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Challenges for German Energy Security in the Context of Nuclear and Coal Phase-Out

Introduction

Ensuring uninterrupted energy supplies is an important political goal related to economic and social development, as well as the need to take into account environmental and climate protection requirements. The abandonment of nuclear energy (expected to take place in 2022), and of coal (scheduled for 2038) for electricity production, coupled with the accelerated expansion of renewable energy, results in increased energy security, and, consequently, leads to less dependence on fossil fuels and their exports. Nevertheless, it is a challenge to stabilise the energy system due to numerous fluctuations in the production of wind energy and solar photovoltaic systems through appropriate measures such as, *inter alia*, the expansion of the power grid, the use of conventional power plants, and energy storage. For the purposes of this study, energy security is understood as the reliability of energy supplies at an economically justified price level, and the ability to maintain the required quality parameters environmental and climate protection conditions.[1]

The goal of this paper is to outline the key challenges for Germany's energy security, understood as the security of supply, in the context of phasing out nuclear energy and coal for electricity production. The concern expressed about the shutdown of nuclear power plants, which also accompanies the coal phase-out, is

[1] B. Molo, 'Problem zapewnienia bezpieczeństwa energetycznego Niemiec w kontekście stopniowej rezygnacji z użytkowania elektrowni jądrowych', *Przegląd Zachodni*, No. 2 (347), 2013, p. 69.

to ensure a high level of security of energy supply. In this context, research questions are posed: Has the gradual decommissioning of nuclear power plants caused a shortage in electricity production? What measures have been taken to ensure energy stability? What are the challenges for Germany to phase out coal for electricity production? In order to achieve the research goal and answer the above mentioned questions, the factor method and comparative analyses, as well as quantitative research, were used alongside a variety of documents, statistical data, studies and press materials that have been scrutinised. The author has relied on research findings on Germany's energy security.

Germany's nuclear phase-out: challenges for the security of supply

The energy transition began with the adoption of the energy concept by the federal government on 28 September 2010.[2] The energy concept includes an extension of the lifetime of nuclear power plants by 8 or 14 years, depending on their age, which meant that the last plant would be shut down in 2036. Nuclear energy was to remain a part of the energy mix as long as it could be replaced by renewable energy sources and that Germany would not have to import electricity. On 28 October 2010, the Bundestag adopted an amendment to the Atomic Energy Act (*Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren*, *Atomgesetz*), which extended the lifetime of nuclear power plants. The disaster at the Fukushima-Daiichi nuclear power plant, which took place in March 2011, revived the public debate in Germany about the dangers of nuclear energy and its further use. On 14 March 2011, a three-month moratorium was imposed on the extension of the operation of nuclear reactors, and on 15 March 2011, the decision to temporarily shut down the seven oldest plants was announced, and the remaining ones were ordered to be checked. However, according to the decisions of the government coalition of 30 May 2011, the eight oldest power plants were to be permanently shut down, i.e. seven during the moratorium (Biblis A, Neckarwestheim 1, Biblis B, Brunsbüttel, Isar 1, Unterweser, Philippsburg 1), and the Krümmel power plant, which was closed in the period before the moratorium. Meanwhile, the remaining nine power plants were planned to be phased out gradually: six more in the years 2014–2021, and the last three in 2022. The change in the political course in response to the Fukushima nuclear disaster was reflected in the documents. On 6 June 2011, the federal government submitted an official paper entitled *Der Weg zur Energie der Zukunft – sicher, bezahlbar, umweltfreundlich*.[3] The document acknowledges the goals included in the energy concept, however, achieved in the context

[2] *Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung*, 28.09.2010, http://www.bundesregierung.de/Content/DE/_Anlagen/2012/02/energiekonzept-final.pdf?__blob=publicationFile [accessed: 28.12.2020].

