Agnes Schwigon, and Michael Steiner, "Bestands- und Ereignisdatenerfassung Gas – Ergebnisse aus den Jahren 2011 bis 2020," *energie | wasser-praxis* 12 (2021) (in German; available online).

27 Bundesnetzagentur, *Eckpunkte zu den Abschreibungsmodalitäten für die Gasnetztransformation* (2024) (in German; available online).

accordingly, no funds are prescribed for such stakeholder consultations. In the interviews, civil society actors described the process as opaque due to the lack of participation opportunities. A major advantage of municipal heat planning is that both specialists and the general public can be involved, thereby creating acceptance for the transition at an early stage. Therefore, municipalities should be encouraged and supported as much as possible in exploiting this advantage.

Conclusion: Timely decommissioning of the network not yet guaranteed

The demand for natural gas for residential heating will decline over the next years. Natural gas distribution networks must be gradually decommissioned so that network charges do not become too expensive for the few remaining customers. Municipal heat planning is a first important step in accelerating the heat transition and is, in theory, a good instrument for planning the decommissioning of natural gas distribution networks. However, the evaluation of the first heat plans shows that the municipalities are ignoring the future of gas networks, citing major uncertainties. In addition, neither municipal nor private gas network owners have any economic interest in decommissioning, nor have there been any regulatory incentives to do so. The EnWG prioritizes cost efficiency and the obligation to connect over climate action. However, climate action should be placed on equal footing with these other objectives in order to make it possible to decommission the gas distribution networks. The consultation on the future of the natural gas distribution networks launched by the German government in March 2024 and parallel processes at the Federal Network Agency are steps in the right direction.[28]

Municipal owners are facing the same limitations due to regulations and a lack of economic incentives, which make decommissioning natural gas networks hard. The re-municipalization of gas networks that were previously privately owned is thus not a necessary prerequisite to making the heat supply climate-friendly. Municipalities and public utilities will need support services in the future to adequately compensate for the decline in the natural gas demand. Such support can include, for example, the development of new financing concepts for the provision of public services. In addition, municipalities should be encouraged to develop a clear roadmap for the existing natural gas distribution network infrastructure, even if this has not yet been explicitly required in the Heat Planning Act.

28 Cf. Federal Ministry for Economic Affairs and Climate Action, *Green Paper Transformation Gas-/Wasserstoff-Verteilernetze* (2024) (in German; available online); Bundesnetzagentur, *Eckpunkte zu den Abschreibungsmodalitäten für die Gasnetztransformation.*

Isabell Braunger is a Research Associate at the Europa-Universität Flensburg | Isabell.Braunger@uni-flensburg.de

Philipp Herpich is a Research Associate at TU Berlin | phe@wip.tu-berlin.de

Franziska Holz is Deputy Head of the Department Energy, Transportation, Environment at DIW Berlin | fholz@diw.de

Julia Rechlitz is a Research Associate in the Department Energy, Transportation, Environment at DIW Berlin | jrechlitz@diw.de

Claudia Kemfert is Head of the Department Energy, Transportation, Environment at DIW Berlin | sekretariat-evu@diw.de

JEL: L95, R53, Q48

Keywords: natural gas infrastructure, heat, infrastructure planning, stranded assets

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

15 2024

Economy. Policy. Science.

DIW BERLIN

119 Report by Karsten Neuhoff, Mats Kröger, and Leon Stolle

A Renewable Energy Pool brings benefits of energy transition to consumers

- Despite the increasing importance of cost-effective renewable energy generation, electricity consumers are concerned about uncertain electricity prices
- A Renewable Energy Pool makes it possible for consumers to have predictable and affordable electricity prices
- Attractive conditions of long-term hedging contracts are passed on to consumers via an RE-Pool

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 April 17, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Alexander Roth

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Ulrike Fokken; Petra Jasper; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 15 2024

AT A GLANCE

A Renewable Energy Pool brings benefits of energy transition to consumers

By Karsten Neuhoff, Mats Kröger, and Leon Stolle

- Despite the rapid cost decline and increasing deployment of wind and solar power, uncertain and high electricity prices remain a concern for consumers
- A Renewable Energy Pool can ensure predictable and affordable electricity prices for consumers and facilitates low-cost financing of new wind and solar projects
- The attractive conditions of long-term hedging contracts are passed on to the consumers via the RE-Pool
- The pool hedges electricity consumers for consumption matching wind and solar production. Flexibility serves as hedge for any miss-match; this strengthens incentives to realize all flexibility
- An RE-Pool would replace the current support of renewable energy sources via the sliding market premium

"By passing on the advantages of renewable energy to the consumers, political support for the energy transition can be strengthened."

— Mats Kröger —

MEDIATHEK

Audio-Interview mit Mats Kröger (in German)
www.diw.de/mediathek

A Renewable Energy Pool brings benefits of energy transition to consumers

By Karsten Neuhoff, Mats Kröger, and Leon Stolle

ABSTRACT

German companies view high and uncertain electricity prices a major challenge. A Renewable Energy Pool (RE-Pool), wherein the favorable conditions of competitive tenders for new wind and solar power projects are passed on to electricity consumers, could hedge such price risks. Consumers' electricity prices are thus hedged for the share of their consumption that corresponds to the RE-Pool's generation profile. This, in turn, strengthens the incentives to invest in flexibility, such as in heat storage systems or batteries, in order to adjust their demand to wind and solar electricity production in the pool. In addition, the RE-Pool profile can serve as a reference against which new products to hedge flexibility can be introduced in the futures and forward markets. The RE-Pool also addresses financing risks linked to regulatory uncertainties faced by renewable energy projects. This reduces financing costs and thus costs for consumers and enhances confidence in future renewable deployment and thus supports investments into the supply chain of project developers and manufacturers. The RE-Pool contributes to an even better use of renewable energy sources in the energy supply and prepares the electricity system for a future powered by a greater share of renewable energy.

The electricity generation costs[1] for renewable energy sources have decreased considerably over the past years. For example, costs declined by 89 percent for solar installations, by 69 percent for onshore wind installations, and by 59 percent for offshore wind installations from 2010 to 2022 (Figure 1).[2] Although over half of the electricity supply now comes from renewable energy sources,[3] their declining costs[4] could not protect electricity consumers against the price shocks on the gas and coal markets in the past years. This is due to the pricing mechanism on the electricity market, where the most expensive installation determines the power price in each hour. This means that the generation costs of gas and coal-fired power plants continue to determine the price of the electricity supply in most hours.

The geopolitical situation as well as the future development of energy and climate policy remain uncertain. Fossil fuel price shocks cannot be ruled out in the coming years, even if prices have declined recently. This uncertainty is also reflected in the expectations of companies as electricity consumers in the European Union. In a 2023 survey conducted by the European Investment Bank, 59 percent of companies expressed major concern about energy prices and 47 percent were worried about uncertainty regarding price development.[5]

In principle, companies and energy providers can insure themselves against fluctuating prices by concluding long-term bilateral power purchasing agreements (PPAs) with electricity producers through which prices and delivery

1 The generation costs, or the levelized cost of electricity (LCOE), is a common measure for comparing the costs of different electricity generation technologies. Both the installation costs and all variable costs are compared to the amount of electricity produced by a system over the entire operating period.

2 International Renewable Energy Agency (IRENA), *Renewable Power Generation Costs in 2022, International Renewable Energy Agency* (Abu Dhabi: 2023) (available online; accessed on March 20, 2024 (in German). This applies to all other online sources in this report unless stated otherwise).

3 Bundesnetzagentur, "Bundesnetzagentur veröffentlicht Daten zum Strommarkt 2023," press release, January 3, 2024 (in German; available online).

4 Bundesnetzagentur, "Bundesnetzagentur veröffentlicht Daten zum Strommarkt 2023."

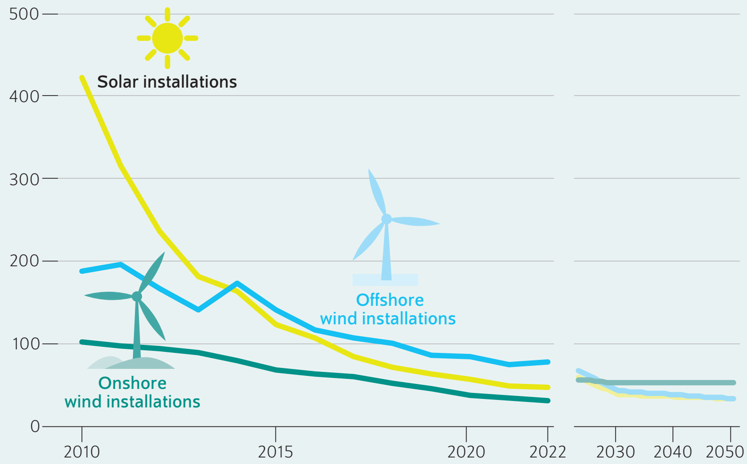
5 European Investment Bank, *EIB Investment Survey – European Union Overview* (2024) (available online). The results are based on interviews with 12,030 companies in the European Union between April and July 2023.

DOI: https://doi.org/10.18723/diw_dwr:2024-15-1

amounts for the coming years are set. However, such bilateral contracts contain challenges for many companies, such as the default risk of the contract partner and collateral that must be submitted. In particular, it is risky for energy-intensive companies to hedge the price of a major share of their electricity demand via long-term PPAs if the prices of their final output are not insured for a comparable time period. Therefore, instruments that avoid the problems of such bilateral contracts and make the electricity market resilient to future price fluctuations are under discussion.

Figure 1

Generation costs of renewable energy sources
In euros per megawatt hour



Notes: The assumed exchange rate is 0.95 euros per US dollar. The data until 2022 represent global values. Data from 2023 are linearly interpolated forecasts for the European Union.

Sources: International Renewable Energy Agency (IRENA), *Renewable Power Generation Costs in 2022;* IEA, *IEA World Energy Outlook* (2023).

The average generation costs of renewable energy sources have continued to decline over the past years.

A Renewable Energy Pool allows electricity consumers and renewable energy project developers to mutually insure against price risks

The RE-Pool[6] consists of three elements (Figure 2). First, a publicly commissioned agency conducts an auction to tender long-term contracts for the output of new wind and solar projects. Second, these contracts are aggregated into a contract pool. The pool includes a diverse portfolio of plants with multiple technologies and at diverse locations that began operating at different times. Thus, long-term hedging contracts are aggregated in the RE-Pool, which reduce wind and solar project developers' investment risk. Third, electricity consumers receive a contract for a share of the electricity generated in the pool, thus hedging electricity price risks. In this concept, the conditions of the renewable energy projects are passed on to electricity consumers via the pool. The pool is budget-neutral for the federal government.

An RE-Pool guarantees financing for future wind and solar projects and addresses uncertainties that could otherwise endanger German expansion targets and increase the cost of the energy transition. At the same time, electricity consumers directly benefit from the cost reductions in renewable energy. Affordable and reliable electricity prices are a prerequisite for further electrification, which is an important component in many sectors in the transition towards a climate-neutral economy. Thereby, they contribute to the success of the industrial transition. By passing on the benefits of wind and solar energy directly to electricity consumers, the RE-Pool also increases political support for the energy transition.

Consumers can benefit from affordable renewable energy via an RE-Pool

The elements of the RE-Pool build upon previously developed and well understood instruments. The long-term contracts are awarded to renewable energy plant operators in auctions by a publicly commissioned entity. The prices of successful bids define the contract price for the respective hedging of a project's electricity price risk, as was previously the case in the auctions according to the German Renewable Energy Act (EEG). If the market price is lower than this contract price during an hour in which the plant is producing electricity, the difference is paid to the operator. In addition to the current German system, the plant operator must reimburse the surplus revenue to the RE-Pool in hours in which the market price is higher than the contract price. Such symmetrical long-term contracts hedge electricity producers against price risks, allowing the projects to be realized at low financing costs.[7]

The previous one-sided hedging via the sliding market premium for new projects would come to an end with the introduction of the RE-Pool. This motivates developers of new wind and solar projects to participate in the pool. A further advantage of the RE-Pool is the ability to hedge against regulatory uncertainties, such as the introduction of price zones or local prices.

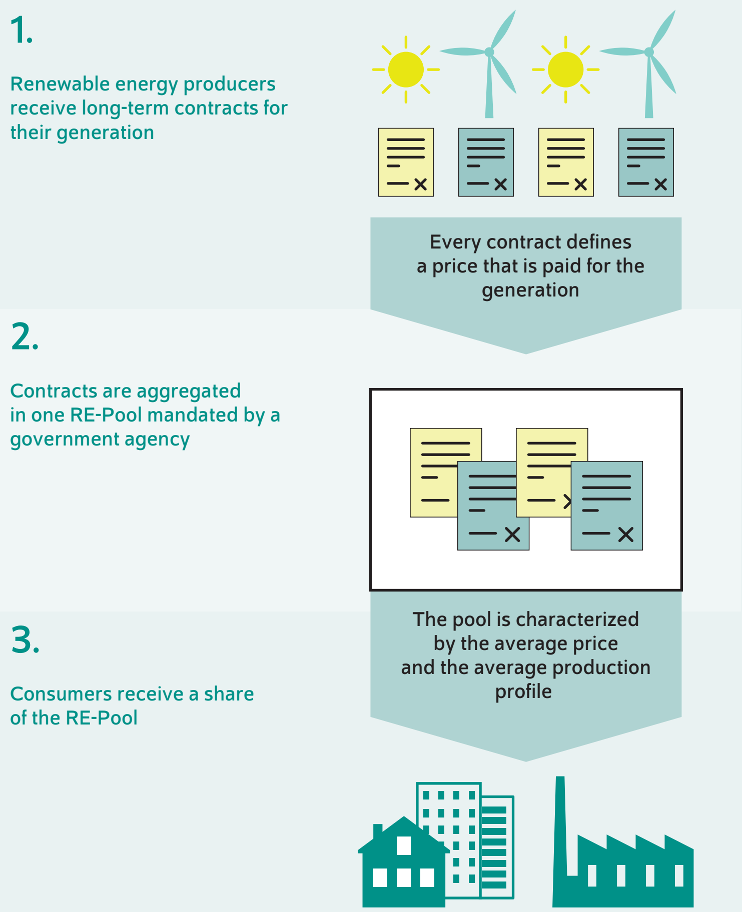
By switching to symmetric hedging, the benefits of the symmetrical contracts can be passed on to the consumers. All of the long-term contracts are aggregated in the RE Pool, which is defined by the sum of its generation and average contract price. Electricity generated from the RE-Pool is then proportionally allocated to the consumers. Under the previous support regime, consumers only incurred costs that were passed on via the EEG surcharge and have been paid from

6 The concept of renewable energy pools as well as the calculations in this Weekly Report are based on Karsten Neuhoff et al., "Contracting Matters: Hedging Consumers and Producers with a Renewable Energy Pool," *DIW Diskussionspapier* no. 2035 (2023) (available online).

7 Cf. Mats Kröger, Karsten Neuhoff, and Jörn C. Richstein, "Contracts for Difference Support the Expansion of Renewable Energy Sources while Reducing Electricity Price Risks," *DIW Weekly Report* no. 35/36 (2022): 205-213 (available online).

Figure 2

Schematic depiction of a renewable energy pool (RE-Pool)



Sources: Karsten Neuhoff et al., "Contracting Matters: Hedging Consumers and Producers with a Renewable Energy Pool," *DIW Diskussionspapier*, no. 2035 (2023); authors' depiction.

An RE-Pool enables cost-effective financing of wind and solar energy projects, allowing the lower costs to be passed on to consumers.

the federal budget since July 2022. Following the introduction of symmetric hedging, however, consumers will benefit from payments during periods of high electricity prices. If symmetric contract structures had already been introduced in the past, it would have led to large payments and to a significant reduction in the burden on consumers during the energy price crisis.[8] The advantage of passing on the hedging contracts is that the payments in years with low electricity prices do not burden the federal budget as in the previous support regime, as the payments and reimbursements of pool consumers and electricity producers balance each other out each period.

As further auctions are held each year as part of Germany's renewable energy expansion targets, the RE-Pool volume would increase steadily over the years. If introduced for all new tenders starting from 2025 (Figure 3), the RE-Pool would consist of onshore wind and solar power installations in the first few years. Due to the longer project development times, offshore wind installations would be added beginning in 2029. In this case, over 100 TWh of generation could be hedged via the pool from 2028 if Germany's renewable targets are reached. The exact price of the RE-Pool depends on the generation costs of different renewable energy technologies and sites reflected in the bidding process. By weighting the forecasted technology-specific generation costs[9] with the respective pool volumes, suggests that pool prices in the range of 50 to 60 euros per megawatt hour.

An important question is what risks electricity consumers are assuming when participating in an RE-Pool, especially if electricity prices fall below the prices in the RE-Pool in the long term. Such a price drop could happen if renewable energy generation costs continue to fall or renewable electricity projects outside the pool would be subsidized. In principle, this could lead to a structural disadvantage for companies participating in the pool. This can be avoided if electricity consumers in the pool receive an exit option, for example with a five-year notice period. In case of an exit, the federal government, as guarantor of the RE-Pool, would have to cover the costs of the remaining contracts. This creates a de facto regulatory guarantee from the federal government to the companies in the RE-Pool, which protects them from disadvantages due to future regulatory measures like a subsidy for installations outside of the pool. On the other hand, a long notice period, for example five years, ensures that consumers remain in the pool and committed to the deal of a mutual insurance of producers and consumers also in periods of temporarily lower whole-sale prices.

RE-Pool access should prioritize consumer segments particularly affected by the transition

There are various options for allocating the electricity generated in the RE-Pool among the consumers: "pro-rata" allocation, auctions, or prioritization.

Under a "pro-rata" allocation, all electricity consumers are hedged according to their share of total electricity consumption. This would be the simplest and most plausible method in the long term. However, it would not provide sufficient hedging for groups of priority consumers who will be particularly affected in the coming years, as the RE-Pool volume must first be built up. A second option would be to allocate the RE-Pool via an auction. This would lead to the companies that are able to pay the most receiving access to the hedge. This would not necessarily benefit companies that require stable and competitive electricity prices in order to invest in transition processes.

8 Cf. Jörn Richstein, Frederik Lettow, and Karsten Neuhoff, "Marktprämie beschert Betreibern erneuerbarer Energien Zusatzgewinne – Differenzverträge würden VerbraucherInnen entlasten," *DIW aktuell* no. 77 (in German; available online).

9 International Energy Agency, *World Energy Outlook 2023* (Paris: IEA, 2023) (available online).

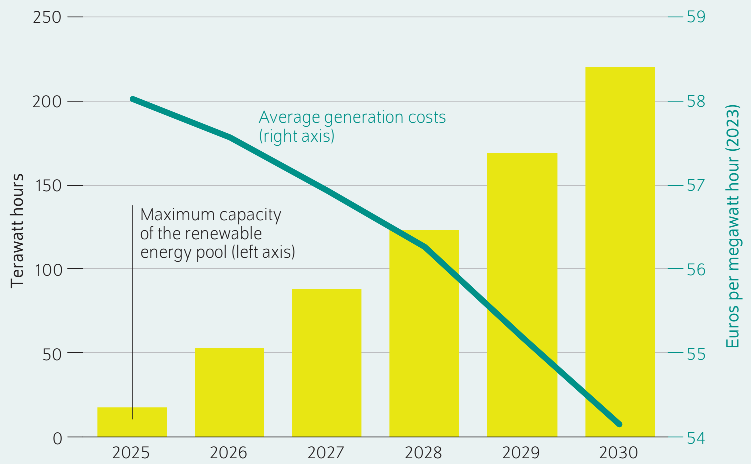
A third possibility is prioritizing allocation to consumer segments that are especially affected by the energy transition. This includes companies who are investing in electrification processes and thus have a particular need for hedging their electricity costs as well as energy-intensive manufacturing companies that are under strong international competitive pressure. The uncertainty of the transition process could be reduced for these groups and the necessary investment security increased. A third group consists of the residents living close to new wind and solar parks. Allocation to this group could increase acceptance for the parks.[10] The public interest in the projects and their positive externalities would justify such prioritized allocation.

Discussions with stakeholders have revealed a significant interest from potential consumers for shares in an RE-Pool. Thus, it can be assumed that the demand for the pool shares would exceed supply in the short term and the setting of access criteria would likely be a subject to competing interests. However, a similar dynamic is to be expected even without an RE-Pool during times of high electricity prices and resulting possible government interventions. In any case, it must be noted that any decisions about prioritization must be discussed and decided upon in an open and transparent parliamentary process.

Figure 3

Volume and price development of an RE-Pool

In terawatt hours (left axis); euros per megawatt hour (2023, right axis)



Sources: Klaus Mindrup and Karsten Neuhoff, "Eneuerbare Energeien und Flexibilität – Optionen für reduzierte und verlässliche Stromkosten," *DIW Politikberatung kompakt*, no. 197 (2023); calculations based on the German federal government's expansion plans for renewable energy sources and predicted generation costs from the 2023 IEA World Energy Outlook.

The maximum volume of the RE-Pool will already be over 100 terawatt hours in 2028 if all new projects are aggregated into the pool beginning in 2025.

RE-Pool offers advantages due to electricity price security and low financing costs

For consumers, the RE-Pool offers the advantage of hedging their electricity costs. They are spared high bills in times of unexpectedly high energy prices, which decreases pressure on the federal government to take action in the market to lower prices via ad hoc measures or to use budgetary resources to relieve electricity consumers. During the 2022 energy price crisis, an RE-Pool would have led to considerably lower cost increases for participating consumers (Figure 4).[11] Moreover, hedging electricity price risk is associated with better plannability and investment security. For instance, private homeowners can better calculate the economics of installing a heat pump. For companies it lowers the risk of investing in electrification processes to reduce emissions.

Consumers could theoretically achieve the same effect using bilateral contracts with electricity suppliers. However, financing costs for wind and solar projects, and thus the electricity generation costs, would be ten percent higher under such bilateral contracts compared to the RE-Pool, as a DIW Berlin study shows.[12] This is the case because, in contrast to a state-guaranteed contract, the counterparty's default risk is greater. In addition, bilateral contracts have a negative impact on the creditworthiness of companies if they reach a large volume. This increases the financing costs and represents a further 20-percent cost increase for the renewable electricity that has been hedged. Furthermore, not all companies can conclude such bilateral electricity contracts in the amount of their actual electricity demand in practice. Thus, the RE-Pool increases the scope of consumers hedged against price fluctuations in the long term and reduces the cost of the energy transition.

Lastly, the RE-Pool has the advantage of a "flatter" generation profile compared to bilateral hedging of electricity consumers via individual projects. By aggregating all of the wind and solar installations in Germany—and in neighboring countries as well in the medium and long term—the generation volatility is reduced. This can be shown schematically for a pool comprised of equal shares of the current German solar and offshore wind installations compared to generation from only onshore wind installations (Figure 5).

RE-Pool creates incentives for flexible electricity demand

Another advantage of an RE-Pool would be that electricity consumers would be incentivized to invest in flexibility as well as to adjust their demand to short-term price signals during operation. These incentives arise because consumers are hedged by their share in the RE-Pool via the RE-Pool's generation profile. Therefore, they are only fully hedged against

10 Jakob Knauf, "Can't buy me acceptance? Financial benefits for wind energy projects in Germany," *Energy Policy* 165 (2022): 112924 (available online).

11 The calculations in Figure 4 assume that the average costs in both policy options are the same. The figure is thus less a prediction of the pool price and more an illustration of the reduced electricity price volatility.

12 Nils May and Karsten Neuhoff, "Financing Power: Impacts of Energy Policies in Changing Regulatory Environments," *The Energy Journal* 42, no. 4 (2021): 131-151 (available online).

Figure 4

Electricity costs with an RE-Pool compared to procurement without hedging

In euros per megawatt hour

Notes: Electricity costs without hedging calculated using price and demand data from 2015 to 2022; with pool also based on RE generation from 2015 to 2022; with flexibility based on a "spread product" that pays the difference between the four highest and lowest hours; same average costs in the scenarios.

Sources: Karsten Neuhoff et al., "Contracting Matters: Hedging Consumers and Producers with a Renewable Energy Pool," *DIW Diskussionspaper*, no. 2035 (2023); authors' depiction.

The RE-Pool stabilizes the electricity costs across the observation period.

the electricity price risk if their demand follows the profile of the pool's generation perfectly. This means that consumers with less flexible demand are exposed to the electricity price risks of the short-term markets for the share of their demand that deviates from the hedge provided by the RE-Pool. This creates incentives to tap into cost-effective flexibility potentials, which keeps costs low for electricity consumers and the entire system. For example, companies can invest in flexibilization of production, for example with storage of heat and industrial intermediate products.

The magnitude of costs incurred by electricity consumers with inflexible demand, and thus also the amount of incentives for investments in flexibility, can be illustrated with the help of market value defined as the revenue a plant would have obtained if it were to sell all production at the spot price of each hour (Figure 6). The green area depicts the 12-month moving average of the market value of an RE-Pool compared to the average of the wholesale spot prices. Generally, this value is below 100 percent because the electricity price tends to be below average when the supply of renewable electricity is high. The green line represents the electricity costs of flexible consumers who can perfectly adjust their demand to the RE-Pool's generation profile. Inflexible consumers, in contrast, incur costs, as they must procure electricity outside of the hedging via the RE-Pool. This would be the case primarily in hours of low production from renewable energy sources, in which the spot market price is higher than the average price of the pool. With the hypothetical RE-Pool assumed in this example, these costs (gray area) would currently be just under 20 percent of the electricity price for electricity customers with completely inflexible demand.

Hedging with the RE-Pool's generation profile does not only lead to incentives in increasing demand flexibility, but should also contribute to further developing the electricity derivatives market. Each company can decide to what extent it invests in its own flexibility or hedges through the forwards and futures market. In turn, this demand for forward products for flexibility allows flexibility providers to secure revenue from the flexible operation of batteries or heat storage systems and thus improves investment framework conditions.

Design of RE-Pool should be compatible with future electricity market reforms

When designing the tender procedures and long-term contracts between the RE-Pool and wind and solar projects, it must be ensured that installations are built and operated in a system-friendly manner and that plants do not produce in periods of negative electricity prices. There are various options for this: One is to hedge the hourly electricity price for producers but have clear regulations stipulating that plants do not receive any remuneration during hours of negative electricity prices. However, this would result in a loss of revenue that is difficult to predict. A further option for lowering producers' revenue risk would be to hedge the potential generation output during hours of negative electricity prices instead of the actual output of the plant. This would restore incentives and maintain revenue security and low financing costs. Various research groups have made comparable proposals in recent months, all of which are based on decoupling the payments for symmetrical hedging from the actual production decisions of the plant operators.[13] An RE-Pool is also compatible with these proposals.

The design of the RE-Pool should be chosen in such a way that electricity consumers are hedged against regulatory uncertainties regarding possible future electricity market reforms. One example of this is the introduction of local prices or electricity price zones, which could replace the German single price zone to better align electricity demand and supply at a local level and thus avoid transmission constraints. The contracts in the RE-Pool should be specified in such a way that both electricity producers and consumers in the RE-Pool are directly hedged against the electricity price at their feed-in or purchase point. However, this could have the effect that the payments to and from the RE-Pool no longer balance each other out. The resulting revenues from introducing locational pricing should be used to eliminate these price differences.[14] This would secure budget neutrality of the RE-Pool.

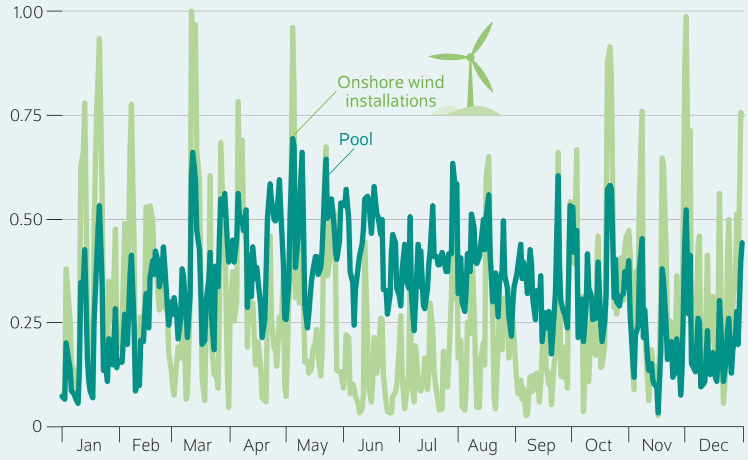
Conclusion: An RE-Pool hedges both electricity producers and consumers against price risks

An RE-Pool is an attractive option for passing on the advantages of electricity producers' hedged electricity prices to the consumers. In an RE-Pool, long-term hedging contracts that lower the investment risk of wind and solar project developers are aggregated into a contract pool. In a second step, this advantage is passed on to the electricity consumers. By lowering the investment risk, the pool reduces the financing costs for renewable energy projects and thus costs for renewables to consumers. It makes it possible for electricity consumers to hedge themselves against future price shocks. Furthermore, it supports investments in flexibility and the development of financial hedging products compatible with renewable energy sources. The RE-Pool is an important part of an electricity market with increasing shares of renewable energy.

Figure 5

Production profile of a hypothetical pool compared to onshore wind installations in 2021

Index of the maximum generation



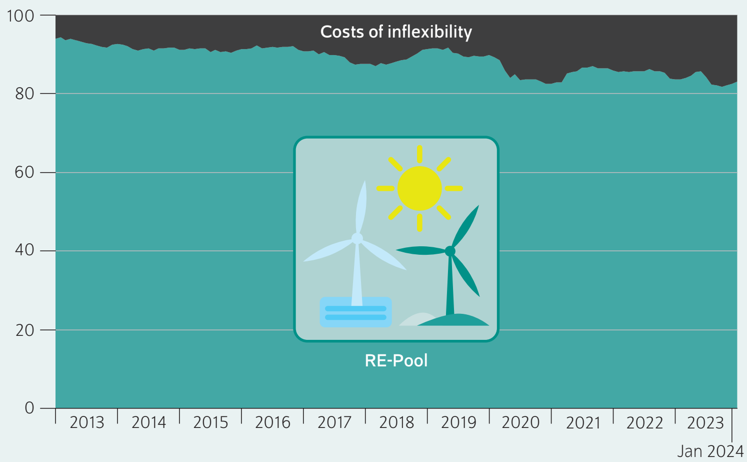
Sources: Karsten Neuhoff et al., "Contracting Matters: Hedging Consumers and Producers with a Renewable Energy Pool," *DIW Diskussionspaper*, no. 2035 (2023); authors' depiction.

An RE-Pool that contains half onshore wind installations and half solar installations significantly reduces production volatility.

Figure 6

Electricity costs for flexible demand

In percent compared to electricity costs for inflexible demand



Notes: Twelve-month moving average of the monthly market values of a hypothetical RE-Pool, weighted with the generation volumes of renewable energy sources from 2023, compared to the spot market price. The green area represents the twelve-month moving average, the dark gray area represents the additional costs for inflexible consumers.

Klaus Minrup and Karsten Neuhoff, "Eneuerbare Energeien und Flexibilität – Optionen für reduzierte und verlässliche Stromkosten," *DIW Politikberatung kompakt*, no. 197 (2023); calculations based on market values and spot market prices from netztransparenz.de.

A flexible consumer hedged by the RE-Pool reduces their electricity costs by nearly one fifth compared to an inflexible consumer.

13 Cf. Ingmar Schlecht, Christoph Maurer, and Lion Hirth, "Financial contracts for differences: The problems with conventional CfDs in electricity markets and how forward contracts can help solve them," *Energy Policy* 186 (2024): 113981 (available online); David Newbery, "Efficient renewable electricity support: Designing an incentive-compatible support scheme," *The Energy Journal* 44, no. 3 (2023): 1-22 (available online); Regulatory Assistance Project, The search for two-sided CfD design efficiency – a Shakespearean history (2023) (available online).

14 Redispatch measures currently implemented by transmission system operators to manage congestion in large pricing zones induce costs, e.g., 4.2 billion euros in 2022 in Germany. (Bundesnetzagentur, *Bericht Netzengpassmanagement* (2023) (in German; available online)). They are recovered through grid tariffs paid by consumers. A split of larger pricing zones or an introduction of locational pricing would reduce or eliminate these costs and instead result in congestion revenue that can be used for reducing grid tariffs and hedging locational price differences in an RE-pool.

Karsten Neuhoff is Head of the Climate Policy Department at DIW Berlin and economics Professor at Technical University Berlin | kneuhoff@diw.de

Mats Kröger is a Research Associate in the Climate Policy Department at DIW Berlin | mkroeger@diw.de

Leon Stolle is a Research Associate in the Climate Policy Department at DIW Berlin | lstolle@diw.de

JEL: L94, Q48, Q41

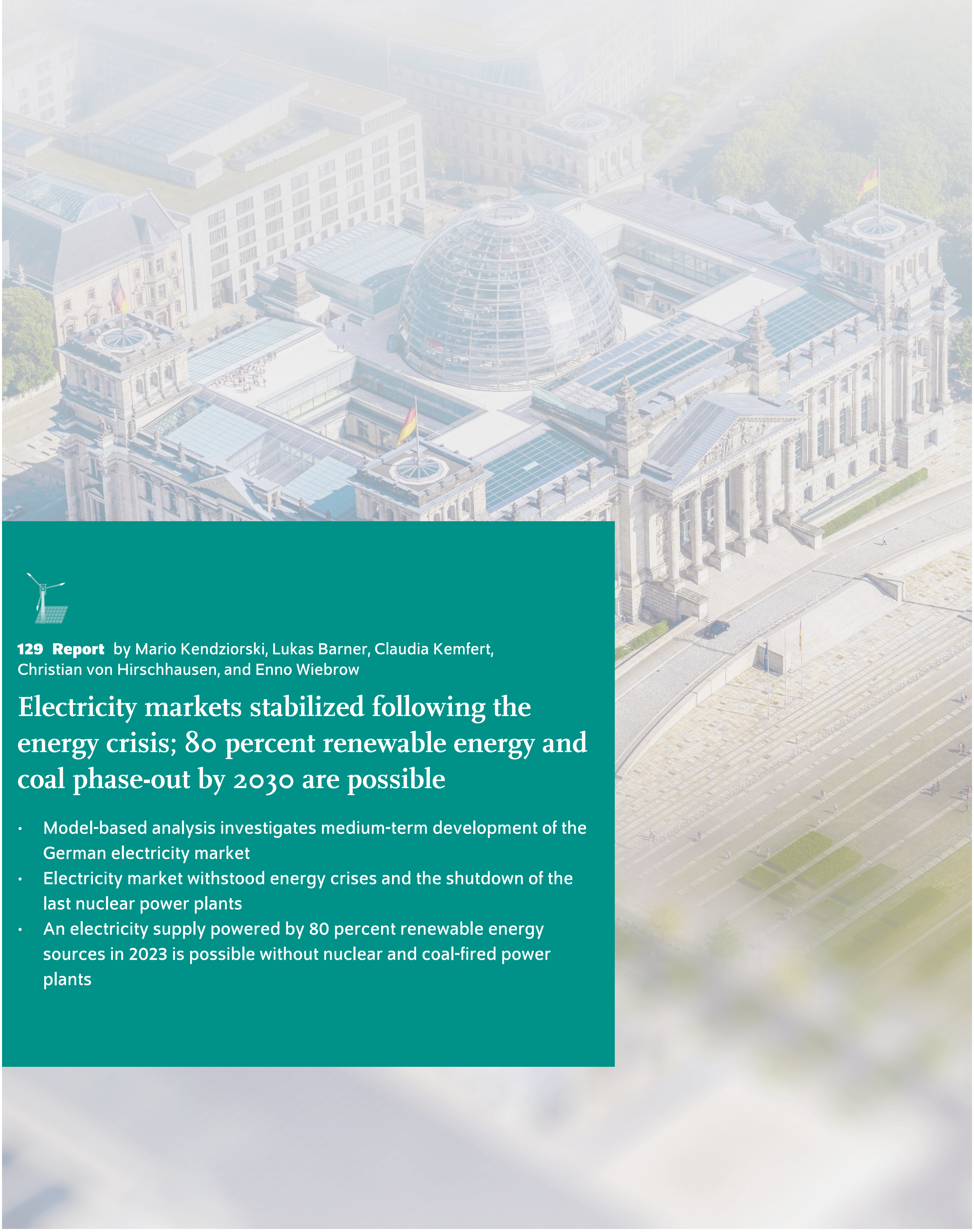
Keywords: Renewable Energy Policy, Electricity Markets, Flexibility

DIW Weekly Report 16+17+18 2024

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN



129 **Report** by Mario Kendziorski, Lukas Barner, Claudia Kemfert, Christian von Hirschhausen, and Enno Wiebrow

Electricity markets stabilized following the energy crisis; 80 percent renewable energy and coal phase-out by 2030 are possible

- Model-based analysis investigates medium-term development of the German electricity market
- Electricity market withstood energy crises and the shutdown of the last nuclear power plants
- An electricity supply powered by 80 percent renewable energy sources in 2023 is possible without nuclear and coal-fired power plants

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 May 8, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Dr. Franziska Klaucke

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Petra Jasper; Frederik Schulz-Greve; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 16+17+18 2024

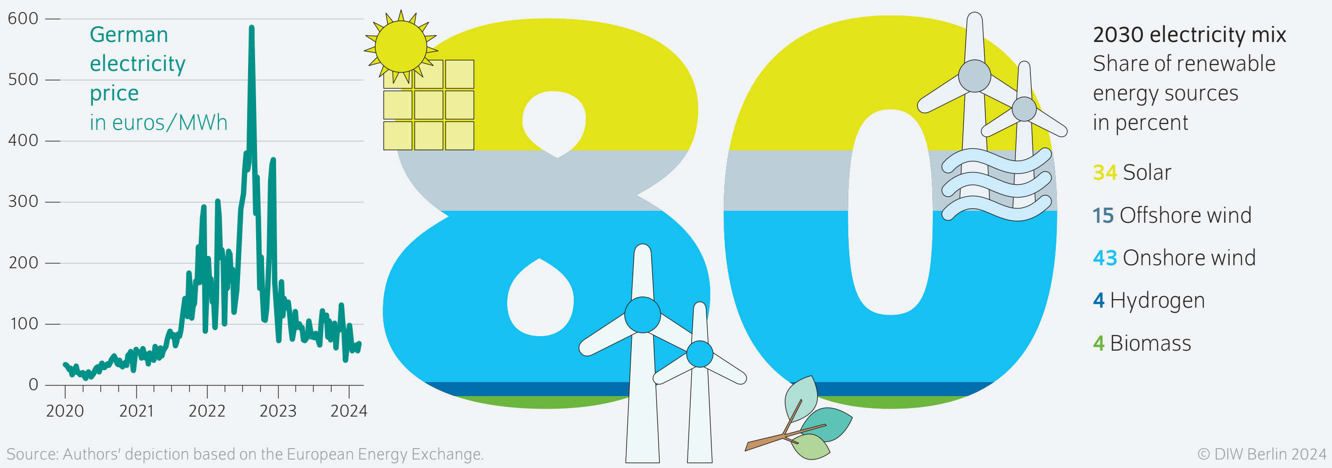
AT A GLANCE

Electricity markets stabilized following the energy crisis; 80 percent renewable energy and coal phase-out by 2030 are possible

By Mario Kendziorski, Lukas Barner, Claudia Kemfert, Christian von Hirschhausen, and Enno Wiebrow

- Model-based analysis investigates the development of the German electricity market during 2022, the year of the energy crisis, and up to 2030
- The German electricity market withstood the energy crisis and the shutdown of the final nuclear power plants; security of supply was always guaranteed
- In addition to war-related gas price increase, prices were also driven by downtime of French nuclear power plants
- An electricity supply powered by 80 percent renewable energy sources in 2030 is possible without nuclear and coal-fired power plants

The German electricity market stabilized following the energy crisis; an electricity supply powered by 80 percent renewable energy sources is possible by 2030



Source: Authors' depiction based on the European Energy Exchange.

