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Article

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Electricity supply in Germany can be secured without Russian supplies and nuclear energy; the 2030 coal-phase out remains possible

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DIW focus

Special issue on the
war in Ukraine

The European Union has increased pressure on Russia by enacting a coal embargo. Following a transition period, Russian coal imports will end in August 2022. Recent studies show that Germany will be able to substitute Russian supplies with imports from other countries by summer 2022. However, with the looming threat of a Russian gas supply stop, plans must be developed to ensure security of supply. In scenario calculations, DIW Berlin analyzed how the German electricity system can respond to a stop of Russian energy supplies (especially coal and natural gas) while still maintaining the accelerated coal phase-out and the 2022 nuclear phase-out plans. The calculations show that a secure electricity supply will be possible in 2023, even without Russian energy supplies. The shutdown of the final three nuclear power plants can and should take place as planned in December 2022. In the short term, coal-fired power plants from the grid reserves will have to be used and the standby mode of some power plants will have to be extended. In the medium term, the accelerated expansion of renewable energy infrastructure as envisaged by the German government in the set of measures known as the Easter Package is expected to lead to a decline in demand for natural gas and coal-fired power generation by 2030. Thus, an accelerated coal phase-out by 2030 as laid out in the coalition agreement is still possible.

To date, Germany has imported nearly 60 percent of its total coal imports from Russia (18 million tons in 2019, excluding coking coal) in addition to significant amounts of natural gas. These coal imports are due to end completely by August 2022. Furthermore, the security of supply of both electricity and heat must be reviewed if Russia cuts supplies to Germany. Prior to the war, the German government had announced that renewable energy infrastructure expansion would be accelerated significantly. This plan was concertized in the set of measures known as the Easter Package.¹ By 2030, the share of renewable energy of energy production should be 80 percent and by 2035, 100 percent. To compensate for natural gas-fired power generation, renewable energy sources and, at times, hard coal and lignite, must be used. This report first analyzes the impact of the coal embargo on Russia on European hard coal supplies and addresses current discussions regarding the coal phase-out in Germany. This is followed by a look at the short-term effects on the German electricity market of a possible end to Russian energy supplies for 2023 and an analysis of the medium-term effects until the early 2030s.

¹ Cf. Federal Ministry for Economic Affairs and Climate Action, Überblickspapier Osterpaket (2022) (in German; available online).

Russian coal imports can be substituted

The share of Russian hard coal of EU imports has increased significantly in recent years, with Germany as the primary recipient: According to Eurostat figures, 51 million tons and thus nearly 60 percent of the hard coal used (minus coking coal) in the European Union came from Russia in 2019. In 2015, the share was only 30 percent, around 41 million tons of a total of 132 million tons imported to the EU. At nearly 18 million tons (2019), Russian hard coal has covered around 60 percent of German hard coal demand over the past years. In addition to Russian coal, Europe also purchases coal from the international hard coal market, mainly from the USA and Colombia, but also smaller amounts from South Africa, Kazakhstan, Indonesia, and Australia (Figure 1). As recently as 2015, imports from these six countries to the EU were significantly higher, totaling just under 70 million metric tons. Recent studies on the international hard coal market using the COALMOD-World model at DIW Berlin show that there is sufficient supply-side capacity for increased demand in the EU, even in the short term, particularly due to a drastic drop in coal demand in the USA.² Despite an increase in coal prices, there is a sufficient and flexible supply of hard coal on the German and European markets. This was also confirmed by the *Verein der Kohleimporteure e.V.* (VDKi) in a member survey.³ Thus, despite the coal embargo on Russia, hard coal supply bottlenecks are not expected.