[3] *Der Weg zur Energie der Zukunft – sicher, bezahlbar und umweltfreundlich*, https://www.bmwi.de/Redaktion/DE/Downloads/E/energiekonzept-2010-beschluesse-juni-2011.pdf?__blob=publicationFile&v=1 [accessed: 28.12.2020].

of phasing out nuclear energy. Rapid completion of the construction of fossil fuel power plants (by 2013) and, as an additional security, by 2020, the addition of up to 10 GW of the secured capacity of the plant was considered essential for ensuring security of supply.[4] On 9 June 2011, in a government statement to the Bundestag, Chancellor Angela Merkel announced the gradual withdrawal from the operation of nuclear power plants by 2022,[5] confirmed the main assumptions and objectives of the 2010 energy concept in terms of developing renewable energy sources, reducing greenhouse gas emissions and energy consumption, and announced the monitoring of the progress of the *Energiewende*. On 30 June 2011, the 13th amendment to the act was passed in the Bundestag; the amended Atomic Energy Act entered into force on 6 August 2011. Thus, in addition to the development of renewable energy sources and energy efficiency, the nuclear phase-out was included in the process of energy transition.

At that time, it was assessed that ending the operation of nuclear power plants would pose a challenge to Germany to ensure the stability of the power system. For example, it was calculated that in 2010–2030, the contribution of large conventional power plants to energy production would decrease significantly. In 2010, it amounted to approximately 62,500 MW, and by 2030 it would have been almost halved (to 26,500 MW). The largest decrease would be recorded in the first decade, i.e. by 2020 the capacity would decrease by 25,000 MW, and by 2030 by another 11,000 MW.[6] Moreover, an accelerated phase-out of nuclear power would result in additional demand for power plant capacity from 2014 on. Renewable energy would not replace the lost capacity in the short and medium term, hence greater use of gas and coal-fired power plants would be necessary. It was emphasized that the gradual phasing out of nuclear reactors would additionally force, in the longer term, the need to increase the efficiency of the power plant and obtain the missing electricity from other sources, including increasing electricity imports.

The discrepancies mainly concerned the role of coal-fired power plants in the energy transition. Most studies considered it necessary to finalize the initiated projects to build conventional power plants, with, for example, the German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen, SRU) questioning the legitimacy of building new coal-fired power plants.[7] According to experts, natural gas was supposed to be a more competitive source, emitting less CO_2 than coal.

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4 *Ibid*., p. 5.

5 2015: Grafenrheinfeld, 2017: Gundremmingen B, 2019: Philippsburg 2, 2021: Grohnde, Gundremmingen C, Brokdorf, 2022: Isar 2, Emsland, and Neckarwestheim 2.

6 H. Bardt, 'Wirtschaftliche Folgen eines beschleunigten Kernenergieausstiegs in Deutschland', *IW-Trends*, No. 2, 2011, pp. 4–6.

7 *Wege zur 100% erneuerbaren Stromversorgung*, SRU Sondergutachten, Sachverständigenrat für Umweltfragen, Berlin 2011, https://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2008_2012/2011_07_SG_Wege_zur_100_Prozent_erneuerbaren_Stromversorgung.pdf?__blob=publicationFile [accessed: 2.03.2021]; *Das Energiewirtschaftliche Gesamtkonzept. Konsequenzen eines beschleunigtes Atomausstiegs aus der Kernenergie in Deutschland*, eine Studie der Prognos AG im Auftrag der vbw, April 2011; *Energiewende kostet, aber es lohnt sich. Dena-Chef Kohler: Atomausstieg ist bis 2020/2025 machbar. Konsequenzen und Kosten sind große Herausforderung. Akzeptanz der Bevölkerung nur mit ehrlicher Diskussion erreichbar*, Deutschen Energieagentur (Dena), Presseinformation vom 18.04.2011.

Studies from 2013–2017 on the German energy market indicated that despite the growing share of renewable energy sources in electricity production, by 2020, there will be no shortages in electricity supplies.[8] However, this depended on the development of the European internal energy market, transmission infrastructure, investment in technology, as well as the further use of coal in electricity production and electricity imports.