FROM THE AUTHORS

"The goal of having at least 80 percent renewable energy by 2030 is entirely realistic. It is important that the pace of the expansion of renewable energy sources does not slow down. Then we can also replace the share of coal-generated electricity with renewable energy by 2030."
— Claudia Kemfert —

MEDIA

Audio Interview with Claudia Kemfert (in German)
www.diw.de/mediathek

Electricity markets stabilized following the energy crisis; 80 percent renewable energy and coal phase-out by 2030 are possible

By Mario Kendziorski, Lukas Barner, Claudia Kemfert, Christian von Hirschhausen, and Enno Wiebrow

ABSTRACT

The German electricity market has recovered well from the 2022 energy crisis. Policymakers should now redirect the focus of energy policy to further expanding renewable energy sources. The year 2023 showed that the German electricity supply remained secure following the shutdown of nuclear power plants. It is possible, affordable, and plausible in light of climate policy to cover 80 percent of electricity consumption with renewable energy sources, as the German Renewable Energy Sources Act plans for by 2030. However, a swift exit from coal, and natural gas in the long run, is required to achieve this, as is suggested by scenario analyses that track the price and volume effects as well as the grid situation on the German electricity market for the present and for 2030. The shutdown of nuclear power plants has been planned for a long time and was by no means a relevant driver of electricity prices. Rather, French nuclear power plants' erratic downtimes as well as war-related increases in gas prices drove up electricity prices. The construction of new nuclear power plants, which has been discussed by policymakers, is irrelevant for the energy transformation over the next decades. The natural gas crisis has also ended. In addition to the coal phase-out, the fossil fuel phase-out is an integral part of the energy transformation.

The 2023 German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, EEG) stipulates that at least 80 percent of electricity consumption must come from renewable energy sources by 2030.[1] This implies that up to 600 terawatt hours (TWh) must be generated from renewable energy, compared to around 260 TWh today. Policymakers somewhat deprioritized this target following the 2022 energy crisis. However, the German and European electricity markets have since stabilized; electricity as well as natural gas prices are now about the same as they were before the start of the Russo-Ukrainian War (Figure 1). This clears the way for the next steps to be taken, in particular accelerating the expansion of renewable energy sources and driving the coal phase-out, and subsequently the natural gas phase-out, forward. This Weekly Report updates earlier model-based scenario analyses[2] and discusses the results from 2022 and beyond.

Energy crisis is over; security of supply was never at risk

Natural gas and electricity prices were already trending upward in the run-up to the Russo-Ukrainian War and prices increased further following the start of the war on February 24, 2022. However, electricity prices have fallen sharply since fall 2022 and are now around the pre-war price level. The same trend can be observed for natural gas prices. In light of a decline in natural gas consumption in the long run, the shock of the interrupted gas delivery from Russia was quickly absorbed.[3]

1 Paragraph 1 of the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, EEG) (in German; available online; accessed on April 8, 2024. This applies to all other online sources in this report unless stated otherwise).

2 Clemens Gerbaulet et al., "Abnehmende Bedeutung der Braunkohleverstromung: weder neue Kraftwerke noch Tagebaue benötigt," *DIW Wochenbericht* no. 48, 25–33 (in German; available online); Mario Kendziorski et al., "Nuclear Turn: Closing Down Nuclear Power Plants Opens up Prospects for the Final Repository Site Search," *DIW Weekly Report* no. 47 (2021): 356–366 (available online).

3 Cf. Franziska Holz etal., "LNG Import Capacity Expansion in Germany – Short-term Relief Likely to Turn into Medium-term Stranded Assets," *IAEE Energy Forum, 2nd Quarter 2023* (2023) (available online) as well as Christian von Hirschhausen et al., "Gasversorgung in Deutschland stabil: Ausbau von LNG-Infrastruktur nicht notwendig," *DIW aktuell* 92 (2024) (in German; available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-16-1

Box 1

Methodology

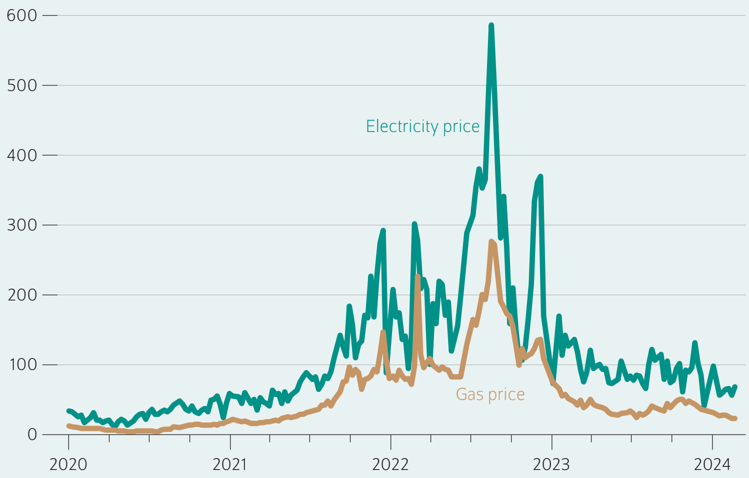
Calculations were conducted using an updated version of the ELMOD electricity market model.[1] Using a two-phase market simulation, the model determines a cost-minimal use of generation capacities at an hourly level. In line with the real market clearing principle, the first phase consists of comparing electricity demand and generation supply within the individual market zones. Based on the merit order principle, the market clearing price is determined by the marginal costs of the most expensive power plant that is required to meet demand cost effectively. In the second phase, the resulting power flows are simulated based on the market result. This allows the use of power plants to be adjusted once again, which can prevent bottlenecks in the electricity grid. Such measures are also known as redispatch measures. In order to ensure a high temporal resolution, generation units from neighboring countries are aggregated and combined into one node each. In addition, the net transfer capacities between neighboring market areas are taken into account and a transmission reliability margin of 20 percent of the transmission capacity is introduced instead of the calculation of (n-1) security. This makes it possible to simulate an entire year in hourly resolution with a high level of detail when representing the German transmission system.

1 The model was developed at TU Dresden. See Florian Leuthold, Hannes Weigt, and Christian von Hirschhausen, "ELMOD – A model of the European Electricity Market," (working paper WP-EM-00, Dresden University of Technology Electricity Market, 2008) (available online). The model has previously been used in various DIW Berlin projects (such as Claudia Kemfert, Friedrich Kunz, and Juan Rosellón, "A welfare analysis of electricity transmission planning in Germany," *Energy Policy* 94 (2016): 446–452 (available online). Today it is maintained and developed further at DIW Berlin. Current calculations are based on Enno Wiebrow et al., "The Effects of Nuclear Power Plant Closures in Germany 2021–2023 on Network Flows and Redispatch – Update of Earlier ELMOD Modeling Results," Presentation at Enerday, Dresden, April 12, 2024.

Figure 1

Electricity and natural gas prices in Germany

In euros per megawatt hours



Source: Authors' depiction based on the European Energy Exchange and ENTSO-E Transparency Platform.

After rising in 2022, electricity and gas prices have fallen back to the level of the previous decade.

Despite major uncertainties, the German electricity market's security of supply was never at risk at any point in time.[4] This was due to large power plants' existing excess capacities as well as the expansion of renewable energy sources. In a scenario for the year 2021, this Weekly Report uses an electricity market model to investigate how the shutdown of the remaining nuclear power plants would have affected the electricity mix, power flows, and prices during the reference year 2021 (Box 1). This year was selected as the reference year because the final six nuclear power plants were still connected to the grid in 2021. Moreover, the electricity market experienced shocks in 2022 due to the attack on Ukraine. Choosing 2022 as the reference year would have significantly distorted the effects.

In this study, we calculated two variants, one with no nuclear power plants and one with six nuclear power plants, to make changes more clearly visible. In addition, using a second scenario for 2030, we investigate how the electricity market could develop in light of the planned coal phase-out. The last six nuclear power plants in Germany that were still connected in 2021 had a combined installed capacity of 8.5 gigawatts (GW) gross and 8.1 GW net,[5] with total generation of 65.4 TWh in 2021. Following the shutdown of the Brokdorf, Grohnde, and Gundremmingen C nuclear power plants at the end of 2021, the final three plants (Emsland, Neckarwestheim 2, and Isar 2) generated 32.8 TWh (around six percent of electricity production) in 2022.[6]

The model results for the 2021 scenario show that in a static view, a combination of existing fossil fuel power plants would have compensated for these amounts of electricity temporarily (Figure 2). This would have led to an increase in CO_2 emissions in the short term. However, in reality, this effect would have already been compensated for due to both the simultaneous expansion of renewable energy sources as well as a decline in electricity consumption. A historical evaluation of the data shows that CO_2 emissions even declined in both 2022 and 2023. Between January 2021 and January 2024 alone, 29 GW of photovoltaics were constructed in addition to a further 6.7 GW of onshore wind power and 0.6 GW of

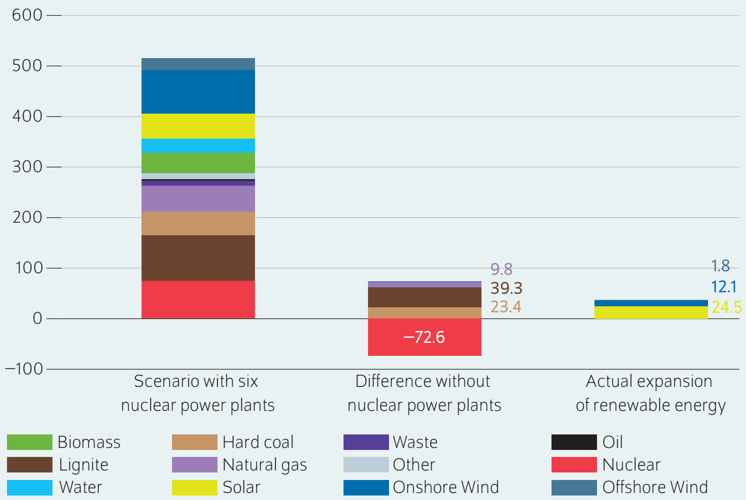
4 See, for example, Enervis Energy Advisors GmbH, *Ein Jahr Atomausstieg in Deutschland – Ein energiewirtschaftlicher Schulterblick* (2024) (in German; available online).

5 The data comes from the Core Energy Market Data Register (*Marktstammdatenregister*) of the Federal Network Agency (*Bundesnetzagentur*) (in German; available online).

6 See AG Energiebilanzen e.V., *Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2023 (in TWh) Deutschland insgesamt* (2024) (in German; available online).

Figure 2

Electricity generation in Germany in 2021 in scenarios with and without nuclear energy as well as an increase in renewable energy sources, 2021–2024
In terawatt hours



Note: The expansion of renewable energy sources (third column) is the generation that has already been compensated for from additionally constructed renewable energy plants from 2021 to 2024.

Source: Authors' calculations.

Without nuclear energy, additional electricity would have been generated from coal-fired and gas power plants, which have already been partially replaced by the expansion of renewable energy sources.

offshore wind power, which, when combined, generated an estimated 40 TWh of additional electricity in this period.[7]

Over the years, German energy policy and infrastructure have adapted to the nuclear phase-out, resulting in no price spikes even after the final reactors were shut down in April 2023.[8] The challenges of the last winters, especially the energy supply risks that were caused by the Russo-Ukrainian War, were overcome successfully and showed that Germany can maintain security of supply without nuclear energy while simultaneously driving the energy transformation forward.

Electricity price effects mainly caused by erratic nuclear power plant outages in France

While the final nuclear power plants played a small role in the German electricity sector due to their small share in the electricity mix, nuclear energy is the dominant power generation technology in France. There, nuclear power plants generated 318 TWh of electricity in 2023, which is around two thirds of total net electricity generation.[9] Nuclear energy thus plays a much more significant role in the French electricity market than in the German. More than half of France's nuclear power plants were disconnected from the grid from time to time in summer 2022 due to maintenance work, corrosion problems, and reduced river levels (Figure 3).[10]

This led to a significant increase in demand for imported electricity in France. Closing this supply gap exacerbated the already tense situation (as a result of high natural gas prices) and led to further price increases.

The electricity price in Germany over the past years shows that generation from the last German nuclear power plants only had a small overall impact on the price. More impactful were the raw material prices for fossil fuels, such as hard coal and natural gas in particular, as these power plants mostly determine the price on the day-ahead market in the hours that renewable energy sources cannot cover demand.[11] The shutdown of the final nuclear power plants in Germany on April 15, 2023, did not result in a higher electricity price. On the contrary, the price even fell in the following month as, among other things, market participants anticipated the shutdown date in good time. In the hypothetical analysis for 2021, the model calculations result in an average electricity price that is 11 euros per MWh higher without the nuclear power plants in operation, which would be a price increase of about 11 percent.[12] However, this change is low compared to the electricity price increase that was caused by higher raw material prices, especially natural gas.

In the nuclear phase-out discussion, these amounts are basically negligible compared to the total costs of nuclear energy, which have been paid for since the start of commercial use primarily by transferring risk to society at large or via subsidies. The costs of interim and final storage of radioactive waste have so far been completely neglected even though these are also significant in Germany and will increase considerably over time (Box 2).[13]

7 The data for the expansion of power generation facilities are from the Core Energy Market Data Register. The additional generation was estimated using the full load hours for the years 2021, 2022, and 2023.

8 See statements from the Vice President of the Federal Network Agency, Barbie Kornelia Haller, in the Bayerischer Rundfunk: Lorenz Storch, "Ein Monat Atomausstieg: Der Strom wurde sogar billiger," *BR24* from May 15, 2023 (in German; available online).

9 Data based on the ENTSO-E Transparency Platform (available online).

10 Cf. Mycle Schneider et al., *World Nuclear Industry Status Report 2022* (available online).

11 Day-ahead spot markets trade in short-term electricity products with a difference of up to one day between the conclusion of the contract and delivery or acceptance. For more information, see the DIW Berlin Glossary (in German; available online). As the prices are determined via the merit order, the generation price of the final power plant that is awarded the contract is the market price. For more information, see for example FtE, *Merit order shifts and their impact on the electricity price* (2022) (available online) or Andrea Gasparella et al., *The Merit Order and Price-Setting Dynamics in European Electricity Markets* (Petten: European Commission, 2024) (available online).

12 These results are consistent with other published model calculations, although these investigated other reference years and scenarios, for example Jonas Egerer et al., "Mobilisierung von Erzeugungskapazitäten auf dem deutschen Strommarkt," *Wirtschaftsdienst* 102, no. 11 (2022) (in German; available online) as well as Dimitrios Glynos and Hendrik Scharf, "Postponing Germany's Nuclear Phase-Out: A Smart Move in the European Energy Crisis?" (working paper, TU Dresden, 2024) (available online). To put this into perspective: Ten euros per MWh corresponds to around 20 percent of the electricity price in 2024.

13 Christian von Hirschhausen and Alexander Wimmers, "Rückbau von Kernkraftwerken und Entsorgung radioaktiver Abfälle in Deutschland: ordnungspolitischer Handlungsbedarf," *Perspektiven der Wirtschaftspolitik 24*, no. 3 (2023): (in German; available online).

Box 2

Nuclear energy is not an option for the energy transformation

Nuclear energy has failed to become a key pillar of the German and global energy supply. Nuclear technology was and is complex, risky and thus more expensive than other energy sources from the outset. Nuclear power plants have not been competitive since the first commercial plants were commissioned in the 1950s and this is still the case today.[1]

In addition, nuclear energy entails proliferation risks, such as misuse for weapons development. The lack of competitiveness is exacerbated if the neglected costs of dismantling the plants and disposing of radioactive waste are taken into account. This means that the minor benefits of nuclear energy are offset by considerable long-term costs that are not foreseeable from today's perspective. Debates about new reactor concepts (also known as fourth-generation reactors) do nothing to change this.[2] New reactor concepts have been discussed for more than 60 years, inspired by the dream of a plutonium economy, but cannot be implemented in large quantities and with systemic relevance in the foreseeable future.[3]

Nuclear energy is by no means experiencing a global renaissance. On the contrary, the output of nuclear power plants worldwide fell by one gigawatt in 2023, while solar power plants with an output of 440 gigawatts were constructed.[4] With the exception of China, the construction of new nuclear power plants has practically come to a standstill, and even in China the share of nuclear energy is below five percent. Only three countries that previously did not have nuclear power plants are now building new plants or having them built, as Russia provides both the technology and financing as a part of its nuclear diplomacy: Turkey, Bangladesh, and Egypt. There is no nuclear energy renaissance; rather, it is in decline around the world. Thus, nuclear energy is not a relevant option for the energy transformation in the coming decades.

1 Cf. Fritz Baade, *Welt-Energiewirtschaft: Atomenergie – Sofortprogramm oder Zukunftsplanung* (Hamburg: Rowohlt, 1958) as well as Christian von Hirschhausen, *Atomenergie: Geschichte und Zukunft einer riskanten Technologie* (Munich: 2023) (in German). A current example of the high costs of nuclear energy is the construction of the Hinkley Point C nuclear power point in the United Kingdom. See Sarah White, Jim Pickard, and Rachel Millard, "UK nuclear plant hit by new multiyear delay and could cost up to £46bn," *Financial Times*, January 23, 2024.

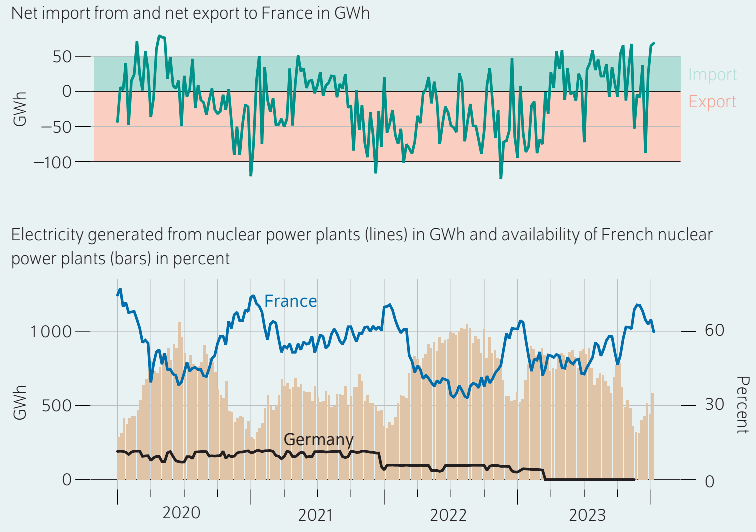
2 Christoph Pistner et al., *Analyse und Bewertung des Entwicklungsstands, der Sicherheit und des regulatorischen Rahmens für sogenannte neuartige Reaktorkonzepte* (Berlin: BASE – Forschungsberichte zur Sicherheit der nuklearen Entsorgung, 2024) (in German; available online).

3 See Christian von Hirschhausen et al., "Energy and climate scenarios paradoxically assume considerable nuclear energy growth," *DIW Weekly Report* no. 45–49 (2023): 293–301 (available online).

4 Cf. Mycle Schneider et al., *World Nuclear Industry Status Report 2023* (2024) (available online).

Figure 3

Generation from nuclear power plants and exchange of electricity between Germany and France



Source: Authors' depiction based on the European Energy Exchange and ENTSO-E Transparency Platform.

Despite the tense supply situation in Germany in 2022, France imported a large amount of German electricity because over half of their nuclear power plants were not connected to the grid.

Network stability also guaranteed

The stability of the electricity network was also guaranteed throughout the entire energy crisis. Model calculations show that no additional substantial grid bottlenecks occurred following the shutdown of the final three nuclear power plants. Currently, Germany has a sufficiently well-developed and meshed electricity grid that enables exchange with neighboring countries and contributes to security of supply. The efficient integration into the European interconnected grid makes it possible to export, and, if necessary, to import surplus electricity, which supports the grid stability and the reliability of energy supply to a considerable extent. In the past years, all shutdowns of nuclear power plants in Germany have run smoothly and occurred without major consequence.[14]

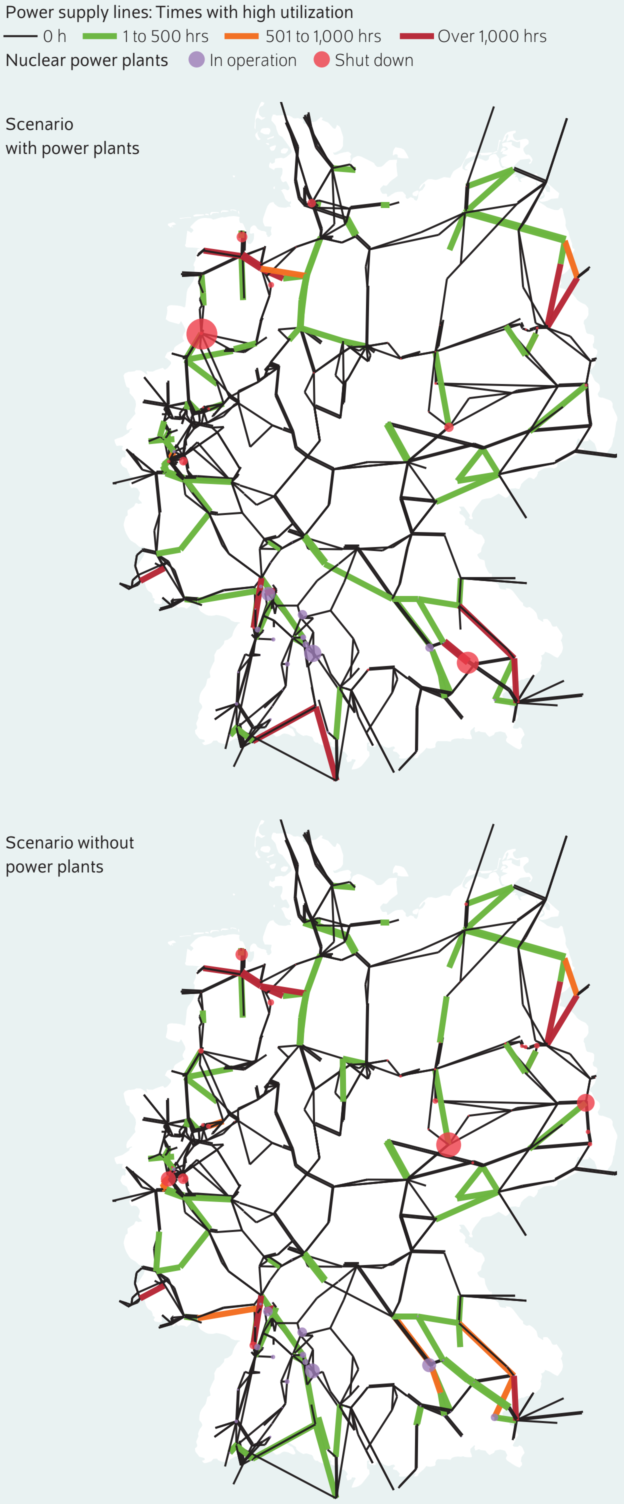
The shutdown of the last six nuclear power plants in 2023 barely changed the grid situation. The hypothetical model simulations for 2021 show that the existing grid bottlenecks would have remained largely unchanged and the adjustment measures (redispatch) would only have had to be

14 The unexpectedly quick shutdown of the six oldest nuclear power plants in March 2011 in response to the Fukushima disaster had only a minimal, short-term impact on the electricity prices and network stability. See Friedrich Kunz et al., "Security of Supply and Electricity Network Flows after a Phase-out of Germany's Nuclear Plants: Any Trouble ahead?" (working paper, European University Institute, 2011) (available online) as well as Friedrich Kunz and Hannes Weight, *Germany's Nuclear Phase Out – A Survey of the Impact since 2011 and Outlook to 2023* (2014) (available online).

Figure 4

Power supply lines in the scenarios with and without nuclear power plants for 2021

According to utilization in hours per year



Source: Authors' depiction.

Shutting down nuclear power plants only minimally changes the grid situation.

increased by around four TWh (Figure 4).[15] For comparison, there was around 21.5 TWh of redispatch in 2021 and the figure increased to 32.5 TWh and 33.1 TWh in 2022 and 2023, respectively; this corresponds to around five percent of German electricity consumption.[16] One driver of bottlenecks is very windy days in which renewable energy cannot be transported to the south sufficiently. The three nuclear power plants located in the north of Germany, Brokdorf, Emsland, and Grohnde, increase the bottleneck in such a situation.[17] German grid operators have already adjusted to largely renewable electricity generation anyway. Various options are currently being discussed for the medium-term design of grid management in a largely renewable electricity system, such as nodal or zonal pricing systems.[18] In addition, the entire sector design must be developed for a renewable electricity system.

Coal phase-out and 80 percent renewable energy are possible by 2030

To investigate the longer-term effects on the German electricity system, a scenario for 2030 is calculated in which all nuclear and coal-fired power plants have been shut down. The basic assumption for this calculation is that the German government's expansion targets for wind power (115 GW of onshore wind power, 30 GW of offshore wind power) and photovoltaic systems (215 GW) have been achieved, the installed capacity of gas-fired power plants (34.7 GW) roughly corresponds to the current level, and biomass power plants (12.8 GW) are used to cover peak loads.[19] In addition, an increase in gross electricity consumption from 525 TWh in 2023[20] to 750 TWh in 2030 is accounted for, which is mainly caused by the increase in electricity demand from electric cars and heat pumps.

The model calculations show that a coal phase-out is still possible by 2030 (Figure 5). The wind and solar energy expansion targets will result in around 80 percent of electricity demand being covered by renewable energy sources in 2030. Periods with little solar or wind generation could be compensated for with flexibility options, for example with flexible demand

15 During a redispatch, individual power plants are shut down or started up contrary to the previously agreed generation plans. For more information, see the DIW Berlin Glossary (in German; available online).

16 Bundesnetzagentur, *Netzengpassmanagement, 4. Quartal 2023* (2024) (in German; available online).

17 The costs incurred by redispatch are passed on to households through grid charges. The shutdown of nuclear power plants and the expansion of renewable energy sources led to additional redispatch and thus to a moderate increase in grid charges from 7.8 cents per kWh in 2021 to 8.08 cents per kWh in 2022 and to 9.52 cents per kWh in 2023. However, a greater price effect can be seen in the area of electricity procurement costs. In 2022, private households paid an average of 16.97 cents per kWh for the procurement and distribution of electricity, compared to an average price paid for procurement and distribution of just 7.93 cents per kWh in 2021. The figures are based on the BDEW electricity price analysis (In German; available online).

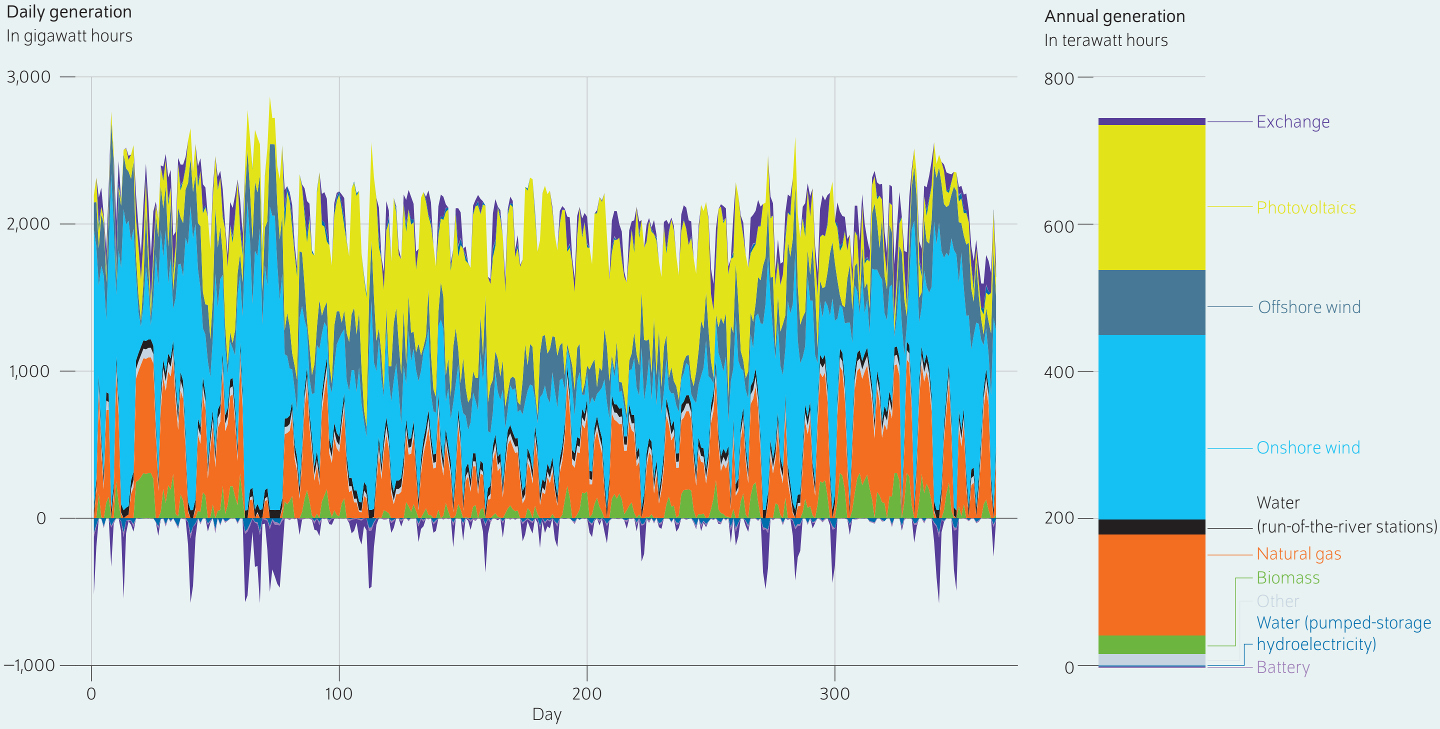
18 Friedrich Kunz, Karsten Neuhoff, and Juan Rosellón, "FTR allocations to ease transition to nodal pricing: An application to the German power system," *Energy Economics* 60 (2016): 176–185 (available online) as well as Karsten Neuhoff et al., "Renewable electric energy integration: Quantifying the value of design of markets for international transmission capacity," *Energy Economics* 40 (2013): 760–772 (available online).

19 See Bundesnetzagentur, *Versorgungssicherheit Strom* (2022) (in German; available online).

20 See AG Energiebilanzen e.V., *Stromerzeugung nach Energieträgern.*

Figure 5

Electricity generation in Germany in 2030



Source: Authors' calculations.

A coal phase-out is possible if the expansion targets for renewable energy sources are met.

in the area of heat pumps, electromobility, or industrial processes.[21] In addition, generation from pumped-storage power plants or importing electricity are further options. In 2030, natural gas power plants would still provide 18 percent of annual generation, but would have a strong negative trend.[22]

During times with lots of generation potential from solar and wind energy, surplus electricity can be exported, while electricity can be imported from neighboring countries when renewable sources are generating little electricity. This leads to an overall slight net import of nine TWh.

As a part of its power plant strategy, the German Federal Government is planning a tender for a total of ten GW of natural gas power plants, which will be financed by the Climate and Transformation Fund. The subsidized natural gas power plants should be H_2 ready and switch to hydrogen operation between 2035 and 2040.[23] However, according to the current state of the technology, switching from natural gas to complete use of hydrogen is not an easy process.[24] Therefore, there is the danger that expanding natural gas power plants could lead to further lock-in effects and delay the natural gas phase-out more.[25] From a system transformation perspective, it is therefore necessary that the power plants required for the energy transformation are designed from the outset to run purely on hydrogen.

Conclusion: With the crisis over, more focus should be on renewable energy

The German electricity market has recovered well from the crises in 2022 and its security of supply was never at risk at any time. In particular, natural gas prices had already eased by the beginning of 2023 and electricity and gas prices are

21 The additional electricity demand can be shifted by price signals to hours in which sufficient electricity is available to avoid peak loads. Buffer tanks integrated into heat pumps make typically a few hours of flexibility possible. Electric cars, independent of their consumption profile and battery size, have several hours of flexibility. In the industrial sector, electricity demand can be reduced by adjusting to high energy prices.

22 These values can vary by a few percentage points depending on the weather year used as the reference year. The weather year 2019 was selected as the reference year for the 2030 scenario.

23 Bundesregierung, *Für eine klimafreundliche und sichere Energieversorgung* (2024) (in German; available online).

24 See Joonsik Hwang, Krisha Maharjan, and HeeJin Cho, "A review of hydrogen utilization in power generation and transportation sectors: Achievements and future challenges," *International Journal of Hydrogen Energy* 48, no. 74 (2023): 28629–28648 (available online).

25 See Claudia Kemfert et al., "The expansion of natural gas infrastructure puts energy transitions at risk," *Nature Energy* 7 (2022): 582–587 (available online). See also Konstantin Löffler et al., "Modeling the low-carbon transition of the European energy system – A quantitative assessment of the stranded assets problem," *Energy Strategy Review* 26 (2019): 100422 (available online).

now at a similar level to the late 2010s. Thus, it is time for policymakers to redirect focus away from the crises and onto the expansion of renewable energy sources.

Grid stability was never at risk at any point during the energy crisis. The shutdown of the nuclear power plants did not lead to additional grid bottlenecks on any significant scale. Questions regarding sector design and network congestion management must be clarified in the transformation to a completely renewable electricity supply. Scenario analyses have shown that an electricity supply without nuclear power plants would have been possible in 2021. They also show that an electricity supply without nuclear and coal-fired power is possible in the future and that the EEG's target of generating at least 80 percent of electricity from renewables is feasible. To achieve this, however, renewable energy sources must be expanded even more and fossil fuels must be phased out in the near future. Along with the coal phase-out, the natural gas phase-out is an integral part of the energy transformation.

An electricity supply with at least 80 percent renewable energies by 2030 is possible without nuclear and coal-fired power plants; it is also cost-effective and makes sense in terms of climate policy. On the way to this renewable supply, bold steps need to be taken in sector design to create the right framework conditions.

Mario Kendziorski is a Visiting Researcher at DIW Berlin | mkendziorski@diw.de

Lukas Barner is a Visiting Researcher at DIW Berlin | lbarner@diw.de

Claudia Kemfert is Head of the Energy, Transportation, Environment Department at DIW Berlin | ckemfert@diw.de

Christian von Hirschhausen is the Research Director of the Energy, Transportation, Environment Department at DIW Berlin | chirschhausen@diw.de

Enno Wiebrow is a Student Research Assistant at TU Berlin | ewi@wip-tu-berlin.de

JEL: L51, L94, Q48

Keywords: Electricity market, renewables, coal exit, natural gas exit, nuclear power

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

21 2024

149 Report by Franziska Holz, Lukas Barner, Claudia Kemfert, and Christian von Hirschhausen

Sanctions against Russian gas would not endanger EU or German gas supply

- Model-based analysis investigates if EU countries could compensate for a disruption of Russian natural gas imports
- It would be possible to forego Russian natural gas even if EU natural gas demand remains high until 2030
- Energy savings and a timely natural gas phase-out reduce dependency on Russia and contribute to climate change mitigation

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 May 23, 2024

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 21 2024

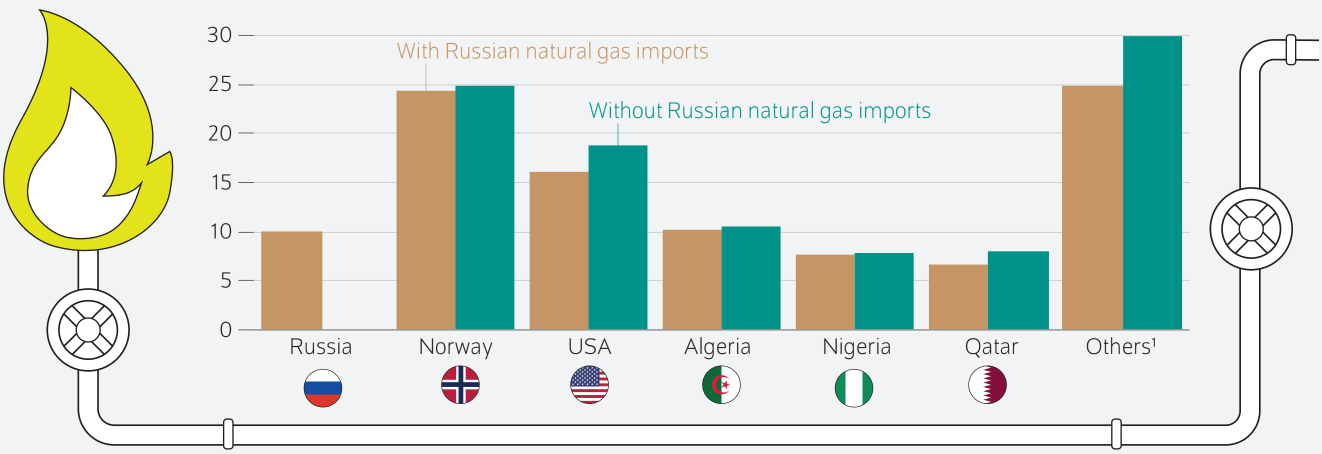
AT A GLANCE

Sanctions against Russian gas would not endanger EU or German gas supply

By Franziska Holz, Lukas Barner, Claudia Kemfert, and Christian von Hirschhausen

- Model-based analysis investigates if EU countries could compensate for a disruption of Russian natural gas imports in different demand scenarios
- It would be possible to completely forego Russian natural gas even if EU gas demand remains high in the EU until 2030
- In almost all scenarios, EU gas demand could be covered by pipeline imports from other countries and LNG without requiring infrastructure expansion
- Central and Eastern European EU countries heavily dependent on Russian natural gas could also have a secure supply without Russian imports
- Increased energy savings efforts and a timely natural gas phase-out would reduce dependency on Russia and contribute to climate change mitigation

An end to Russian natural gas imports could be compensated for by other suppliers
Share in EU imports in 2030, assuming stable natural gas demand in two model scenarios



Source: Authors' calculations.

1 Such as the Netherlands, Azerbaijan, Turkmenistan, and Egypt.

FROM THE AUTHORS

"No EU Member State needs to be concerned about its gas supply if Russian gas is sanctioned. Gas from other producers and small energy savings can compensate for the loss of Russian gas. Further expanding LNG capacities is not needed."

— Franziska Holz —

MEDIA

Audio Interview with Franziska Holz (in German)
www.diw.de/mediathek

Sanctions against Russian gas would not endanger EU or German gas supply

By Franziska Holz, Lukas Barner, Claudia Kemfert, and Christian von Hirschhausen

ABSTRACT

As a result of the Russian attack on Ukraine, natural gas prices skyrocketed in 2022 and Germany in particular felt the impact of its strong dependency on Russia. Prices have since relaxed, the European natural gas industry has overcome the uncertainty due to the energy crisis in 2022, and the industry also survived the slump in Russian natural gas imports without supply interruptions. However, Russia continues to export liquefied natural gas (LNG) to Europe and still has some countries in Central and Eastern Europe under control in terms of energy policy, which has so far prevented EU sanctions on Russian natural gas exports. Both the German and European natural gas supplies would be secure in the long term without Russian imports, as shown by model calculations using the Global Gas Model which depicts the global natural gas industry in great detail. Security of supply is, thus, not standing in the way of further EU sanctions against Russia. Increased efforts to save energy and a timely natural gas phase-out would reduce dependency on gas imports, which will also contribute to climate change mitigation.

Russian natural gas exports to the European Union have reduced drastically over the course of the Russo-Ukrainian War. As a result, there have been concerns in the EU that Russian imports could not be adequately replaced. Member States were therefore not able to agree on sanctions against Russian natural gas, unlike for coal and pipeline-based oil exports. The EU is currently considering a new push for gas sanctions against Russia that are directed against the transshipment of Russian liquefied natural gas (LNG) in European ports.

As the gas transit agreement between Russia and Ukraine will expire at the end of 2024 and the Russo-Ukrainian war is still ongoing, a complete stop of all Russian imports to the EU is conceivable. In contrast, it is less likely that international relations will recover and that the volume of Russian gas imports will increase again. Therefore, this Weekly Report uses a model to analyze the effects of various scenarios on the European natural gas supply. The analysis also considers differentiated developments regarding the global natural gas supply and demand that could occur depending on various climate policy scenarios.