Coal-fired power plants in the German electricity sector and the planned coal phase-out pathway

In addition to imported hard coal, domestic lignite from the Rhineland, the Leipzig region, and Lusatia will continue to contribute to the electricity supply for some years to come. However, in the coalition agreement from 2021, the German government agreed to end coal-fired power generation in 2030 if possible, earlier than envisaged in the Coal Phase-out Act (2035-2038). At the beginning of 2022, 17 gigawatts of lignite capacity were still in operation, of which 1.7 gigawatts are scheduled for final closure later in the year.⁴ Furthermore, 1.9 gigawatts of lignite capacity have entered the security standby, of which 1.1 gigawatts is scheduled for final closure on October 1, 2022.⁵ In addition, about 15 gigawatts of hard coal capacity are currently in operation, of which two gigawatts are scheduled for closure by the end of 2022.⁶ A further four gigawatts of hard coal capacity are on the grid reserve.⁷ Due to increasing electricity production from renewable energy sources, rising costs for CO₂ certificates, and relatively low natural gas prices, the utilization of, and generation from, coal-fired power plants has steadily declined in recent years. In 2015, coal-fired power plants in Germany produced over 270 terawatt hours of electricity, while only 130 terawatt hours were produced in 2020.⁸ By extending run times during the year and potentially using capacities from the security standby and grid reserve, coal-fired power plants can help replace Russian natural gas in the electricity sector in the next couple of years. In the following sections, the security of the German electricity supply is discussed for 2023, i.e., after the shutdown of the remaining nuclear power plants, and for 2031, i.e., after the phase-out of coal-fired power generation.

² Christian Hauenstein and Franziska Holz, "The U.S. Coal Sector between Shale Gas and Renewables: Last Resort Coal Exports?" DIW Berlin Discussion Paper 1880 (2020) (available online); Paola Yanguas Parra, Christian Hauenstein, and Pao-Yu Oei, "The Death Valley of Coal - Modelling COVID-19 Recovery Scenarios for Steam Coal Markets," *Applied Energy* 288 (2021): 116564 (available online).

³ VDKi, "Russische Kohle kann ersetzt werden," press release from April 8, 2022 (in German; available online).

⁴ Decommissioning regulated in the Coal-fired Power Generation Termination Act (KVBG) and the public law contract on the reduction and termination of lignite-fired power generation in Germany (Öffentlich-rechtlicher Vertrag zur Reduzierung und Beendigung der Braunkohleverstromung in Deutschland).

⁵ Energy Industry Act (EnWG), § 13: decommissioning of lignite-fired power plants.

⁶ Bundesnetzagentur, Kohleausstieg (in German; available online).

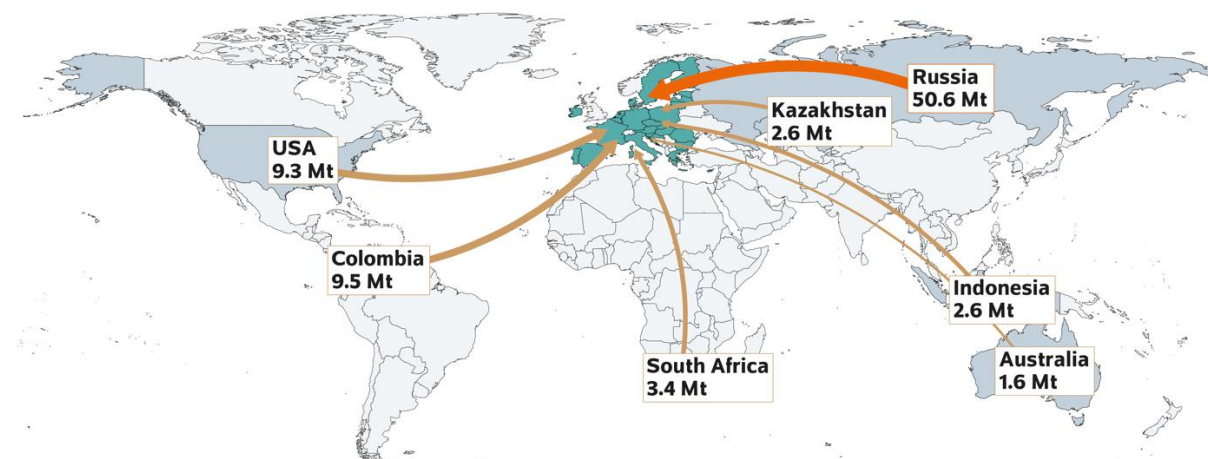
⁷ Bundesnetzagentur, Kraftwerkliste (in German; available online).