Leaving aside specific issues, it should be emphasized that in the following years, due to the phase-out of nuclear energy, no "gap in electricity production" was recorded. The increase in the share of renewable energy sources in electricity production compensated for the decrease in the share of nuclear energy. Between 2011 and 2020, electricity production from nuclear power plants decreased by 43.7 TWh, while from renewable energy sources it increased by 130.7 TWh, and from lignite and hard coal it decreased by 58 TWh and 69 TWh, respectively. In 2020, electricity production in natural gas-fired power plants was slightly higher than in 2011 (86 TWh) and amounted to 92 TWh. As a result of the shutdown of eight oldest nuclear power plants in 2011, the volume of electricity generated from nuclear energy decreased in 2010–2011 from 141 TWh to 108 TWh; and by 2020 by 43.7 TWh (see Table 1). As of 31 December 2011 and 31 December 2022, significant amounts of nuclear electricity will be withdrawn from the grid (64 TWh in total).[9] According to the schedule, the Grohnde, Brokdorf and Gundremmingen C nuclear power plants with a total gross capacity of 4,254 GW will be decommissioned at the end of 2021, and the nuclear power plants Isar 2, Neckarwestheim 2 and Emsland (total gross capacity 4,285 GW) by the end of 2022.[10]

Table 1. Total electricity production (selected years) in TWh

	2010	**2011**	**2015**	**2019**	**2020**
Nuclear energy	141	108	92	75	64.3
Renewable energy	105	124	189	242	254.7
Lignite	146	150	155	114	92
Hard coal	117	112	118	58	43
Natural gas	89	86	62	91	92
Other	29	27	26	24	22
Total	627	607	642	604	568

Source: Agora-Energiewende, https://www.agora-energiewende.de/ [accessed: 20.02.2021].

[8] L.P. Feld *et al.*, *Neustart in der Energiepolitik jetzt!*, Stiftung Marktwirtschaft, 2014, p. 65, https://www.stiftung-marktwirtschaft.de/fileadmin/user_upload/KK-Studien/KK_58_Energiewende_2014.pdf [accessed: 10.01.2018].

[9] P. Graichen, F. Hein, '10 Jahre nach Fukushima: Welche Folgen hat der Atomausstieg für die Energiewende?', Agora Energiewende, https://static.agora-energiewende.de/fileadmin/user_upload/10_Jahre_Fukushima_Agora_v4.pdf [accessed: 2.03.2021].

[10] *Die Energiewende im Corona-Jahr: Stand der Dinge 2020. Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2021*, p. 73, Agora Energiewende, https://static.agora-energiewende.de/fileadmin/Projekte/2021/2020_01_Jahresauswertung_2020/200_A-EW_Jahresauswertung_2020_WEB.pdf [accessed: 20.02.2021].

Contrary to common assumptions, Germany did not become an importer of electricity due to the withdrawal from nuclear energy. On the contrary, after 2011, electricity exports grew steadily, with the highest volume in 2015, i.e. 85.3 TWh. The development of renewable energy in Germany combined with low CO_2 emission prices under the EU ETS resulted in the fact that from 2011 to 2017, significant amounts of German electricity produced from coal were exported to neighbouring countries.[11] As in previous years, also in 2020 there was a surplus of electricity exports over imports and amounted to 20.9 TWh (for comparison, in 2019 it was nearly 35 TWh; the largest surplus was recorded in 2017 – 55 TWh). A total of 68.6 TWh (2019: 74.5 TWh) flowed from the German energy networks abroad, while 47.6 TWh came to Germany from abroad (2019: 39.6 TWh). In 2020, the largest electricity exports went to Austria (15.2 TWh), followed by Switzerland (12.3 TWh) and Poland (11.2 TWh). And the largest electricity imports to Germany came from France (13 TWh), followed by the Netherlands (8.7 TWh) and Switzerland (7.4 TWh).[12] The reasons for the decline in the surplus of electricity exports over imports are varied, with the main factor being the increase in the CO_2 price in European emissions trading from an average of EUR 6 in 2017 to EUR 24 in 2020 and the persistently low purchase price of natural gas.[13] As a consequence, gas-fired power plants have become more competitive on the European electricity market compared to German coal-fired power plants. In other words, German coal-based electricity was replaced with imported electricity from gas-fired power plants.[14] However, according to the Federal Statistical Office, one of the reasons for the growing imports of electricity is the declining share of coal and nuclear power plants in electricity production in Germany. Large transmission network operators assume that Germany will be more dependent on electricity imports in the future in order to be able to maintain electricity supplies in extreme situations, when the safe performance of the electricity system drops significantly.[15]

The growing share of renewable energy sources in electricity production leads to supply, which is largely dependent on meteorological fluctuations. Therefore, there is a need to compensate the demand for electricity with production from non-renewable energy sources. The total net nominal capacity of the power plant was 229.2 GW, including 214.1 GW on the electricity market, of which 127.7 GW based on renewable energy sources (51,479 MW for solar energy, 53,733 MW for onshore wind energy, 741 MW offshore wind energy, 8,597 MW biomass), nuclear energy 8,114 MW, lignite 17,812 MW, hard coal 16,200 MW, natural gas 27,233 MW.[16]

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11 P. Graichen, F. Hein, *op. cit*.