A disruption of Russian natural gas imports is a scenario that has been frequently analyzed, even before the Russo-Ukrainian War.[1] Theoretically, a reduction of supplies can be compensated for in three ways. First, Russian imports could be replaced by imports from other sources; second, demand can be reduced and energy can be saved; and third, infrastructure bottlenecks can be eliminated, for example through more efficient pipeline management. These measures are reflected in the political strategies from 2022, such as in the RePowerEU package.[2]

1 Cf. for example Hella Engerer et al. "European Natural Gas Supply Secure Despite Political Crises" *DIW Economic Bulletin* no. 8 (2014) (available online; accessed May 21, 2024. This applies to all other online sources in this report unless stated otherwise); Franziska Holz et al., "European Natural Gas Infrastructure: The Role of Gazprom in European Natural Gas Supplies," *DIW Politikberatung kompakt* no. 81 (2014) (available online). The topic has been discussed ever since, cf. for example Nikita Moskalenko et al., "Europe's independence from Russian natural gas — Effects of import restrictions on energy system development," *Energy Reports* 11 (2014): 2853–2866 (available online).

2 European Commission, *REPowerEU-Plan* (2022) (available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-21-1

EU countries were able to quickly compensate for lower Russian exports in 2022

As a result of the ongoing Russo-Ukrainian War, Russia interrupted its supply of natural gas to pipelines exporting directly to Germany and Poland. Nevertheless, Russia is currently still supplying numerous EU Member States, both via Türkiye as well as via LNG and, paradoxically, via Ukraine (Box 1). For example, as of winter 2023–2024, more than 95 percent of Austria's gas imports are from Russia.[3] The ongoing dependency of Central and Eastern EU Member States on Russia is an important reason that the EU did not sanction Russian natural gas exports.

In each of the first two quarters of 2021—before the Russo-Ukrainian War began—the EU purchased over 40 billion cubic meters of natural gas from Russia, which corresponded to over 45 percent of the EU's total gas imports. In the same period in 2023, this amount was reduced to 10.5 billion cubic meters per quarter. Of that, three billion cubic meters were delivered via Ukraine and around 2.5 billion cubic meters via Türkiye. Moreover, around five billion cubic meters of Russian LNG are imported each quarter.[4]

However, the gas transit agreement between Russia and Ukraine will end on December 31, 2024. At the same time, it is unlikely that the Nord Stream and Nord Stream 2 Baltic Sea pipelines will be recommissioned in the near future due to the ongoing war and physical damage to the pipelines as a result of explosions in September 2022. Overall, this leads to the question of whether Europe would have a sufficient supply without Russian natural gas via Ukraine and Türkiye and LNG imports.

Figure 1

Development of global natural gas demand until 2050 by climate action scenario

In billion cubic meters per year

Source: Authors' calculations.

The current global natural gas demand of 3,800 billion cubic meters falls to zero by 2050 in both scenarios.

Development of European natural gas markets depending on supply and demand

This Weekly Report uses the Global Gas Model (GGM), which has been used in research and policy advice for many years (Box 2), to analyze the medium and long-term European natural gas supply. For Europe, the effects of global climate policy trends in particular are decisive for global natural gas production and demand as well as geopolitical developments related to Russia. Therefore, two global climate action scenarios on the demand side are combined with three scenarios for Russian exports on the supply side.

Scenarios for the development of EU gas demand and Russian supply limitations

The different climate policy ambitions are depicted in two exemplary scenarios. In the first scenario, which could be considered our reference scenario, global natural gas demand is reduced rapidly until 2050, as would be expected with ambitious climate policy (scenario with rapidly declining natural gas demand). In the second scenario, natural gas demand is reduced at a delayed pace until it falls to zero in 2050 (scenario with slowly declining natural gas demand). This would be conceivable if, for example, natural gas first had to compensate for the missing power generation from closing nuclear power plants. In this scenario, natural gas demand in the EU remains at a constant level until the 2030s. Simultaneously, there is a marked decline in European natural gas production. Thus, this scenario has the highest import dependency in the next years (Figure 1).[5]

3 Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, *Österreichs Energie-Infoportal* (2024) (in German; available online).

4 Cf. the data in Ben McWilliams et al, *European Natural Gas Imports* (Bruegel Datasets) (available online), which has been continuously updated since June 2022.

5 Other scenarios are conceivable, such as those in which a complete natural gas phase-out is not achieved by 2050. Two scenarios were defined that do not meet the requirements of the Paris Agreement. In the Moderate Climate Ambition scenario, global natural gas demand declines and there are moderately improved climate action ambitions in Europe. In the No Climate Ambition scenario, in contrast, there is unlimited use of natural gas without climate action. Both scenarios result in lower medium-term import demand in Europe than the scenario with slowly decreasing demand described in this Weekly Report. Cf. the data specifications of these scenarios (available online).

Box 1

The history of natural gas and geopolitics

Natural gas has been a significant part of the European energy system since the 1970s. Since then, geopolitics has played a central role in issues such as price setting and security of supply. To secure the supply of Germany and other European countries, long-term contracts have been concluded with governments, such as one with the Netherlands in the 1970s and one with Norway in the 1980s.[1] As natural gas markets became globalized through the development of LNG transport, these agreements were expanded to other continents. As of 2024, the global LNG market is dominated by American, Australian, and Qatari suppliers.

Natural gas delivered via pipeline from the Soviet Union was part of the Western European energy mix even during the Cold War. However, it has been viewed critically by the USA from the beginning.[2] While the USA's embargo threats in the 1960s still blocked rapprochement, some Western European countries and the Soviet Union concluded long-term contracts from the early 1970s onward that established the delivery and financing of pipelines by Germany in exchange for the Soviet natural gas supplies.

Up until the 1990s, the Member States of the current EU obtained Soviet natural gas almost exclusively via Ukraine. Back then, this pipeline system had a capacity of nearly 150 billion cubic meters per year, more than one third of the current natural gas consumption in the EU.[3] Following the collapse of the Soviet Union, Russia diversified its export routes, primarily to avoid geostrategic dependencies on the newly independent Ukraine.[4]

This diversification began in the 1990s with the construction of the Yamal–Europe pipeline via Belarus and Poland and continued in the late 2000s with the first Nord Stream project through the Baltic Sea.[5] Since 2011, Germany and parts of Western and Eastern Europe have been supplied via the Nord Stream pipeline, which had a capacity of 55 billion cubic meters per year.[6]

From the outset, Nord Stream 2 also served to bypass Ukraine as a transit country without being necessary for the energy sector.[7] This also became clear in the transit agreement concluded between Russia and Ukraine in 2019. This agreement prescribes the transit of only 65 billion cubic meters in 2020 and 40 billion cubic meters each year in 2021 through 2024.

Recently, Russian export possibilities to Europe were further diversified by opening up the route via Türkiye as well as by building up substantial liquefaction capacities. At the same time, the sales of pipeline gas were diversified with the construction of the first pipelines connecting to China.

1 Anne Neumann, Sophia Rüster, and Christian von Hirschhausen, "Long-Term Contracts in the Natural Gas Industry – Literature Survey and Data on 426 Contracts (1965–2014)," *DIW Data Documentation* no. 77 (2015) (available online).

2 For more on this, see Otto Wolff von Amerongen, *Der Weg nach Osten: Vierzig Jahre Brückenbau für die deutsche Wirtschaft* (Munich: Droemer Knaur, 1992): 208ff (in German).

3 However, due to a lack of pipeline maintenance and the decommissioning of individual border-crossing points, this capacity has declined in the past decades.

4 Cf. Hella Engerer und Christian von Hirschhausen, "Ukrainische Energiewirtschaft: Beschwerlicher Weg in die Eigenständigkeit," *DIW Wochenbericht* no. 17 (1996): 277–284 (in German; available online).

5 For a game theory analysis, cf. Christian von Hirschhausen, Berit Meinhart, and Ferdinand Pavel, "Transporting Russian Gas to Western Europe — A Simulation Analysis," *The Energy Journal* 26, no. 2 (2005): 49–68 (available online); as well as Franz Hubert and Svetlana Ikonnikova, "Investment Options and Bargaining Power: Investment Options and the Eurasian Supply Chain for Natural Gas," *The Journal of Industrial Economics* 59, no. 1 (2011): 85–116 (available online).

6 Engerer and von Hirschhausen, "Ukrainische Energiewirtschaft."

7 See Anne Neumann et al., "Erdgasversorgung: Weitere Ostsee-Pipeline ist überflüssig," *DIW Wochenbericht* no. 27 (2018): 589–597 (in German; available online).

Both demand scenarios are combined with different assumptions about the availability of Russian natural gas in Europe: The New Normal Scenario roughly corresponds to the current situation as of 2024, with partially available capacities via Ukraine and Türkiye as well as unlimited imports of Russian LNG. This is compared to a scenario with a complete stop of Russian imports to Europe (Sanctions Scenario) and to a scenario assuming large volumes of imports from Russia (Pre-War Scenario). The last scenario is somewhat different from the situation before 2022 because it includes the increased diversification efforts of European imports compared to the 2010s.

Russian natural gas could be replaced in the entire EU

It became clear in 2022 that Russian natural gas could be largely replaced by a combination of imports from other sources and a decline in demand. However, Central and Eastern European countries are still purchasing Russian pipeline gas and LNG. As the New Normal Scenario shows, it is possible to continue this import strategy in the short term, both with rapidly declining demand (Figure 2, top) as well as delayed declining demand (Figure 3, top). The share of Russian gas would fall to around ten to 15 percent of the European natural gas supply in the long run.

The model calculations show that completely foregoing Russian natural gas (Sanctions Scenario) would be possible for the EU and would require demand to decline only slightly. This is made possible as a result of sufficient available import capacities and ample natural gas volumes on the global market (Figure 2, center).[6] In this case, more LNG would be

6 The prices calculated in the model increase only moderately in the EU Member States (approx. ten percent). However, it must be noted that equilibrium prices are calculated, which do not include factors such as uncertainty and short-term adjustments. However, such factors caused the enormous price increase in 2022 to, at times, almost ten times the pre-war price.

imported overall, for example from the USA. Even in a scenario in which natural gas demand in the EU remains consistently high until 2030, a complete supply stop of Russian natural gas to the EU would be possible (Figure 3, center).

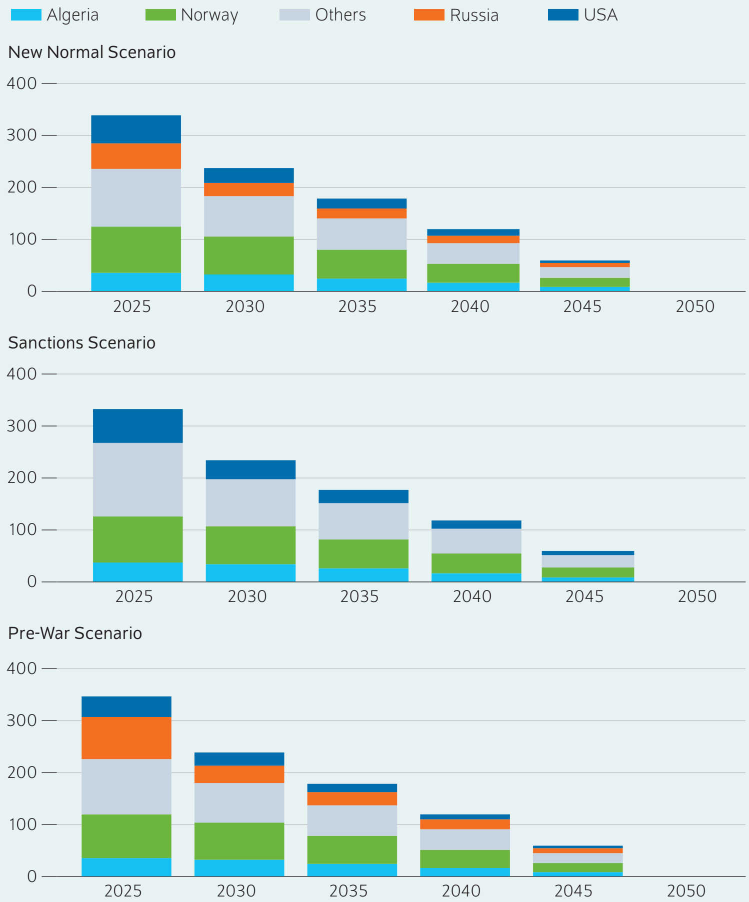
In the Pre-War Scenario, in which a greater volume of Russian imports becomes available again in the EU, Russia would export more natural gas to Europe in a scenario with initially stable and high demand (Figure 3, bottom) than in the scenario with rapidly declining demand (Figure 2, bottom). However, due to greater diversification, Russia would not be as dominant as supplier as it was before the war.

Norway became the EU's most important natural gas supplier in 2022 and will remain so in the alternative scenarios and in the next decades. The share of EU imports coming from Norway will depend on the role of Russia, especially in the coming years. In the longer term, the extent of climate action will determine the volume of Norwegian imports, which is lower in the rapid phase-out scenario compared to the scenario with a slow decline in demand. The medium and long-term natural gas strategy is controversial in Norway, as deposits north of the Arctic Circle must be exploited to maintain the current annual production capacity of over 100 billion cubic meters. Due to its proximity to the EU and privileged political relations, Norway can also supply more than 50 billion cubic meters per year to the EU in the 2030s and retain an important role until Europe phases out natural gas use completely.

Figure 2

EU-wide natural gas consumption until 2050 with rapidly declining demand

In billion cubic meters per year by country of production depending on Russian supply scenario



Source: Authors' calculations.

© DIW Berlin 2024

A complete loss of Russian imports, as in the Sanctions Scenario, could be compensated for by increasing the imports from other countries.

Current LNG import terminal construction plans are too large, even with high demand until 2030

LNG became a larger share of European imports than in previous years relatively quickly in 2022 in order to compensate for the decline in Russian natural gas. This was possible because, on the one hand, a significant amount of unused LNG import capacity was available along the European coasts. On the other hand, LNG supply and global liquefication capacities have increased since 2016, with the entry of the USA and Russia into the LNG trade being particularly significant.

Accordingly, LNG imports play a larger role in the model results than they did in the 2010s (Figure 4). In the New Normal and Sanctions Scenarios, other pipeline imports, especially from Norway, North Africa, and the Caspian Sea region, can only partially compensate for the marked decline in pipeline imports from Russa.

The share of LNG of total imports increases primarily in the scenario with a slow decline in demand that assumes continuously high consumption until the beginning of the 2030s with lower EU production. At its peak, up to 167 billion cubic meters of LNG would be imported to the EU in this scenario, which would be nearly 50 percent of total gas imports.

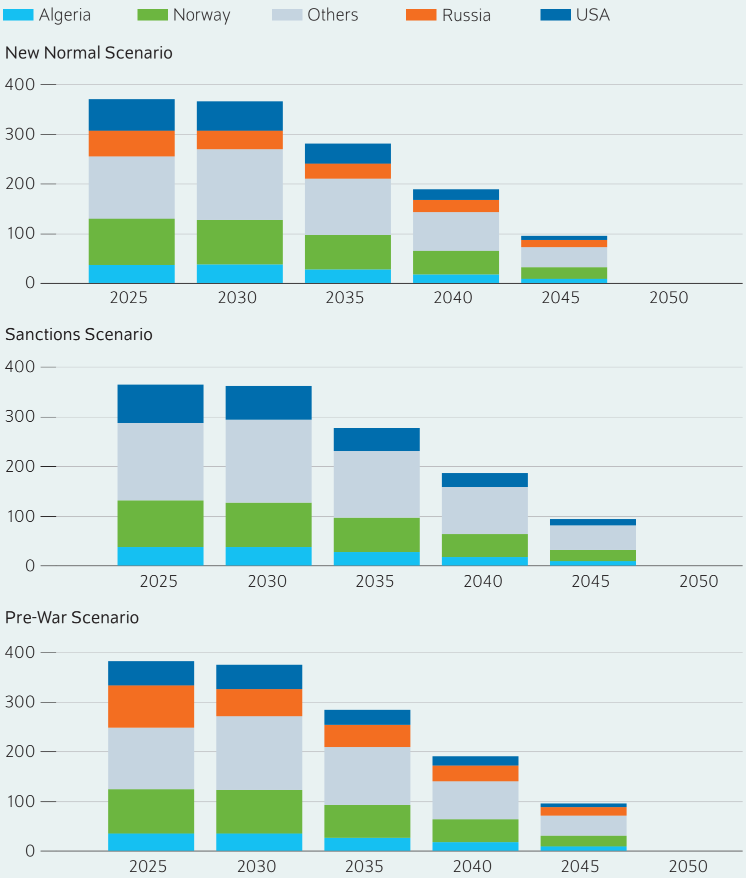
In almost all combined scenarios, however, these LNG imports could be realized without requiring the LNG terminal expansions currently being planned, which shall increase capacity in the EU to well over 200 billion cubic meters per year.[7] A small expansion of LNG import capacities, namely in Croatia and Italy, would be necessary only in the scenario with high demand and a complete end of Russian imports. The existing capacities in continental Northwestern Europe would be used with higher capacity utilization rates than they have been in past years, especially in the New Normal and Sanctions Scenarios with a low volume of imports and no imports from Russia, respectively. In the scenario where demand declines immediately, the EU would require at most 127 billion cubic meters of LNG imports if there were no Russian imports.

7 Institute for Energy Economics and Financial Analysis, *European LNG Tracker* (2024) (available online). Numbers excluding Spain and Portugal, as the LNG terminals there cannot be used for imports to the rest of the EU due to low pipeline capacities to France.

Figure 3

EU-wide natural gas consumption until 2050 with slowly declining demand

In billion cubic meters per year by country of production depending on Russian supply scenario



Source: Authors' calculations.

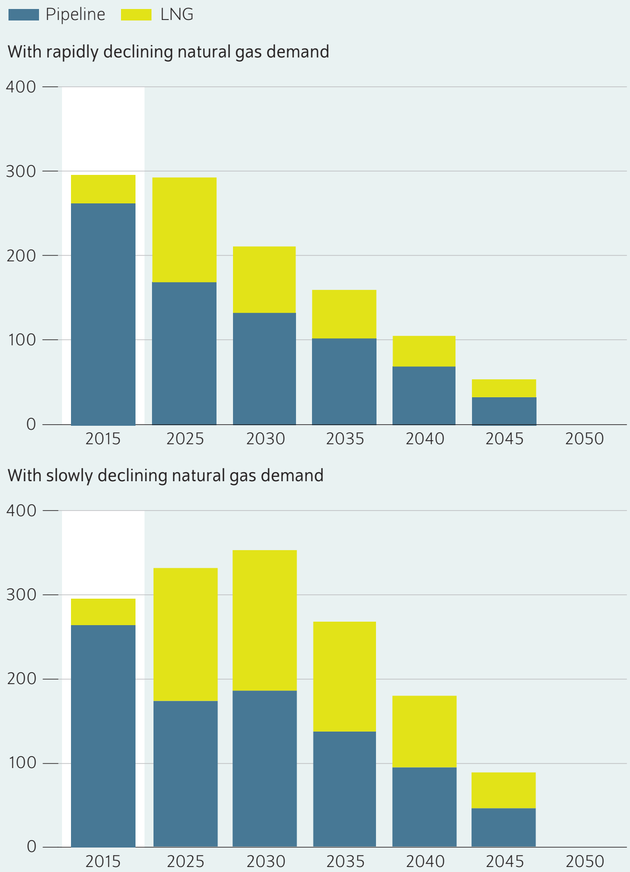
© DIW Berlin 2024

A complete disruption of imports from Russian can be compensated for, even in a scenario with high demand until 2030.

Figure 4

Pipeline and LNG imports to the EU in the Sanctions Scenario

In billion cubic meters per year depending on demand scenario



Sources: International Energy Agency (for 2015); authors' calculations.

© DIW Berlin 2024

LNG imports play a significant role, especially in the scenario with slowly declining demand.

Europe has an extensive pipeline network which enables importers in countries without LNG ports to purchase LNG from the world markets. Germany, for example, imported LNG without its own terminals via harbors in Belgium and the Netherlands. However, the large LNG import capacities of the Iberian Peninsula (Spain and Portugal, with a total of over 60 billion cubic meters of import capacity) are cut off from the rest of Europe due to limited pipeline capacities between Spain and France.[8]

Central and Eastern Europe can secure their natural gas supply without Russia

Many Central and Eastern European EU Member States, such as Hungary and Austria, continue to be heavily dependent on Russian natural gas. The model calculations show that these countries could also compensate for a complete end of Russian imports (Figure 5). LNG imports from the USA and Qatar would play a particularly important role, as would natural gas delivered via pipelines from Norway and the Caspian Sea region (for example Azerbaijan and Turkmenistan). For some countries, domestic gas production continues to be important, especially for Romania.

8 The problem of low cross-border capacity between Spain and France has been known for many years, cf. for example Engerer et al., "European Natural Gas Supply Secure Despite Political Crises." There were brief political efforts to agree on an expansion during the energy crisis in 2022, but nothing came to fruition.

Russia can increase exports to Asia, but will have to accept losses

Russia can only partially compensate for the end of its exports to Europe by redirecting natural gas exports to Asia. In the short term, the export possibilities are limited to LNG and the Power of Siberia pipeline running to China. It can be assumed that pipeline capacities can be expanded in the medium and long term.

Russian gas exports have been increasingly oriented towards Asia for some time now, regardless of the geopolitical situation.[9] This is the result of both growing demand in Asia as well as overall demand shrinking in Europe.

However, China has a lower willingness to pay than previous European importers, meaning a decline in Russia's revenue can be expected. Russia also obtains low prices (because they are set by the government) with the volumes that have shifted to the domestic market.

Efficient infrastructure utilization is a cost-effective option for improving security of supply

In addition to diversifying natural gas imports and reducing demand, more efficient use of existing natural gas infrastructure can also contribute to further easing the situation in Europe. Up until now, this infrastructure has not been used efficiently, especially in cross-border gas trade. In this case, the commercial pipeline capacities are negotiated bilaterally, meaning it may not be possible to use the entire available infrastructure.

Also within some Member States, the current congestion management scheme, the entry-exit system, prevents full infrastructure utilization and creates artificial scarcity.[10] With efficient use, in contrast, cross-operator optimization would be possible, as has long been the practice in the electricity sector in the USA.[11] Inefficient network management in the natural gas industry has been criticized since the market's liberalization in Europe in 1998, but has still not been resolved despite gradual progress.[12]

9 Franziska Holz, Philipp M. Richter, and Ruud Egging, "A Global Perspective on the Future of Natural Gas: Resources, Trade, and Climate Constraints," *Review of Environmental Economics and Policy* 9, no. 1 (2015): 85–106.

10 [10] In the entry-exit system, the gas supplier must purchase network capacity on a piecemeal basis, which can be restricted relatively freely by the individual network operators.

11 See Fred C. Schweppe et al., *Spot Pricing of Electricity* (Boston, USA: Kluwer, 1988); as well as William W. Hogan, "Contract Networks for Electric Power Transmission," *Journal of Regulatory Economics* 4, no. 3 (1992): 211–242 (available online).

12 For more on this, see Christian von Hirschhausen, "Infrastructure, Regulation, Investment and Security of Supply: A Case Study of the Restructured US Natural Gas Market," *Utilities Policy* 16, no. 1 (2008): 1–10 (available online); as well as Jeff D. Makholm, *The Political Economy of Pipelines: A Century of Comparative Institutional Development* (The University of Chicago Press, 2012).

Box 2

Global Gas Model

The Global Gas Model was developed by researchers at the Norwegian University of Science and Technology (NTNU) and DIW Berlin and has been regularly updated for over ten years.[1] The model depicts all relevant actors in the natural gas industry: natural gas producers, natural gas traders, LNG export terminals (liquefaction), LNG ships, LNG import terminals (regasification), pipeline operators, storage operators, and a final demand comprised of different sectors. Costs, capacity assumptions, and assumptions about the costs of expanding infrastructure capacities are included in the model for each actor and each country. The model distinguishes between 136 regions (nodes) that are connected to each other via pipeline or LNG transport routes. In the model calculations, both the current import and transport capacities as well as the possibility of expanding pipeline or harbor capacities are considered. Natural gas suppliers can exercise market power, especially Russia, the USA, Qatar, Iran, Saudi Arabia, and Algeria. The model calculations are performed at five-year steps until 2060. Assumptions must be made about future demand and production volumes in all countries that are needed to parameterize the demand and supply functions. For the results presented in this Weekly Report, the model data were updated and the start year was set to 2020 in order to be able to calculate investments for the first observation year (2025). Furthermore, an updated and open-source version is now available.[2]

1 Ruud Egging and Franziska Holz, "Global Gas Model: Model and Data Documentation v3.0 (2019)," *DIW Data Documentation* no. 100 (2019) (available online).

2 The model code and data are available online.

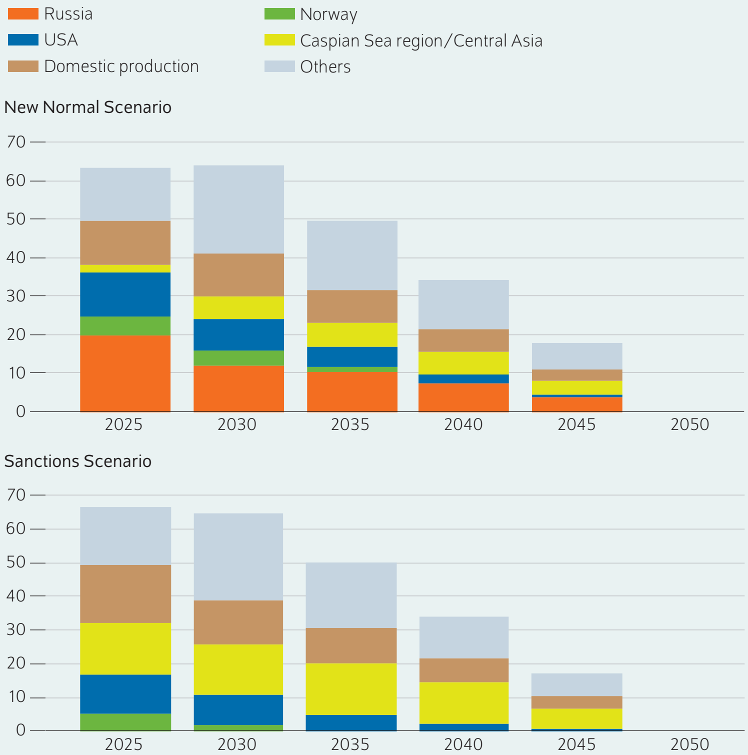
Conclusion: Natural gas phase-out is the best instrument for avoiding future import dependency

Overall, the German and European energy industries survived the loss of Russian pipeline exports without major disruptions. Energy savings efforts, diversifying suppliers, and flexible network management have offset the bottlenecks. The wholesale prices of natural gas have declined sharply since September 2022, supply disruptions have not occurred, and the "crisis" in the natural gas industry has been over since at least spring 2023.

However, the EU is still purchasing gas from Russia via pipeline and as LNG. The issue of gas sanctions against Russia is not off the table in view of the ongoing war in Ukraine. Currently, the EU is considering sanctions against Russian LNG. Thus, the European Commission wants to ban the use of European harbors for the onward shipment of Russian LNG to third countries, which is currently happening, for example in Zeebrugge (Belgium).

Figure 5

Natural gas demand in Central and Eastern European countries with slowly declining demand
In billion cubic meters per year by country of production



Note: The countries included here are Estonia, Latvia, Lithuania, Poland, Slovenia, Croatia, Austria, Hungary, Czechia, Slovakia, Bulgaria, and Romania.

Source: Authors' calculations.

Even the Eastern European EU Member States that are still very dependent on Russia could compensate for a disruption of Russian imports.

Model calculations show that the EU can maintain a sufficient supply of natural gas without Russian imports even if demand remains at today's level. In the short term, additional deliveries from Norway and LNG imports at existing import terminals are contributing to diversification. In the medium and long term, the European energy sector is heading to a natural gas phase-out. The rapid switch to renewable energy sources can significantly contribute to reducing import dependencies and, thus, the supposed risk of some European countries to be blackmailed. Hence, security of supply is no reason for the EU to not sanction Russian gas imports.

European natural gas infrastructure, such as pipelines, LNG terminals, and compressor stations, has been significantly expanded since the 2005–2006 Russia–Ukraine gas dispute and only requires minor expansion, even with moderate climate action and continued high natural gas demand. In particular, the currently planned expansion of European LNG capacities seems to be too extensive. Efficient use of existing pipeline capacities, in contrast, strengthens security of supply and keeps costs low.

Franziska Holz is Deputy Head of the Energy, Transportation, Environment Department at DIW Berlin | fholz@diw.de

Lukas Barner is a Research Associate at TU Berlin | lukas.barner@tu-berlin.de

Claudia Kemfert is Head of the Energy, Transport, Environment Department at DIW Berlin | sekretariat-evu@diw.de

Christian von Hirschhausen is Professor of Economic and Infrastructure Policy at TU Berlin | cvh@wip.tu-berlin.de

JEL: C61, L71, L95, Q34

Keywords: global gas markets, Europe, Russia, energy security

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

27 2024

179 **Report** by Sandra Bohmann, and Merve Kücük

High-income households emit more greenhouse gases, primarily due to transport behavior

- Study analyses carbon footprint of private households in Germany
- High-income households cause twice as many emissions as low-income households
- Drivers of emissions are meat consumption, household size, and in particular air travel

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 July 3rd, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Dr. Alexander Schiersch

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Petra Jasper; Adam Mark Lederer; Frederik Schulz-Greve; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 27 2024

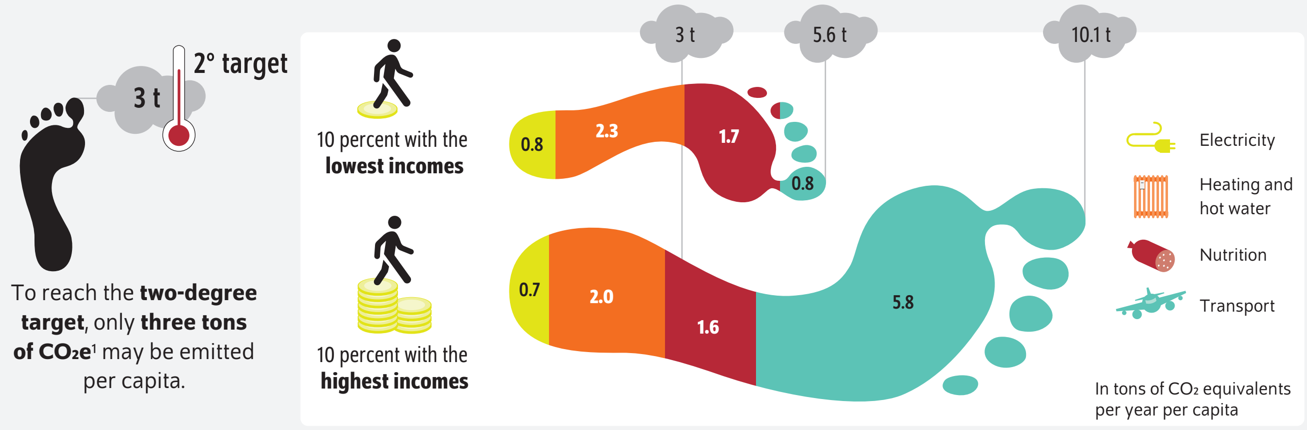
AT A GLANCE

High-income households emit more greenhouse gases, primarily due to transport behavior

By Sandra Bohmann, and Merve Kücük

- Study using 2023 SOEP data analyses the per capita carbon footprint in Germany in the areas of residential energy use, nutrition, and transport
- At 6.5 tons of carbon emissions per capita per year, emissions in these areas are twice as high as required to achieve the two-degree target
- High-income households cause twice as many emissions as low-income households
- Main drivers of emissions are meat consumption, the number of people living in a household, per capita living space, and particularly air travel
- In addition to individual efforts, politicians should set the course by introducing an animal welfare levy, a ban on short flights, and simplifying housing swaps

Regardless of income, the carbon footprint of private individuals is definitely too large



1 Emissions of greenhouse gases other than CO_2 are converted into CO_2 equivalents according to their global warming potential.
Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from the v39 wave (2022).

FROM THE AUTHORS

"Air travel in particular increases an individual's carbon footprint and is one of the main reasons why higher-income households have a carbon footprint that is twice as high as lower-income households. A single long-haul flight causes more emissions per capita than housing and food-related emissions in an entire year combined."
— Sandra Bohmann —

MEDIA

Audio Interview with Merve Kücük (in German)
www.diw.de/mediathek

High-income households emit more greenhouse gases, primarily due to transport behavior

By Sandra Bohmann, and Merve Kücük

ABSTRACT

Greenhouse gas emissions must be reduced by 65 percent compared to 1990 by 2030 to achieve national climate targets. Nearly one third of greenhouse gas emissions in Germany are caused by private household consumption. Using Socio-Economic Panel (SOEP) data, this Weekly Report calculates the amount of CO_2 equivalents emitted by households due to residential energy use, nutrition, and transport in Germany. Consumption in these three areas alone results in average emissions that exceed the emissions budget targeted for private individuals more than twofold, with transport and residential energy-related emissions accounting for the largest share of emissions. Emissions increase as income increases, especially in the area of transport, with air travel as the main driver. Meat consumption is the main contributor to nutrition-related emissions, and household size and building type contribute the most to residential energy-related emissions. By identifying the most significant driver of emissions in each of the three areas, targeted political instruments can be identified, such as simplifying housing swaps and the energy-efficient renovation of residential buildings, banning short-haul flights, and introducing an animal welfare levy.

Human emissions of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide, and methane are the main driver of climate change.[1] According to the Federal Environment Agency (*Umweltbundesamt*, UBA), around 673 million tons of greenhouse gases were emitted in Germany in 2023, ten percent less than in 2022.[2] However, the Federal Climate Change Act stipulates that emissions must be reduced by at least 65 percent compared to 1990 levels by 2030. However, as of 2022, only 40 percent of this reduction had been achieved.[3]

To reduce greenhouse gas emissions more effectively, it is important to understand their primary driver. Policymakers should consider both the reduction potential in industry as well as in private households: After all, around one third of emissions in Germany can be attributed to private household consumption.[4] This Weekly Report calculates and analyzes the average per capita residential energy consumption (housing), nutrition, and transport-related emissions in Germany using individual and household information.

The analyses are based on unpublished preliminary data from the 2023 Socio-Economic Panel (SOEP) survey.[5] We calculate per capita residential energy, nutrition, and transport-related carbon footprint[6] of private households based on respondents' information on their consumption behavior (Box). First, the carbon footprint of the entire household is calculated. In a second step, the household's total

1 To be able to compare the effects of the various climate-active gases on the climate, they are converted into CO_2 equivalents. For this purpose, emissions of greenhouse gases other than CO_2 are converted into CO_2 equivalents according to their global warming potential.

2 Umweltbundesamt, *Treibhausgasemissionen sinken deutlich* (2024) (in German; available online; accessed on June 11, 2024. This applies to all other online sources in this report).

3 Bundesregierung, *Ein Plan fürs Klima* (2024) (in German; available online); Umweltbundesamt, *Treibhausgasminderungsziele Deutschlands* (2023) (in German; available online).

4 Statistisches Bundesamt, *CO2-Emissionsintensität der deutschen Wirtschaft 2020 weiterhin rückläufig* (2022) (in German; available online).

5 The Socio-Economic Panel (SOEP) is an annual representative survey of private households. It began in West Germany in 1984 and expanded its scope to include the new federal states in 1990; cf. Jan Goebel et al., "The German Socio-Economic Panel (SOEP)," *Journal of Economics and Statistics* 239, no. 29 (2018): 345-360.

6 Carbon footprints indicate how many tons of CO_2 equivalents (tCO_2e) one person generates per year. It is a measure of one individual's impact on the climate, see the DIW Berlin Glossary on the carbon footprint (in German; available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-27-1

emissions are divided by the number of household members, including children.

Greenhouse gas emissions of private households exceed climate thresholds twofold

According to the SOEP survey data, annual per capita emissions in the three areas (residential energy consumption, nutrition, and transport) are around 6.5 tons of CO_2 equivalents (tCO_2e). Each person in Germany emits an annual average of 0.7 tCO_2e through the use of electricity in their home (Figure 1). A further 2.2 tCO_2e are due to heating and hot water preparation. Nutrition has an average impact of 1.6 tCO_2e, while 2.0 tCO_2e can be attributed to transport. Calculations using SOEP data are thus very close to the UBA's calculations, which are calculated using a different methodology.[7] The values in both calculations are significantly higher than the one to three tons that are—depending on the specific calculation—climate-compatible according to climate experts and the UBA.[8]

Greenhouse gas emissions increase with income

Our calculations confirm that households' carbon footprint increases as equivalized income rises,[9] primarily due to more transport-related emissions (Figure 2). In terms of nutrition and heating, higher-income households tend to have slightly lower per capita emissions. The following sections take a closer look at the composition of emissions in the areas of residential energy, nutrition, and transport, and explain the differences between the income groups using information on all households for which an area-specific carbon footprint was calculated.

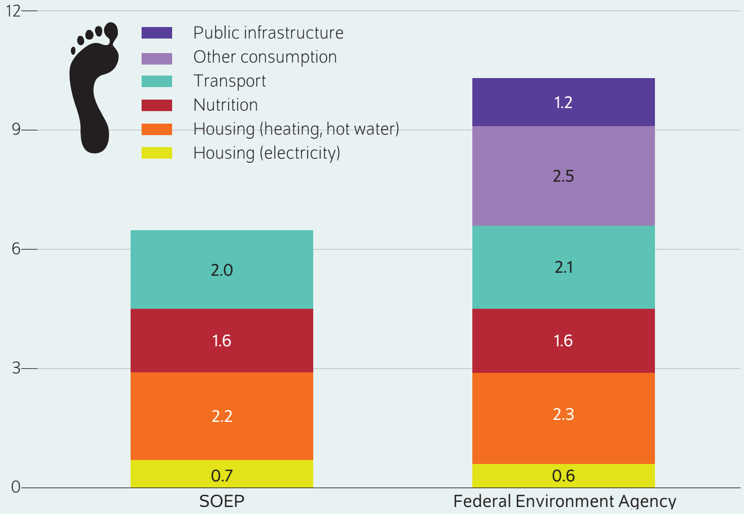
Living with others reduces CO_2 emissions

Emissions from residential use of electricity, heating, and hot water preparation are considered together below. On average, 2.9 tons of residential energy-related CO_2e are emitted per person per year. As people who live together share the use of electricity and heat, the number of people living in a household is decisive for the emissions caused per person

Figure 1

Greenhouse gas emissions in Germany per capita and year

In tons of CO_2 equivalents



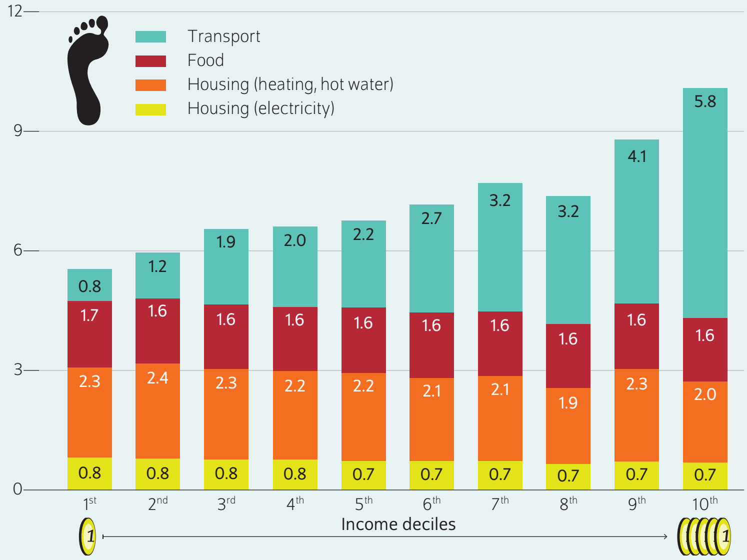
Source: Federal Environment Agency (UBA); authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

Emissions from the areas of housing, food, and transport surveyed in the SOEP cover around two thirds of the total carbon footprint.

