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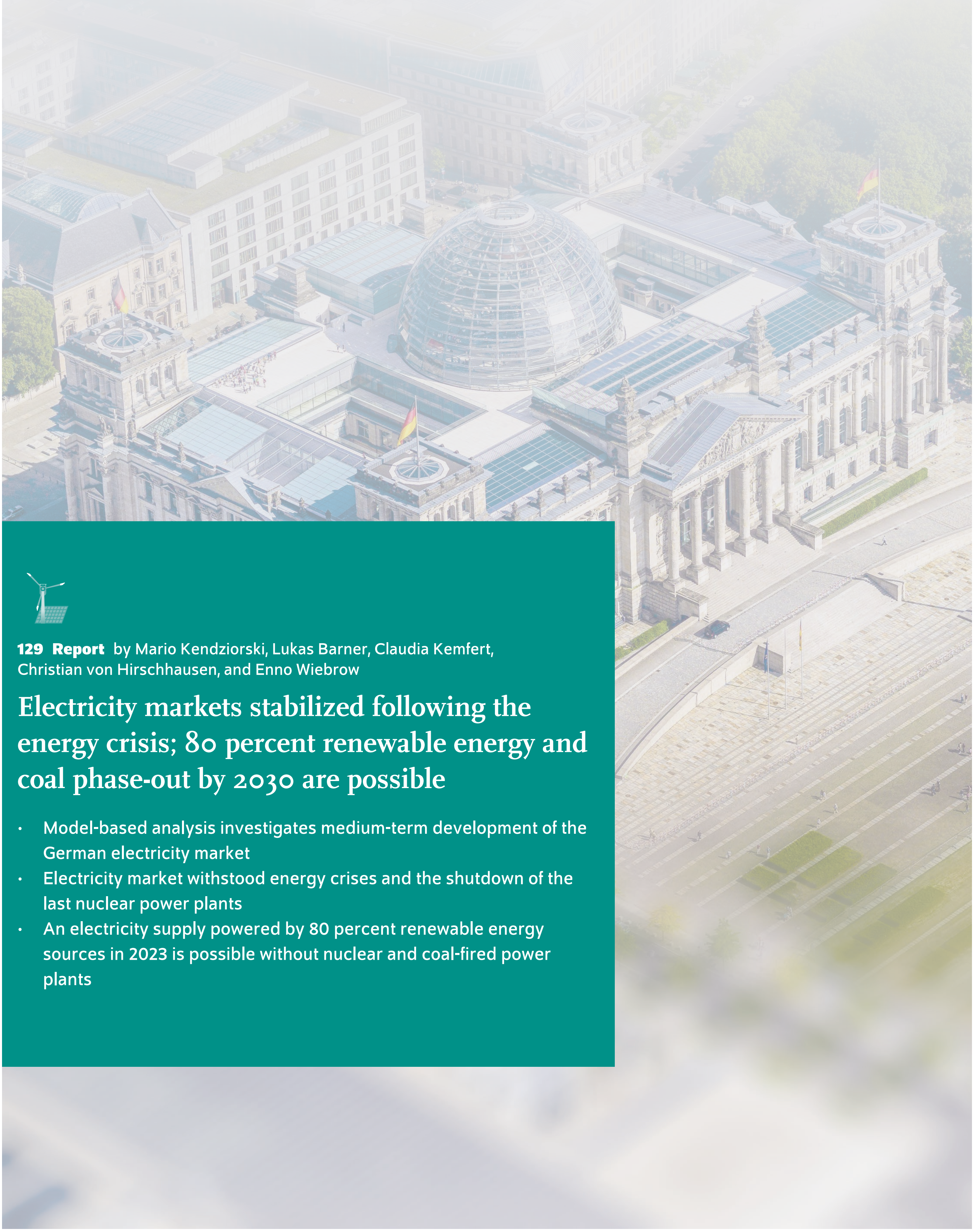