12 See *Energieverbrauch in Deutschland im Jahr 2020*, Stand: 14. März 2021, Arbeitsgemeinschaft Energiebilanzen e.V., https://www.ag-energiebilanzen.de/ [accessed: 20.01.2021].

13 B. Janzing, 'Deutschland muss bald Strom importieren', *taz. die Tageszeitung*, 31.12.2020, p. 11, https://taz.de/Deutschland-muss-bald-Strom-importieren/!5737103/ [accessed: 20.01.2021].

14 *Die Energiewende im Corona-Jahr…*, *op. cit*., p. 26.

15 'Deutscher Strom-Exportüberschuss geht zurück', *Handelsblatt*, 31.12.2020, https://www.handelsblatt.com/politik/deutschland/energie-deutscher-strom-exportueberschuss-geht-zurueck/26761454.html?ticket=ST-123457-9E4nU4KazwrICNvT6Cdb-ap4 [accessed: 20.01.2021].

16 'Power plant list', 19.01.2021, Bundesnetzagentur, https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/SecurityOfSupply/GeneratingCapacity/PowerPlantList/PubliPowerPlantList_node.html [accessed: 20.01.2021].

By way of comparison, in 2011, power plants with a gross electrical capacity of 167 GW were installed in Germany. The shares broken down by energy sources were as follows: wind energy 17.4%, hard coal 16.9%, photovoltaics 14.3%, natural gas 13%, lignite 12.2%, water 6.6%, other 10.4%.[17] In addition to conventional power plants that can replace installations from unstable renewable energy sources, efficient energy storage technologies are necessary to maintain a stable and safe supply to the grid with a constantly growing share of renewable energy power plants.

Both gross inland electricity consumption and gross electricity production are falling. In 2020, gross domestic electricity consumption was 552.2 TWh; for comparison, in 2011: 604 TWh, in 2017: 600.5 TWh, and in 2019: 576.7 TWh. On the other hand, gross electricity production decreased from 609.4 TWh in 2019 to 572.2 TWh in 2020. For comparison, in 2011 it amounted to 607 TWh, and in 2017 to 652.9 TWh. The share of hard coal and lignite in the electricity mix (*Strommix*) is declining – in 2020, respectively 7.6% (2019: 9.4%; 2018: 12.8%; 2015: 18.2%; 1990: 27.7%) and 16.1% (2019: 18.7%; 2018: 22.6%; 2012: 25.8%; 2010: 23.3%; 1990: 31.1%), with renewable energy and gas growing land – in 2020, respectively 43.9% (2019: 39.8%; 2018: 34.9%; 2015: 29.2%; 1990: 3.6%) and 16.1% (2019: 14, 8%; 2018: 12.7%; 2017: 13.2%; 2015: 9.5%; 1990: 6.5%).[18] High CO_2 prices favour the competitiveness of modern, low-emission gas-fired power plants and drive out high-emission or less efficient power plants. In 2020, renewable energy sources supplied 251 TWh of electricity, and fossil fuels (natural gas, lignite and hard coal, mineral oils) in total 231.3 TWh. As expected, electricity production from nuclear power plants fell after the Philippsburg II power plant shutdown at the end of 2019 (2020: 75.1 TWh, 2019: 64.4 TWh).[19]

It is worth noting that lower domestic and foreign demand for electricity due to the coronavirus pandemic resulted in the strengthening of the trend of shifting from production in conventional power plants to the generation of electricity from renewable sources. However, lignite still plays a key role in ensuring security of energy supply, especially in winter.