Figure 2

Per capita carbon footprint in Germany by income decile

In tons of CO2 equivalents, annual average



Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

Higher emissions in the upper income deciles are primarily due to their transport behavior.

7 Cf. the website of the Federal Environment Agency, *Durchschnittlicher CO_2-Fußabdruck pro Kopf in Deutschland* (Stand: 2024) (in German; available online).

8 Federal Environment Agency, *Wie hoch sind die Treibhausgasemissionen pro Person?* (2024) (in German, online verfügbar). Hans Joachim Schellnhuber, a climate researcher at the Potsdam Institute for Climate Impact Research (PIK), calculated a carbon footprint of around three tons per year and per person for Germany, which would have to be achieved in order to comply with the Paris Climate Agreement—an individual CO_2 budget, so to speak, cf. Dirk Messner et al., "The Budget Approach: A Framework for a Global Transformation toward a Low-Carbon Economy," *Journal of Renewable and Sustainable Energy* 2, no. 3 (2010) (available online). How exactly this figure of three tons per year and per person was calculated is explained very well on the website of the ARD program Panorama (FAQ: *Wer verursacht wie viele Treibhausgase?*) (in German; available online).

9 The income situations of households of different sizes and compositions are made comparable using equivalized income. To calculate the equivalized income, the incomes of all persons living in the household are added together and converted using a needs scale appropriate to the household structure. For more information, see the DIW Berlin Glossary entry on equivalized income (in German; available online). For more on the carbon footprint of German households, cf. Gilang Hardadi, Alexander Buchholz, and Stefan Pauliuk, "Implications of the distribution of German household environmental footprints across income groups for integrating environmental and social policy design," *Journal of Industrial Ecology* 25, no. 1 (2021): 95–113.

Box

Data and methodology

The carbon footprint of households in Germany due to residential energy consumption, nutrition, and transport are calculated using preliminary data from 2023 from the Socio-Economic Panel (SOEP). As no weighting factors are currently available for 2023, preliminary weights from the 2022 survey are used, which take into account the households lost since the last published survey in 2021. People who first participated in the survey in 2023 are thus not included. Furthermore, all refugee samples are not taken into account. Due to these restrictions, the sample is reduced to 7,304 respondents.

The calculations are based on individual and household information taken from household and personal surveys. A similar approach is followed in each of the three areas analyzed: Information provided by respondents on how much they spend on and how much they consume of goods whose production results in greenhouse gases emissions is converted into CO_2 equivalents using the corresponding emission factors per unit of consumption. Emission factors from official sources are used, as the value chains in the individual countries differ and the use of national sources is thus the most suitable and exact for calculating emissions.[1]

Emissions from specific areas were calculated as follows: Emissions caused by energy consumption in private households are calculated via the type of resource used (electricity, gas, district heating, heating oil, solar energy, ambient heat, wood, coal, biomass, and liquefied gas) and the amount of energy used for each of the resources from the household survey that are used. Transport emissions were calculated using data on car ownership, the type of fuel used, transport expenditure, and the frequency of long and short-haul trips via bus, train, tram, and airplane. Nutrition emissions were calculated using the information provided by respondents on gender, age, weight, and frequency of meat and fish consumption.

Missing information on the type of heating is imputed logically, meaning it is assumed that a household uses the same type of heating as they did in the previous survey as long as they have not moved. Missing information on housing expenditure or consumption are not imputed. When calculating emissions relating to nutrition, we assume that the average diet profile of the adults in the household applies for the children as well. In the area of transport, the top and bottom one percent are replaced by percentile boundaries.[2]

For each of the three areas, the analyses include all households for which the area-specific information was available. This means the number of cases vary between the individual areas.

Data cleaning took place in several phases of the area-specific emission calculations. In a similar way, we confirmed that all outliers for each individual area are taken into account. These processes can lead to less pronounced differences in emissions by income.

1 Emissions factors from the Federal Office for Economic Affairs and Export Control (*Bundesamt für Wirtschaft und Ausfuhrkontrolle*) were used for electricity in the area of housing, natural gas, liquefied gas, local and district heating, coal (average value from hard coal and lignite), heating oil, biogas, liquefied petroleum gas, and wood: Bundesamt für Wirtschaft und Ausfuhrkontrolle, *Informationsblatt CO_2-Faktoren* (2022) (in German; available online). Emissions factors from the Federal Environment Agency are used for diesel and gas: Umweltbundesamt, *CO_2-Emissionsfaktoren für fossile Brennstoffe* (2022) (in German; available online).

2 To calculate the percentiles, a data set sorted by size is divided into 100 equal parts. Outliers with values larger than the 99th percentile of the sample and smaller than the bottom first percentile are replaced with limit values.

due to residential energy consumption. A four-person household generates an average of 1.5 tCO_2e per person and year, whereas a single-person household generates just under 4.0 tCO_2e per year (Figure 3).

Using a linear regression model, we investigate the correlation between various household characteristics and residential energy-related emissions per person (Table). The decisive factor is therefore the number of people in the household. In addition, the living space available per person has a significant, albeit smaller, influence on emissions: For each additional square meter of space, emissions per person rise by 0.022 tCO_2e per year. These two factors alone explain nearly half of the observed differences in residential energy-related emissions per capita. In contrast, the income available per person has no significant effect when the factors of people and space per person are taken into account.

The type and age of residential buildings also plays a role: People living in multiple-family residential buildings with more than four housing units create around half a ton fewer emissions per person than people living in detached single or two-family homes or farming infrastructure (Figure 4). In addition, the carbon footprint of people living in newer buildings is lower.[10] Calculations also show that the use of solar energy decreases the per capita carbon footprint in a household by around 0.7 tCO_2e on average.

Meat consumption affects nutrition-related emissions

Around one quarter of global greenhouse gas emissions can be attributed to food production, in particular from livestock farming, fisheries, and land use.[11] Compared to livestock

10 Cf. Sections 10 through 45 of the Buildings Energy Act (*Gesetz zur Einsparung von Energie und zur Nutzung erneuerbarer Energien zur Wärme- und Kälteerzeugung in Gebäuden*, GEG) (in German; available online).

11 Hannah Ritchie, "Food production is responsible for one-quarter of the world's greenhouse gas emissions," Our world in data (2019) (available online).

Table

Influence of household characteristics on housing-related greenhouse gas emissions

In tons of CO_2 equivalents

	Average	95-percent confidence interval	
Reference: single-person household			
Two-person household	−0.82	−0.91	−0.738
Three-person household	−1.15	−1.28	−1.02
Four-person household	−1.33	−1.49	−1.18
Five+ person household	−1.52	−1.76	−1.28
Equivalized income (in thousands of euros)	0.01	−0.004	0.02
Square meter per person	0.022	0.021	0.023
Constant[1]	2.16	2.03	2.29
Observations	4,056		

1 The constant shows the average emissions of a single-person household. Adding the estimated value of the other household sizes to the constant results in the average per capita emissions of each household size.

Note: Linear regression model. The 95 percent confidence interval means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated effect. The estimates of the influence of household characteristics are based on information from 4,056 households.

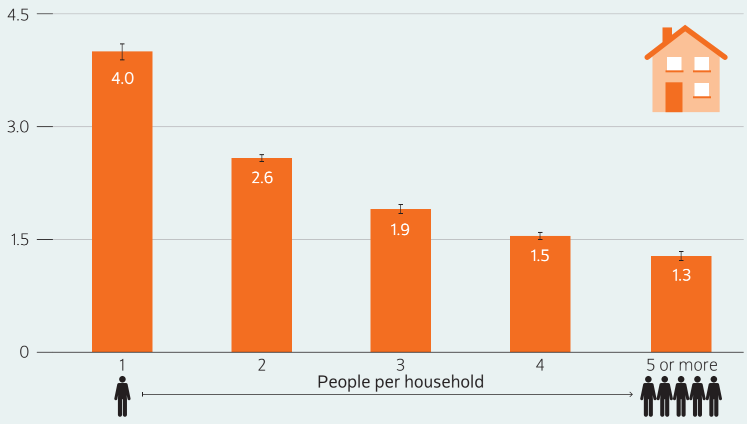
Legend: A two-person household emits 0.82 tons of CO2 equivalents less than a single-person household. Each square meter of living space leads to 0.02 tons more CO2 equivalents being emitted per year and per capita.

Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

Figure 3

Greenhouse gas emissions from residential energy consumption per person by household size

In tons of CO_2 equivalents, annual average



Notes: The height of the columns corresponds to the average per capita emissions due to heating, electricity consumption, and hot water preparation. The vertical black lines show the confidence intervals. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

People living alone cause more than twice as many greenhouse gas emissions as people in three-person households.

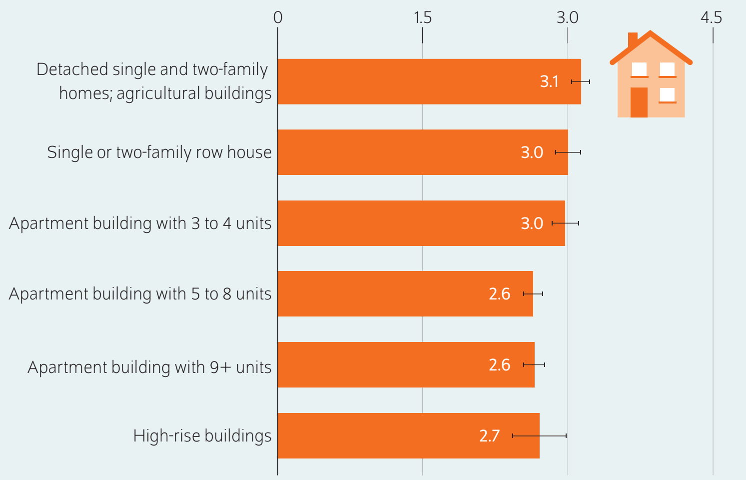
farming and animal feed production, plant-based foods have a significantly lower carbon footprint. Therefore, the frequency of animal product consumption is an important factor in individual nutrition-related emissions. Studies show that the origin of the food we eat is less important than where our food comes from, as transportation emissions are significantly lower than production-related emissions.[12]

Based on the respondents' information on their dietary preferences and weekly frequency of beef, pork, poultry, and fish consumption, nutrition-related emissions are calculated in combination with gender and age as indicators for the respondents' necessary caloric intake.[13] The diet profiles are assigned to five categories in accordance with the UBA's CO_2 calculator: vegan, vegetarian, low-meat, a mix of meat and plant-based foods, and high-meat diet. A low-meat diet corresponds to average meat consumption of 50 grams per day, while a balanced meat and plant-based foods diet and a meat-heavy diet refer to daily meat consumption of 165 grams

Figure 4

Greenhouse gas emissions per person due to heating and electricity consumption by building type

In tons of CO_2 equivalents, annual average



Note: The horizontal black lines show the confidence intervals. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

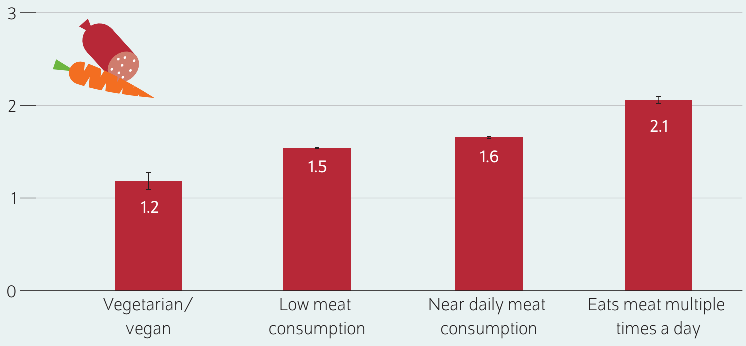
People living in detached or semi-detached homes have a larger housing-related carbon footprint than people living in buildings with multiple residential units.

12 Christopher L. Weber and H. Scott Matthews, "Food-miles and the relative climate impacts of food choices in the United States," *Environmental Science & Technology* 42, no. 10 (2008): 3508–3513 (available online); Hannah Ritchie, "You want to reduce the carbon footprint of your food? Focus on what you eat, not whether your food is local," Our world in data (2020) (available online).

13 Age and gender-specific average weights are used to estimate the calorie requirements of the household members, cf. Statista, *Mittelwerte von Körpergröße, -gewicht und BMI bei Männern in Deutschland nach Altersgruppe im Jahr 2021* (2021) (in German; available online); Statista, *Mittelwerte von Körpergröße, -gewicht und BMI bei Frauen in Deutschland nach Altersgruppe im Jahr 2021* (2021) (in German; available online); Robert Koch Institut, *Körpermaße bei Kindern und Jugendlichen in Deutschland* (2007) (in German; available online).

Figure 5

Food-related greenhouse gas emissions per capita by diet
In tons of CO_2 equivalents, annual average



Note: The vertical black lines show the confidence intervals. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated average.

Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

Vegans and vegetarians have the smallest food-related carbon footprint.

and 290 grams, respectively.[14] According to the statistics by the Federal Office for Agriculture and Food (*Bundesanstalt für Landwirtschaft und Ernährung*, BLE), a declining trend in average meat consumption has been observed in recent years.[15] In 2023, the largest decline was observed in beef consumption, which is particularly harmful to the climate.[16]

One percent of SOEP respondents indicate they follow a vegan diet, while 12 percent report following a vegetarian diet.[17] A high number of the latter nonetheless report eating meat or fish occasionally (less than once a month and less than two to three times a week, respectively). The large majority of the German population follows a low-meat diet (47 percent) or a diet with a mix of meat and plant-based foods (42 percent). Around one in ten respondents reports to eating meat products several times a day.

Per capita (including children), the average nutrition-related emissions in Germany are 1.6 tCO_2e. A vegetarian diet results in an average of only 1.2 tCO_2e per year (Figure 5). People who eat meat less than once a week emit around 1.5 tCO_2e on average per year, while people who eat meat multiple times a day emit around 2.1 tCO_2e per year.

One intercontinental flight emits more CO_2 than one year of residential energy and nutrition-related emissions

Transport-related emissions are calculated using household information on car ownership, the fuel type used, use of public transport (short-distance commuting with all public transport types as well as long-distance commuting with trains and buses) as well as the number of domestic, European, and intercontinental flights and cruises taken.

On average, the per capita transport-related emissions are around 2.0 tCO_2e per year, about half of which come from car trips. The greatest share of transport-related emissions is due to flights. Emissions from car trips average 1.0 tCO_2e per capita. An average round-trip flight within Germany causes 0.24 tCO_2e; for the same amount, a person could travel 8,000 kilometers by train.

According to the UBA, a domestic or European round-trip flight emits 0.2 or 0.5 tCO_2e, respectively, while an intercontinental round-trip flight emits 4.7 tCO_2e.[18] Therefore, there are major differences in transport-related emissions per person depending on if and where they fly. While each person in Germany only flies once a year on average, frequent fliers fly ten or more times per year. People who do not fly at all have a transport-related carbon footprint of around 1.0 tCO_2e (Figure 6), while people who take flights within Europe emit around 2.3 tCO_2e per year according to the calculations. For people who have taken one or more intercontinental round-trip flights, their transport-related emissions are 9.3 tCO_2e on average.

People in the highest income decile (the ten percent with the highest household incomes) emit seven times as much CO_2e as people in the lowest income decile in the area of transport (Figure 7). Emissions from car trips vary between 0.3 tCO_2e for people in the lowest income decile and 1.4 tCO_2e for people in the higher income deciles. At 4.1 tCO_2e, flight-related emissions in the highest income decile are around ten times higher than in the lowest income decile at 0.4 tCO_2e. The frequency at which individuals in the highest income decile fly intercontinentally results in their emissions being 40 percent higher than the emissions of the ninth income decile.

Conclusion: Greatest emissions inequality is in transport

Calculating the greenhouse gas emissions of German households that can be attributed to residential energy consumption, nutrition, and transport showed that there are clear main drivers in each area: For residential energy, it is

14 This description is based on the definitions from the UBA, cf. Umweltbundesamt, *Mein CO_2-Schnellcheck* (in German; available online). The SOEP survey asked about the frequency of meat consumption per week or month. The data was converted into grams for this evaluation.

15 Bundesanstalt für Landwirtschaft und Ernährung, "Pro-Kopf-Verzehr von Fleisch sinkt auf unter 52 Kilogramm," press release from April 4, 2024 (in German; available online).

16 Different types of meat differ in their emissions intensitiy: the production of beef causes more than twice as many emissions per kilogram as lamb and more than six times the emissions of poultry meat, cf. Statista, *Ökologischer Fußabdruck von Fleisch, Fisch und Fleischalternativen in Deutschland im Jahr 2019* (2020) (in German; (available online).

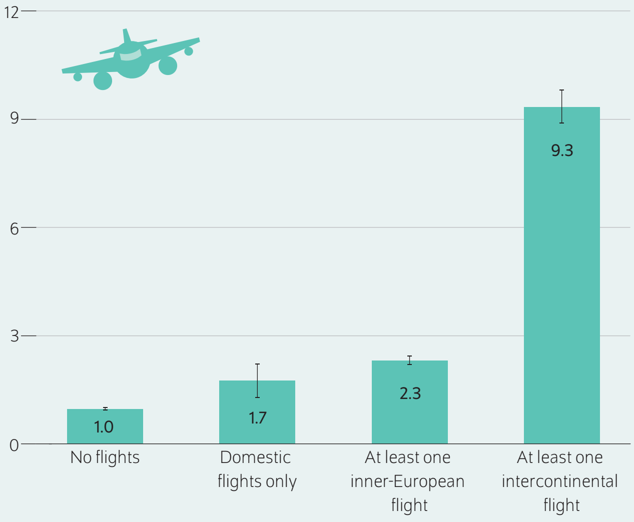
17 Other representative studies come to similar results, cf. Forsa, *Ernährungsreport 2023. Ergebnisse einer repräsentativen Bevölkerungsbefragung* (2023) (in German; available online). Thus, the share of vegans and vegetarians in Germany is around two and eight percent, respectively.

18 Umweltbundesamt, *Flugreisen möglichst vermeiden und Alternativen nutzen* (2022) (in German; available online).

Figure 6

Transport-related greenhouse gas emissions per capita by air travel behavior

In tons of CO_2 equivalents, annual average



Note: The vertical black lines show the confidence interval. This means that the unknown actual value is within this interval in 95 percent of cases. Therefore, the probability of error is five percent. The narrower the interval, the more accurate the estimated effect.

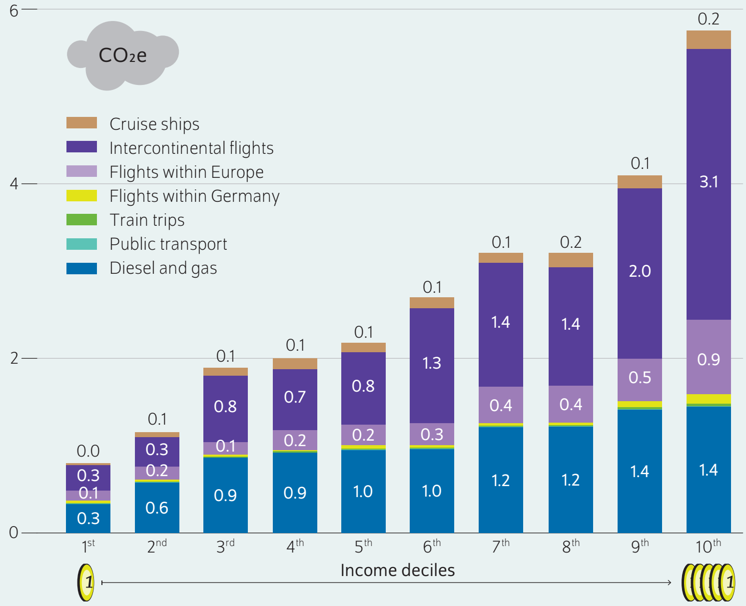
Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

People who take intercontinental flights cause nearly ten times as many emissions as people who do not fly.

Figure 7

Transport-related greenhouse gas emissions per capita by income decile

In tons of CO_2 equivalents, annual average



Source: Authors' calculations using preliminary data from the 2023 SOEP survey (v40), weighted with preliminary weights from wave v39 (2022).

The highest-income group causes seven times as many greenhouse gas emissions through their transport behavior as the poorest ten percent.

primarily the number of people living in a household that is crucial for the individual carbon footprint. Frequent meat consumption is the main driver of nutrition-related greenhouse gas emissions and flying is the main contributor to transport-related emissions. While the income-related differences are small and higher income groups tend to have lower per capita emissions in the areas of residential energy consumption and nutrition, people from higher-income households cause significantly more emissions than people from lower-income households in the area of transport.

To achieve the goal of carbon neutrality by 2045 as laid out in the Federal Climate Change Act, massive individual as well as political efforts are required: Policymakers must implement and support measures that increase energy efficiency in residential energy consumption, promote environmentally-friendly eating habits, and expand sustainable transport options while reducing the emissions-intensive options. In addition to promoting climate-friendly technologies, their research, and piloting, as well as the economic incentives and accompanying social compensation measures, regulation-based policy instruments also are needed in the transition to a low-carbon economy.

The analyses in this Weekly Report point to a number of policy measures that foster the ecological transition while taking social justice into account. For example, a thermal insulation strategy for the most inefficient buildings could result in the most emissions savings and make low-income households less vulnerable from energy price fluctuations.[19] In addition, using existing housing more efficiently could create major savings in the building sector. One instrument to achieve this would be to simplify housing swaps, as was discussed in the *Bundestag* in 2023 and as has been enshrined in Austrian tenancy law since 1982.[20] This would not only combat the housing shortage, but also reduce greenhouse gas emissions due to residential energy consumption.

Reducing the number of flights offers the greatest potential for reducing transport-related emissions. The air traffic tax increase effective May 1, 2024, which, if passed on in full to customers, will increase the price of short-haul flight tickets by 15 euros and long-haul tickets by 70 euros, is likely to only have a minor impact on flight demand, especially among the higher income groups that fly more frequently. The French ban on domestic flights over distances that can be reached in 2.5 hours by train, which was implemented at the beginning of 2023 using an environmental protection

19 Sophie Behr et al., "Thermal retrofitting of worst performing buildings mitigates risk of high heating costs," *DIW Weekly Report*, no. 19/20 (2024) (available online).

20 Jusline, *Gesamte Rechtsvorschriften MRG* (2021) (in German; available online).

clause in European law, [21] goes much further in this respect and also provides positive incentives for the expansion of rail transport.[22] Although short-haul flights only make up a small share of flight-related emissions, they are particularly damaging, as the most greenhouse gases are emitted during takeoff and landing.[23] From a climate policy perspective, it would be even more important to limit the number of long-haul flights via international agreements.

Policy measures aimed at changing eating habits can be viewed skeptically by the public, as cultural habits play an important role in dietary choices. However, according to studies, reducing heavy meat consumption is beneficial to the both climate and our health.[24] The animal welfare levy that was endorsed by the *Bundesrat* as well as farmers' associations at the beginning of 2024 would be a step in the right direction.[25] Studies show that quite high approval rates (50 to 70 percent) can be achieved with lower price increases of around 19 cents per kilogram of meat, especially when the increases are linked to animal welfare.[26] Possible slight regressive effects could at least be mitigated by lowering the value-added tax on plant-based foods.[27] Overall, a variety of different measures will be required to reduce the amount of greenhouse gases produced by private households.

21 Cf. Article 20 of EU Regulation no. 1008/2008 (available online).

22 Zentrum für Europäischen Verbraucherschutz e.V., *Frankreich verbietet kurze Inlandsflüge* (2023) (in German; available online). Studies show that emissions can be reduced by 95 percent without sacrificing travel time by replacing short-haul flights of up to 400 km with rail travel. The introduction of bans on short-haul flight also reduces the time that a newly built high-speed rail line has to be operated before the greenhouse gas emissions generated during construction are amortized from sixty to ten years. Cf. Anne de Bortoli and Adélaïde Féraille, "Banning short-haul flights and investing in high-speed railways for a sustainable future?" *Transportation Research Part D: Transport and Environment*, vol. 128, (2024) (available online).

23 D.M.M.s. Dissanayaka, Varuna Adikariwattage, and H.R. Pasindu, "Evaluation of CO_2 Emission at Airports from Aircraft Operations within the Landing and Take-Off Cycle," *Transportation Research Record* (2020): 444–456; Paola Di Mascio et al., "Optimization of Aircraft Taxiing Strategies to Reduce the Impacts of Landing and Take-Off Cycle at Airports," *Sustainability* 14, no. 15 (2022): 9692 (available online).

24 Wenming Shi et al., "Red meat consumption, cardiovascular diseases, and diabetes: a systematic review and meta-analysis," *European Heart Journal* 44, no. 28 (2023): 2626–2635; Huifeng Zhang et al., "Meat consumption and risk of incident dementia: Cohort study of 493888 UK Biobank participants," *The American Journal of Clinical Nutrition* 114, no. 1 (2021): 175–184; Tian-Shin Yeh, Deborah Blacker, and Alberto Ascherio, "To meat or not to meat? Processed meat and risk of dementia," *The American Journal of Clinical Nutrition* 114, no. 1 (2021): 7–8.

25 Bundesrat, *Drucksache 105/21* (2021) (in German; available online).

26 Grischa Perino and Henrike Schwickert, "Animal Welfare Is a Stronger Determinant of Public Support for Meat Taxation than Climate Change Mitigation in Germany," *Nature Food* 4, no. 2 (2023): 160–169 (available online).

27 David Klenert, Franziska Funke, and Mattia Cai, "Meat Taxes in Europe Can Be Designed to Avoid Overburdening Low-Income Consumers," *Nature Food* 4, no. 10 (2023): 894–901 (available online).

Sandra Bohmann is a Research Associate in the Socio-Economic Panel (SOEP) Research Infrastructure at DIW Berlin | sbohmann@diw.de

Merve Kücük is a Research Associate in the Climate Policy Department at DIW Berlin | mkucuk@diw.de

JEL: Q51, Q58

Keywords: greenhouse gas emissions, consumption behavior, emissions

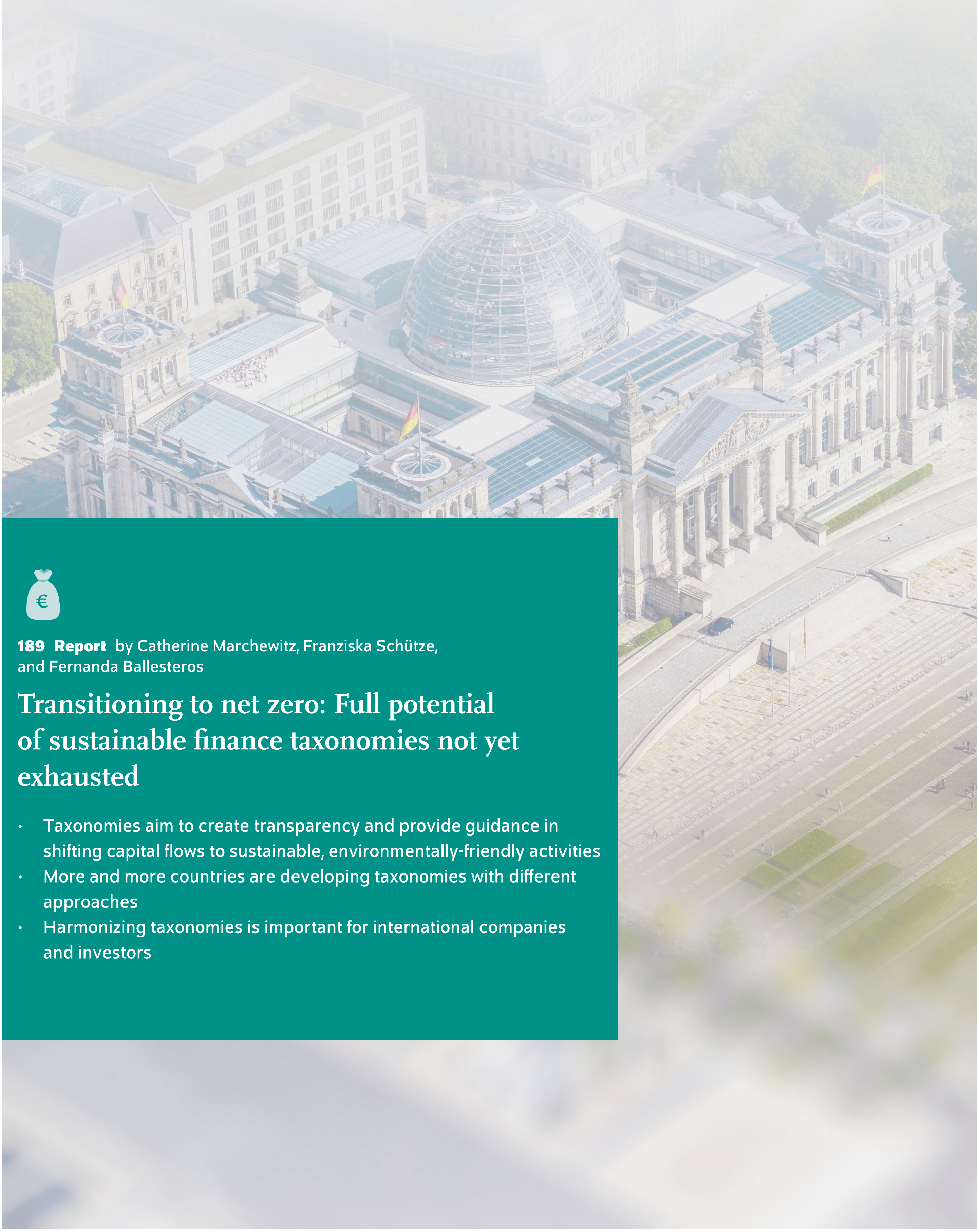
DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

28 2024



189 Report by Catherine Marchewitz, Franziska Schütze, and Fernanda Ballesteros

Transitioning to net zero: Full potential of sustainable finance taxonomies not yet exhausted

- Taxonomies aim to create transparency and provide guidance in shifting capital flows to sustainable, environmentally-friendly activities
- More and more countries are developing taxonomies with different approaches
- Harmonizing taxonomies is important for international companies and investors

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 July 10, 2024

ISSN 2568-7697

DIW Weekly Report 28 2024

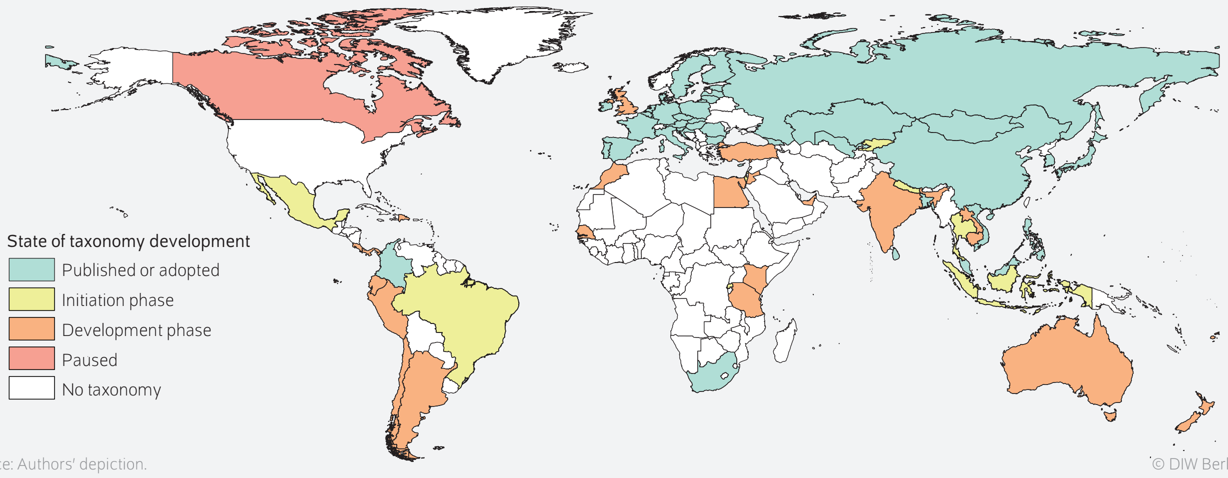
AT A GLANCE

Transitioning to net zero: Full potential of sustainable finance taxonomies not yet exhausted

By Catherine Marchewitz, Franziska Schütze, and Fernanda Ballesteros

- Taxonomies should create transparency and provide guidance in shifting capital flows to sustainable, environmentally-friendly activities
- More and more countries are developing taxonomies with different approaches
- Harmonizing taxonomies is important for companies and investors operating internationally
- Taxonomies should apply to all relevant market participants and include mandatory reporting requirements
- Selection criteria for sustainable activities should be in accordance with international climate targets

More and more countries worldwide are implementing taxonomies to shift capital flows to sustainable economic activities



Source: Authors' depiction.

FROM THE AUTHORS

"Taxonomies are crucial for defining sustainable activities and therefore for financing the transition to climate neutrality. To increase their effectiveness and to avoid carbon leakage, taxonomies should be harmonized at the international level."

— Catherine Marchewitz —

MEDIA

Audio Interview with Catherine Marchewitz (in German)
www.diw.de/mediathek

Transitioning to net zero: Full potential of sustainable finance taxonomies not yet exhausted

By Catherine Marchewitz, Franziska Schütze, and Fernanda Ballesteros

ABSTRACT

Sustainable finance taxonomies such as the European Union (EU) taxonomy can support the transition to a climate-neutral economy. As a classification system, these taxonomies serve to offer transparency and guidance as to how capital flows can be shifted to sustainable and environmentally-friendly activities. In this Weekly Report, we analyze 26 sustainable taxonomies from countries and regions around the world using five criteria. Our study shows that although many taxonomies follow a holistic sustainability approach, mandatory criteria have often yet to be developed. The share of a country or region's emissions that is covered by the taxonomy varies considerably, as the taxonomies follow different approaches for determining the activities that are aligned with them. Taxonomies often only apply to a limited group of market participants and are rarely linked to mandatory reporting obligations. The results emphasize that better coordination between the existing taxonomies worldwide is needed and that the criteria and thresholds for selecting activities in alignment with taxonomies should be in accordance with the Paris Agreement. This way, taxonomies can develop their full potential in guiding the transition.

The EU aims to become climate neutral by 2050 as announced in the 2019 Green Deal.[1] A classification system for sustainable economic activities, known as the EU taxonomy for sustainable activities, plays a crucial role in this transition. The taxonomy defines which activities are classified as sustainable for each economic sector.[2] The EU Sustainable Finance Action Plan links the EU taxonomy to further disclosure requirements. For example, large capital market-oriented companies[3] in the EU have been required to disclose the share of their activities that are aligned with the taxonomy since the 2022 business year, and other companies will gradually follow.[4] Banks must also disclose their share of activities aligned with the taxonomy, known as the green asset ratio.[5] Financial providers that advertise products with environmental features must report their taxonomy alignment.[6]

This classification system is primarily an instrument for providing information and should increase transparency for private consumers as well as institutional financial market actors so that they can invest their capital more sustainably. This should also enable them to better assess the risk of stranded assets[7] and take these findings into account when allocating their investments.

1 In Europe alone, investments of up to 350 billion euros per year in low-carbon infrastructure, such as renewable energy plants or electricity grids and storage facilities, will be required by 2030. Cf. Lena Klaaßen und Bjarne Steffen, "Meta-analysis on necessary investment shifts to reach net zero pathways in Europe," *Nature Climate Change* 13 (2023): 58–66 (available online; accessed on July 1, 2024. This applies to all other online sources in this report unless stated otherwise).

2 Franziska Schütze et al., "EU taxonomy is increasing the transparency of sustainable investments," *DIW Weekly Report* no. 51 (2020) (available online).

3 The first step will affect all companies that are already required to report under the Non-financial Reporting Directive (NFRD). This includes capital market-oriented companies with more than 500 employees.

4 As a part of the Corporate Sustainability Reporting Directive (CSRD EU Regulation 2022/2464 (available online)), the group of companies obligated to report will expand by non-capital market-oriented companies with over 250 employees or sales revenue greater than 50 million euros or a balance sheet total of over 24 million euros.

5 In accordance with Article 8 of the EU Taxonomy Regulation, cf. European Union, *Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088* (2020) (available online).

6 As part of the Sustainable Finance Disclosure Regulation (SFDR), see European Commission, *Sustainability-related disclosure in the financial services sector* (2024) (available online).

7 Stranded assets are investments or assets that can no longer be used and which thus become unprofitable. For example, investments in a coal-fired power plant that can no longer be operated due to climate policy measures can massively lose value.

DOI: https://doi.org/10.18723/diw_dwr:2024-28-1

Box 1

Taxonomy development and terminology

A sustainable finance taxonomy[1] (referred to here as a "taxonomy") classifies sustainable activities and investments. The emergence of such taxonomies in various countries, regions, and international organizations was driven in particular by the Paris Agreement and the UN Sustainable Development Goals. However, the names of the taxonomies vary, including the words "sustainable," "green," "climate," "transition," and "social" in their titles, indicating different types of taxonomies. Sustainable taxonomies are by definition the most comprehensive, as the term "sustainable" has an ecological, economic, and social dimension.[2] Thus, a green taxonomy focuses on pure green activities or those that positively contribute to the environmental goals covered by the taxonomy. However, the granularity, scope, criteria, and environmental objectives of the taxonomies can differ broadly. Social taxonomies focus mainly on the positive contribution to social objectives, such as decent work and adequate living standards.[3] In contrast, transition taxonomies take a more dynamic approach, as they identify activities that are not currently in accordance with the Paris Agreement and have a lack of suitable "green" alternatives. If a taxonomy exclusively promotes green activities, it excludes important parts of the economy that still need to be transformed. A green or sustainable taxonomy can also contain elements of transition activities.

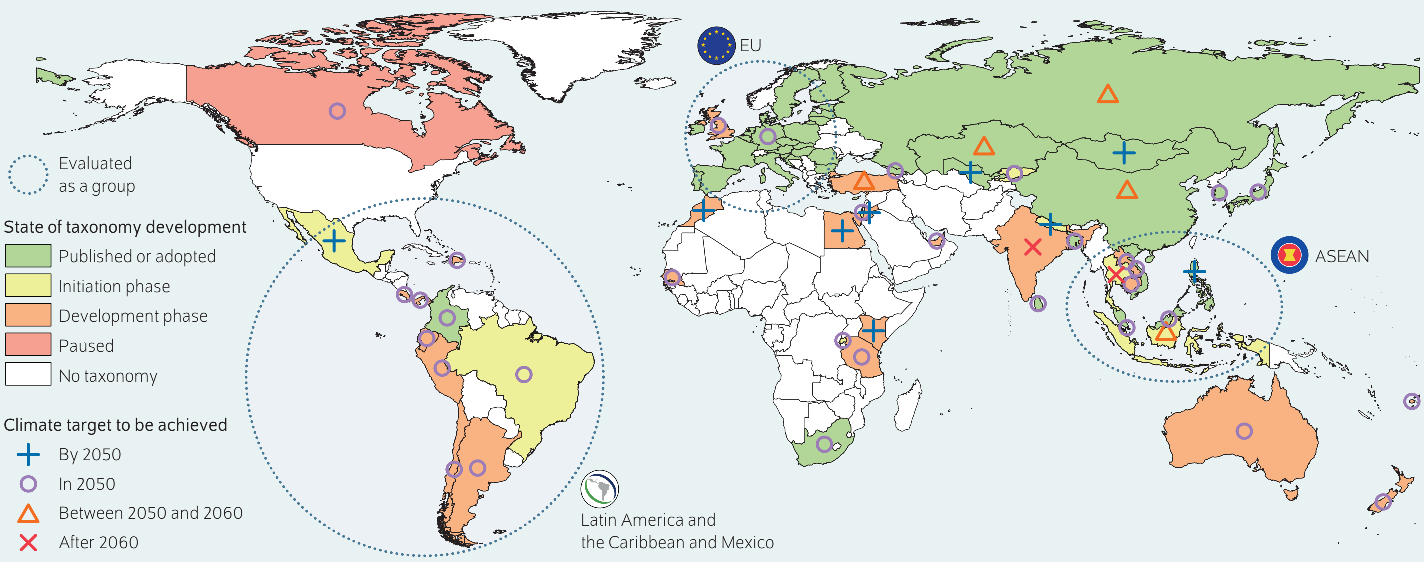
1 In this Weekly Report, we use the general term "sustainable finance taxonomy" unless the taxonomy is classified specifically as a green finance taxonomy.