⁸ AG Energiebilanzen, Auswertungstabellen (in German; available online).

Figure 1

Hard coal import routes into the EU (2019)

In millions of tons (Mt)



Note: Hard coal, not including coking coal.

Source: Eurostat data, authors' calculations.

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Short-term outlook: electricity supply for 2023 is secure

In another recent study, DIW Berlin developed scenarios depicting how natural gas supplies in Germany could be substituted if Russia cuts supplies.⁹ In addition to more imports from other natural gas suppliers and domestic production, the main focus is on energy savings (conservation). In particular, electricity generation is assumed to have a large potential for natural gas savings due to increased electricity generation from other sources. The scenario with the greatest short-term natural gas savings in the electricity sector results in about 43 terawatt hours_{el} (billion kilowatt hours). This is about 45 percent of electricity generation from natural gas (comparison year 2020)¹⁰ for which replacement capacity would need to be found. This means replacing uncoupled electricity generation (power plants without heat cogeneration) from the public supply of natural gas and about 40 percent of uncoupled electricity generation from industrial plants.¹¹

The following depicts the changes to the electricity mix that may result from the reduction of natural gas-fired electricity generation, with 2020 as the comparison year and 2023 as the observation year.¹² It is assumed that 2023 is the year with the largest replacement requirements with coal due to the nuclear power plant shutdown, which eliminates 64 terawatt hours of electricity generation compared to 2020.¹³ About half of this decline can materialize at the end of 2022. At the same time, it is assumed

⁹ Franziska Holz et al., "Energy supply security in Germany can be guaranteed even without natural gas from Russia," DIW focus 7 (2022) (available online).

¹⁰ Gross electricity production from natural gas had its highest value for 2010-2021 in 2020 at 95 terawatt hours. Cf. AG Energiebilanzen, Auswertungstabellen (in German; available online).

¹¹ For CHP power plants operated with natural gas, the savings potential is lower due to the continued heat supply requirement. A reduction potential of 10 percent in public utility CHP power plants and of 40 percent in industrial CHP power plants is assumed for natural gas electricity generation.

¹² AG Energiebilanzen, Auswertungstabellen (in German; available online). In 2020, gross electricity consumption in Germany was 2.5 percent and 3.5 percent below the gross electricity consumption in 2021 and 2019, respectively. It is assumed that the electricity demand will remain at a below-average level in 2022 and 2023 due to the current, ongoing tense situation in the energy markets; the resulting high electricity prices; and curtailed industrial production due to high energy costs. While further electrifying the transportation and heating sectors tends to counteract this, it will only have a greater impact on electricity demand in later years.