In the context of the nuclear phase-out, concerns have been expressed about maintaining a certain level of energy supply security. According to the Federal Network Agency (*Bundesnetzagentur*), the energy transition and the growing share of decentralized generation capacities do not have a negative impact on the quality of electricity supply in Germany. In 2019, the interruption in electricity supplies per end user (System Average Interruption Duration Index, SAIDI) was 12.2 minutes. For comparison, in 2010 it was 14.9 minutes; in 2011 – 15.3 minutes, and in 2018 – 13.9 minutes.[20]

Many of the decommissioned nuclear power plants are located in the south of Germany, hence the phase-out of nuclear energy leads to a significant additional

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[17] *Energie in Deutschland. Trends und Hintergründe zur Energieversorgung*, BMWi, Februar 2013, p. 23, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/energie-in-deutschland.pdf?__blob=publicationFile&v=7 [accessed: 20.01.2021].

[18] *Die Energiewende im Corona-Jahr…*, *op. cit.*, p. 17. See *Energieverbrauch in Deutschland im Jahr 2020*, *op. cit.*

[19] *Ibid*.

[20] P. Graichen, F. Hein, *op. cit.*

demand for electricity in this part of the country, and consequently the power grid needs to be redeveloped with additional routes from north to south. The originally prepared projects were to be ready by the end of 2022, when the last nuclear power plants will be shut down. Out of a total of 7,669 km, 1,505 km were completed by the end of the third quarter of 2020, which corresponds to a 20% completion rate. For comparison, at the end of 2019, 1,278 km were completed (17% of the total). Of the 1,831 km planned in the Power Grid Expansion Act (*Energieleitungsausbaugesetz*, EnLAG, amendment in 2018), more than half, i.e. 994 km, was completed by the end of the third quarter of 2020, and another 558 km were approved, while 279 km were in pending approval. Over 90% of EnLAG projects should be launched by the beginning of 2024, and full implementation is planned for the end of 2026. At the same time, the overall length of the network resulting from the Federal Requirement Plan Act (*Gesetz über den Bundesbedarfsplan*, *Bundesbedarfsplangesetz*, BBPlG) is 5,868 km, of which by the end of the third quarter, 511 km were completed, which corresponds to an implementation rate of 9%. Building permits for 254 km were issued. According to the current planning, over 3,000 km should be completed by the end of 2025; and the last projects are to be implemented by 2031.[21]

Challenges for Germany's energy security in the context of the coal phase-out

The decision to abandon nuclear power, and the immediate shutdown of the oldest nuclear power plants soon resulted in greater use of coal. From the perspective of achieving the goal of reducing greenhouse gas emissions, it was counterproductive, hence the issue of the coal phase out was discussed from the mid-2000s.[22] On 6 June 2018, the federal government established the Commission for Growth, Structural Change and Employment (*Kommission für Wachstum, Strukturwandel und Beschäftigung*), whose main goal was to develop a plan for decommissioning coal-fired power plants and CHP plants. On 26 January 2019, the Commission published its final report,[23] in which it recommended the closure of the last coal-fired power plant by 2038 at the latest. In 2032, the possibility of accelerating the closure of all lignite mines and power plants, i.e. by 2035, would be explored. Chancellor Angela Merkel officially approved the Commission's final report and suggested that the federal government should follow its recommendations. On 22 May 2019, the federal government adopted the key points of the Structural Reinforcement Act for Mining

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21 *Die Energiewende im Corona-Jahr*…, *op. cit.*, pp. 62–63; Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, Bundeskartellamt, *Monitoringbericht 2020*, p. 21, https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Berichte/2020/Monitoringbericht_Energie2020.pdf?__blob=publicationFile&v=7 [accessed: 10.03.2021].

22 M. Löhr, *Energietransitionen. Eine Analyse der Phasen und Akteurskoalitionen in Dänemark, Deutschland und Frankreich*, Wiesbaden 2020, pp. 204–205.

23 Kommission "Wachstum, Strukturwandel und Beschäftigung", *Abschlussbericht*, Beschluss vom 26.01.2019, https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/abschlussbericht_kommission_wachstum_strukturwandel_und_beschaeftigung_beschluss.pdf [accessed: 20.12.2020].