2 Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, *Nachhaltigkeit* (in German; available online).

3 EU Platform on Sustainable Finance, *Report on Social Taxonomy. Platform on Sustainable Finance* (2022) (available online).

Figure 1

State of sustainable finance taxonomy development worldwide



Note: For classification purposes, the figure also shows the year by which each country aims to become climate neutral.

Sources: Authors' depiction (state of taxonomy development), net zero tracker (climate targets).

As of the end of 2023, over 50 countries and regions have introduced their own taxonomies or have begun developing one.

Figure 2

Potential contribution of the taxonomies to the net-zero transition

Taxonomies	Policy embeddedness	Sectoral coverage	Screening approach	Target group	Reporting and disclosure	Overall score
ASEAN[1]	4	4	4	2	2	3.2
Bangladesh	4	3	2	2	3	2.8
Brazil*	4	4	2	2	2	2.8
China	3	4	2	2	3	2.8
Columbia	4	4	4	2	1	3
EU	4	4	3	4	3	3.6
Georgia	4	3	3	2	3	3
Hong Kong*	4	2	4	2	2	2.8
Indonesia*	4	3	2	2	2	2.6
Israel*	3	3	3	2	1	2.4
Japan	3	3	4	2	2	2.8
Kazakhstan	4	3	2	2	2	2,6
LAC[2]	4	4	1	2	2	2.6
Malaysia	4	3	1	2	2	2.4
Mexico*	4	3	3	2	2	2.8
Mongolia	4	4	2	2	1	2.6
Philippines	4	4	2	2	2	2.8
Russia	3	3	2	2	2	2.4
Rwanda*	3	3	3	2	2	2.6
Singapore*	4	4	4	2	2	3.2
South Africa	3	2	2	2	2	2.2
South Korea	4	4	3	2	2	3
Sri Lanka	4	3	4	2	2	3
Thailand*	4	2	4	2	2	2.8
Uzbekistan	2	2	2	3	1	2
Vietnam	3	3	3	3	2	2.8
Average	3.7	3.2	2.7	2.2	2	2.8

Potential contribution to transition
No Little Moderate High

1 Association of Southeast Asian Nations
2 Latin America and the Caribbean

Note: * Frameworks are still in the development phase. The assessment can therefore not be regarded as final. The cut-off date for the information considered in the analysis is 12/31/2023.

Source: Authors' depiction.

The 26 taxonomies were analyzed using five criteria. The higher the score, the higher the transition potential.

Box 2

Criteria for estimating the transition potential of taxonomies

The transition to climate neutrality is different in every country due to individual circumstances. A "transition score" (TS) has been developed as an objective scoring system to enable a comparable assessment of transformation potential. This score consists of five criteria that summarize the data on the taxonomies in a structured manner:[1] policy embeddedness, sectoral coverage, screening approach, target group, and reporting and disclosure (Table 1).

There are four stages of fulfillment for each criterion with assigned scores, here indicated in brackets:[2] no contribution [1], little contribution [2]; moderate contribution [3]; or high contribution [4].

Table 1

Analysis criteria for measuring a taxonomy's potential contribution to the economic transition

Criterion	Definition
Policy embeddedness	This criterion captures whether a taxonomy refers to the climate targets in international frameworks such as the Paris Agreement and the SDGs as well as national or regional climate targets. It also assesses whether it includes more comprehensive sustainability goals
Sectoral coverage	This criterion refers to the share of emissions explicitly covered in a taxonomy, i.e., the sectors or technologies explicitly mentioned in the respective taxonomy framework.[1]
Screening approach	This criterion captures whether taxonomies define (technical) selection criteria or thresholds for including economic activities and whether these follow a credible, science-based decarbonization pathway.
Target group	This criterion refers to which market players in the financial sector and the real economy and which financial instruments (e. g. bonds, loans, guarantees, funds) are affected by the taxonomy.
Reporting and disclosure	This criterion assesses whether a taxonomy is linked to reporting obligations for countries in the respective country.

1 We used the World Emissions Clock (WEC) to evaluate the percentual coverage of the country-specific greenhouse gas emissions per sector (available online).

Source: Authors' depiction.

1 For a more detailed description of the criteria and scoring, cf. Marchewitz et al., "Sustainable Finance Taxonomies."

2 The criteria were weighted equally, as all five criteria are necessary for the economic transition. A different weighting was also applied in the publication this Weekly Report is based on, but this did not fundamentally change the ranking.

Rising number of taxonomies worldwide

In recent years, a large number of sustainable finance taxonomies[8] have emerged to promote the provision of capital for the transition to a climate-neutral economy. (Box 1). By the end of 2023, 26 countries and regions had introduced their own taxonomies or begun developing them (Figure 1). A further 25 countries have initiated the development of a taxonomy but have yet not published a draft.

To accelerate the transition to a climate-neutral economy, both the introduction of technologies, such as green hydrogen in emission-intensive sectors like steel or cement, as well as green projects and activities, such as expanding solar and

8 We use the words "taxonomy"/"taxonomies" in this Weekly Report to refer to sustainable finance taxonomies.

wind energy, must be supported.[9] A taxonomy that supports both can offer companies in these sectors better access to financing options. Building upon this classification system, this Weekly Report investigates the potential of the taxonomies developed worldwide to support the transition to a climate-neutral economy.[10]

Many taxonomies are not suitable for supporting the transition

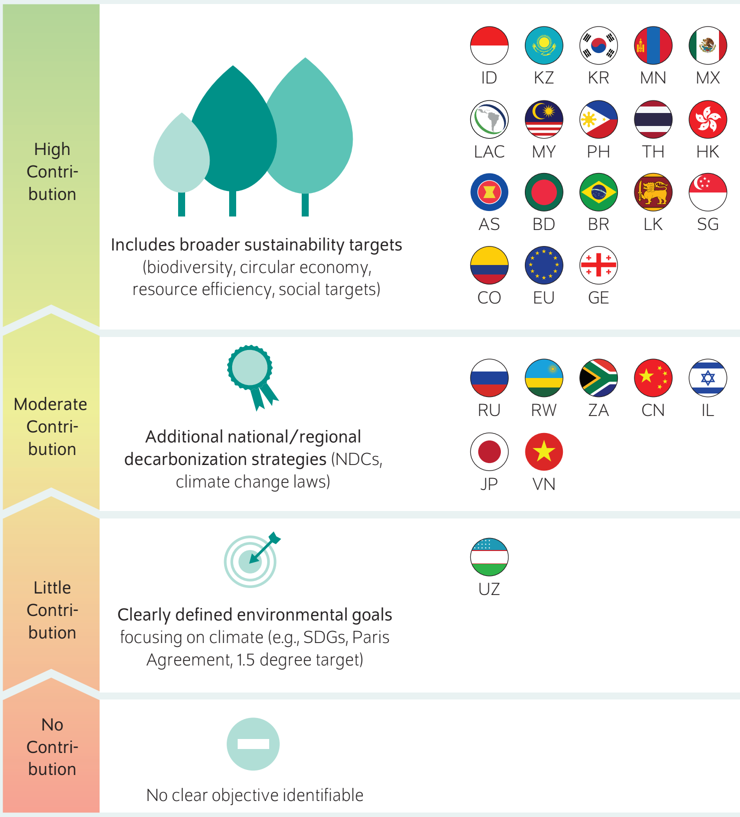
We used five criteria to analyze official documents of the 26 taxonomies already published and built a transition score (TS). The higher the TS, the higher the transition potential. The TS makes it possible to compare the taxonomies (Box 2), and the results of the comparison reveal a scattered picture (Figure 2).[11] The TS ranges from 2.0 to 3.6 points with an average score of 2.8. The taxonomies with the highest TS (three or more points, so a "moderate to high contribution") are from the Association of Southeast Asian Nations (ASEAN), Columbia, EU, Georgia, Singapore, South Korea, and Sri Lanka. The taxonomies with the lowest scores (between two and 2.4 points, "little contribution") are from Israel, Malaysia, Russia, South Africa, and Uzbekistan.

Many taxonomies strive for a holistic sustainability approach

In terms of **policy embeddedness**, i.e., how the taxonomy refers to the goals in international frameworks such as the Paris Agreement, the analysis paints a predominantly positive picture (Figure 3). Eighteen of the 26 taxonomies received all four points for this criterion, while seven received three points and Uzbekistan's taxonomy two points. Some taxonomies also refer specifically to the nationally determined contributions (NDCs).[12] In addition, the taxonomies frequently mention the Paris Agreement targets, the Sustainable Development Goals (SDGs), and the respective country's national climate and energy policies. Several taxonomies aim to extend their scope to a broader range of environmental objectives, such as biodiversity and the transition to a circular economy. Thirteen taxonomies, including the Columbian, Mongolian, Russian, South African, and Rwandan taxonomies, include nature-related aspects or plan to do so. Others consider specific regional aspects, such as the Islamic financial system in Malaysia. Countries such as Georgia, Mongolia, and Mexico have already included social aspects, while countries such as Brazil plan to include them. This indicates that many taxonomies follow a holistic sustainability approach,

Figure 3

Policy embeddedness of the taxonomies



Source: Authors' depiction.

Many taxonomies follow a comprehensive sustainability approach and refer to national and international targets.

even if the relationships between different environmental and social topics are not completely considered and the corresponding criteria have still not been developed.

Share of emissions covered in taxonomies varies considerably

The share of emissions from the economic sectors explicitly covered in the respective taxonomies[13] varied greatly in 2022 (Figure 4). Explicitly covered means that criteria and threshold values have been developed for these economic activities. Six taxonomies cover less than 50 percent of emissions,[14] while ten others cover more than 90 percent of emissions.[15]

9 Mritiunjoy Mohanty and Runa Sarkar, *The Role of Coal in a Sustainable Energy Mix for India* (Routledge: 2024) (available online).

10 Catherine Marchewitz et al., "Sustainable Finance Taxonomies – Enabling the Transition towards Net Zero? A Transition Score for International Frameworks," *DIW Berlin Discussion Papers* 2083 (2024) (available online).

11 Marchewitz et al., "Sustainable Finance Taxonomies." A detailed evaluation of the individual taxonomies can be found in the annex. The current evaluation is based on the documents as of December 31, 2023. The value can change for countries in the development phase as soon as the taxonomy has been finalized and published.

12 Georgia, Indonesia, Columbia, Latin America and the Caribbean (LAC), Malysia, Singapore, Sri Lanka.

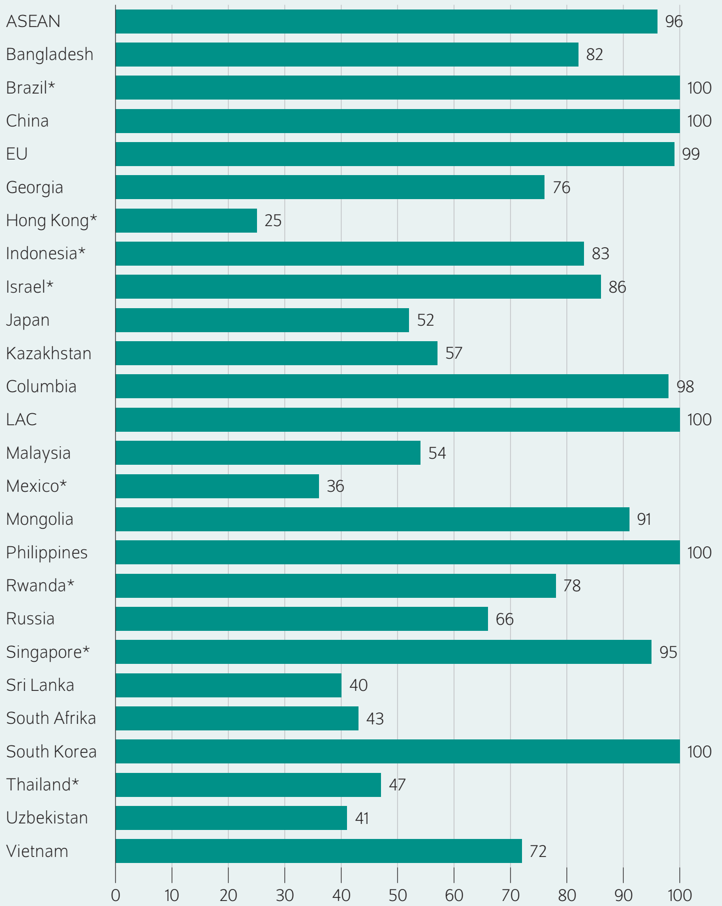
13 Some of the taxonomies do not yet cover all sectors because they are still in development.

14 These values are preliminary: For example, Hong Kong and Thailand have announced that they want to include more sectors in the next revisions, as previously only drafts have been published.

15 Association of Southeast Asian Nations (ASEAN), Brazil, China, Columbia, South Korea, LAC, Mongolia, Philippines, Singapore. The Philippines are a special case here, as its taxonomy uses a sector-agnostic approach that does not classify specific activities.

Figure 4

Sectors explicitly covered in the taxonomies
In percent of total emissions



Note: * Frameworks are still in the development phase. The assessment can therefore not be regarded as final. The cut-off date for the information considered in the analysis is 12/31/2023.

Source: Authors' depiction. Data source for emissions: World Emissions Clock.

The share of emissions in the economic sectors explicitly covered in the taxonomies varies considerably.

Box 3

Approaches for screening economic activities in alignment with the taxonomy

Generally, three approaches are used to classify economic activities as aligned with a taxonomy. These approaches partially overlap and are independently used or used together in combination (G20 SFWG, 2022). One approach involves technical screening criteria (TSC design), which is used by many taxonomies, including the EU taxonomy.[1] According to the TSC design, an economic activity is aligned with the taxonomy if its expected contribution to an environmental objective defined in the taxonomy meets a series of criteria and threshold values for emission intensity. As the type of technology underlying an activity is not restricted, the TSC design is technology neutral. In contrast, the whitelist design (WL) used in the taxonomies of Bangladesh, China, Georgia, Russia, and Mongolia explicitly mentions the activities aligned with the taxonomy and is thus technology specific. A "whitelist" means that an activity is only in alignment if it (i) is specifically listed in the taxonomy and (ii) it meets the relevant national environmental performance standards. Finally, some taxonomies follow a principles-based approach. This approach defines a set of core principles and is open to the type of technology used, such as in the ASEAN, Malaysian, Filipino, and Singaporean taxonomies. Most taxonomies combine their chosen approach with additional screening criteria, such as social minimum safeguards and/or the "Do No Significant Harm" principle as well as specific exclusion criteria.

1 For example, EU, Colombia, South Korea, South Africa, Indonesia and Vietnam, as well as partially Uzbekistan.

The rest of the taxonomies cover between 50 and 90 percent of emissions.

Different approaches to determining taxonomy-aligned activities

The results show considerable differences in the **screening approach**, meaning which selection criteria or thresholds are defined for covering economic activities (Box 3). The ASEAN, Columbian, Japanese, Hong Kong, Singaporean, and Thai taxonomies received the most points in this category (Figure 5), as they define dynamic and science-based thresholds that change over time. They also contain transitional activities, either by using a traffic light system or by requiring the threshold values to be adjusted regularly. The Malaysian and Latin American and the Caribbean (LAC) taxonomies received the fewest points, as they generally only define principles and do not include measurable thresholds and criteria.

Taxonomies often only apply to a limited group of market participants and financial products

In regard to the **taxonomy's target group**, most taxonomies specify which market participants they apply to or can potentially apply to. However, they are usually only aimed at a limited group of actors or remain vague (Figure 6). The EU taxonomy scored four points here, as the target groups are very broad, as described above.[16] The Vietnamese and Uzbekistani taxonomies received three points each, as they

16 Cf. European Union, *Regulation (EU) 2020/852.*

at least include mandatory obligations for a defined list of actors and products. The rest of the taxonomies only received two points each, as they either only define a limited target group or set out a voluntary specification. Furthermore, in some cases, such as Bangladesh, China, Kazakhstan, Russia, and Vietnam, the taxonomy only applies to specific financial instruments, such as green bonds.[17]

Figure 5

Screening approach for taxonomy-aligned economic activities

Source: Authors' depiction.

The screening approaches for selecting economic activities in alignment with the taxonomy differ considerably.

Taxonomies rarely linked to reporting obligations

Many taxonomies have not been directly linked to mandatory **disclosure and reporting obligations** (Figure 7). In most cases, companies are not required to disclose information or to report about their alignment with the taxonomy. As taxonomies are often voluntary frameworks, they are not linked to reporting obligations, even if some taxonomies refer to existing international standards and frameworks.[18] The taxonomies of Bangladesh, China, Georgia, and the EU are some of the few that have mandatory regulations. All market participants who belong to the taxonomies' target group must disclose information and report about their taxonomy-related activities.

Thresholds help decarbonize activities in emission-intensive sectors

Most taxonomies classify not only economic activities that are already carbon neutral (such as solar and wind energy, electric vehicles, or similar) as sustainable, but also some activities in emission-intensive sectors. In these sectors, the exact criteria and thresholds are decisive for the question of to what extent they can potentially contribute to a climate-neutral economy. However, the thresholds are not regularly adjusted or are not dynamic in many taxonomies. This can mean that corresponding investments are not in accordance with the Paris Agreement or lead to stranded assets. To illustrate the importance of dynamic thresholds, the criteria and thresholds for the energy and transportation sectors used in the taxonomies of the EU, Thailand, and Indonesia are compared below (Table 2).

The path to carbon neutrality in the energy sector as well as in most industrial sectors has not yet been defined in the EU taxonomy. For example, a binary threshold was determined for the CO_2 intensity of electricity generation (for example for electricity from hydropower plants, biomass, heat cogeneration, or gas-fired power plants). The taxonomy in Thailand, in contrast, has a traffic light system and contains two thresholds for the energy sector that decrease over time. The traffic light system in the Indonesian taxonomy is also based on international benchmarks in the strictest category but does not require any threshold reductions.[19]

In the transport sector, the EU taxonomy defines a dynamic threshold for passenger and light commercial vehicles that declines over the years. In the Thai taxonomy, however, there is already a threshold of zero emissions for passenger and light commercial vehicles.

The examples illustrate that different countries and regions adjust thresholds differently, which can affect the speed of the transition.

Conclusion: Global standards for taxonomies are essential

Taxonomies are important for defining sustainable activities and thus for financing the transition to a climate-neutral economy. With clear criteria and standards, taxonomies can contribute to creating a robust market for investments in climate-friendly activities.

17 While bonds continue to be an important component of project financing, other financial products such as loans, funds, insurance products, and blended financing also play an important role. In many cases, loans remain the predominant form of project financing, which is indicative of the diversity and complexity of the financial landscape. Cf. Frédéric Holm-Hadulla et al., "Firm debt financing structures and the transmission of shocks in the euro area," *Economic Bulletin Articles* 4 (2022) (available online).

18 The study only examined whether the taxonomy refers to disclosure and reporting obligations. It did not examine whether there are reporting obligations in the respective country that in turn refer to the taxonomy.

19 The ASEAN Taxonomy traffic light system contains similar thresholds for the energy sector: For "green" (level 1), the threshold is below 100 g CO_2e/kWh. The "yellow" category is divided into "level 2" and "level 3" with the thresholds of 100 to 425 and 425 to 520 g of CO_2e/kWh.

Figure 6

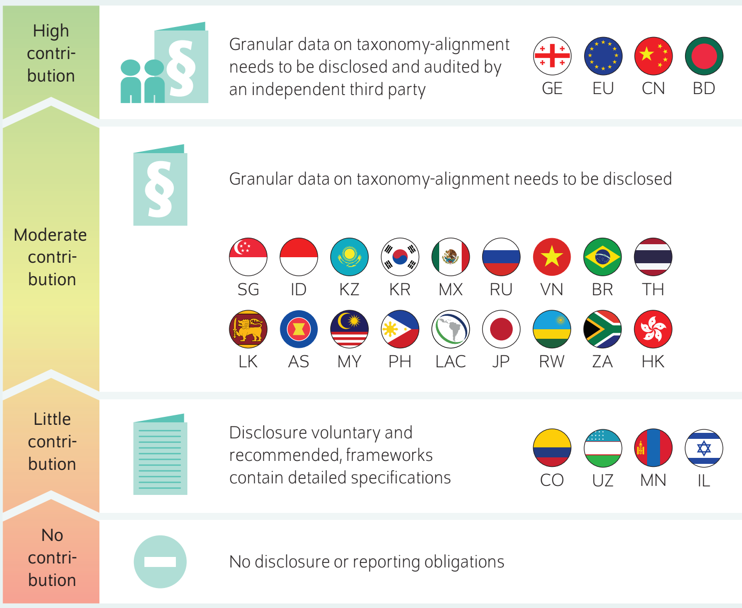
Taxonomy target group

Source: Authors' depiction.

Taxonomies often only apply to a limited group of market participants and financial products.

Figure 7

Taxonomy disclosure and reporting obligations



Source: Authors' depiction.

Taxonomies are rarely linked to disclosure and reporting obligations.

Table 2

Threshold examples in the energy and transport sectors for the EU, Thailand, and Indonesia

	EU	Thailand	Indonesia
Energy sector*	Threshold for green: < 100 gCO_2e/kWh, previously no reduction path	Threshold for green in traffic light system: < 100 gCO_2e/kWh Reduction to < 50 gCO_2e/kWh by 2040	Threshold for green in traffic light system: < 100 gCO_2e/KWh
	No traffic light system, hence no yellow category	Yellow in traffic light system: will be reduced from < 382 to < 148 gCO_2e/kWh in five-year steps to zero by 2040	Yellow in traffic light system: < 510 gCO_2/KWh (based on the IEA Sustainable Development Scenario (SDS))
Transportation (Passenger vehicles and light commercial vehicles)	Threshold: < 50 g CO_2 pro kilometer driven (g CO_2/km) Emissions must be reduced to zero by 2026	No transition period (meaning threshold is zero emissions)	Not explicitly contained in the taxonomy/thresholds have not yet been defined

Notes: * (Life cycle emissions in electricity generation). gCO_2e/kWh = grams of CO_2 equivalent per kilowatt hour.

Sources: Authors' depiction; EU, Thai, and Indonesian taxonomies.

In conclusion, we find that the potential of the taxonomies analyzed here to shift capital flows in accordance with the Paris Agreement has not yet been exhausted. To realize the full potential of taxonomies, they should contain environmental and social standards that are scientifically sound and provide a clear path to climate neutrality. Moreover, an adjustment to international climate targets for all sectors must be ensured. This requires a dynamic approach, meaning the taxonomy must continually be revised and adjusted based on new scientific findings. In addition, a taxonomy should be applied to all relevant financial instruments and actors in the financial sector and in the real economy and be a part of corporate reporting.

Despite efforts to achieve international harmonization, there are major differences and divergent definitions of what is "green" or "sustainable" around the world. Many firms and investors are active in multiple countries. To increase the effectiveness of the taxonomies and to avoid shifting emissions abroad (carbon leakage), taxonomies should be harmonized at the international level.

Taxonomies worldwide should be better coordinated so that sustainability policies and programs across countries and regions can be evaluated coherently and carbon leakage and capital market fragmentation can be avoided.[20]

20 WWF and Climate & Company, *When Finance talks Nature, WWF France in cooperation with Climate & Company* (2022) (available online).

Catherine Marchewitz is a Research Associate in the Climate Policy Department at DIW Berlin | cmarchewitz@diw.de

Franziska Schütze is a Research Associate in the Climate Policy Department at DIW Berlin | fschuetze@diw.de

Fernanda Ballesteros is a Ph.D. Student in the Climate Policy Department at DIW Berlin | fballesteros@diw.de

JEL: G18, P00, Q01, Q58

Keywords: Sustainable Finance Taxonomy, Green Finance, Transition Finance, EU Taxonomy, climate policy, transition plans

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

45 2024

263 **Report** by Sophie M. Behr, Till Köveker, and Merve Kücük

Heat Monitor 2023: Despite continued price increases, lower decline in households' heating energy consumption

- Heating energy consumption in German building sector decreases by four percent in 2023
- Heating energy prices increase by another third compared to 2022
- Larger variations in prices are observed for district heating compared to gas and oil

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 November 6, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Prof. Dr. Franziska Holz

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Petra Jasper; Adam Mark Lederer; Frederik Schulz-Greve; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 45 2024

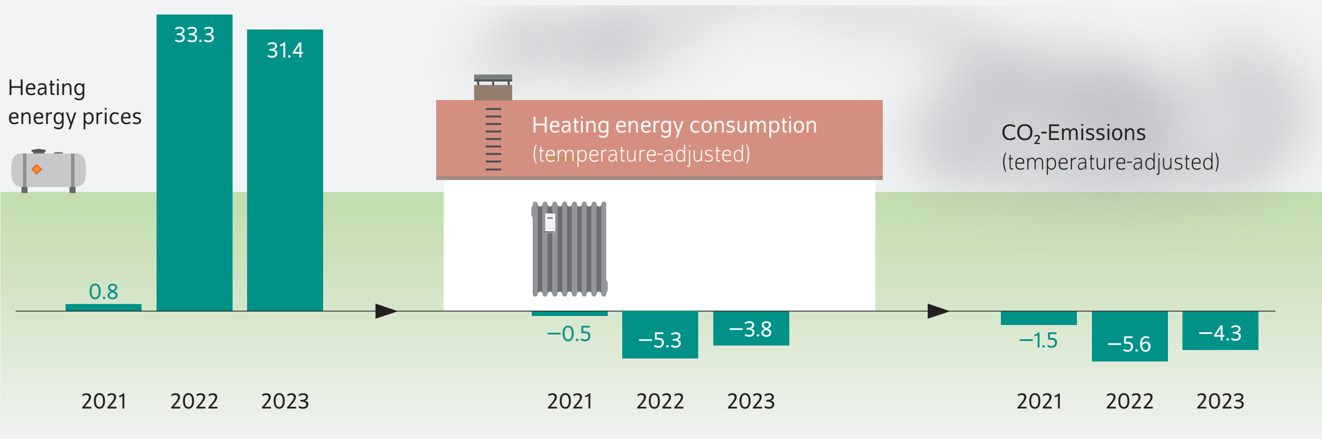
AT A GLANCE

Heat Monitor 2023: Despite continued price increases, lower decline in households' heating energy consumption

By Sophie M. Behr, Till Köveker, and Merve Kücük

- Temperature-adjusted heating energy consumption and CO_2 emissions in Germany's building sector went down by four percent in 2023 – a smaller reduction than in 2022
- Data from the energy service provider ista shows that the lowest heating energy consumption was in Mecklenburg-Western Pomerania, while the highest demand was in Saarland
- Heating energy prices continued to rise in 2023 – taking them up by yet another third compared to the previous year
- Variation in prices is higher for district heating than for gas and oil
- As a continued increase in residential energy savings is unlikely, meeting climate targets will require pushing of energy-efficient building retrofits

Despite further increases in heating energy prices, households reduced their energy consumption less than in the previous year
Change from previous year in percent



Source: ista SE, authors' own calculations.

Note: The values for 2023 are preliminary. Billed heating energy prices as a weighted average of natural gas, heating oil and district heating prices.

FROM THE AUTHORS

"The high heating costs have heavily burdened many households, despite the gas price cap introduced in 2023. Households' capacity to achieve further energy savings is limited. Tenant households, in particular, have little influence over energy-efficient retrofits or heating systems in their rented residential spaces." — ***Merve Kucuk*** —

MEDIA

Audio Interview with Sophie M. Behr (in German)
www.diw.de/mediathek

Heat Monitor 2023: Despite continued price increases, lower decline in households' heating energy consumption

By Sophie M. Behr, Till Köveker, and Merve Kücük

ABSTRACT

In 2023, heating energy prices increased by substantial 31 percent compared to the previous year, following a 33 percent increase already seen in 2022. Calculations based on data from the energy service provider *ista* show average price increases were the highest in the German state of Rhineland-Palatinate, and the lowest in Hamburg. Owing to these price hikes and ongoing energy-saving efforts, the temperature-adjusted heating energy consumption of two- and multi-apartment buildings in Germany covered in this study fell by an average of four percent compared to the previous year, which was slightly less than the decline observed in 2022. The biggest energy savings were seen in households in Saxony. At the same time, temperature-adjusted CO_2 emissions per square meter also fell, although to a slightly lesser extent than in 2022. With heating energy prices stabilizing, the momentum in emissions reductions is expected to slow down. If Germany is to meet its climate targets, further efforts are needed, particularly in improving energy efficiency in the building sector and in switching to renewable heating systems.

The impact of the gas price crisis continued to be felt strongly in 2023. Since Gazprom began restricting gas supply in the second half of 2021, and all the more so after Russia launched its attack on Ukraine in February 2022, gas and other heating fuels have become significantly more expensive in Germany. After dramatic price hikes in the first year of the war, prices continued their steep upward trend over the course of 2023.

In both 2022 and 2023, as a response to a looming gas shortage and the ever-increasing burden on private households, the German government took various measures in an attempt to reduce energy consumption while simultaneously alleviating the burden on private households. In December 2022, for instance, households' monthly heating bill for gas and district heating was paid by the government.[1] In January 2023, a gas and heating price cap was introduced to be applicable for private households and small and medium-sized enterprises. For natural gas consumers, the cap was set at 12 cents per kilowatt-hour (kWh). This price was applied to 80 percent of the projected annual heating energy consumption in September 2022.[2] Any consumption beyond that had to be paid at the regular market price. Similarly, for households using district heating, heating costs were capped at 9.5 cents per kWh. The relief granted by the state had to be clearly indicated on the heating bill. The aim of this instrument was to maintain the incentive to reduce heating energy consumption through higher energy prices while simultaneously protecting consumers from overly high prices.[3] This measure came into force on March 1, 2023 (and also retroactively included January and February) and expired on December 31, 2023.

1 Bundesregierung, "Energie-Rabatt für Haushalte und Unternehmen," 2023 (in German; available online, accessed October 14, 2024; this applies to all other online sources in this report unless stated otherwise).

2 If a household reduces its heating energy consumption by more than 20 percent in comparison to the previous year, the annual statement will show these entire savings reimbursed at the new, higher energy price, meaning that the greater incentives created by the new higher prices apply to the entirety of saving.

3 The gas and heating price cap applied to private households, small and medium-sized enterprises with a gas consumption of less than 1.5 million kilowatt-hours per year, as well as clubs and associations. Cf. Bundesregierung, "Fragen und Antworten zu den Energiepreisbremsen," 2024 (in German; available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-45-1

Box 1

Database und methodology used for Heat Monitor 2023

In partnership with *ista SE (former ista Deutsschland GmbH)*, one of the largest energy service providers in Germany, the DIW Berlin has developed the *Heat Monitor Germany in 2014*. The Monitor reports regional and national trends in heating energy consumption, energy prices and heating expenditures for residential buildings on an annual basis. The calculations are based on (1) building-level heating bills from *ista SE* for about 300000 residential buildings with two or more apartments (more than two million apartments), (2) climate adjustment factors from the German Weather Service (*Deutscher Wetterdienst*), and (3) census survey results from the German Federal Statistical Office. The heating bills contain information on energy consumption, billing periods, heating fuel type, energy costs, and building location and size.

The heating bills capture residential buildings with two or multi apartments – i.e., the sample covers buildings, owned or rented, with at least two households. We further limit the sample of buildings to those with heated living space of between 15 and 250 square meters per apartment. Note that we do not have a random sample from the population of residential buildings in Germany. In comparison with the 2014 microcensus supplementary survey, buildings with three to six apartments and larger buildings (13 or more apartments) are overrepresented in the sample. We offset this by weighting average heating consumption according to the relative importance of each building size category in the statistical population. To accomplish this, we use results from the 2010 microcensus supplementary survey that indicate the shares of each building size category by spatial planning region (ROR).

For each building, we calculate the temperature-adjusted heating energy consumption by adjusting total energy consumed for heating for local changes in the climate and weather. To ensure comparability across time and space, we use information from the German Weather Service. The available weighting factors normalizes heating consumption to climatic condition in Potsdam, the reference location.[1]

We calculate the annual quantity of heating energy consumption in relation to the heated living space of a building. This is carried out in several steps: First, building-specific consumption values are limited to the amounts of energy used for heating space (excluding warm water). Second, the consumption value is multiplied by the heating value corresponding to the building's energy fuel type, giving us the absolute heating energy consumption in kilowatt-hours (kWh) for a building in a billing period. Third, the values are allocated to a specific heating year, since the closing date for measurement is not always December 31 of the relevant year. Fourth, we adjust the consumption values for the climatic conditions during the heating period in question and divide it by the amount of heating space in the building. The units are kilowatt-hours required per square meter of heated living space per year (kWh/sqm).

Lastly, average heating demand values at the regional level are computed as the weighted arithmetic mean for the overall building stock of a region – for weights, we use the proportion of buildings in each housing size category (two, three to six, seven to twelve, 13 to 20, and over 21 apartments) at the regional level.

Heating bills are created with a time lag. The values of the 2021 heating period are calculated based on a smaller sample than the values for earlier years. For 2023, around 50 percent of the homes are available, compared to 2022. The results for 2023 should therefore be regarded as preliminary. For heating consumption, a correction was made by calculating a hypothetical value for 2023 energy consumption and by correcting the energy consumption for 2022 with the national trend. It is possible, however, that an update may nevertheless result in retroactive corrections.

To calculate the price and consumption changes in the different regions, the prices for one kilowatt hour of heating energy and the temperature-adjusted heating energy requirements per square meter in 2023 are compared with those from 2022. As the contracts of households do not reflect the wholesale price, but usually a price fixed for one or two years is paid, the energy prices in 2023 differed greatly depending on when the new contract was concluded and what the energy cost level was at the time. Energy prices also differ significantly from region to region. For these reasons, only the energy prices and requirements of buildings for which data is available in both 2022 and 2023 are compared. Buildings that appear in the data set for 2022 but for which no data is currently available for 2023 are not included in this analysis. Therefore, the changes in prices and requirements per federal state or region shown in Figures 3 and 4 and in the text cannot be directly compared with the figures in the table, which are based on all buildings available for the respective year.

1 The effect of different temperature correction methods was determined in a study from 2022. The study shows that the results of the temperature-corrected values do not differ greatly. See Peter Mellwig et al., "Klimaschutz im Gebäudebereich: Erklärungen für stagnierende CO_2-Emissionen trotz erfolgreicher Sanierungsmaßnahmen," Short study commissioned by Agora Energiewende 2022 (in German; available online).

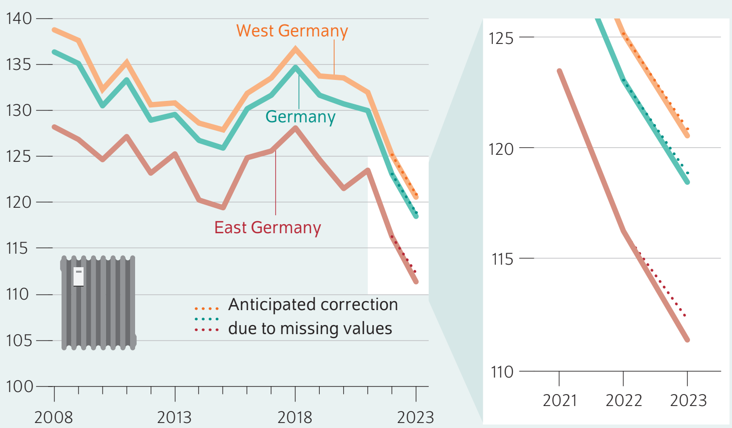
In response to the energy price crisis, Germany has stepped up its efforts to lessen its dependence on fossil fuels in the building sector. The goal was to further reduce Europe's dependence on (Russian) gas imports, on the one hand, and meet the climate targets outlined in the Paris Agreement, on the other. In 2022 and 2023, emissions from the German building sector totaled 108 and 102 million tonnes of CO_2 equivalent, respectively,[4] which is considerably higher

4 To be able to compare the impact of different climate-active gases, they are converted into CO_2 equivalents. This involves converting emissions of greenhouse gases other than CO_2 into CO_2 equivalents based on their global warming potential.

Figure 1

Heating energy consumption in two- or multi-apartment buildings

Annual heating energy consumption in kilowatt-hours per square meter of heated living space; temperature-adjusted



Note: 2023 values are preliminary. The corrections shown on the graph are estimates of the correct figure for the complete dataset.

Source: ista SE; authors' own calculations.

© DIW Berlin 2024

East German households consume less heating energy than their West German counterparts, with an increasing gap between the two during the energy price crisis.

than the 67 million tonnes of CO_2 equivalent specified in Germany's climate action targets for 2030.[5]

DIW Berlin's Heat Monitor Germany analyzes heating energy consumption, energy prices, and heating expenditures as well as the resulting CO_2 emissions for residential buildings on an annual basis. The calculations are based on heating energy bills for two- and multi-apartment buildings. The comprehensive dataset, which comprises around 300,000 buildings and was provided by energy service provider *ista SE* (formerly *ista Deutschland GmbH*)[6], is weighted on the basis of the German microcensus, and therefore paints a representative picture for the whole of Germany. Our analysis for 2023 is based on energy bill data already available for over 170,000 buildings (Box 1).

This year's analysis focuses on the continued savings in heating energy consumption as well as the development of heating costs and prices in the first year after the beginning of the energy price crisis. The analysis of heating energy prices and consumption, which previously included gas and oil heating only, was extended this year to include district heating. The increasing share of district heating, which currently accounts for around 15 percent of homes in Germany, is thus taken into account as a potentially sustainable heat source in the heat supply.[7] Consequently, the average prices for 2023 and the historical comparison years listed in this report now also include district heating.

Heating energy consumption remains higher in the west than in the east and south of Germany

Heating energy consumption[8] in two- and multi-apartment buildings continued to fall in 2023 (Figure 1). In fact, the average temperature-adjusted heating consumption of 118 kWh per square meter of heated living space was 3.8 percent lower than in the previous year (123 kWh) and nine percent lower than in 2021 (130 kWh). The combination of higher heating energy prices, alongside appeals to save energy during the 2022/2023 heating period, and targeted measures to reduce heating energy consumption (such as hydraulic balancing, additional energy efficiency measures, heating curve adjustments) had a noticeable impact on the heating energy consumption in 2023. However, the increase in prices could not be offset by the savings in demand, resulting in higher expenditures for households.

We observe significant regional differences in heating energy consumption, specifically between the west and northwest of Germany, on the one hand, and the east and south, on the other. Once again, Mecklenburg-Western Pomerania consumed the least heating energy at 99 kWh per square meter. As in the previous year, Saarland was at the other end of the scale with the highest consumption of 137 kWh per square meter (Table and Figure 2). Taken together, the western German states consumed 121 kWh per square meter, exceeding the heating energy consumption of their eastern German counterparts, which required an average of 111 kWh (Figure 1). A possible explanation for this could be the higher retrofit rates for residential buildings in the eastern German states.[9]

At the regional level, the differences between the highest and lowest level of consumption are even more pronounced. Central Mecklenburg/Rostock had the lowest average heating energy consumption in Germany at 87 kWh per square meter, followed by Western Pomerania at 98 kWh. East Fresia, in contrast, consumed far more heating energy with 140 kWh per square meter. The Saar region was in second place with 137 kWh.

5 Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, "Das neue Klimaschutzgesetz – Jahresemissionsmengen nach Bereichen bis 2030," 2024 (in German; available online)

6 Alongside its competitor Techem, ista is one of the two largest billing companies for heating and hot water in Germany. In 2017, the two companies combined held a market share of around 50 percent.

7 This corresponds to around six percent of residential buildings in Germany, cf. BDEW (2024): Wie heizt Deutschland 2023? BDEW-Studie zum Heizungsmarkt (in German; available online, accessed on November 1, 2024).