129 Report by Mario Kendziorski, Lukas Barner, Claudia Kemfert, Christian von Hirschhausen, and Enno Wiebrow

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

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DIW Berlin — Deutsches Institut für Wirtschaftsforschung e. V.
Mohrenstraße 58, 10117 Berlin
www.diw.de
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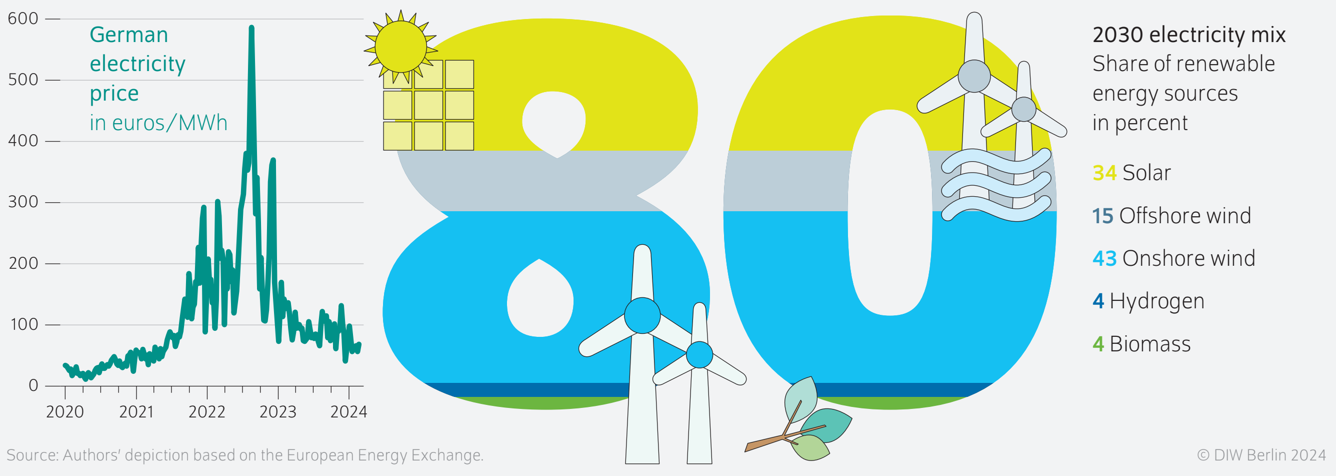
AT A GLANCE

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).

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Box 1

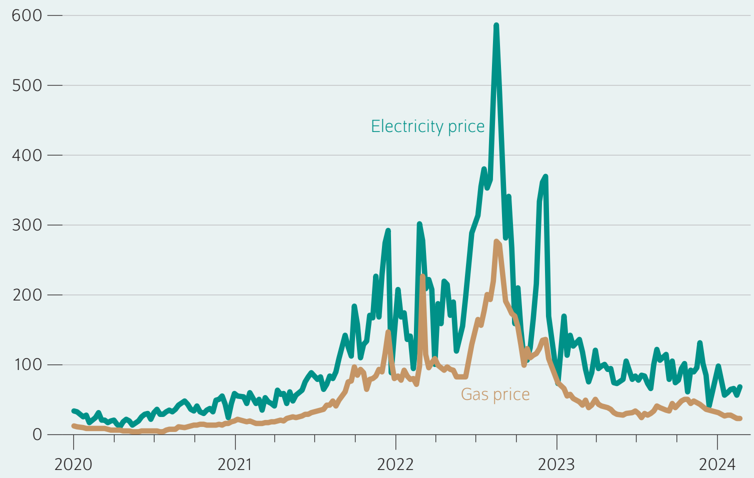
Methodology

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

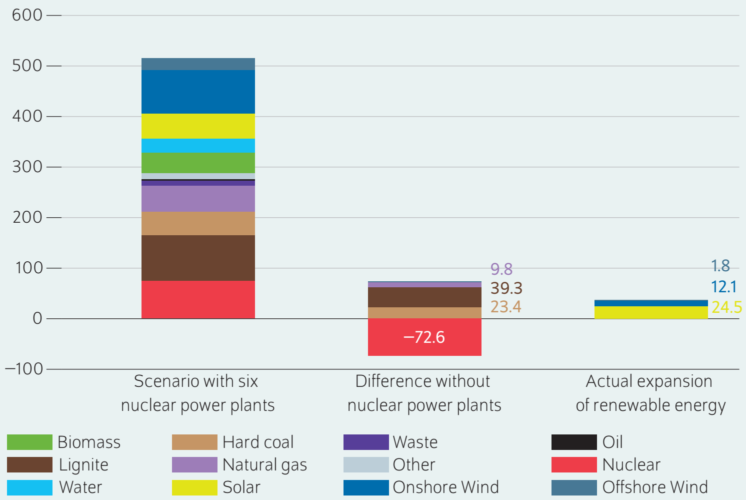
4 See, for example, Enervis Energy Advisors GmbH, *Ein Jahr Atomausstieg in Deutschland – Ein energiewirtschaftlicher Schulterblick* (2024) (in German; available online).