Regions, and on 28 August 2019, a draft act developed on their basis (*Entwurf eines Strukturstärkungsgesetzes Kohleregionen*). On 29 January 2020, the federal government adopted a draft act on the phase-out of coal-fired power plants and amending other acts (*Entwurf eines Gesetzes zur Reduzierung und zur Beendigung der Kohleverstromung und zur Änderung weiterer Gesetze*). The draft act on the phase-out of coal-fired power plants (*Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung*) contained rules and a timetable for shutting down coal-fired power plants and combined heat and power plants, and set the end of 2038 as the end date for the use of coal for energy production.

Leaving aside specific issues related to the course of legislative work, it should be noted that on 3 July 2020, the Bundestag adopted the Act to Reduce and End Coal-Fired Power Generation (*Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung*) and the Structural Reinforcement Act for Mining Regions (*Strukturstärkungsgesetz Kohleregionen*). The Bundesrat approved the laws on the same day. The first of the above acts provides for the reduction of the installed capacity of coal-fired power plants to 30 GW in 2022 (15 GW hard coal, 15 GW lignite), to 17 GW in 2030 (8 GW hard coal, 9 GW lignite) and 0 GW in 2038. In addition, in 2026, 2029 and 2032, the possibility of "abandoning coal" in 2035 is to be investigated. For blocks phased out by the end of 2029, RWE and LEAG operators are to receive a total of EUR 4.35 billion (EUR 2.6 billion for RWE, EUR 1.75 billion for LEAG), and for power plants shut down from 2030, they will not receive compensation. Plant shutdown dates and compensation rules are governed by an agreement between the federal government and operators. The decommissioning of hard coal-fired power plants will take place until 2027 through auctions, in which operators will be able to apply for a bonus. Its maximum amount per 1 MW will be reduced every year (from EUR 165 thousand in 2020 to EUR 89 thousand in 2027). Bids assuring maximum emission savings for the lowest amount will be selected. From 2028, hard coal power plants will be shut down by the Federal Network Agency without granting any compensation. In the case of units put into operation after 2010, the evaluation of the act provides for the possibility of adjusting the shutdown conditions for power plants in the event of an overload. The Structural Development Act provides for the transfer of EUR 14 billion to the federal states with power plants and lignite mines (Saxony, Brandenburg, Saxony-Anhalt and North Rhine-Westphalia). Another EUR 26 billion, the federal government has, among others, invest in the development of transport infrastructure in coal regions and the expansion of research institutes. In addition, EUR 1.09 billion is to be allocated to the restructuring of regions where power plants operate or there were coal mines.[24] On 14 August 2020, the Act to Reduce and End Coal-Fired Power Generation entered into force.

In accordance with the adopted solutions, the Federal Network Agency conducts tenders for hard coal power plants and smaller lignite power plants (up to 150 MW of net nominal power) and the so-called statutory reduction.[25] The volume

[24] 'Bundestag beschließt das Kohleausstiegsgesetz', https://www.bundestag.de/dokumente/textarchiv/2020/kw27-de-kohleausstieg-701804 [accessed: 30.08.2020].

[25] Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, Bundeskartellamt, *Monitoringbericht 2020*, *op. cit.*, p. 20.

of the first auction on 1 September 2021 stood at 4,000 MW, and the volume of the second auction, which was scheduled for 4 January 2021, was 1,500 MW. On 30 April 2021, three auctions with a volume of 2,480.826 MW have been planned. 4.7 GW of hard coal capacity will be decommissioned by June 2021. In addition, a small 300 MW lignite block was closed at the end of 2020, and another 900 MW is expected to take place at the end of 2021.[26] In order to ensure security of supply, the Federal Network Agency may transfer some of the planned hard coal-fired power plants to the grid reserve. These power plants are then no longer operating in the electricity market, but are only used in the rare cases where they are needed to ensure grid and system stability.

The simultaneous abandonment of nuclear and coal energy poses a serious challenge to the stability of the German electricity system. Only in the years 2021–2023, are conventional power plants with a total capacity of 14,893 MW to be withdrawn from the market (see Table 2).