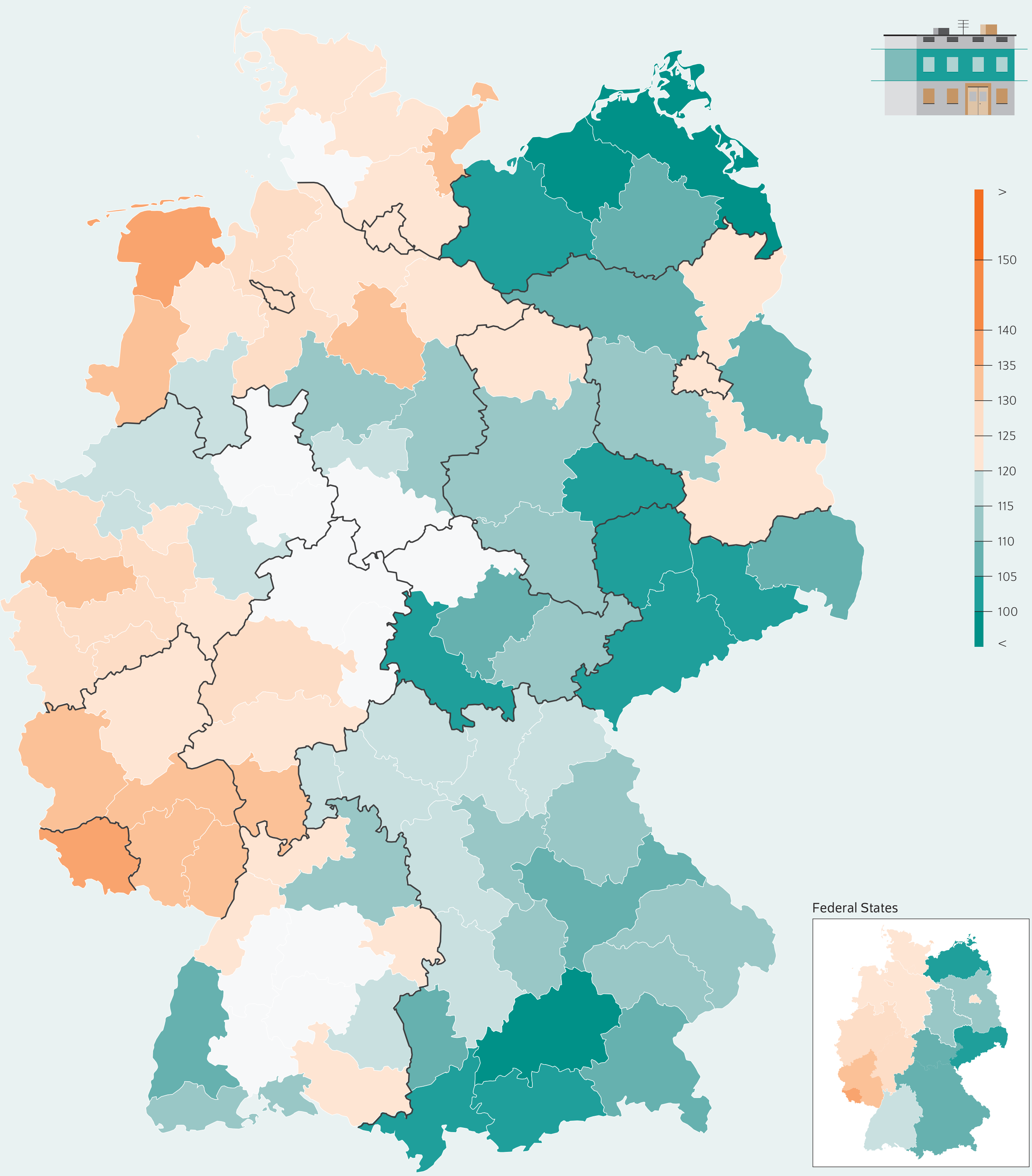
8 Heating energy consumption is adjusted for local changes in the climate and weather (Box 1).

9 Cf. Sophie Behr, Merve Kücük, and Karsten Neuhoff, "Energetische Modernisierung von Gebäuden sollte durch Mindeststandards und verbindliche Sanierungsziele beschleunigt werden," DIW aktuell 87 (2023) (in German; available online).

Figure 2

Heating energy consumption in two- or multi-apartment buildings by region (ROR)

Annual heating energy consumption in kilowatt-hours per square meter of heated living space; temperature-adjusted



Note: Also available online as an interactive graphic on heating energy prices, demand and expenditure at https://www.diw.de/waermemonitor_2021-2023.

Source: ista SE; authors' own calculations.

Less heating is used from the Baltic Sea to Allgäu than in the west and northwest of Germany.

Table

Results of Heat Monitor 2023

Spatial planning region (ROR)	Number of ROR	Annual heating energy use (kilowatt-hour per square meter heated living space) Average			Billed heating prices (euro cents per kilowatt-hour) Median			Annual heating expenditure (euros per square meter) Average		
		2021	2022	2023[1]	2021	2022	2023[1]	2021	2022	2023[1]
Schleswig-Holstein Mitte	101	136.27	124.14	124.48	8.09	10.73	13.93	10.63	12.40	16.27
Schleswig-Holstein Nord	102	136.66	129.45	122.07	7.55	9.72	11.63	10.29	12.16	13.87
Schleswig-Holstein Ost	103	147.36	132.75	130.25	6.32	8.64	11.19	9.04	11.48	13.58
Schleswig-Holstein Süd	104	138.03	127.53	122.16	6.67	9.45	12.47	8.73	11.36	13.97
Schleswig-Holstein Süd-West	105	162.58	153.21	N/A	5.24	7.60	11.75	9.03	12.62	15.09
Hamburg	201	137.30	126.85	120.61	7.41	10.65	11.56	9.60	12.20	12.92
Braunschweig	301	123.97	116.12	113.40	6.81	9.56	12.03	8.17	10.35	12.85
Bremen-Umland	302	144.80	135.64	126.34	5.70	7.46	11.46	8.12	9.93	13.41
Bremerhaven	303	143.45	130.58	126.30	5.80	8.09	11.50	8.13	10.47	13.58
Emsland	304	146.86	139.12	130.58	5.81	7.91	11.57	8.10	9.84	13.84
Göttingen	305	131.75	119.26	N/A	5.87	7.29	N/A	7.77	8.63	N/A
Hamburg-Umland-Süd	306	140.74	130.91	123.94	5.56	7.87	10.49	8.07	10.63	13.08
Hannover	307	125.96	117.83	113.08	6.61	9.02	11.68	8.50	10.67	13.09
Hildesheim	308	132.94	125.48	117.68	6.06	8.58	11.67	8.03	10.34	13.09
Lüneburg	309	137.34	130.58	123.13	5.63	7.48	12.07	7.77	9.97	14.38
Oldenburg	310	142.97	129.45	123.45	5.84	8.87	10.85	8.30	10.41	12.08
Osnabrück	311	129.73	118.38	119.23	5.99	8.24	11.74	7.84	9.82	12.82
Ost-Friesland	312	157.03	144.46	139.77	6.17	7.58	11.43	9.27	10.32	14.08
Südheide	313	146.87	134.56	132.80	5.84	7.92	11.66	8.58	10.92	14.51
Bremen	401	140.37	132.12	125.84	6.77	8.64	11.08	8.69	10.31	12.80
Aachen	501	139.95	131.76	126.71	6.50	9.00	11.79	9.21	11.41	13.96
Arnsberg	502	129.12	121.16	117.50	5.89	8.56	11.80	7.64	9.73	13.03
Bielefeld	503	142.05	132.13	N/A	6.14	7.77	N/A	8.50	9.93	N/A
Bochum/Hagen	504	142.75	131.64	127.02	6.75	8.85	11.91	9.48	11.08	13.76
Bonn	505	145.22	134.14	128.38	6.48	9.34	11.53	9.36	11.79	14.22
Dortmund	506	139.75	129.20	123.59	6.52	8.88	11.66	9.29	11.63	13.49
Duisburg/Essen	507	142.95	132.98	126.94	7.20	9.40	12.28	10.23	11.80	14.32
Düsseldorf	508	148.10	136.58	130.18	6.23	8.39	11.75	9.36	11.41	14.35
Emscher-Lippe	509	136.64	127.42	119.25	7.47	10.11	12.06	10.05	12.31	13.48
Köln	510	140.87	133.04	125.64	6.24	8.87	11.79	8.77	11.39	13.94
Münster	511	130.94	120.82	115.82	5.84	7.75	11.36	7.67	9.08	12.12
Paderborn	512	131.58	120.38	N/A	6.11	7.59	N/A	8.18	9.58	N/A
Siegen	513	137.89	126.03	121.74	5.84	8.26	11.70	7.98	10.16	13.12
Mittelhessen	601	129.85	124.58	129.90	6.27	7.95	11.81	7.94	9.90	14.84
Nordhessen	602	128.92	122.20	N/A	6.38	8.50	N/A	8.09	10.26	N/A
Osthessen	603	121.06	113.31	N/A	5.71	7.55	N/A	6.87	8.46	N/A
Rhein-Main	604	134.23	127.49	121.39	6.30	8.22	11.55	8.42	10.14	13.27
Starkenburg	605	142.70	137.05	133.18	6.17	8.38	11.65	8.80	11.25	14.57
Mittelrhein-Westerwald	701	135.88	128.83	124.24	6.25	8.07	11.73	8.33	10.24	13.70
Rheinhessen-Nahe	702	140.63	135.38	133.81	6.30	8.21	11.74	8.94	11.31	14.57
Rheinpfalz	703	140.98	136.62	133.61	6.36	8.36	11.49	8.95	10.92	14.33
Trier	704	138.64	139.52	130.48	6.11	8.07	11.57	8.56	11.62	14.47
Westpfalz	705	143.98	142.16	133.27	6.02	7.46	11.42	8.61	10.46	15.15
Bodensee-Oberschwaben	801	116.71	114.49	120.92	5.71	6.87	9.03	6.84	8.59	11.80
Donau-Iller (BW)	802	120.99	117.40	115.04	6.11	8.07	11.57	7.67	9.77	13.17
Franken	803	124.32	119.99	111.71	5.98	7.90	12.03	7.78	10.09	13.77
Hochrhein-Bodensee	804	123.21	121.24	113.62	5.86	7.56	10.68	7.32	9.38	11.86
Mittlerer Oberrhein	805	129.00	124.06	121.38	6.43	8.11	11.34	8.21	10.31	13.38
Neckar-Alb	806	120.27	122.12	N/A	6.63	8.40	N/A	7.33	9.42	N/A
Nordschwarzwald	807	116.10	116.16	N/A	6.07	8.00	N/A	7.25	9.80	N/A
Ostwürttemberg	808	127.10	126.36	122.05	5.99	7.69	9.50	7.76	9.99	12.83
Schwarzwald-Baar-Heuberg	809	112.37	112.48	N/A	5.91	7.50	N/A	6.87	9.11	N/A
Stuttgart	810	126.35	121.76	N/A	6.64	8.30	N/A	8.24	10.22	N/A
Südlicher Oberrhein	811	114.87	114.29	109.88	5.90	7.42	11.11	7.06	9.36	12.11
Unterer Neckar	812	131.65	125.54	123.77	7.57	9.37	12.06	9.88	11.54	14.53
Allgäu	901	105.77	101.13	102.38	6.09	7.46	10.93	6.12	8.30	10.32
Augsburg	902	122.20	117.38	115.06	5.79	8.57	11.30	7.22	10.02	11.98
Bayerischer Untermain	903	129.98	131.68	119.30	5.77	7.84	11.93	7.63	10.30	13.96

Spatial planning region (ROR)	Number of ROR	Annual heating energy use (kilowatt-hour per square meter heated living space) Average			Billed heating prices (euro cents per kilowatt-hour) Median			Annual heating expenditure (euros per square meter) Average		
		2021	2022	2023[1]	2021	2022	2023[1]	2021	2022	2023[1]
Donau-Iller (BY)	904	120.42	121.00	109.71	5.98	7.93	11.72	7.40	10.01	12.64
Donau-Wald	905	119.10	114.58	113.26	5.88	7.52	11.57	6.95	9.28	12.64
Industrieregion Mittelfranken	906	122.56	119.74	113.42	6.69	8.31	11.86	7.94	9.60	12.45
Ingolstadt	907	115.30	115.34	110.52	6.09	7.94	11.38	7.07	9.31	11.72
Landshut	908	114.70	112.85	110.20	5.86	7.59	11.61	6.73	8.90	12.08
Main-Rhön	909	122.57	118.63	116.06	6.22	7.37	11.46	7.45	9.01	12.36
München	910	106.40	103.50	98.50	6.65	9.86	11.82	7.11	9.98	11.36
Oberfranken-Ost	911	121.00	119.51	115.22	5.90	7.60	11.77	7.15	9.23	12.66
Oberfranken-West	912	124.71	123.05	116.85	6.05	7.35	11.34	7.50	9.73	12.44
Oberland	913	109.18	108.15	103.34	6.03	7.83	11.06	6.58	9.12	11.35
Oberpfalz-Nord	914	129.87	119.46	111.30	6.10	8.32	11.37	7.58	10.48	12.26
Regensburg	915	116.66	116.26	109.14	5.92	7.67	11.49	6.93	9.46	11.68
Südostoberbayern	916	111.62	110.32	108.15	6.00	7.85	11.45	6.75	9.06	12.01
Westmittelfranken	917	124.42	122.10	116.63	6.04	8.00	11.87	7.49	10.17	13.37
Würzburg	918	125.69	121.28	117.55	6.14	7.33	11.17	7.67	9.49	12.11
Saar	1001	147.98	140.68	136.54	6.83	9.72	12.32	9.68	12.95	15.58
Berlin	1101	136.85	127.67	123.56	7.28	10.47	12.87	9.51	12.32	13.97
Havelland-Fläming	1201	124.36	114.56	110.64	7.94	10.13	12.80	8.83	10.08	12.51
Lausitz-Spreewald	1202	128.93	122.07	124.02	8.11	10.17	12.61	8.67	10.00	12.30
Oderland-Spree	1203	127.00	118.23	107.02	8.78	10.13	12.39	9.12	10.16	12.23
Prignitz-Oberhavel	1204	132.19	119.74	109.17	8.48	12.24	14.60	9.07	11.55	13.05
Uckermark-Barnim	1205	124.90	118.33	120.12	7.65	11.16	11.67	7.46	9.38	10.13
Mecklenburgische Seenplatte	1301	112.50	110.53	109.67	8.67	10.85	12.70	7.93	8.89	11.04
Mittleres Mecklenburg/Rostock	1302	98.25	90.68	87.33	8.96	10.22	13.16	7.87	7.87	10.04
Vorpommern	1303	110.99	107.42	98.21	9.12	12.47	12.99	8.38	10.52	11.23
Westmecklenburg	1304	116.88	109.13	103.96	8.24	9.80	11.95	8.10	9.24	10.44
Oberes Elbtal/Osterzgebirge	1401	116.92	110.11	101.96	8.25	13.36	13.44	8.10	10.52	11.15
Oberlausitz-Niederschlesien	1402	121.32	115.11	109.97	7.24	8.97	11.84	7.55	8.80	10.82
Südsachsen	1403	118.10	112.15	103.56	7.34	8.42	10.55	7.62	8.71	9.96
Westsachsen	1404	113.53	107.32	100.37	8.15	9.49	12.74	8.06	8.42	10.53
Altmark	1501	134.69	121.67	121.11	7.61	9.05	8.84	9.33	11.88	10.22
Anhalt-Bitterfeld-Wittenberg	1502	121.31	127.16	102.83	8.20	10.09	13.36	8.81	10.57	12.97
Halle/S.	1503	123.51	117.10	111.64	7.94	9.38	11.92	8.52	9.82	11.80
Magdeburg	1504	122.57	118.41	114.34	8.03	10.65	12.43	8.49	10.92	11.89
Mittelthüringen	1601	113.44	103.85	105.99	7.63	14.71	11.77	7.37	10.45	10.07
Nordthüringen	1602	120.00	111.84	N/A	7.55	9.50	12.82	8.58	9.28	13.78
Ostthüringen	1603	111.70	104.85	112.77	7.86	8.63	12.09	7.72	8.06	11.07
Südthüringen	1604	119.49	115.31	104.41	7.13	8.24	11.33	7.45	8.28	10.37
Schleswig-Holstein	1	140.70	129.56	124.45	7.05	9.58	12.47	9.58	11.89	14.61
Hamburg	2	137.30	126.85	120.61	7.41	10.65	11.56	9.60	12.20	12.92
Lower Saxony	3	133.86	124.29	120.03	6.21	8.47	11.61	8.24	10.22	13.20
Bremen	4	140.37	132.12	125.84	6.77	8.64	11.08	8.69	10.31	12.80
Northrhein-Westfalia	5	141.36	131.30	125.46	6.49	8.75	11.83	9.17	11.14	13.83
Hesse	6	133.67	127.27	125.25	6.25	8.21	11.62	8.29	10.22	13.81
Rheinland-Palatinate	7	139.62	135.24	130.56	6.24	8.07	11.61	8.67	10.82	14.34
Baden-Wuerttemberg	8	123.69	120.53	117.44	6.41	8.10	11.15	7.96	10.02	13.09
Bavaria	9	116.23	113.43	108.58	6.24	8.40	11.59	7.21	9.63	11.97
Saarland	10	147.98	140.68	136.54	6.83	9.72	12.32	9.68	12.95	15.58
Berlin	11	136.85	127.67	123.56	7.28	10.47	12.87	9.51	12.32	13.97
Brandenburg	12	127.19	118.35	114.52	8.17	10.55	12.80	8.71	10.20	12.21
Mecklenburg-Western-Pomerania	13	109.31	103.83	98.76	8.77	10.87	12.71	8.08	9.17	10.66
Saxony	14	117.08	110.81	103.15	7.76	10.04	11.99	7.84	9.12	10.51
Saxony-Anhalt	15	123.61	119.68	111.95	8.00	9.98	12.13	8.62	10.55	11.92
Thuringia	16	114.96	107.58	108.32	7.60	10.62	11.94	7.68	9.04	11.00
Germany	17	130.01	123.10	118.44	6.74	8.99	11.81	8.44	10.49	12.99
East Germany	18	123.47	116.33	111.36	7.78	10.36	12.40	8.50	10.29	11.90
West Germany	19	131.99	125.15	120.58	6.43	8.57	11.63	8.43	10.55	13.33

1 Preliminary data.

Notes: Heating energy use is adjusted for changes in temperature; billed heating costs are a weighted average of natural gas and oil prices.

Source: ista SE; authors' own calculations.

Box 2

Calculation of CO_2 emissions

To calculate a building's CO_2 emissions, the heating energy consumption per square meter is multiplied by the emission factors of each energy carrier (Table). To allow for a comparison with emissions in the building sector for the whole of Germany, only direct CO_2 emissions are calculated. Upstream emissions resulting from energy extraction, transport, and transformation (for example when generating electricity and district heating) are not taken into account.

To calculate representative average annual CO_2 emissions per square meter, the annual CO_2 emissions per square meter are weighted for each property according to the share of the building category in the statistical population. The weighting is similar to the calculation for temperature-adjusted heating energy consumption (Box 1). In other words, the different building size categories are weighted according to their share in the microcensus.

Table

CO_2 emission factors depending on energy carrier

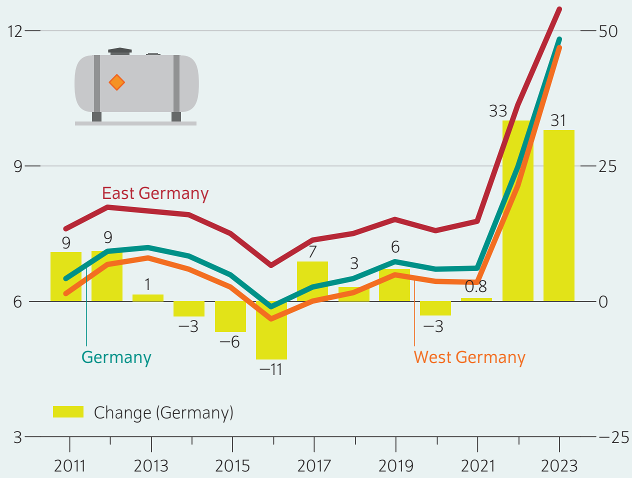
Energy carrier	CO_2 emission factor
Natural gas (H)	0.201
Natural gas (L)	0.201
Oil	0.266
Heavy oil	0.293
Lignite	0.359
Coke	0.389
Hard coal	0.345
Liquified gas	0.236
District heating	0
Electricity	0
Pellets	0
Wood	0
Wood chips	0

Source: Umweltbundesamt 2014

Figure 3

Energy prices

Weighted median of natural gas, oil prices, and district heating in euro cents per kilowatt-hour (left axis), change in percent (right axis)



Source: ista SE; authors' own calculations.

In the two years 2022 and 2023, the increase in energy prices adds up to 75 percent.

Another area where we observe stark differences between German states is in the billed heating prices (Table). Median heating prices were the lowest in Bremen with 11.08 cents per kWh, followed by Baden-Württemberg with 11.15 cents. In contrast, Berlin and Brandenburg had the highest heating prices with median prices of 12.87 and 12.80 cents per kWh, respectively. Regional differences at the more granular level were even more pronounced. Households in Prignitz-Oberhavel and Central Schleswig-Holstein paid 14.60 and 13.93 cents per kWh, making their median prices the highest. Median heating prices in Altmark, Saxony-Anhalt, were lowest at just 8.84 cents per kWh, followed by Bodensee-Oberschwaben at 9.03 cents.

Strong regional differences in price changes and consumption per square meter

The median heating energy price for 2023, accounting for rebates granted under the energy price cap, was 11.81 cents per kWh. In 2023, Germany saw a 31.4 percent increase over the previous year, which was almost as high as the increase in the first year after the start of the war on Ukraine, when energy prices rose by 33.3 percent (Figure 3). This corresponds to a 75-percent increase in average prices compared to 2021.

There are several reasons for this sharp increase in energy prices despite the price cap. First, the cap applied to gas and district heating only;[10] second; the average prices for 2022 were far lower than the price cap; and third, the price cap applied only to 80 percent of past consumption. If a household was only able to reduce its consumption by less than 20 percent compared to 2022 and the new contractual price would have been higher than the level of the price cap, the resulting average price for this household would exceed the price cap.

Arguably the main reason why heating energy prices continued to increase in 2023, as compared to 2022, was that

10 In 2023, there was also an electricity price cap. However, this only impacted heating energy prices for a very small number of households, as only a very small proportion of buildings in Germany have electric heating. Since the present analysis is limited to the three dominant heating energy sources—gas, oil, and district heating—the electricity price cap has no effect for the sample considered.

some households did not have to pay the higher energy prices until 2023. Thanks to the one to two-year energy price plans signed up for in advance, they were not subject to price increases in 2022. The different contract structures therefore resulted in a significant increase in price variation. Accordingly, there are households that came through the crisis almost unscathed, while others ended up paying very high prices. At the federal state level, Rhineland-Palatinate saw the biggest price increase with 45.2 percent, while the state of Hamburg recorded the smallest increase with just 8.8 percent in comparison to the previous year.

The biggest energy savings in 2023 were recorded in Saxony, which reduced their heating energy consumption by 5.8 percent. Saarland and Brandenburg, in contrast, saw the smallest reductions in consumption (2.6 and 2.8 percent, respectively). One of the reasons households did not save more, despite the steep price increases, was likely the energy efficiency of the buildings, something over which particularly tenant households generally have no influence. Hence, the relation between price increases and reduced heating energy consumption is not clear (Figure 4). The fact that reduced consumption cannot fully offset these sharp price increases is also reflected in the steep rise in overall heating expenditures, with 2023 seeing an increase in heating energy expenditure of around 24 percent over the previous year (compared to 2021, the last year before the energy crisis, the increase was as high as 54 percent).

Price and demand structure for district heating differs noticeably from gas and oil

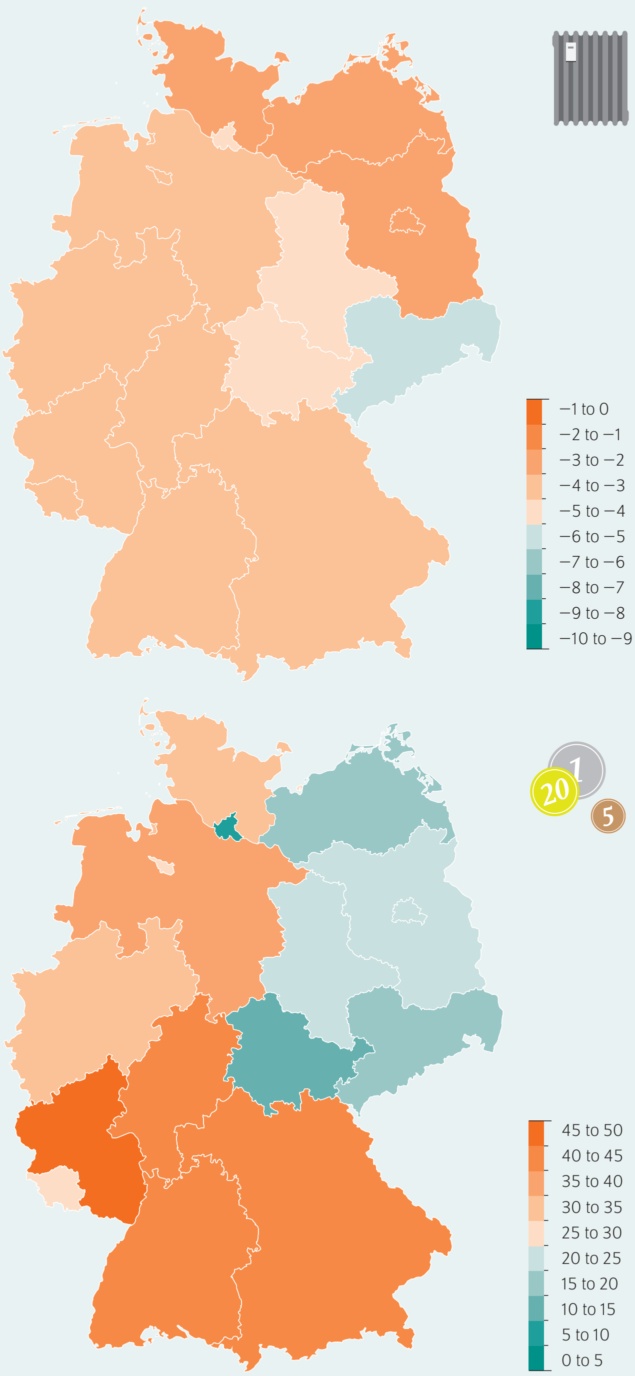
District heating and heat networks have the potential to make a significant contribution to the decarbonization of heat supply: They can be operated with sustainable energy sources and are more efficient than building-internal gas and oil-based heating systems. In order to map the potential switch to sustainable sources in heat generation, this year for the first time the Heat Monitor's analysis of heating energy prices covers not just oil and gas but also district heating. The analysis clearly shows that the price range for district heating is considerably wider than for gas and oil (Figure 5). Similarly, the median price of district heating per kilowatt-hour is, on average, substantially higher than those for gas and oil.

That said, at 97 kWh per square meter, heating consumption for district heating is 24 percent lower than for oil (127 kWh) and 19 percent lower than for gas (120 kWh) (Figure 6). Differences in price and demand for district heating arise, among other reasons, from the fact that heat is supplied directly with district heating, whereas with gas and heating oil, there are conversion losses due to heat generation in the house. Another reason for the lower average heating energy consumption for district heating is that buildings supplied with district heating have, on average, more residential units than buildings, which are heated with gas or oil. These larger buildings have less outer walls per square meter of living space, resulting in lower heating energy requirements.

Figure 4

Change in (temperature-adjusted) heating energy consumption and heating energy prices in two and multi-apartment buildings (2022–2023)

In percent



Note: Billed heating costs are a weighted average of natural gas, oil, and district heating prices. To calculate the changes, only buildings that could be observed in both 2022 and 2023 are taken into account and weighted using the microcensus. For this reason, this figure is not comparable with the table.

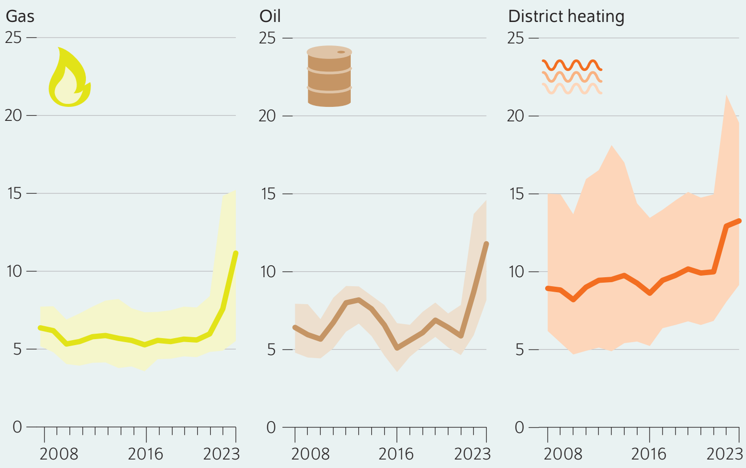
Source: ista SE; authors' own calculations.

Savings in consumption were not necessarily related to price increases: Households in Saxony saved the most on heating energy, even though prices did not rise that much there in 2023.

Figure 5

Heating energy prices in two- and multi-apartment buildings by energy source

Euro cents per kilowatt-hour



Note: The shaded areas show the price variance.

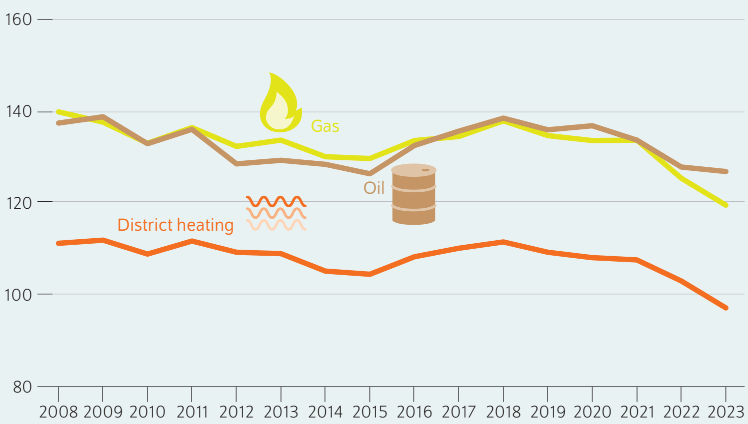
Source: ista SE; authors' own calculations.

Average prices for district heating are higher than for gas and oil and also show a stronger variation.

Figure 6

Heating energy consumption in two- and multi-apartment buildings by energy source

Annual heating energy consumption in kilowatt-hours per square meter of heating living space; temperature-adjusted



Source: ista SE; authors' own calculations.

Heating energy consumption per square meter is significantly lower for district heating than for oil and gas.

Emissions reductions losing momentum

Last year, building sector emissions in Germany amounted to 102 million tonnes of CO_2 equivalent.[11] This is 51 percent less than in 1990. Nevertheless, for Germany to meet its 2030 climate targets, the building sector has to reduce its emissions by 69 percent compared to 1990 levels.

A building's CO_2 emissions depend on multiple factors (Box 2), in particular its energy efficiency and the heating system used. The emissions per square meter for the two- and multi-apartment buildings examined here continue to be on a downward trend (Figure 7). With 19.1 kilos per square meter of heated living space, the CO_2 emissions attributed to heating were eight percent lower in 2023 than in the previous year. Temperature-adjusted, however, this corresponds to a 4.3 percent reduction only, as 2023 was a relatively mild year. Thus, although the downward trend has continued, the reduction in emissions was lower in 2023 than the 5.6 percent observed in the previous year (16 percent without temperature adjustment). Given the smaller decrease in heating energy consumption, it is not surprising that emissions levels are no longer falling as dramatically, but the momentum in the building sector is still not enough to meet Germany's climate targets.

Conclusion: Greater investment in building energy efficiency needed

In 2023, once again, households faced strong increases in heating costs compared to the previous year—amounting to 31 percent, on average. That being said, there were strong regional variations. These resulted, on the one hand, from the different types of fuel used, as well as from the different types of contracts used by electricity and gas suppliers. Other important factors might be the different points in time at which contracts were concluded or oil tanks filled.

The analysis shows that, in 2023, the (now expired) energy price cap to protect households from potentially extreme heating cost hikes was indeed effective. For the majority of households, the unit prices billed were not substantially higher than the price cap of 12 cents. When it came to district heating, on the other hand, the average price of heating energy was 13 cents per kWh—well above the price cap of 9.5 cents per kWh. With the price cap only applying to 80 percent of forecasted consumption and anything above this being charged at given market energy prices, 2023 saw a very high average price for district heating in many places.

Despite similar price increases as in 2022, heating energy savings in 2023 were lower than in the previous year. Temperature-adjusted, private households consumed 3.8 percent less heating energy than in 2022. In the previous year, the saving was 5.3 percent. One reason for this might be that

11 Umweltbundesamt, "Treibhausgasminderungsziele Deutschlands," 2024 (in German; available online).

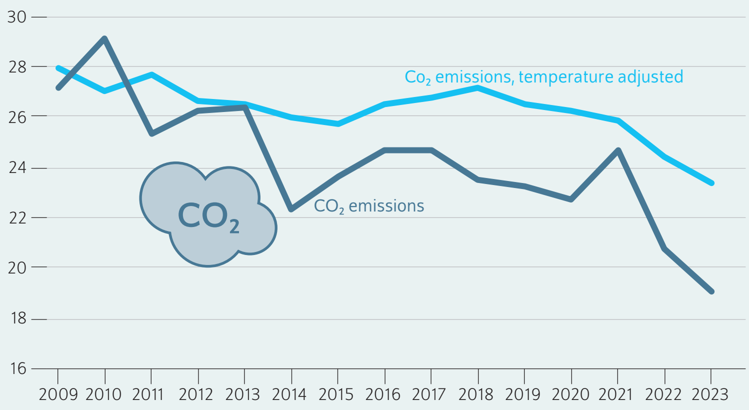
in 2023, much less attention was devoted to saving heating energy than in 2022. Another reason might be that the potential to save energy through changes in consumer behavior had already been exhausted in some households. In some regions, however, savings were more than twice as high as the national average. This indicates that savings in heating energy and therefore also emissions are still possible in the short term – whether through behavioral adjustments or energy-efficient renovations.

The months following the energy price crisis of 2022/2023 saw the price pressure on the supply side decrease as wholesale energy prices dropped and started to stabilize. In the years ahead, however, the cost of CO_2 emissions from fossil fuels is likely to increase heating costs for private households. That said, the energy price crisis has demonstrated that higher heating costs have a limited impact on people's heating behavior and therefore also CO_2 emissions.

When it comes to reducing emissions, the momentum is thus unlikely to continue unless it is supported by other means. Yet, emissions have to be reduced for the climate targets in the building sector to be met. The Expert Commission on Gas and Heat has proposed a number of specific measures to achieve these reductions. The advice and in-kind contributions intended to help households reduce their heating energy and electricity consumption should therefore be strengthened. Even more importantly, however, the energy-efficient retrofits of inefficient buildings as well as the switch to sustainable heating systems such as heat pumps must be accelerated. If this is not vigorously pursued, we can expect that heating energy consumption and thus also emissions in the building sector will rise again in the coming years.

Figure 7

Development of CO_2 emissions in the residential building sector
In kilograms of CO_2 per square meter of heated living space



Source: ista SE; authors' own calculations.

CO_2 emissions from residential buildings fall steadily, albeit at a very slow pace.

Sophie Behr is a research associate in the department of Climate Policy of DIW Berlin | sbehr@diw.de

Till Köveker is a research associate in the department of Climate Policy of DIW Berlin | tkoeveker@diw.de

Merve Kucuk is a research associate in the department of Climate Policy of DIW Berlin | mkucuk@diw.de

JEL: R31, Q21, Q40

Keywords: Heating demand, heating costs, building energy efficiency, residential buildings, gas prices

DIW Weekly Report

A policy bulletin from the German Institute for Economic Research

46 2024

Economy. Policy. Science.

DIW BERLIN

277 Report by Martin Gornig and Katrin Klarhöfer

Energy-efficient building renovation: Price-adjusted investments declining; trend reversal needed to reach climate targets

- Energy-efficient building renovation investments have increased in nominal terms but declined in price-adjusted terms since 2013
- Not enough energy-efficient building renovation has occurred to achieve climate targets in building sector
- German Federal Government must provide more funding to reverse the trend

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89–0 Fax: –200
Volume 14 November 21, 2024

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 46 2024

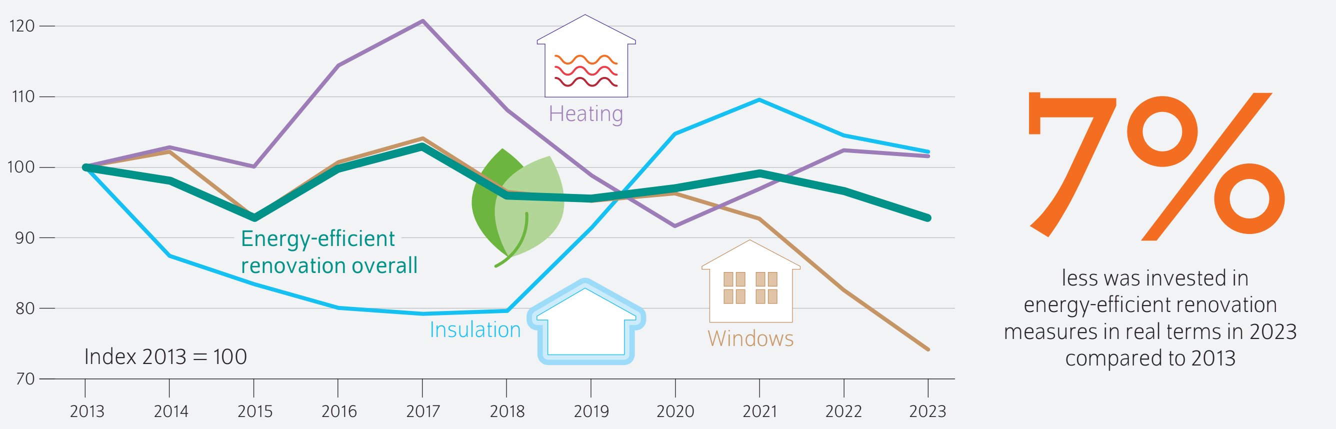
AT A GLANCE

Energy-efficient building renovation: Price-adjusted investments declining; trend reversal needed to reach climate targets

By Martin Gornig and Katrin Klarhöfer

- Investments in energy-efficient building renovation in Germany increased by 12 billion euros to 72 billion euros between 2021 and 2023, in part due to rising energy prices
- However, investments fell by over six percent in price-adjusted terms because due to the simultaneous increase in construction prices
- To achieve climate targets, considerably more real investments in insulation, new windows, heating, and other measures are needed
- Also needed are corresponding framework conditions as well as investment aid in Germany and across Europe
- German Federal Government increased funding for 2024 to 16.7 billion euros, but more is needed to reverse the trend in energy-efficient renovation

Excluding price increases, property owners have been investing less in energy-efficient renovation in 2024 compared to 2014



Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

FROM THE AUTHORS

"Most energy-efficient renovation is performed on residential buildings. However, commercial and public buildings also hold an enormous amount of potential. Sometimes these buildings are so poorly insulated that larger investments could possibility reduce heating emissions in this area faster."
— Martin Gornig —

MEDIA

Audio Interview with Martin Gornig (in German)
www.diw.de/mediathek

Energy-efficient building renovation: Price-adjusted investments declining; trend reversal needed to reach climate targets

By Martin Gornig and Katrin Klarhöfer

ABSTRACT

In light of rising oil and gas prices, investments in energy-efficient building renovation in Germany have risen recently in nominal terms. In 2023, around 72 billion euros were spent on the energy-efficient renovation of residential, public, and commercial buildings, about 12 billion more than in 2021. Nevertheless, investments declined by over six percent in price-adjusted terms, as construction prices rose sharply during this time as well. To reach climate targets, however, significantly more real investments in energy-efficient building renovation are needed, as are framework conditions in Germany and Europe. Investment aid for energy-efficient renovation measures also plays an important role. The German Federal Government increased funding for these measures for 2024 to 16.7 billion euros. However, policymakers will need to provide even more funding in the future due to rising financing and construction costs if they actually want to increase the rate of energy-efficient building renovation.