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 FfE, *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.

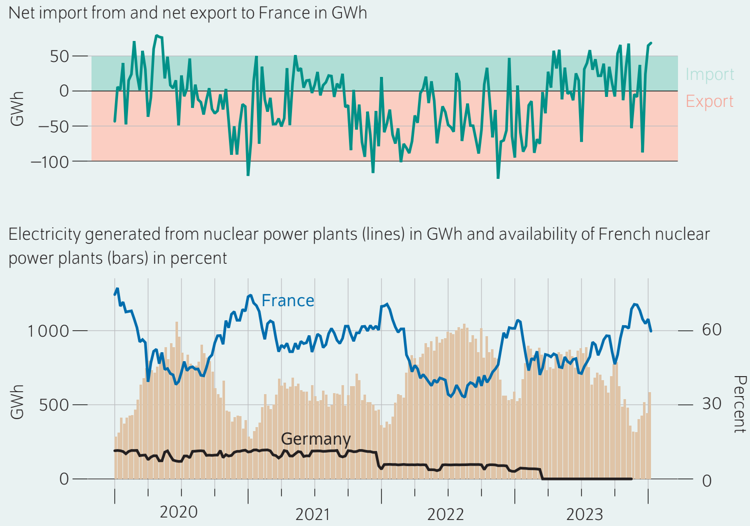
2 Christoph Pistner et al., *Analyse und Bewertung des Entwicklungsstands, der Sicherheit und des regulatorischen Rahmens für sogenannte neuartige Reaktorkonzepte* (Berlin: BASE – Forschungsberichte zur Sicherheit der nuklearen Entsorgung, 2024) (in German; available online).

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]

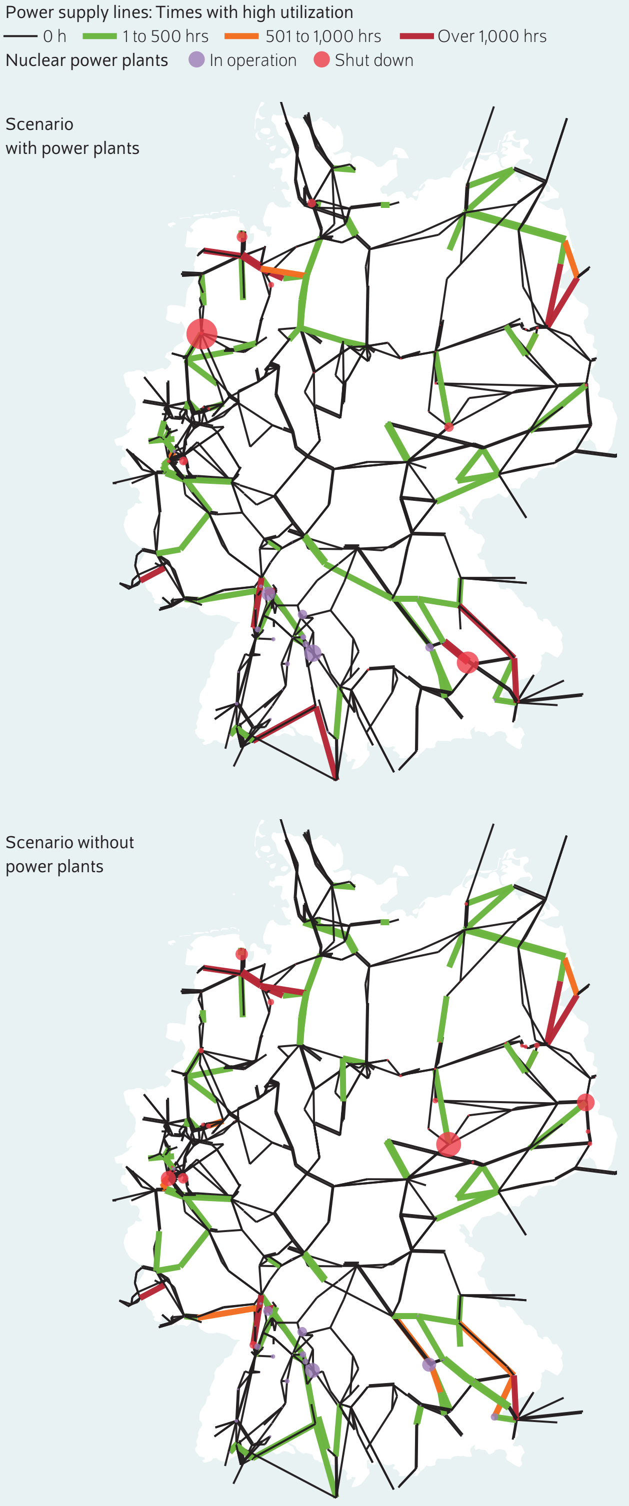
The shutdown of the last six nuclear power plants in 2023 barely changed the grid situation. The hypothetical model simulations for 2021 show that the existing grid bottlenecks would have remained largely unchanged and the adjustment measures (redispatch) would only have had to be

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).