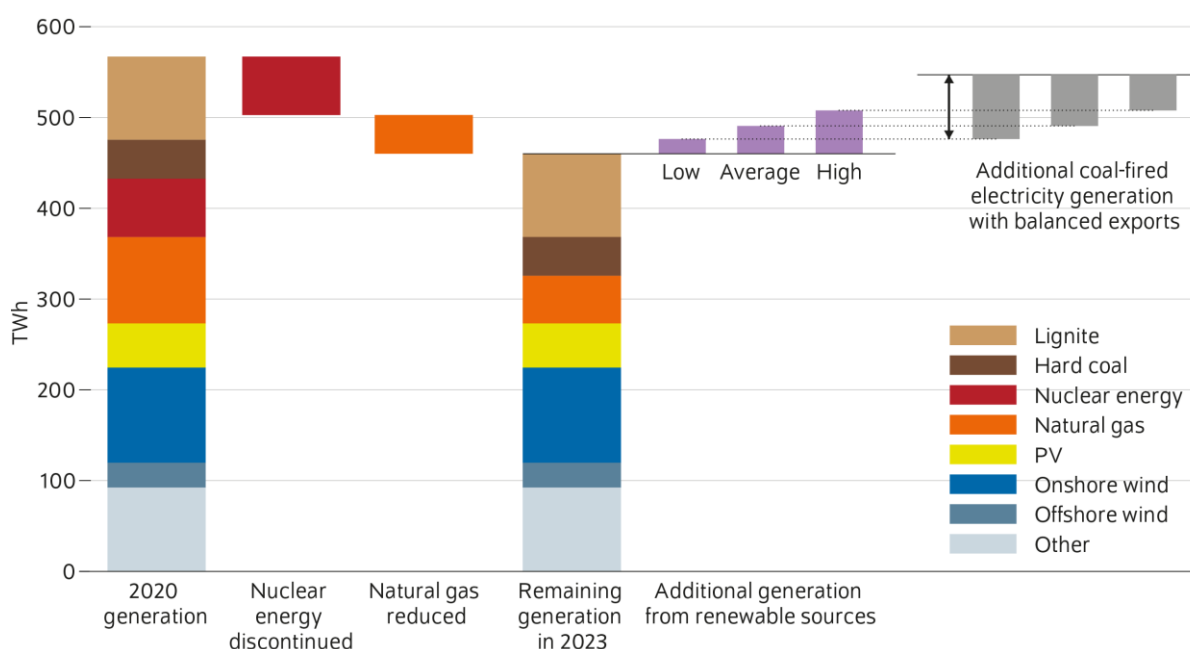
¹³ The German government has confirmed that extending the operating lives of the remaining three nuclear power plants (Neckarwestheim-2, Isar-2, and Emsland) is neither economically nor organizationally feasible, cf. Federal Ministry for Economic Affairs and Climate Action and the Federal Ministry for Environment, Nature Conservation, and Nuclear Safety, Prüfung des Weiterbetriebs von Atomkraftwerken aufgrund des Ukraine-Kriegs (2022) (in German; available online). Cf. for a model-supported analysis of the nuclear power phase-out: Mario Kendziorowski et al., "Nuclear Turn: Closing Down

that photovoltaics are expanded to 71.5 gigawatts and onshore wind to 62.5 gigawatts by the end of June 2023.¹⁴ Because electricity generation from these sources is fluctuating and weather dependent, the expected electricity generation from renewable energy sources is analyzed using historical data from 1980 to 2019 (see Figure 2).¹⁵ The analysis shows that around 184 terawatt hours (2020: 153 terawatt hours) of annual electricity production can be expected from photovoltaics and onshore wind, with plausible deviations of around 15 terawatt hours downwards and 17 terawatt hours upwards. The expected additional electricity generation from coal-fired power plants at maximum natural gas savings is between around 41 and 73 terawatt hours in 2023.¹⁶ This represents the range of coal-fired electricity generation considered plausible under the specified conditions. Apart from the expansion and generation from renewable energy sources and the development of the electricity demand, the actual electricity generation in 2023 will be influenced by the development of the prices of fuel (including natural gas) and CO₂ certificates.¹⁷

Figure 2

Additional electricity production from renewable energy sources and coal for 2023

In terawatt hours



Source: Authors' depiction using AG Energiebilanzen data.

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Nuclear Power Plants Opens up Prospects for the Final Repository Site Search," DIW Weekly Report, no. 47 (2021) (available online).

¹⁴ BMKW, Überblickspapier Osterpaket (2022) (in German; available online).

¹⁵ Stefan Pfenninger and Iain Staffell, "Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data," *Energy* 114 (2016): 1251-1265 (available online) as well as Iain Staffell and Stefan Pfenninger, "Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output," *Energy* 114 (2016): 1224-1239 (available online).

¹⁶ For simplicity's sake, a balanced export balance is assumed here. Overall, total coal electricity production is between 175 and 207 terawatt hours in 2023. If renewable energy sources are expanded more slowly than expected or if consumption is higher than expected here, or if electricity exports to neighboring European countries are higher, electricity generation could be increased to about 220 terawatt hours by using coal-fired power plants in operation, from the grid reserve, and on security standby (without re-activating power plants shut down in 2021). Cf. BDEW, *Kurzfristige Substitutions- und Einsparpotenziale Erdgas in Deutschland* (2022) (in German; available online).