In its most recent report, the Council of Experts on Climate Change warned that much more progress needs to happen in the building sector than has occurred to date to reach the greenhouse gas reduction targets in Germany.[1] Reducing heating energy consumption in the building stock is one way to significantly reduce greenhouse gas emissions. For over a decade, there have been calls to improve the energy condition of the building stock by increasing building envelope insulation (walls, windows, roof) and installing more efficient heating systems.[2]

Energy-efficient renovation is difficult to measure, but there are suitable indicators

It is difficult to evaluate the extent to which energy-efficient renovation measures have actually improved the energy condition of the building stock over the past years. Detailed studies on this topic are extremely complex and only available for specific years.[3] Studies based on smaller samples can only determine rough trends in the development of energy-efficient building renovation over a few years. Moreover, they are limited to the existing residential building stock. According to the available data, the annual energy-efficient renovation rate, which is the share of a building's surface area that has undergone energy-efficient renovation in a certain year, has hardly changed since 2000 and is estimated to be less than one percent for 2017.[4]

An alternative approach for measuring energy-efficient renovation is based on the amount of money invested in this type of renovation instead of focusing on physical indicators.

1 Expert Council on Climate Change, *Review of Projection Data: Compliance with climate target for 2021 to 2030 not confirmed. Special Report in accordance with Section 12 (4) KSG* (2024).

2 Jürgen Blazejczak, Dietmar Edler, and Wolf-Peter Schill, "Steigerung der Energieeffizienz: ein Muss für die Energiewende, ein Wachstumsimpuls für die Wirtschaft," *DIW Wochenbericht* no. 4 (2014): 47-60 (in German; available online). Accessed on November 4, 2024. This applies to all other online sources in this report unless stated otherwise).

3 Holger Cischinsky and Nikolaus Diefenbach, *Datenerhebung Wohngebäudebestand 2016. Forschungsbericht* (Darmstadt: Institut Wohnen und Umwelt, 2018) (in German); Michael Hörner, Markus Rodenfels, and Holger Cischinsky, *Der Bestand der Nichtwohngebäude in Deutschland ist vermessen. Projektinformationen* (Darmstadt: Institut Wohnen und Umwelt, 2021) (in German).

4 Puja Singhal and Jan Stede, "Wärmemonitor 2018: Steigender Heizenergiebedarf, Sanierungsrate sollte höher sein," *DIW Wochenbericht* no. 36, 519–628 (in German; available online).

DOI: https://doi.org/10.18723/diw_dwr:2024-46-1

Box

Determining investments in energy-efficient building renovation

Investments in energy-efficient building renovation are estimated by combining aggregate statistical official evaluations from the DIW Construction Volume that have been broken down with extrapolated survey results from the construction service provider Heinze GmbH's Modernization Volume (Figure). The DIW Construction Volume contains the total of all services that are involved in the construction or maintenance of buildings and structures. In this respect, the Construction Volume goes beyond the construction investment figures of the Federal Statistical Office because their figures do not take into account consumable construction services, which are primarily repairs that do not increase in value (i.e., maintenance services provided by the main construction and finishing trades). Unlike in the official statistics, the DIW Construction Volume differentiates between construction services on the existing building stock and on new buildings.

Existing measures, or rather the volume of existing construction measures, are estimated from a macro perspective by looking at the differences between total construction output according to construction statistics and new construction output derived from construction activity statistics.[1] This has the advantage of allowing consistent comparisons over time. However, the model calculations using the difference approach lack structural information.

To identify such structural information, the results from the model calculations based on official statistics are considered. These are then compared with extrapolations of modernization volumes based on surveys. The extrapolation results are based on special analyses on the years 2014, 2018, 2020, and 2022 by Heinze GmbH.[2]

In Heinze GmbH's studies, the modernization volume is calculated by linking secondary statistical market data with survey results from target groups relevant to the modernization market. The main source of housing market data is a survey of representatively selected tenant and owner households. In addition, commercial housing developers are surveyed. The results for non-residential construction are based on evaluations of questionnaires on modernization measures run by architects. In addition, surveys of tradespeople are used. Using these sources, the existing measures can be differentiated by sector. Insulation measures (roofs, facades, etc.); replacement of windows and exterior doors; and the renewal of heating, air conditioning, and ventilation systems are considered components of energy-efficient renovation.

Structural information on the importance of the above sectors from a micro approach is consistently integrated into DIW construction volume calculation. A prerequisite for this is that the results of the two methods correspond with each other. This applies to the quantitative total result as well as the specific definition of construction services. Thus, investment construction services are the focus of the Heinze GmbH survey results. Due to its connection to the architect survey, this applies to non-residential construction especially. In the case of residential construction, on the other hand, work performed by the occupant, including neighborhood assistance and undeclared work, is not valued, unlike in the Construction Volume.

The structural information gleaned from the Heinze GmbH surveys is therefore not directly related to the Construction Volume as a whole, but only to the investment part. A model calculation to separate construction services into investment and non-investment measures is required to integrate the values from the structural information from Heinze. For this purpose, DIW Berlin specifically evaluated the structural information on repair measures from the Heinze surveys and made corresponding extrapolations for the average maintenance measures. The measures were differentiated over time by linking them to the development of gross fixed assets in structural engineering, for which DIW Berlin developed special model calculations.[3]

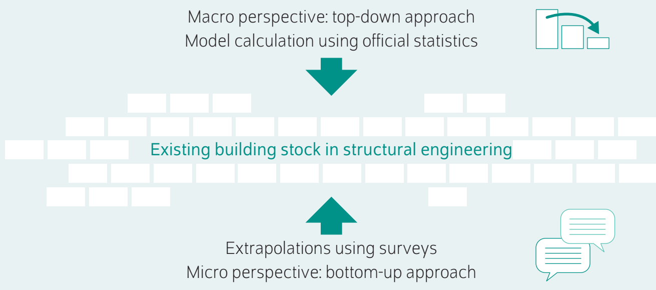
1 Martin Gornig, Claus Michelsen, and Hannah Révész, "Strukturdaten zur Produktion und Beschäftigung im Baugewerbe. Berechnungen für das Jahr 2020," *BBSER-Online-Publikation* 32 (2021) (in German; available online).

2 Katrin Klarhöfer, Christopher Kramp, and Christian Tiller, "Bestandsinvestitionen 2022. Struktur der Investitionstätigkeit in den Wohnungs- und Nichtwohnungsbeständen," *BBSR-Online-Publikation* 80 (2024) (in German; available online).

3 Susanne Hotze et al., "Struktur der Bestandsinvestitionen 2014. Investitionstätigkeit in den Wohnungs- und Nichtwohnungsbeständen," *BBSR-Online-Publikationen* no. 03 (2016) (in German; available online).

Figure

Analytical approach for determining investments in the building stock



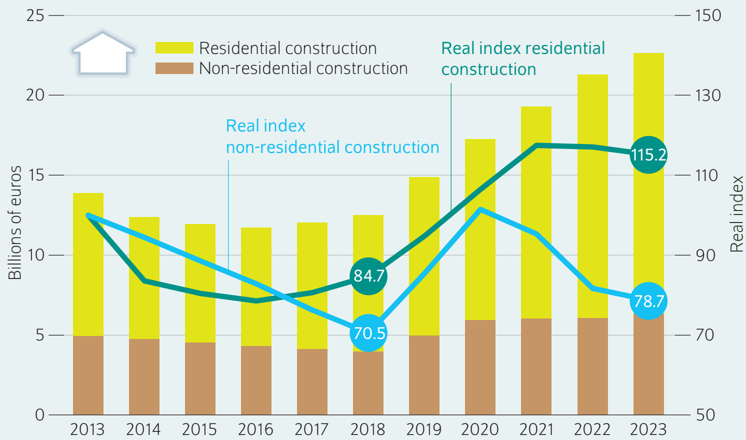
Source: Authors' depiction.

The extent of construction measures on the building stock is narrowed down by statistical model calculations and survey-based extrapolations.

How much has been spent on energy-efficient renovation can be estimated by observing construction activity. However, it is not possible to determine the specific additional amount spent on improving energy efficiency that results, for example, from installing a triple-glazed window compared to a double-glazed one. Nevertheless, it is possible to determine

Figure 1

Investments in roof, basement, and exterior door insulation
In billions of euros at current prices, as an index of price-adjusted values, 2013 = 100

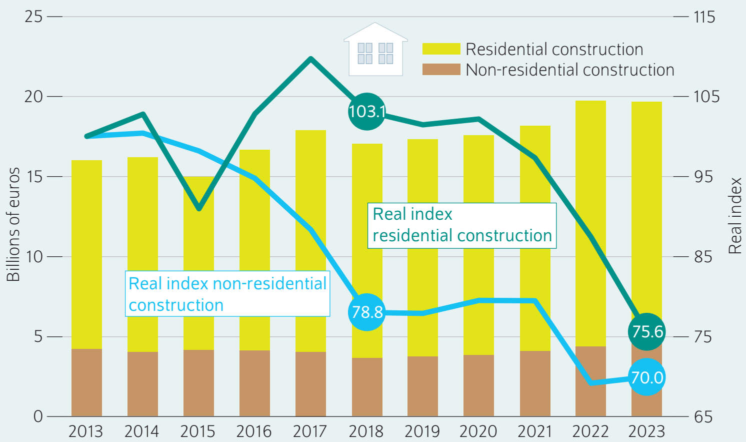


Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

Investments in the insulation of residential buildings have not increased in real terms since 2021.

Figure 2

Investments in the replacement of windows and exterior doors
In billions of euros at current prices, as an index of price-adjusted values, 2013 = 100



Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

When accounting for the enormous price increases of recent years, investments in windows and doors have declined considerably.

the total cost of window installation, including preparatory and finishing work. These gross costs are much higher than the additional spending specifically related to energy-efficient renovation. Previous studies on residential construction suggest that the investment costs are twice as high as the specific additional spending.[5]

The total amount invested in energy-efficient building renovation is estimated by breaking down aggregate statistical official evaluations that are a part of the DIW Construction Volume and by extrapolating survey results from the Modernization Volume of the construction service provider Heinze GmbH (Box). The Federal Institute for Research on Building, Urban Affairs and Spatial Development (*Bundesinstitut für Bau-, Stadt- und Raumforschung*, BBSR[6]) and the Federal Environment Agency (*Umweltbundesamt*, UBA[7]) regularly publish these results, which are based on the DIW Construction Volume and the Heinze Modernization Volume, on the investment volume in the energy-efficient renovation of residential and non-residential buildings.

Furthermore, this Weekly Report presents a differentiated evaluation of three energy-efficient renovation sectors: roof/wall insulation, window/door replacements, and heating/air conditioning system renewal.[8] In addition, the real development of investments in energy-efficient renovation are presented here to account for the strong price increases of recent years. A mix of price indicators are used to measure deflation, as the official price statistics do not directly reflect the individual energy-efficient renovation sectors. Roof/wall insulation, windows/doors, and heating/air conditioning are thus assigned to price indices for suitable product areas and economic classes.

Roof/wall insulation stagnating following growth

A significant share of expenditure on energy-efficient renovation is spent on improving the insulation of the building envelope. At current prices, over 16 billion euros were invested in insulating roofs, basement ceilings, and facades of residential buildings in 2023. Once again, roughly six billion euros were spent on insulating commercial and public non-residential buildings (Figure 1).

The nominal amount invested in insulation, especially of residential buildings, increased significantly over the past years. For example, the amount invested in the insulation of residential facades and roofs in 2023 was nearly twice as high as in 2018. However, when considering the enormous price increases since 2021, the real value of investments in the insulation of residential buildings did not increase in 2022 or 2023.

5 Institut der deutschen Wirtschaft, *Energetische Modernisierung des Gebäudebestandes: Herausforderungen für private Eigentümer. Untersuchung im Auftrag von Haus & Grund Deutschland* (2012) (in German); Prognos, *Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren. Untersuchung im Auftrag der KfW-Bankengruppe, Berlin* (2013) (in German).

6 Including photovoltaics: Martin Gornig, Claus Michelsen, and Hannah Révész, *Strukturdaten zur Produktion und Beschäftigung im Baugewerbe. Berechnungen für das Jahr 2020* (Bundesinstitut für Bau-, Stadt- und Raumforschung: 2024) (in German; available online).

7 Without photovoltaics: Jürgen Blazejczak et al., "Ökonomische Indikatoren von Maßnahmen zur Steigerung der Energieeffizienz – Materialien Berichtsjahr 2019," *Umwelt, Innovation, Beschäftigung* no. 3 (2020) (in German).

8 The 2023 values are based on preliminary calculations.

The insulation of non-residential buildings developed considerably less dynamically. Spending on building insulation in the commercial and public sectors rose again from 2019. However, only in 2020 were the nominal increases sufficient enough to reach the real investment level of 2013. Investments in the insulation of non-residential buildings, in contrast, were only around 80 percent of the initial level in 2024.

Window and exterior door replacements trending downward

The amount spent on window and exterior door replacements in residential buildings has barely changed over many years (Figure 2). For example, around 13.5 billion euros were spent on window and exterior door replacements from 2017 to 2020. Only recently has spending increased noticeably. However, the nominal increases were considerably lower than the high price increases due to the extremely high costs of glass production. Accordingly, real investments in window/exterior door replacements in the past three years have declined sharply: In 2023, the real investment level was nearly 25 percent lower than it was in 2013.

In price-adjusted terms, investments in the replacement of windows and exterior doors of commercial and public non-residential buildings declined even more markedly during the observation period. In 2023, real investments were 30 percent lower than in 2013. In nominal terms, about five billion euros have been spent on window and exterior door replacements by commercial and public building owners in 2024.

Renewed growth in heating system renewal since 2020

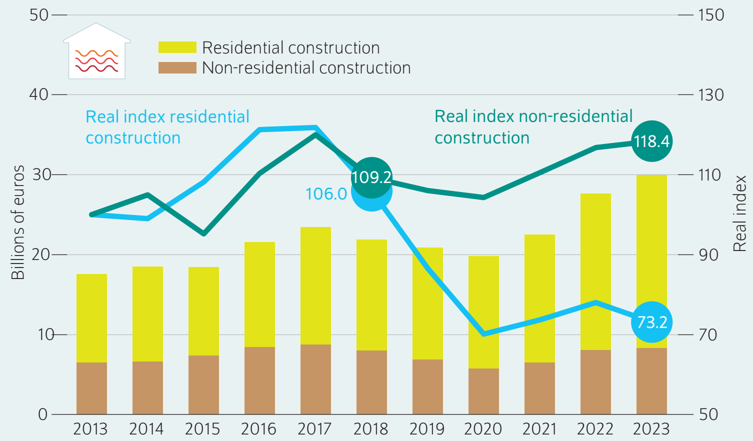
Compared to energy-efficient retrofitting of building envelopes via insulation or the replacement of windows and exterior doors, spending on heating system renewal has experienced stronger growth (Figure 3). Spending on heating system renewal in the residential housing stock has nearly doubled in nominal terms over the last 10 years. Although heating construction prices rose even more sharply than prices for energy-saving measures on the building envelope, the increases in spending were enough to maintain a high level of real investments in the renewal of heating systems in residential buildings. It is assumed that households are also investing in new gas heating systems before they become subject to strict regulations. However, investments narrowly missed reaching the peak value of real investments from 2017 in 2023.

Investments in heating and air conditioning (AC) technology for non-residential buildings have been on an upward trend for many years. From 2011 to 2017, spending on heating and AC technology increased from roughly six to nearly nine billion euros. Moreover, because the increase in spending outpaced price increases in this sector, real investments rose as well. Compared to 2017, however, commercial and public building owners' spending has declined considerably. As heating and AC technology prices experienced a strong increase at the same time, real investments declined by nearly 30 percent compared to 2013.

Figure 3

Investments in the renewal of heating and air conditioning systems

In billions of euros at current prices, as an index of price-adjusted values, 2013 = 100



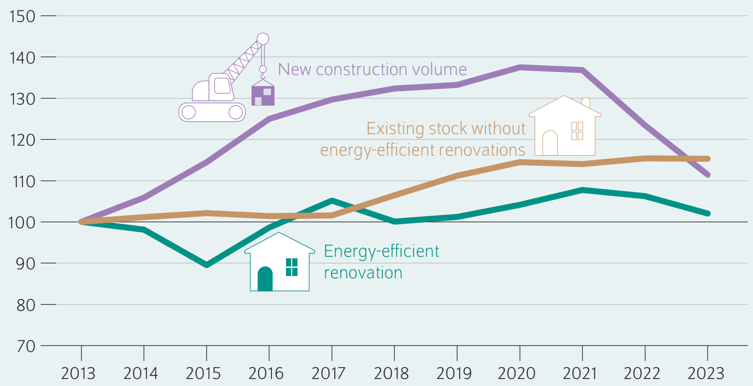
Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

The development of real investments in heating and air conditioning systems differs greatly between residential and non-residential buildings.

Figure 4

Development of real investments in energy-efficient renovation of residential buildings, in existing building stock, and newly constructed buildings

Index 2013 = 100



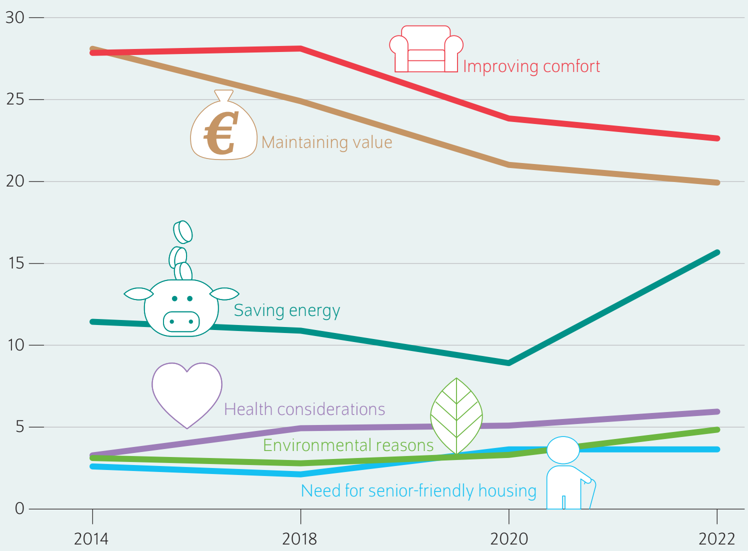
Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

Overall, real investments in the energy-efficient renovation of residential buildings were marginally higher in 2024 compared to 2014.

Figure 5

Reasons for modernizing residential buildings

Shares in percent



Note: This information was provided by property owners who live in their own property as well as owners who rent out their property.

Sources: Heinze GmbH; authors' calculations.

While saving energy is still not the most important reason for modernizing, it has increased in significance recently.

Energy-efficient renovation of residential buildings losing momentum overall

Overall, a bleak picture emerges when looking at investments in the energy-efficient renovation of residential buildings: Over the past 10 years, annual spending on this type of renovation increased by more than 65 percent to nearly 53 billion euros. However, when considering price increases, real investments in 2023 were barely higher than in 2013 (Figure 4). The first low point of real investments in energy-efficient renovation of residential buildings was in 2015 and was followed by a significant recovery in real investment activity. It had reached its previous peak value in 2021, when the annual total investment amount was about eight percent greater than the base year value. However, the considerable price increases in 2022 and 2023 almost canceled out the real growth in investments entirely.

Investments in the energy-efficient renovation of buildings thus developed markedly worse than in other areas of residential construction. Construction of new housing in particular experienced strong growth until 2020. Despite the current weak phase, investments in new construction were around 11 percent higher in price-adjusted terms in 2023 than in 2013. Other measures on existing buildings, such as the modernization of sanitary facilities or general maintenance, also resulted in real growth over the entire period. In price-adjusted terms, such spending was 15 percent higher in 2023 than in 2013.

There are diverse reasons for this investment restraint.[9] For many years, comparatively low oil and gas prices, which reduced pressure to undertake energy-efficient renovation, were a significant factor. Due to the climb in energy prices since 2021, saving energy has increased in importance as a reason for modernizing owner-occupied or rented residential buildings (Figure 5).[10] While only nine percent of investors cited energy savings as a reason for modernizing buildings in 2020, the figure had risen to 16 percent in 2022.

The parallel sharp rise in financing costs and construction prices is likely why the change in reasons for modernizing has not been reflected in a real increase in investments in energy-efficient renovation of residential buildings. In addition, the survey on modernization reasons shows that even in 2022, increasing comfort and maintaining value were still seen as more important investment reasons, with response rates of 23 percent and 20 percent, respectively.

Energy-related renovation in commercial and public structural engineering continuing its downward slide

Combining the results for investments in the individual sectors of energy-efficient public and commercial building renovation results in a concerning picture. In 2023, nearly 20 billion euros were spent on the energy-efficient renovation of non-residential buildings, around 25 percent more than in 2013. However, as prices for construction work rose by over 50 percent during the same period, one quarter less is being invested in the energy-efficient renovation of public and commercial buildings in real terms compared to 10 years ago (Figure 6).

Investment activity in energy-efficient renovation developed markedly worse than in other sectors of public and commercial structural engineering. In particular, the construction of new buildings increased considerably. In 2023, investments in new construction were about 25 percent higher than in 2013 in price-adjusted terms despite the current weak phase. Measures other than energy-efficiency measures on existing buildings also suffered real losses. In price-adjusted terms, spending was 17 percent lower in 2023 compared to 2013. The decline was thus noticeably lower than in energy-efficient renovation.

For many years, public and commercial investors were hesitant to renovate buildings to improve energy efficiency, likely due to comparatively low oil and gas prices. In addition, the structural change in the non-residential housing stock is occurring more strongly in new construction than in residential construction. Currently, it should also be noted that public authorities in particular are tied to nominal investment

9 Martin Gornig und Katrin Klarhöfer, "Investments in energy-efficient building renovation are on a downward slide," *DIW Weekly Report* no. 32/33 (2023): 225-232 (available online).

10 Katrin Klarhöfer, Christopher Kramp, and Christian Tiller, "Bestandsinvestitionen 2022. Struktur der Investitionstätigkeit in den Wohnungs- und Nichtwohnungsbeständen," *BBSR-Online- Publikation* no. 80 (2024) (in Germna; available online).

budgets and have only been able to partially adjust their budget estimates to the sharp rise in construction prices.

Conclusion: Trend reversal in energy-efficient building renovation urgently needed

There is no doubt that the energy efficiency of the building stock needs urgent improvement. In light of the weak real investment activity in recent years, energy-efficient renovation of the existing building stock must be quadrupled. Binding minimum standards and renovation targets must be set to reverse the trend in renovation activities.[11] The long-term expected development of energy prices is a decisive factor for the willingness to invest in energy-efficient renovation. Political decisions on carbon pricing play a key role here irrespective of fluctuating raw materials prices. A reliably foreseeable path of further energy cost increases is essential for creating investment incentives to reach the climate targets.

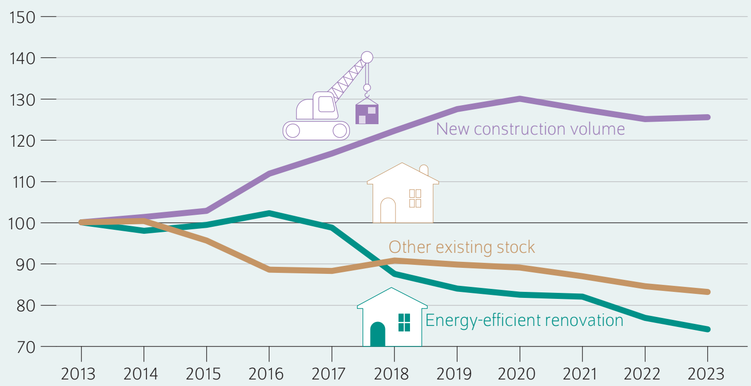
Furthermore, there must be appropriate funding conditions to achieve a noticeable increase in investments in the energy-efficient renovation of existing buildings. At the end of 2023, the German Federal Government reorganized the funding measures in the building sector as part of the Climate Action Program. The Federal Funding for Efficient Buildings program is the main approach to energy-efficient improvements in the building stock.[12] Since the beginning of 2024, the *Kreditanstalt für Wiederaufbau* and the Federal Office of Economics and Export Control (*Bundesamt für Wirtschaft und Ausfuhrkontrolle*) have made newly structured funding programs available for the energy-efficient renovation of residential and non-residential buildings.

The new focus of the funding programs has been accompanied by a sharp increase in funding for energy-efficient renovation. Funds in the amount of 16.7 billion euros for 2024 have been earmarked in the *Klima- und Transformationsfonds* for Federal Funding of Efficient Buildings.[13] This represents an increase of almost 50 percent compared to the funding for 2023.[14] Compared to the long-term average, the subsidies are even over three times as high.[15] However, the higher funding will likely not be enough to provide the strong impetus needed for renovation activities. The increase in nominal funding is offset by higher construction and financing costs in particular. Interest charges are likely to be almost three times higher compared to the end of the 2010s, even after the European Central Bank's further interest rate cuts. Construction costs have risen by an average of more than 40 percent in the same period. If policymakers really want to provide a strong impetus for energy-efficient renovation activities in existing residential buildings, they must be prepared to invest significantly higher amounts of funding in the coming years.

When designing the subsidy programs, care should be taken to ensure that the approved measures can be implemented in a flexible manner. Although the decline in new residential construction has significantly reduced construction capacity utilization,[16] there are still partial bottlenecks in individual trade services.

Figure 6

Development of real investments in energy-efficient renovation of non-residential buildings, in existing building stock, and newly constructed buildings
Index 2013 = 100



Sources: DIW Berlin Construction Volume; Heinze GmbH Modernization Volume; authors' calculations.

Real investments in non-residential construction are characterized by lots of new construction and little energy-efficiency renovation.

11 Sophie M. Behr, Merve Kücük, and Karsten Neuhoff, "Energetische Modernisierung von Gebäuden sollte durch Mindeststandards und verbindliche Sanierungsziele beschleunigt werden," *DIW aktuell* no. 87 (2023) (in German; available online).

12 Deutscher Bundestag, "Klimaschutzprogramm 2023 der Bundesregierung," Drucksache 20/8150 (2023) (in German; available online).

13 Bundesregierung, "Der Klima- und Transformationsfonds 2024," (2023) (in German; available online).

14 Deutsche Industrie- und Handelskammer, "Weiterhin langsamer Mittelabfluss beim Klima- und Transformationsfonds," May 3, 2024 (in German; available online).

15 Gornig and Klarhöfer, "Investments in energy-efficient building renovation are on a downward slide."

16 Martin Gornig and Laura Pagenhardt, "Decline in nominal construction volume expected for the first time since the financial crisis; residential construction situation worsening," *DIW Weekly Report* no. 1/2 (2024) (available online).

Martin Gornig is the Research Director of Industrial Policy in the Firms and Markets Department at DIW Berlin | mgornig@diw.de

Katrin Klarhöfer is a Project Staff Member in the Market Research Division at Heinze GmbH | katrin.klarhoefer@heinze.de

JEL: E22, Q40

Keywords: Energy-efficient building renovation, construction industry, building investment

DIW Weekly Report 47+48 2024

A policy bulletin from the German Institute for Economic Research

Economy. Policy. Science.

DIW BERLIN

Corrected version (Table on page 293)

287 Report by Wolf-Peter Schill, Julius Jöhrens, Dominik Räder, Hendrik Beeh, Josef Klingl, and Markus Werner

The future is battery electric: Climate change mitigation in road freight transport

- Road freight transport was responsible for around six percent of total German greenhouse gas emissions in 2022
- Market developments, costs, and efficiency advantages favor battery-electric trucks with stationary charging
- Government should continue to support expansion of charging infrastructure with fast charging options

LEGAL AND EDITORIAL DETAILS

DIW BERLIN

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
Phone: +49 30 897 89 – 0 Fax: – 200

Volume 14 December 4, 2024

Publishers
Prof. Dr. Tomaso Duso; Sabine Fiedler; Prof. Marcel Fratzscher, Ph.D.; Prof. Dr. Peter Haan; Prof. Dr. Claudia Kemfert; Prof. Dr. Alexander S. Kritikos; Prof. Dr. Alexander Kriwoluzky; Prof. Karsten Neuhoff, Ph.D.; Prof. Dr. Carsten Schröder; Prof. Dr. Katharina Wrohlich

Editors-in-chief
Prof. Dr. Pio Baake; Claudia Cohnen-Beck; Sebastian Kollmann; Kristina van Deuverden

Reviewer
Dr. Alexander Schiersch

Editorial staff
Rebecca Buhner; Dr. Hella Engerer; Petra Jasper; Adam Mark Lederer; Frederik Schulz-Greve; Sandra Tubik

Layout
Roman Wilhelm; Stefanie Reeg; Eva Kretschmer, DIW Berlin

Cover design
© imageBROKER / Steffen Diemer

Composition
Satz-Rechen-Zentrum Hartmann + Heenemann GmbH & Co. KG, Berlin

Subscribe to our DIW and/or Weekly Report Newsletter at
www.diw.de/newsletter_en

ISSN 2568-7697

DIW Weekly Report 47+48 2024

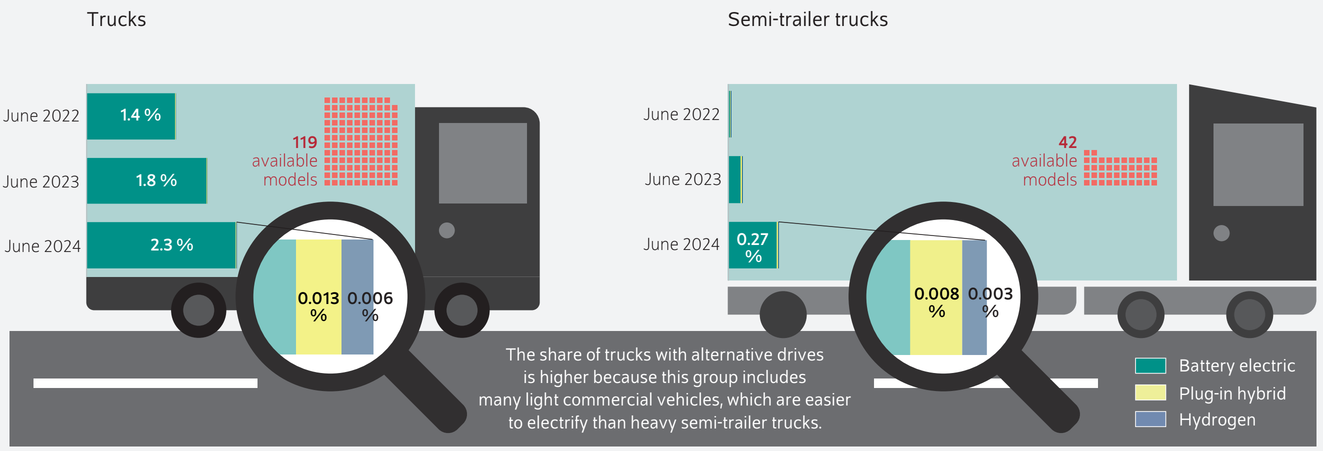
AT A GLANCE

The future is battery electric: Climate change mitigation in road freight transport

By Wolf-Peter Schill, Julius Jöhrens, Dominik Räder, Hendrik Beeh, Josef Klingl, and Markus Werner

- Heavy-duty road freight transport was responsible for around six percent of total German greenhouse gas emissions in 2022
- Battery-electric truck fleet is growing from a low level, while hydrogen trucks are stagnating
- Number of available models has increased; major manufacturers are mainly selling battery-electric drives
- Market developments, costs, and efficiency advantages clearly favor battery-electric trucks with stationary charging
- Government should continue to support the expansion of the charging infrastructure with fast charging options for trucks

Market development favors battery-electric drives in road freight transport



Sources: Data from the Federal Motor Transport Authority, aggregated and visualized in the Open Energy Tracker; ifeu's truck database.

FROM THE AUTHORS

"The market development as well as energy efficiency and cost advantages clearly favor battery-electric drives in road freight transport. Policymakers should set a clear focus on this technology and specifically eliminate bottlenecks in the expansion of the charging infrastructure to create investment security for manufacturers and logistics firms."

— Wolf-Peter Schill —

The future is battery-electric: Climate change mitigation in road freight transport

By Wolf-Peter Schill, Julius Jöhrens, Dominik Räder, Hendrik Beeh, Josef Klingl, and Markus Werner

ABSTRACT

Road freight transport must switch to alternative drive technologies, such as battery-electric or hydrogen vehicles, to mitigate its impact on the climate. Preliminary results from an ongoing research project show that the fleet of battery-electric trucks as well as the number of models on offer have recently grown significantly, albeit from a very low level. This is not the case for hydrogen trucks. Considerable amounts of investment from the private sector are flowing into the charging infrastructure. Compared to hydrogen trucks, battery-electric vehicles have major advantages when it comes to energy efficiency, foreseeable energy costs, and their expected and realistic contribution to climate change mitigation. Policymakers should therefore set a clear focus on ramping up battery-electric trucks while expanding the charging infrastructure, the fast charging network more vigorously in particular. To face possible challenges, especially when it comes to grid connections, battery swapping systems, or overhead line systems—which have a large technological overlap with battery-electric trucks—could be tested further. Furthermore, the energy efficiency advantages of battery-electric trucks should be considered in the greenhouse gas reduction quota system.

Germany has set a goal to become climate neutral by 2045. This requires climate change mitigation measures in all economic sectors, including road freight transport. One important strategy for this sector is switching from diesel trucks to battery-electric or hydrogen trucks.

This Weekly Report provides an overview of the current fleet and market development trends of battery-electric and hydrogen trucks as well as of the expansion of the charging and refueling infrastructure. Next, it discusses the advantages and drawbacks of alternative technologies as well as their possible contributions to climate change mitigation. The data used in this Weekly Report are drawn from preliminary results of an ongoing research project of the Institute for Energy and Environmental Research (*Institut für Energie- und Umweltforschung Heidelberg*, ifeu), TU Dresden, and DIW Berlin.[1]

Necessity of and options for climate change mitigation in road freight transport

Road freight ranges from urban distribution and delivery transport via light commercial vehicles to trans-national heavy goods transport. A variety of vehicles are used for such transport, differing in aspects such as configuration and permitted gross weight. Vehicles heavier than 3.5 tons are known as heavy-duty vehicles. The Federal Motor Transport Authority (*Kraftfahrt Bundesamt,* KBA) differentiates between straight trucks (*Lastkraftwagen*) and tractor units (*Zugmaschinen*). Especially relevant for heavy goods transport is the subgroup of semi-trailer trucks.[2] Semi-trailer trucks cover daily distances of 400 to 500 kilometers on average, much greater than other trucks (around 300 kilometers).

1 This Weekly Report is based on two recently published project reports: Julia Pelzeter et al., *Bewertung von Technologiekonfigurationen für den Straßengüterverkehr* (ifeu, TU Dresden, DIW Berlin: 20224) (in German; available online. Accessed on October 28, 2024. This applies to all other online sources in this report unless stated otherwise) as well as Julius Jöhrens et al., *Komplementärtechnologien zu BEV-Lkw – ein techno-ökonomischer Vergleich* (ifeu, TU Dresden, DIW Berlin: 2024) (in German; available online).

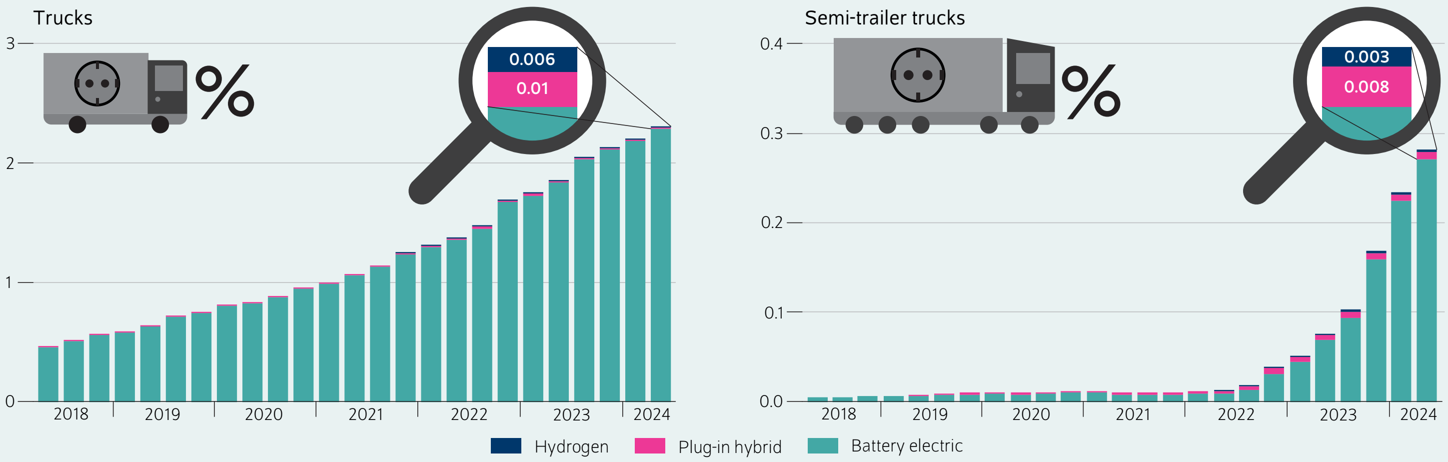
2 Colloquially and also in this report, the term "truck" is used in such a way that it includes both trucks and tractor units as defined by official statistics.

DOI: https://doi.org/10.18723/diw_dwr:2024-47-1

Figure 1

Road freight vehicle fleet in Germany

Share of alternative drives in percent



Note: Hydrogen includes fuel cells and hydrogen combustion engines.

Sources: Data from the Federal Motor Transport Authority, aggregated and visualized in the Open Energy Tracker (in German; available online).

The battery-electric vehicle fleet is growing from a low level, while the hydrogen fleet is barely growing.

Road freight causes significant greenhouse gas emissions in Germany, and the emissions keep rising. Commercial vehicles weighing over 3.5 tons were responsible for 28 percent of emissions from the transport sector and for around six percent of total German greenhouse gas emissions in 2022.[3] Around two thirds of these commercial vehicles weighed over 26 tons; they are mainly used for long-distance routes.

Various alternative drive options

Possible strategies for climate change mitigation in road freight are avoiding transport, switching to rail freight, and using alternative drives. There appears to be limited potential for avoiding transport and switching to rail freight.[4] Thus, the focus is on switching from diesel trucks to battery-electric vehicles, which requires an expansion of the fast-charging infrastructure. There are also two hydrogen-based options: Vehicles with hydrogen combustion engines and vehicles with fuel cells and an electric motor. Both types require hydrogen refueling stations.

There has also been some discussion of retaining diesel engines while using biofuels or synthetic fuels based on green hydrogen (e-fuels). However, we do not investigate these options further in this Weekly Report as they do not appear to be affordably scalable.[5]

No technology-specific goals to date

The German Federal Government's Climate Action Programme 2030 stipulates that around one third of heavy road freight transport mileage must be electric or powered by electric fuels by 2030.[6] Using alternative drives for road freight thus poses an especially large opportunity for decarbonization.[7] However, there are no concrete targets for newly registered trucks or the fleet of electric trucks, unlike for electric passenger vehicles.

In 2024, stricter fleet targets for carbon emissions of newly registered heavy commercial vehicles were set at the European level.[8] By 2030, newly registered trucks over 7.5 tons must have 45 percent lower CO_2 emissions compared to 2019. By 2035 and 2040, they must have 65 and 90 percent lower emissions, respectively, than in 2019.[9] These targets

3 Authors' calculations based on the Transport Emission Model (TREMOD), version 6.61 as well as data from the Federal Environment Agency (*Umweltbundesamt*, UBA) (in German; available online).