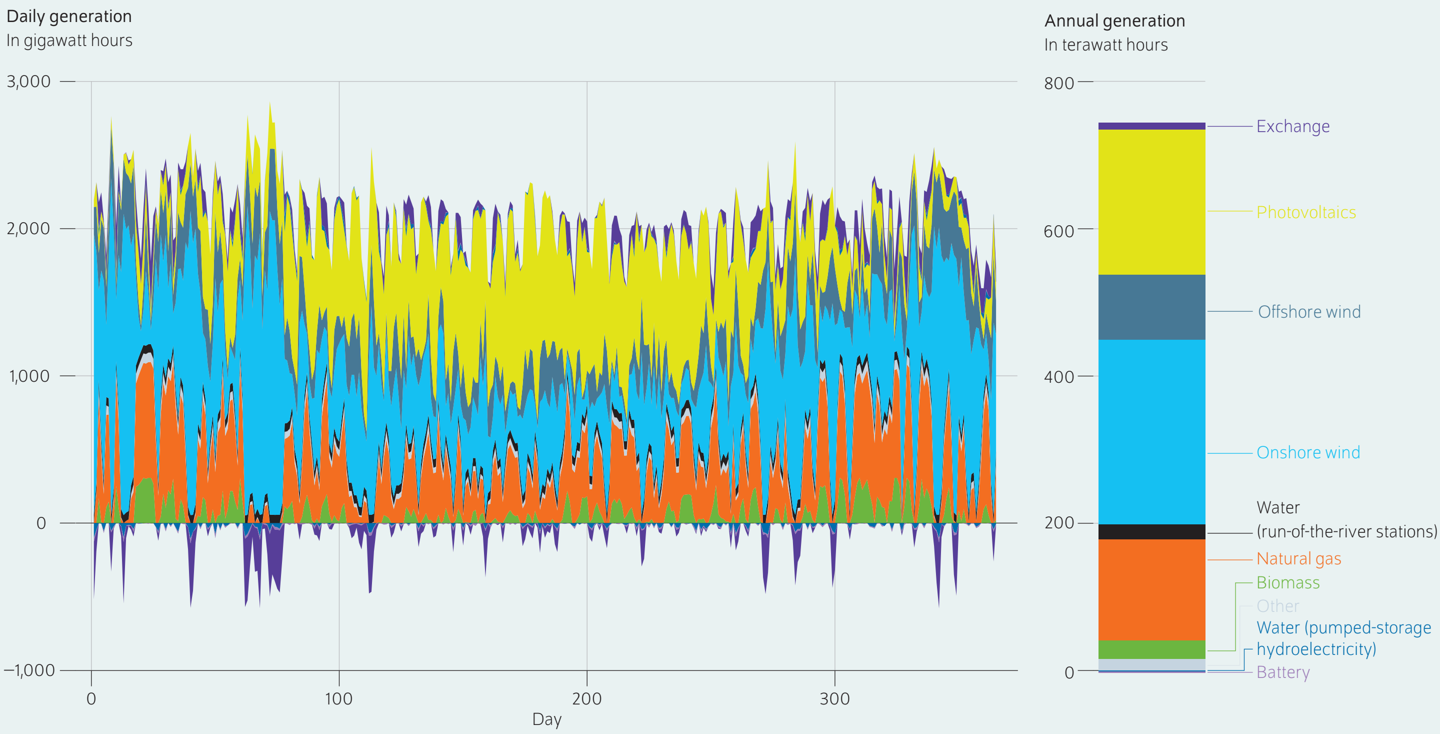
18 Friedrich Kunz, Karsten Neuhoff, and Juan Rosellón, "FTR allocations to ease transition to nodal pricing: An application to the German power system," *Energy Economics* 60 (2016): 176–185 (available online) as well as Karsten Neuhoff et al., "Renewable electric energy integration: Quantifying the 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

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