¹⁷ This analysis is limited to the German electricity sector and does not include possible developments in the electricity sector of neighboring countries. Such developments are detailed in other studies, such as Karlo Hainsch et al., "Make the European Green Deal Real - Combining Climate Neutrality and Economic Recovery," *Politikberatung Kompakt* 153 (2020) (available online) as well as Mario Kendziorowski et al., "100% erneuerbare Energie für Deutschland unter besonderer Berücksichtigung von Dezentralität und räumlicher Verbrauchsnähe – Potenziale, Szenarien und Auswirkungen auf Netzinfrastrukturen," *Politikberatung kompakt* 167 (2021) (in German; available online).

The additional coal-fired electricity generation in Germany is provided by increased utilization of the operating lignite and hard coal-fired power plants as well as by additional generation from hard coal-fired power plants from the grid reserve and lignite-fired power plants on security standby.¹⁸ It is still possible to shut down the coal-fired power plants in 2022 as planned. However, to safeguard the electricity supply for 2023, the hard-coal-fired power plants scheduled for closure in 2022 should be put on reserve temporarily and the hard coal-fired units already on reserve should remain there. In addition, the units of the Neurath lignite-fired power plant scheduled for decommissioning in 2022 are to be temporarily placed on security standby and the lignite units already on security standby should remain there until the end of winter 2023/24. Lignite-fired power plants on security standby can contribute to electricity production to a limited extent, most likely in the second half of the year.

Even without the uncoupled natural gas power plants and following the decommissioning of the final nuclear power plants, there is sufficient capacity to cover electricity demand at all times (Figure 3).¹⁹ Thus, the aforementioned plans for 2023 are not expected to have a negative impact on the security of supply. Moreover, the capacities of the uncoupled natural gas power plants (around 15 gigawatts) are still available, though likely at very high prices due to high natural gas prices. Should these capacities be used in extreme situations, for example to cover exceptionally high demand or if other power plant capacities fail, high gas consumption is still not expected as a result due to the brief period of utilization.