4 Cf. The second section of the Spring Report 2024: Sachverständigenrat für Wirtschaftsfragen, *Güterverkehr zwischen Infrastrukturanforderungen und Dekarbonisierung* (2024) (in German; available online).

5 Wolf-Peter Schill, "E-Fuels: Ja, aber nicht für Pkw," commentary in DIW Wochenbericht no. 17 (2021): 304 (in German; available online); as well as Falko Ueckerdt and Adrian Odenweller, E-Fuels – Aktueller Stand und Projektionen (2023) (in German; available online).

6 Bundesregierung, *Klimaschutzprogramm 2030 der Bundesregierung zur Umsetzung des Klimaschutzplans 2050* (2019) (in German; available online).

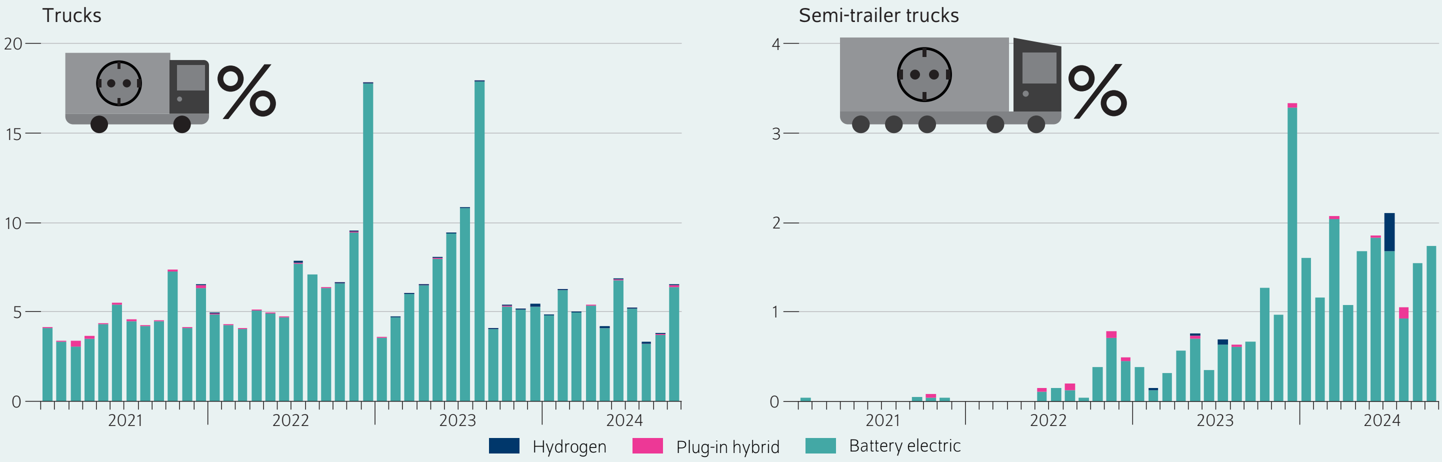
7 Sachverständigenrat für Wirtschaftsfragen, *Güterverkehr zwischen Infrastrukturanforderungen und Dekarbonisierung.*

8 Regulation (EU) 2024/1610 of the European Parliament and of the Council of 14 May 2024 (available online).

9 There are exceptions for small-volume manufacturers, mining, agriculture, and forestry, as well as for vehicles for military, civil defense, public safety, and medical care purposes.

Figure 2

Monthly new road freight vehicle registrations
Share of alternative drives in percent



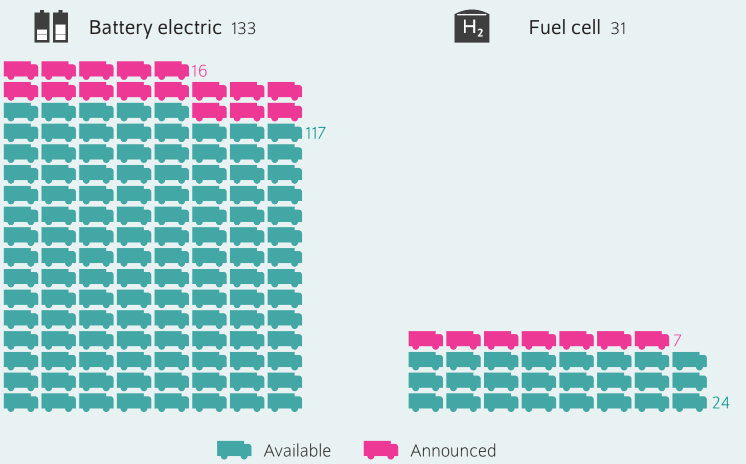
Note: Hydrogen includes fuel cells and hydrogen combustion engines.

Sources: Data from the Federal Motor Transport Authority, aggregated and visualized in the Open Energy Tracker (in German; available online).

Registrations of heavy battery-electric semi-trailer trucks increased considerably recently.

Figure 3

Announced and available vehicle models in Germany
Number as of October 2024



Note: Because there are different configurations per model, only the highest battery capacity and the smallest number of axels are evaluated as separate models. Hydrogen combustion engines are not included in these figures.

Source: The ifeu's truck database.

Most vehicle models are battery electric.

can probably only be achieved with a rapid increase in newly registered trucks with electric drives.[10]

Current market development favors battery-electric vehicles

Currently, there are around 3.8 million trucks in Germany, 530,000 of which weigh more than 3.5 tons. In addition, there are 236,000 semi-trailer trucks (Figure 1).[11] Diesel engines dominate overwhelmingly in both sectors: 92 percent of trucks and 97 percent of semi-trailer trucks have diesel engines. Only around 2.3 percent of trucks are pure battery-electric trucks; most are light commercial vehicles weighing less than 3.5 tons. Only 0.3 percent of semi-trailer trucks are battery electric.

However, the shares of new registrations of battery-electric vehicles are markedly higher (Figure 2). This has resulted in a considerable recent increase in the fleet of battery-electric vehicles, albeit from a low level. On average over the last

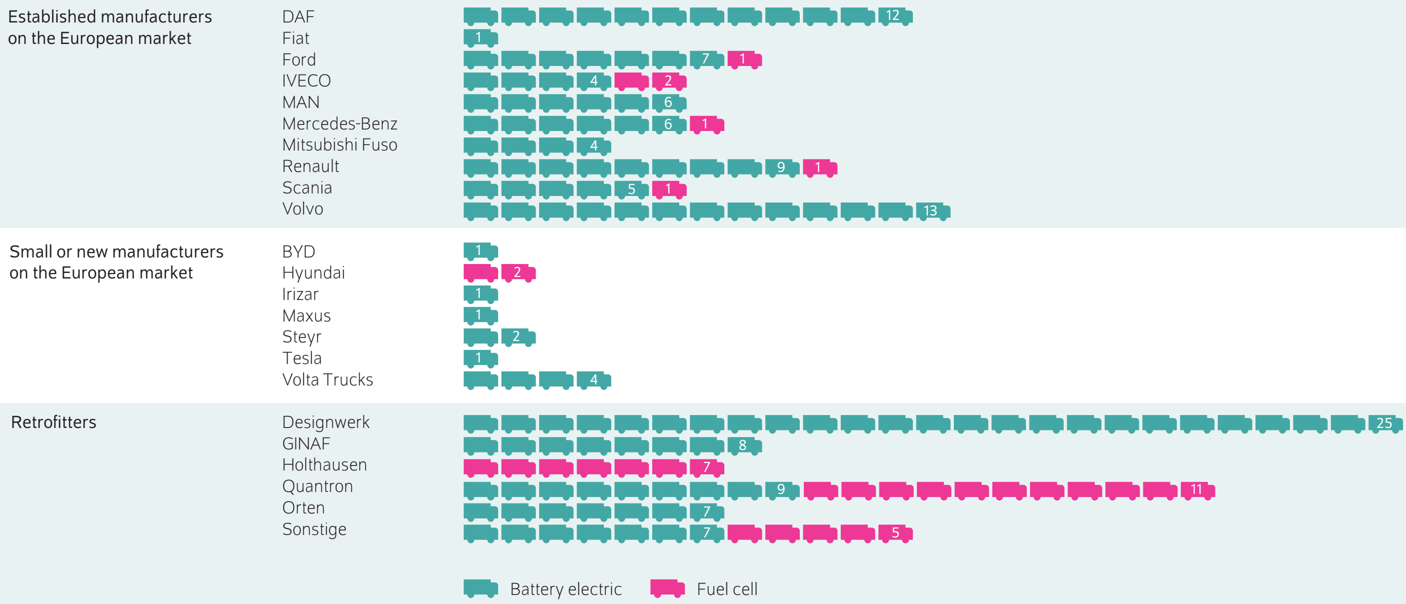
10 For more on the decarbonization of road freight and the possible roles different technologies can play, cf. Alexander Roth and Wolf-Peter Schill, hosts, "Elektro-Lkw, Teil 1: Batterien oder Wasserstoff," fossilfrei (podcast) episode 18, June 14, 2024 (in German; available online); and Alexander Roth and Wolf-Peter Schill, hosts, "Elektro-Lkw: Technologieoffenheit als Kampfbegriff?" fossilfrei (podast) episode 19, June 28, 2024 (in German; available online).

11 The data in this section is drawn from the KBA's statistics on commercial vehicles (FZ 25, available online), the quarterly vehicle fleet (FZ 27, available online), and monthly new registrations (FZ 28, available online) (all in German). This data is regularly evaluated and visualized in the Open Energy Tracker (available online).

Figure 4

Vehicle models listed by manufacturer

Number as of October 2024



Notes: Retrofitters are specialist firms that usually have a low number of vehicles they produce, as they mainly focus on retrofitting vehicles of other manufacturers.

Source: The ifeu's truck database.

The major manufacturers mainly offer battery-electric trucks. Most fuel cell trucks are offered by retrofitters.

12 months, five percent of all new trucks as well as 1.6 percent of all new semi-trailer trucks were pure battery electric.[12]

Despite being a frequent topic of policy discussion, hydrogen has not yet played any meaningful role in road freight. Currently, there are around 400 pure battery-electric trucks for every hydrogen truck in the fleet, while there are more than one hundred times as many battery-electric semi-trailer trucks as hydrogen semi-trailer trucks. Further, there is no positive trend in new registrations of hydrogen vehicles.

Considerable increase in number of electric vehicle models

A wide variety of available models is important for the market potential of electric trucks due to factors such as route profiles, differing requirements in the logistics sector depending on the type of good being transported, and the often strong brand loyalty of truck operators.

In total, 164 different models in the sector of heavy trucks and semi-trailer trucks weighing over 3.5 tons could be identified on the German market in October 2024 (Figure 3).[13] One hundred and forty-one of these models (86 percent) are already available and 23 have been announced (14 percent). Thus, compared to an earlier evaluation in October 2022 when 65 models were available, the number of models on offer has more than doubled.

Around 80 percent of these models are battery electric, while the remaining 20 percent have a fuel cell drive. Hydrogen vehicles are rather well represented in the model range compared to their current niche role in existing and new vehicle registrations.[14] However, a small number of specialist companies produce a large share of hydrogen trucks, and most of them concentrate on converting vehicles from other manufacturers. Of the major manufacturers in Europe, in contrast, only six offer or have announced fuel cell vehicles (Figure 4).

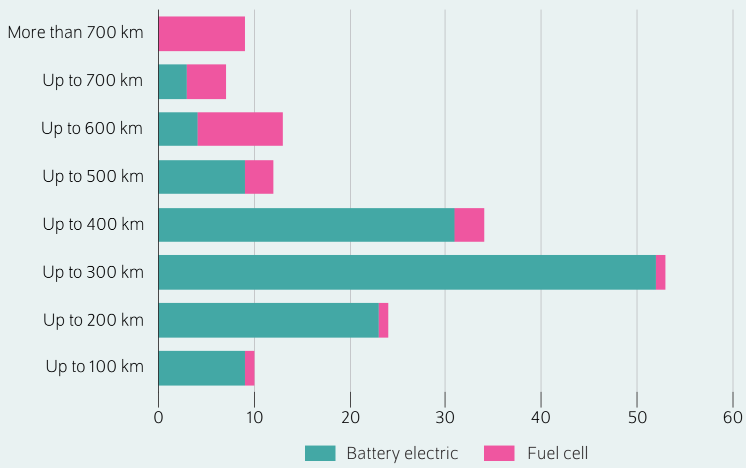
12 Among other things, changes to the fleet targets for newly registered trucks as well as to subsidy programs account for outliers in individual months. At the federal level, for example, there was a subsidy financed by the Climate and Transformation Fund (*Klima- und Transformationsfonds, KTF*) for the purchase of battery-electric or hydrogen commercial vehicles until 2023. This subsidy was ended without a replacement following the ruling of the Federal Constitutional Court on November 15, 2023, and the subsequent budget consolidation. However, there are still individual subsidy programs at the state level, cf. ifeu overview (in German; available online).

13 A vehicle model is determined by eight parameters: manufacturer, drive system, drive power, battery capacity, hydrogen tank capacity, fuel cell capacity, and number of axels. As there can be many different configurations per model (for example, battery capacity or number of axels), only the greatest battery capacity and the smallest number of axels are evaluated as separate models.

14 This also applies when compared to the significantly larger passenger vehicle market, in which only two fuel cell models are currently available in Germany.

Figure 5

Range of available and announced vehicle models
Number of models as of 2024



Note: The figure shows the total number of available and announced models.

Source: The ifeu's truck database.

The range of most vehicles on offer can cover distances required for regional transport.

A good 80 percent of the models, almost exclusively battery-electric trucks, have a range of less than 500 kilometers. The focus is on ranges of 200 to 300 kilometers, which can cover regional transport (Figure 5).[15] There are a few battery-electric models with a range of over 500 kilometers, but most of these are equipped with a fuel cell drive. Range is an important aspect in ongoing discussions about potential benefits of fuel cell vehicles, which is clearly reflected in the available models.

The available models cover all size classes of commercial vehicles.[16] More than half of the models have a gross vehicle weight of over 12 tons. While the larger vehicles tend to have a somewhat greater range, the range profile is similar for all vehicle sizes. This also applies to the semi-trailer trucks that are common in long-distance transport, as these can currently usually only be ordered with the same battery sizes as trucks over 12 tons.

Various manufacturer strategies

Individual manufacturers differ greatly in their view on the strategic importance of hydrogen drives. While the TRATON Group (MAN / Scania), for example, has strongly emphasized the economic advantages of battery-electric vehicles in recent years and views them as the clear focus of its corporate strategy,[17] Daimler is pursuing a dual strategy with battery-electric drives and fuel cells to power heavy long-haul transport.[18] Other manufacturers use a "three-pillar model" including renewable fuels (Volvo)[19] or a "technology-neutral multi-drive approach" (Iveco).[20] Only Renault Trucks will explicitly exclude fossil combustion engines from 2040 onward.[21] Volvo, MAN, DAF, and Iveco also include the hydrogen combustion engine as an option to varying degrees.

Information provided by manufacturers at "cleanroom discussions",[22] which have been initiated by the Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr, BMDV) to better assess the future roll-out of low-carbon trucks, shows that the market share of pure battery-electric drives in heavy commercial vehicles is expected to increase significantly in the coming years. By 2030, they will make up around half of all sales in the over 12 tons weight class. Various other technologies will play more of a supplementary role.

Ramp-up of charging and refueling infrastructure

Battery-electric and hydrogen drives face different challenges when it comes to their public energy supply infrastructure. In many cases, battery-electric trucks can recharge the majority of their battery at a depot, provided that the grid connections and vehicle profiles allow it. However, a certain amount of fast charging is required, especially in long-distance transport.[23] Hydrogen trucks, on the other hand, cannot be refueled in depots, but are generally dependent on public hydrogen refueling stations, as the construction and operation of refueling stations is expensive compared to electric depot charging stations.

Expansion of the fast-charging infrastructure

The established Combined Charging System (CCS) standard is available for charging infrastructure up to a capacity of 400 kilowatts. Currently, 31,000 CCS charging stations are publicly available in Germany.[24] In general, they are designed for passenger cars, but some can also serve trucks.

15 The range is calculated per vehicle model using the net battery capacity as well as typical energy consumption (battery capacity/energy consumption = range).

16 Here we consider the size classes N2 (< 12 tons) and N3 (> 12 tons). Light commercial vehicles (N1) are not included.

17 MAN, *Strategie – MAN auf einen Blick* (2024) (in German; available online); Scania, *Das Bekenntnis von Scania zu batteriebetriebenen Elektrofahrzeugen* (2021) (in German; available online).

18 Daimler Truck, *Diskussion Batterie vs. Wasserstoff: Daimler Truck setzt mit beiden Technologien konsequent auf Doppelstrategie* (2022) (in German; available online).

19 Volvo Trucks, Gemeinsam in Richtung null Emissionen: Unser Weg zur Dekarbonisierung des Transports (2024) (in German; available online).

20 IVECO Group, *Iveco Group präsentiert Multi-Antriebs-Strategie und stellt innovative Lösungen auf der IAA TRANSPORTATION 2024 vor* (2024) (in German; available online).

21 Renault Trucks, *Renault Trucks bietet ab 2023 eine elektrische Baureihe für jedes Marktsegment an* (2021) (in German; available online); cf. Renault Trucks, *Towards low-carbon transport* (2024) (available online).

22 NOW, *Marktentwicklung klimafreundlicher Technologien im schweren Strassengüterverkehr. Nationale Organisation Wasserstoff und Brennstoffzellentechnologie* (2024) (in German; available online).

23 Daniel Speth and Patrick Plötz, "Depot slow charging is sufficient for most electric trucks in Germany," *Transportation Research Part D: Transport and Environment*, vol. 128 (2024).

24 Bundesnetzagentur, *Ladeinfrastruktur in Zahlen* (2024) (in German; available online). Information on the charging infrastructure is regularly prepared in the Open Energy Tracker (in German; available online).

Corrected version (Table)

Table

Truck charging infrastructure activities
As of October 2024

	State	Private sector				
	Initial charging network (BMDV, BMWK)	e.On, MAN	Milence	Aral Pulse	TST+EWR (PVSM Energy)	CityWatt
Planned locations	350	125 (DE), 170 (EU + UK)	25 (DE), 70 (EU)	30	41	N. a.
Planned charging points	4,200	400	570 by 2025, 1,700 by 2027 (EU)	N. a.	N. a.	N. a.
Existing locations	0	1 (DE)	0 (DE) / 4 (EU)	25 (DE) / 26 (EU)	1	50
Type of location	Rest areas	Near highways (first location)	Near highways, truck stops, city center	Aral truck stops	Near highways	City centers/industrial areas, near highways, federal highways
Planned finish date	Until 2030	TBD	2025	2024	2025	2024
Charging capacity	1,800 x MCS, 2,400 x CCS	Initially 400 kW CCS, MCS to be added later	CCS+MCS (at five existing locations first)	CCS 300 kW	CCS 400 kW	CCS 300 kW

Source: Authors' research.

However, much higher charging capacities may be necessary to recharge the batteries of heavy long-distance transport trucks quickly enough during the drivers' breaks. To solve this issue, a new fast charging standard is being developed and is nearly ready to be introduced, the Megawatt Charging System (MCS). The MCS should make charging capacities of up to 3.75 megawatts (3,750 kilowatts) possible.[25]

Recently, various private sector actors have announced plans to build specific truck charging stations in over 200 locations, and construction has already begun on some of them (Table). On the government side, the BMDV and the Federal Ministry for Digital and Transport (*Bundesministerium für Digitales und Verkehr*, BMDV) have launched an initiative for a fast-charging network for trucks[26] that includes around 350 locations on federal highways. An initial tender for truck charging stations at around 130 unmanaged rest areas has already been launched,[27] with another to follow. For all planned station locations, the electrical connection capacities required and corresponding grid connections have already been planned and applied for.

The public fast charging infrastructure is primarily needed to make it possible for battery-electric trucks to cover the typical long-distance transport profiles. This infrastructure will likely be of great importance for compliance with the stricter European fleet CO_2 targets from 2030 onward. Until public truck charging infrastructure is widely available, many battery-electric trucks can rely on depot charging, especially trucks used for regional transport, which can in turn promote the market ramp-up of electric trucks.[28]

Challenges for hydrogen refueling stations

To date, hydrogen refueling stations have mainly been planned for passenger cars at a pressure level of 700 bar. However, trucks require a lower pressure of 350 bar, which only around half of the existing refueling stations can currently provide. As of September 2024, there are 42 refueling stations with a pressure level of 350 bar.[29] Some manufacturers are also considering using liquid hydrogen in future vehicle models, which entails uncertainty regarding the construction of new refueling stations.[30] The previous funding for hydrogen refueling stations from the Climate and Transformation Fund (*Klima- und Transformationfonds*, KTF) was discontinued due to funding problems.

While there are concrete private sector activities and government tenders being undertaken for the battery-electric truck charging infrastructure, there is much more planning uncertainty when it comes to the construction of hydrogen refueling stations. On the government side, the main issue is how to ensure compliance with the European minimum infrastructure requirements[31] and whether the targets need to be adapted to the new market reality.[32]

25 The charging infrastructure capacity for passenger vehicles is considerably lower in contrast. Currently, direct current fast charging stations can achieve a maximum of 0.4 megawatts. Typical alternating current charging stations only achieve 0.022 megawatts.

26 BMWK and BMDV, "Startschuss für das Lkw-Schnellladenetz," press release from July 3, 2024 (in German; available online).

27 BMDV, "Ausschreibung für Lkw-Schnellladeinfrastruktur gestartet," press release from September 16, 2024 (2024) (in German; available online); Nationale Leitstelle Ladeinfrastruktur, *Standorte für das LKW-Schnellladenetz an Rastanlagen mit benötigten Netzanschlussleistungen* (in German; available online); Nationale Leitstelle Ladeinfrastruktur, *Standorte für das LKW-Schnellladenetz an Rastanlagen mit benötigten Netzanschlussleistungen* (in German; available online).

28 Pelzeter et al., *Bewertung von Technologiekonfigurationen für den Straßengüterverkehr.*

29 BMDV, *Informationsveranstaltung zum nationalen Strategierahmen gemäß EU-Verordnung über den Aufbau der Infrastruktur für alternative Kraftstoffe (AFIR)* (2024) (in German; available online).

30 Cf. Sachverständigenrat für Wirtschaftsfragen, *Güterverkehr zwischen Infrastrukturanforderungen und Dekarbonisierung.*

31 These involve, among other things, location density and the quantities dispensed, cf. BMDV, *Informationsveranstaltung zum nationalen Strategierahmen*

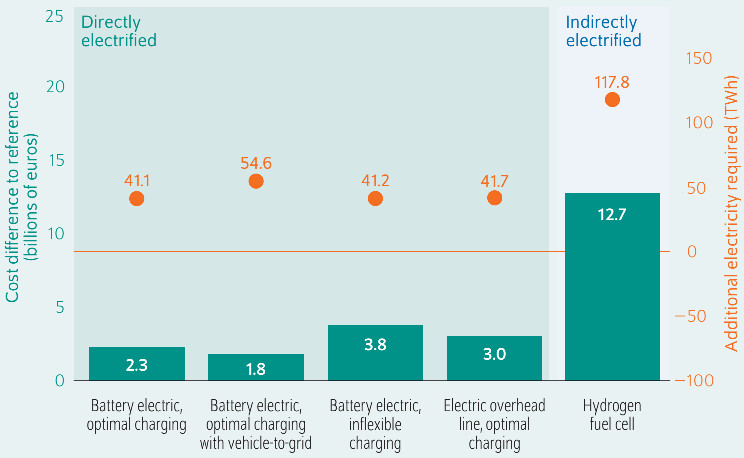
32 Cf. Sachverständigenrat für Wirtschaftsfragen, *Güterverkehr zwischen Infrastrukturanforderungen und Dekarbonisierung.*

Box

Electricity sector analysis: Advantages of hydrogen storage do not outweigh energy-efficiency drawbacks

Figure

Change in electricity sector costs compared to the reference (diesel trucks) as well as the electricity consumed by vehicles
Billions of euros (left axis), terawatt hours (right axis)



Notes: Calculations for 2030 under the assumption that heavy road transport has been completely electrified with the technology in question. Green hydrogen is assumed to be produced in Germany.

Source: Carlos Gaete-Morales et al., "Power sector effects of alternative options for de-fossilzing heavy-duty vehicles—Go electric, and charge smartly," *Cell Reports Sustainability* 1, no. 6 (2024): 100123 (available online).

The electricity sector costs of battery-electric trucks are lower than for hydrogen fuel cell trucks, even when the batteries are inflexibly charged.

An analysis using DIW Berlin's open-source electricity sector model DIETER shows that battery-electric vehicles with fast charging capabilities result in the lowest electricity sector costs of all options under observation. Even if the battery-electric vehicles are not optimally charged, they still have clear advantages compared to hydrogen fuel cell vehicles or synthetic hydrogen-based e-fuels. The advantages are even greater if the batteries are flexibly charged based on the electricity market price in combination with vehicle-to-grid charging, where electricity is fed back to the grid at times.

Battery-electric vehicles have such an advantage due to the poor energy efficiency of hydrogen and e-fuels, which are assumed to be domestically produced in the model. Domestic production results in considerable costs for the renewable energy used. However, it is often argued that this drawback could be offset by the advantageous storage capacity of hydrogen and e-fuels, which will become more important in a future energy system with a high share of variable wind and solar energy. However, the model analyses show that the energy efficiency drawbacks of hydrogen and e-fuels clearly outweigh their storage advantages (Figure).[1]

1 Carlos Gaete-Morales et al., "Power sector effects of alternative options for de-fossilizing heavy-duty vehicles—Go electric, and charge smartly," *Cell Reports Sustainability* 1, no. 6 (2024): 100123 (available online). A condensed version in German is available in DIW Aktuell: Wolf-Peter Schill et al., "Klimaschutz im Güterverkehr: Batterieelektrische Antriebe können günstiger mit erneuerbarem Strom versorgt werden als Wasserstoff-Lkw," *DIW Aktuell* no. 94 (2024) (in German; available online).

Challenges facing battery-electric trucks and possible contributions of other technologies

The developments on the vehicle market and in the charging infrastructure as well as energy efficiency and energy system analyses suggest that battery-electric vehicles in combination with stationary charging will become a key building block of climate-friendly heavy road freight transport. However, a systematic comparison of different criteria shows that this technology is also facing various challenges,[33] including integration into the power grid and the effects on the stability of the energy system, the space required for the charging infrastructure, the raw materials required for batteries, the operational changes required for logistics firms, and the cost of vehicles.

Hydrogen has some advantages, but many drawbacks

Hydrogen drives have advantages when it comes to some of the observed criteria. For example, they do not require fast charging infrastructure to be connected to the power grid, and thus neither any reinforcement measures in the higher voltage network. The space requirement and the need for operational adjustments at logistics firms are also rated as slightly more favorable than for battery-electric trucks.[34] However, hydrogen trucks have some of their own challenges when it comes to infrastructure expansion and energy costs, which ultimately comes down to their poor energy efficiency (Box). In addition, uncertainty around future energy cost appears to be significantly higher for hydrogen trucks than for battery-electric trucks. This is due to the fact that the hydrogen market hardly exists to date, but it has a large number of potential future consumers.

In light of the foreseeable high hydrogen demand from other sectors, especially industry, it seems questionable whether significant quantities of green hydrogen can be made available for road freight in the medium term. Barely any projects have been realized so far, both in domestic production as well as planned hydrogen imports.[35]

33 This section is based on an analysis by Jöhrens et al., *Komplementärtechnologien zu BEV-Lkw.*

34 Pelzeter et al., *Bewertung von Technologiekonfigurationen für den Straßengüterverkehr.*

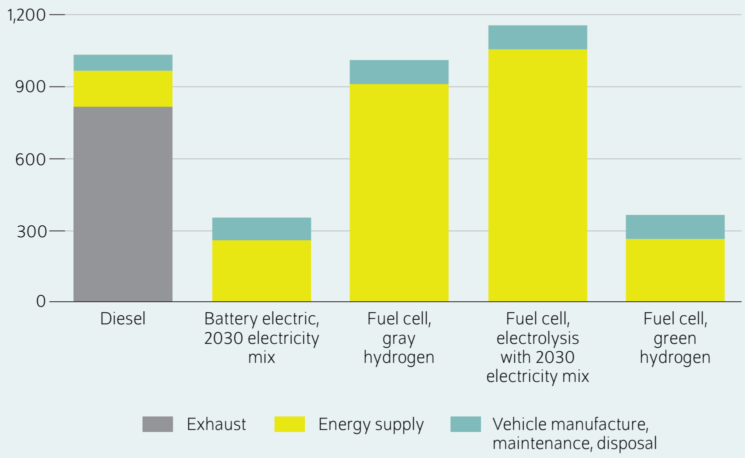
35 Cf. the Ampel-Monitor Energiewende for the state of elctrolysis and its targets as well as Martin Kittel et al., "National Hydrogen Strategy: Clear focus and consistent implementation necessary," *DIW Weekly Report* no. 40+41+42 (2023) (available online).

This also raises the question if hydrogen trucks can even contribute to quickly reducing greenhouse gas emissions in Germany. Their emissions balance over the life cycle, when including vehicle production, seems to offer little advantage in the medium term (Figure 6),[36] especially if gray hydrogen (hydrogen produced from natural gas) is used. It seems plausible that gray hydrogen will be used because the production costs of green hydrogen are likely to remain higher than the costs of gray hydrogen for some time. The emissions balance is even worse if hydrogen is produced via electrolysis powered by average grid electricity. Even if electrolysis were powered entirely by renewable electricity (green hydrogen), there would not be any emissions advantage over grid-powered battery-electric trucks, as the share of renewable energy in the power grid is set to rise to at least 80 percent by 2030. When considering life cycles, battery-electric trucks thus have considerable emissions advantages compared to hydrogen trucks, at least until 2030. Furthermore, the analysis shows that the production of vehicles (including batteries) only makes up a small share of the climate impact compared to power supply during the use phase.

Figure 6

Climate impact of semi-trailer trucks in long-haul transport in 2030

Grams of CO_2 equivalent per kilometer



Note: Considering the entire life cycle.

Source: Julius Jöhrens et al., "Perspektivische Kosten und Klimabilanz von Lkw mit alternativen Antrieben 2030," *enERSyn Schwerpunktpapier*, no. 2 (forthcoming, 2024).

Compared to battery-electric vehicles, fuel cell vehicles do not cause fewer emissions over the life cycle even when using green hydrogen.

Other electric technologies advantageous in subsectors

Other electric technologies that are not currently widely available on the market but have been tested could partially compensate for some weak spots of battery-electric trucks. Such technologies include electric road systems such as overhead line systems or third-rail systems, which dynamically power electric trucks as they drive, making it possible to reduce the size of vehicle batteries. Overhead line systems for trucks have already been comprehensively tested in Germany.[37] In addition, battery swapping systems for trucks are under discussion. While such systems are already widespread in China, they have not yet been tested much in Germany. Semitrailers with electric axels and their own battery (e-trailer), which could initially be used in combination with diesel tractors, are another possibility.

Some of these technologies have been evaluated as advantageous with respect to a few challenging aspects for the market ramp-up of battery-electric trucks with fast charging (Figure 7).[38] Such challenges include network integration, the contribution to the stability of the energy system, and the space requirement. However, there is still no single technology that equally addresses all of the drawbacks of battery-electric trucks. In addition, each type of technology has its own challenges: An overhead line system, for example, requires high initial investment costs for the core network, and battery swapping systems must be standardized.

Greenhouse gas reduction quota could create strong incentives for hydrogen use

The greenhouse gas reduction quota (GHG quota) is a market-based climate change mitigation instrument that aims to reduce the use of fossil fuels in the transport sector. Companies that create fossil fuel emissions in transport are required to reduce their emissions (including fuel production), with the reduction quota increasing each year. Currently, the quota is 9.35 percent compared to the fossil fuel reference value; in 2030, it will rise to 25.1 percent.[39] There are various options for reducing emissions, such as using electric drives or using more electric fuels such as hydrogen. Companies do not have to meet the quotas themselves, but can rather trade emissions via certificates.

However, the GHG quota does not adequately account for the better energy efficiency of battery-electric trucks compared to hydrogen trucks. As a result, higher certificate revenues can be achieved by using hydrogen compared to a correspondingly lower amount of electricity that can cover the same mileage with a battery-electric truck. If this revenue is used to subsidize the sale of green hydrogen at refueling stations, the price of hydrogen would decline by around two euros pro kilogram at the current GHG quota price of around 70 euros per ton of CO_2. If the certificate prices once again rise to the 2022 level of around 400 euros per ton due to rising reduction quotas, green hydrogen could be subsidized to be sold

36 Julius Jöhrens et al., "Perspektivische Kosten und Klimabilanz von Lkw mit alternativen Antrieben 2030," *enERSyn Schwerpunktpapier* no. 2 (forthcoming).

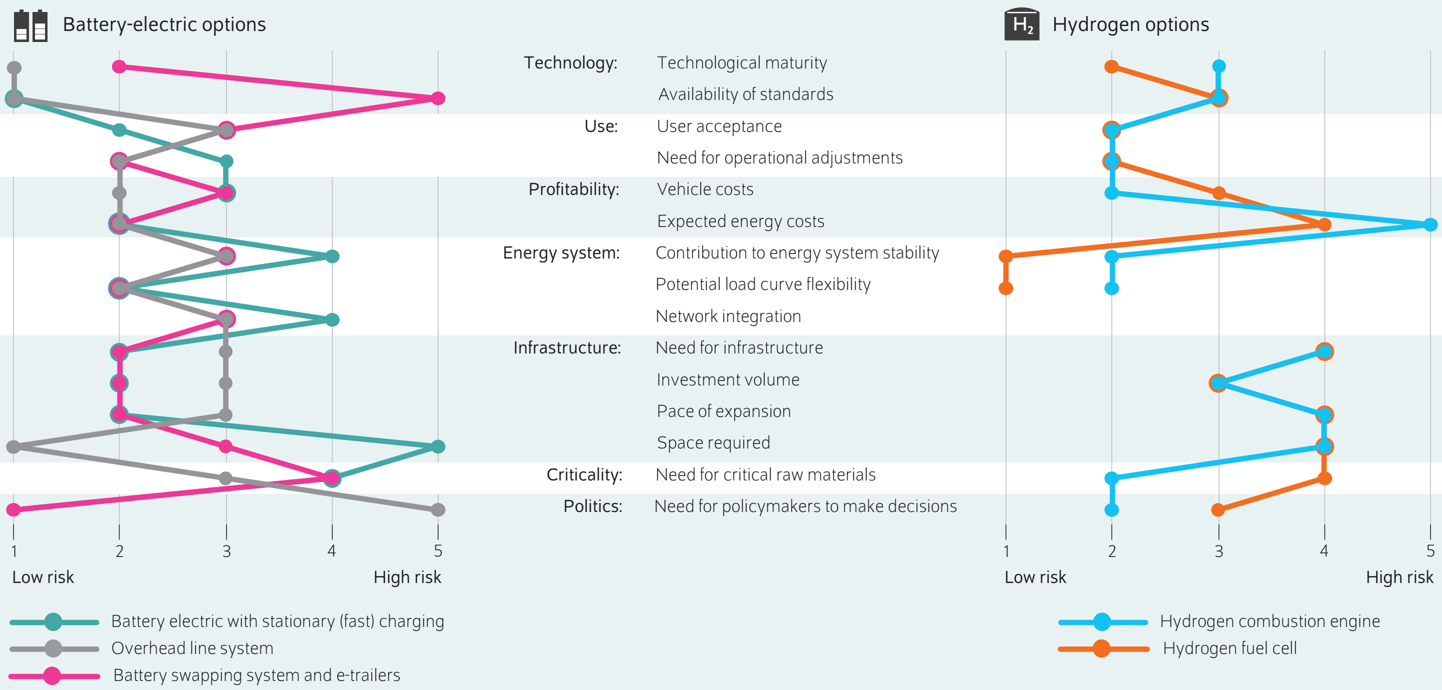
37 Julius Jöhrens et al., "Current technical findings on the eHighway system from field tests and accompanying research in Germany," Working paper compiled by the German cross-project Working Group on eHighway Technology (AG Technikbewertung) (2022) (available online).

38 Jöhrens et al., *Komplementärtechnologien zu BEV-Lkw*.

39 More information is available on the German customs website (in German; available online).

Figure 7

Evaluation of the risks for the market ramp-up of different technologies considering 15 criteria



Notes: Here it is assumed that hydrogen does not have to be produced domestically and can instead, for example, be imported from abroad. The network integration criterion only refers to the power grid and does not apply to hydrogen drives.

Source: Julia Pelzeter at al., *Bewertung von Technologiekonfigurationen für den Straßengüterverkehr* (ifeu, TU Dresden, DIW Berlin: 2024) (in German; available online).

Battery-electric vehicles have higher market ramp-up risks than other options when it comes to four criteria.

for around 12 euros per kilogram. This is in the range of current refueling station prices for hydrogen and would drastically decrease the energy costs of fuel cell trucks, which are presently high. In this way, the greenhouse gas emissions rate in its current form could create stronger incentives for the use of hydrogen drives than for battery-electric drives.

Conclusion: Focus should be on battery-electric drives and fast charging

In the debate on the use of alternative drives in heavy road freight transport, actors from vehicle manufacturing, logistics, and the hydrogen business often argue that a broad technology portfolio is required to quickly and effectively reduce greenhouse gas emissions. Some also argue that a portfolio with as many different types of technologies as possible makes sense from an industry policy perspective to provide market opportunities for domestic manufacturers.[40]

However, current market developments, systematic energy efficiency considerations, the energy system effects, and the medium-term expected contributions to emissions reduction suggest that a clear political focus on battery-electric trucks with stationary battery charging is more advantageous. On the one hand, this focus corresponds with the reality of the market and thus supports current private sector activities. On the other hand, these technologies correspond with what is currently the most plausible path for medium and long-term effective climate change mitigation in heavy road freight transport. Federal policy should clearly communicate battery-electric trucks as a key technology to give truck manufacturers and operators security in upcoming investments. Government funding of too many alternative technology options could, in contrast, lead to planning uncertainty for vehicle manufacturers, infrastructure providers, and logistics specialists and thus ultimately delay the transition of truck drives.

The current activities in the private sector for ramping up the charging infrastructure for battery-electric trucks should continue to be supported by the government; the corresponding tenders are a first positive step in this direction. Activities to provide the space needed as well as the required network connections also seem sensible. Furthermore, the regulations for the GHG quota should be adjusted to adequately account for the energy efficiency advantages of battery-electric trucks.

40 Cf. Sachverständigenrat für Wirtschaftsfragen, *Güterverkehr zwischen Infrastrukturanforderungen und Dekarbonisierung.*

As for keeping opportunities open for other technologies, focus should be on alternatives that are closely related to battery-electric trucks technologically and can possibly be combined modularly with fast charging concepts. Here, battery swapping systems as well as e-trailers could develop into complementary technologies. The technologically closely related option of overhead line trucks could also be kept open with a larger demo project.

Hydrogen trucks, in contrast, would require completely different vehicle and infrastructure technology as well as corresponding pathway decisions from truck operators. In light of the diverse challenges and so as to not further delay the drive transition, the continued support of hydrogen-powered heavy road freight transport appears unwise.

Hendrik Beeh is a Research Associate in the Mobility Division at the ifeu Institute | hendrik.beeh@ifeu.de

Julius Jöhrens is Head of the Drive Technologies topic area in the Mobility Division at the ifeu Institute | julius.joehrens@ifeu.de

Josef Klingl is an Intern in the Mobility Division at the ifeu Institute | josef.klingl@ifeu.de

Dominik Räder is a Research Associate in the Mobility Division at the ifeu Institute | dominik.raeder@ifeu.de

Wolf-Peter Schill is Head of the Transformation of the Energy Economy Research Area in the Energy, Transportation, Environment at DIW Berlin | wschill@diw.de

Markus Werner is a Research Associate in the Chair of Electric Railways at the Technical University Dresden | markus.werner@tu-dresden.de

JEL: L62, Q42, R40, R48

Keywords: road freight transport, battery-electric vehicles, electric road systems, hydrogen