Table 2. New plant capacity and plant closures (MW)

	2021	**2022**	**2023**	**2021–2023**
Expected expansion of conventional power plant capacity from 2021 to 2023				
Natural gas	563	1,798	-	2,361
Battery storage	13	-	-	13
Pumped storage	16	-	-	16
Other energy sources (not renewable)	35	58	-	93
Total	627	1,856	-	2,483
Expected power plant output from 2021 to 2023				
Coal phase-out according to KVBG*	2,410	1,625	-	4,035
Closure after the security standby period – Lignite-fired power plants	562	1,059	757	2,378
Nuclear power plants according to § 7 Section 3 AtG**	4,058	4,049	-	8,107
Notifications of final shutdown in accordance with Section 12b (5) EnWG***	373	-	-	373
including natural gas	189	-	-	189
including mineral oil	184	-	-	184
Total	7,403	6,733	757	14,893

* KVBG – Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung (Kohleverstromungsbeendigungsgesetz); ** AtG – Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren (Atomgesetz); *** EnWG – Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz).

Source: 'Power plant list', 19.01.2021, Bundesnetzagentur, https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/SecurityOfSupply/GeneratingCapacity/PowerPlantList/PubliPowerPlantList_node.html [accessed: 20.01.2021].

One of the instruments for maintaining the security of energy supply is to increase the number of gas-fired power plants that would flexibly complement the unstable generation from renewable sources (especially in autumn and winter).

[26] *Die Energiewende im Corona-Jahr…*, *op. cit.*, p. 72.

Their available capacity would increase from 30 GW (currently) to approx. 43 GW in 2030 and 73 GW in 2050, which would fill the gap left by the nuclear and coal shutdown units (by 2038). Natural gas would be successively replaced with emission-neutral hydrogen.[27] In the National Hydrogen Strategy (*Nationale Wasserstoffstrategie*) adopted by the federal government on 10 June 2020, it was assumed that the demand for hydrogen will increase from 55 TWh in 2019 to 90–110 TWh in 2030. According to government estimates, only about one fifth of the German demand for hydrogen in 2030 will be able to be covered from domestic sources, which will mean a permanent dependence on imports. Depending on the technological development and the incurred expenditures as well as the wide use of hydrogen, the demand for hydrogen in 2050 is expected to be between 250 and 800 TWh.[28] The document recognizes green hydrogen (obtained from the electrolysis of water using electricity from renewable sources) as a solution that meets the needs of sustainable development in the long term, therefore its production will be widely supported. The government's goal is to achieve 5 GW of electrolysis capacity by 2030 (10 GW by 2040), which is expected to generate 14 TWh of hydrogen per year. Germany assumes that in the coming years an EU hydrogen market will be created, where its other carbon-neutral variants will also be available: blue – obtained from natural gas using carbon capture and storage (CCS) technology – and turquoise – obtained for by methane pyrolysis.

The development of interconnections with other countries (further integration of the European energy market) and increasing the flexibility of electricity flows between countries have a positive effect on the security of energy supplies. The ALEGrO and NordLink projects, together with the Combined Grid Solution, provide 2,800 MW of new interconnector transmission capacity.[29] In addition, Germany focuses on the development of energy storage technologies and demand management instruments (including tariffs promoting the use of electricity beyond peak power consumption).[30]

In the context of coal phase-out, the question is also whether the electricity supply will continue to be secured at all times, also in autumn and winter.

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[27] M. Kędzierski, 'Niemcy: coraz większy zakres rozbudowy sieci elektroenergetycznej, *Analizy OSW*, 11.02.2021, https://www.osw.waw.pl/pl/publikacje/analizy/2021-02-11/niemcy-coraz-wiekszy-zakres-rozbudowy-sieci-elektroenergetycznej [accessed: 10.03.2021].

[28] *Die Nationale Wasserstoffstrategie*, Bundesregierung, Juni 2020, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.pdf?__blob=publicationFile&v=20 [accessed: 20.12.2020]; K. Westphal, S. Dröge, O. Geden, 'Die internationalen Dimensionen deutscher Wasserstoffpolitik', *SWP-Aktuell*, No. 37, Mai 2020, https://www.swp-berlin.org/fileadmin/contents/products/aktuell/2020A37_Wasserstoffpolitik.pdf [accessed: 20.12.2020].