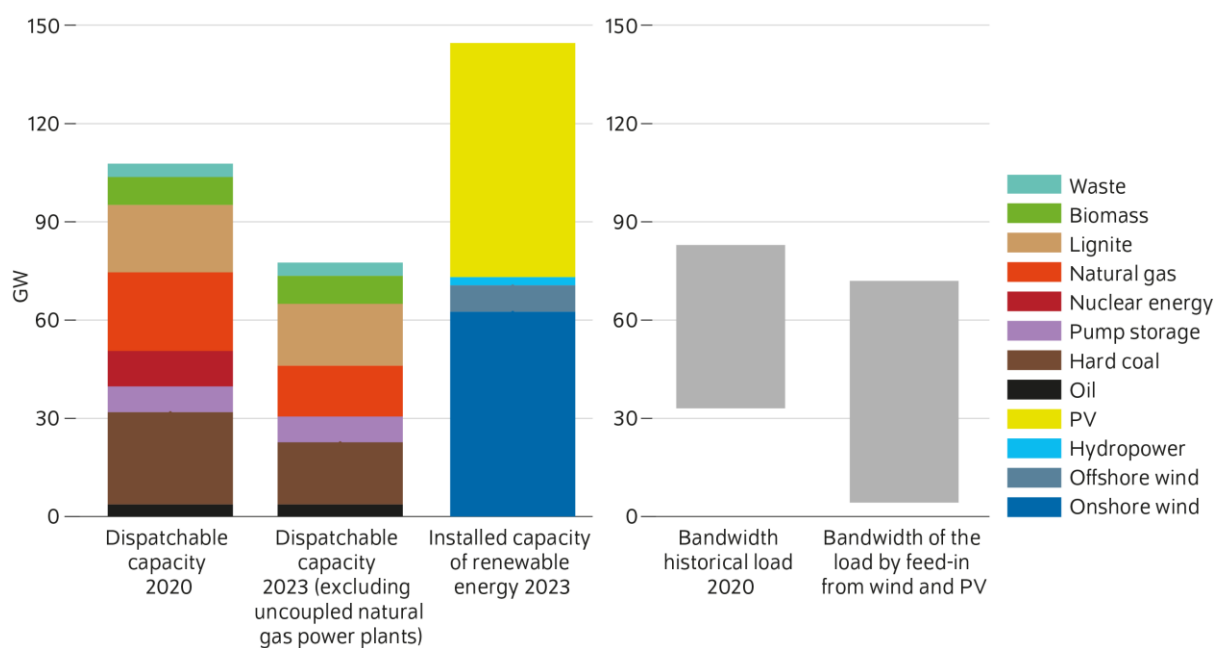
¹⁸ Due to the decommissioning of the last nuclear power plants in Germany on December 31, 2022, which operated at 7,000-8,000 full load hours (FLH) per year, lignite-fired power plants will shift to the left in the merit order and be expected to have high utilization. It is assumed that the lignite-fired power plants still in operation (15.3 gigawatts in 2023) can achieve an average capacity utilization of up to 7,000 FLH. Likewise, utilization of up to 5,000 FLH can be expected for coal-fired power plants in operation, as they are ahead of uncoupled gas-fired power plants in the merit order. It is assumed that hard coal-fired power plants in the grid reserve (around 6.4 gigawatts in 2023 including capacity scheduled for decommissioning in 2022) can achieve an average capacity utilization of up to 3,500 FLH. For lignite-fired power plants on security standby (approx. 3.4 gigawatts in 2023, including the units at the Neurath power plant scheduled for decommissioning in 2022), a maximal capacity of around 5,550 FLH/year is assumed. Cf. BDEW, *Kurzfristige Substitutions- und Einsparpotenziale Erdgas in Deutschland* (2022) (in German; [available online](#)).

¹⁹ A similar load as in 2020 is assumed for 2023. The bandwidth of the load shown here represents the range from the minimum to the maximum of the load. However, the fringes of this range are rarely reached and represent extreme situations that are only reached for brief periods of time.

Figure 3

Power plant capacity in 2020 and 2023 and load (total and after feed-in from wind and photovoltaics) in Germany

In gigawatts



Note: The uncoupled gas capacities are still available in 2023. However, they are not shown here for 2023 to illustrate the sufficient amount of dispatchable capacity even without these plants. The hard coal and lignite capacities for 2023 include the corresponding capacities in the grid reserve and standby pool, respectively.

Source: Authors' calculations using Bundesnetzagentur data.

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Medium-term outlook: coal phase-out by 2030 possible with a strong expansion of renewable energy infrastructure

In the medium term, renewable energy sources replace a majority of fossil fuel generated electricity. This is made plausible by current model results, which show the German electricity system in the context of Europe-wide scenarios.²⁰ Coal-fired electricity generation increases in the short term to about 170 terawatt hours and 190 terawatt hours in 2022 and 2023, respectively, as a substitute for natural gas and nuclear generation (assuming average generation from renewable energy sources and maximum natural gas savings; see previous section). Due to the expected expansion of renewable energy infrastructure, however, hard coal and lignite powered electricity can markedly decrease from 2024 on. Figure 4 shows the electricity production for 2031 in Germany based on the 1.5 C scenario calculations from the openENTRANCE project.²¹ Here, the share of renewable energy sources in the electricity sector is around 95 percent in 2030. In addition to renewables, some non-Russian natural gas will remain in the energy mix. However, no coal will be used to generate electricity after 2030. The rapid expansion of renewable energy infrastructure required for this is roughly in line with the German government's current expansion targets. However, this scenario relies more heavily on onshore wind than photovoltaics compared to the Easter Package.

If Russian energy sources were abandoned in German energy supplies, there would be higher utilization of lignite-fired power plants in the three regions mentioned (Rhineland, Leipzig region,

²⁰ Current calculations using the GENeSYS-MOD energy system model based on Hans Auer et al., "Quantitative Scenarios for Low Carbon Futures of the pan-European Energy System," *Open Entrance Deliverable 3.1* (2020) ([available online](#)).

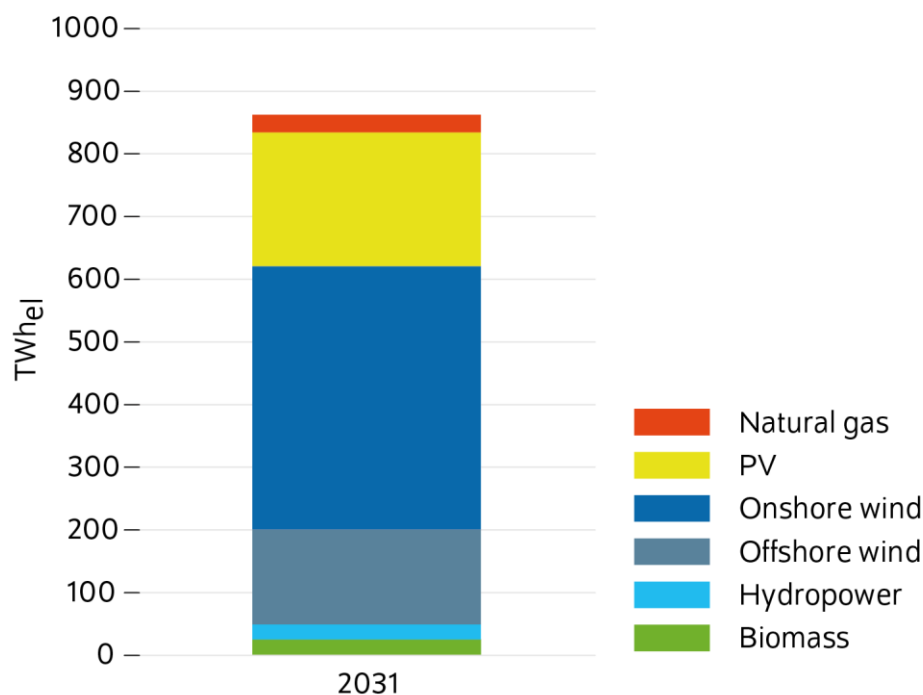
²¹ See the project [website](#).

Lusatia) in the short term. However, there are sufficient reserves in the open-cast lignite mines for the lignite-fired power generation required under the current plans. It is not necessary to resettle further villages for underlying lignite reserves; this applies to Lützerath in the Rhineland and Mühlrose in Lusatia as well. Even if production at the Jänschwalde open-cast mine (Lusatia) ends early²² and annual lignite production at the neighboring Nochten (Lusatia) open-cast mine is increased in the meantime, there is still no need to use the Mühlrose special field.

Figure 4

Electricity generation in Germany in 2031

In terawatt hours



Source: Based on updated model runs from the OpenEntrance project. Authors' depiction.

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Conclusion: Secure electricity supply without Russian deliveries in the short and medium term

Even if Russian natural gas and coal exports to Germany stop completely, the electricity supply is secure in 2023 (after the nuclear phase-out) as well as in the medium term. However, to achieve this, renewable energy infrastructure expansion must be accelerated as envisaged in the Easter Package and there must be a short-term, intensive use of hard coal and lignite-based electricity generation. German coal imports from Russia can be substituted relatively easily by sourcing from international coal markets. There will be sufficient power plant capacity in 2023 despite the shutdown of the three remaining nuclear power plants and the potential sharp decline in natural gas power production. Accelerating the expansion of renewable energy infrastructure limits natural gas and coal-fired electricity generation; the coal phase-out by 2030 as envisioned in the coalition agreement is still possible. The integration of the German and European electricity markets remains crucial to the security of supply in the medium term.

²² LEAG, Gericht entscheidet: LEAG muss Tagebau Jänschwalde am 15. Mai 2022 anhalten (2022) (in German; available online).

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