[29] The first hybrid interconnector was made available thanks to the Combined Grid Solution. It will connect the Kriegers-Flak offshore wind farm and create a 400 MW link between Denmark and Germany. Thanks to the ALEGrO interconnector, the first interconnection to Belgium was implemented as a high voltage direct current (HVDC) transmission with a transmission capacity of around 1000 MW (underground cable). The NordLink connection, once fully operational, will create the first direct connection with Norway with a capacity of 1,400 MW in the first quarter of 2021. *Die Energiewende im Corona-Jahr…*, *op. cit.*, pp. 59–61.

[30] M. Kędzierski, *op. cit.*

According to press reports, transmission system operators are investigating which of the coal-fired power plants slated for closure in 2021 are of systemic importance, because in such a situation they would be kept ready for operation as a grid reserve.[31]

Germany's electricity exports are expected to decline as coal and nuclear power are phased out. The coal-fired power plants alone, to be shut down in 2021, generate around 10 TWh. As the Brokdorf, Grohnde and Gundremmingen C nuclear power plants will also be closed at the end of 2021, Germany could again become a net importer for the first time since 2002 as early as 2022[32]. Moreover, the loss of stable generation capacity with too slow expansion of renewable energy installations and power grids may lead to a situation where, in the mid-2020s, Germany would turn from a net exporter of energy to its importer.

According to the amendment to the Act on the Development of Renewable Energy Sources (*Gesetz für den Ausbau erneuerbarer Energien*, EEG) adopted in December 2020, the installed capacity of onshore wind farms is to reach 71 GW (currently 54 GW) by the end of the decade, and photovoltaics – 100 GW (52 GW).[33] Hence, the growing role of wind energy makes Germany face up to the need to increase the capacity of north-south connections. The problem remains the insufficient capacity of the system, which currently prevents the transport of some energy from wind farms, which is why they are forced to disconnect from the grid more and more often in order to avoid overloading. The pace of expansion of the power grids is still too slow in relation to the changes taking place in the system. Delays in the implementation of investments caused, among others, by protracted construction permit proceedings and protests from residents. The lack of social acceptance for overground power lines in 2015 led to the change of previous plans and routing of routes underground, which in turn not only extended the investment time.[34]

The amended Federal Requirement Plan Act includes the target of the share of renewable energy sources in electricity consumption in 2030 at the level of 65%. It includes 35 new projects, 9 of which are new routes and 26 are replacements or extensions of the existing sections. The amendments to the document, adopted by the Bundestag on 28 January 2021, also apply to the shortening of court proceedings to one instance in the case of lawsuits concerning new routes, which is expected to simplify and speed up the planning and issuing of building permits. The amendment to the act also allows transmission network operators to create energy storage under certain conditions and use them only for grid management.[35]

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31 B. Janzing, *op. cit.*

32 *Ibid*.

33 *Gesetz für den Ausbau erneuerbarer Energien* (*Erneuerbare-Energien-Gesetz*, EEG), https://www.gesetze-im-internet.de/eeg_2014/BJNR106610014.html [accessed: 30.01.2021].

34 M. Kędzierski, *op. cit*.

35 'Novelle des Bundesbedarfsplangesetzes', 12.02.2021, https://www.bmwi.de/Redaktion/DE/Artikel/Service/Gesetzesvorhaben/novelle-des-bundesbedarfsplangesetzes.html [accessed: 20.02.2021].

Conclusions

Germany's energy security has been scrutinised in the context of the energy transition, which main pillar is the acceleration of the development of renewable energy sources in connection with the abandonment of the use of nuclear energy and coal for electricity production. The short-term consequence of abandoning nuclear energy was an increase in the share of coal in electricity generation, and in the longer term, due to the abandonment of coal, it will primarily be an increase in the share of renewable energy sources and, to a lesser extent, natural gas, so as to ensure security of energy supply. In view of the forecasts of a gap in the power system caused by the decommissioning of coal-fired power plants, it will be necessary to implement appropriate measures to ensure the security of electricity supply, including the construction of energy storage, acceleration of the expansion of transmission networks and interconnectors with neighbours, and in particular the use of hydrogen.

References

Bardt, H., 'Wirtschaftliche Folgen eines beschleunigten Kernenergieausstiegs in Deutschland', *IW-Trends*, No. 2, 2011.

Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, Bundeskartellamt, *Monitoringbericht 2020*, https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Berichte/2020/Monitoringbericht_Energie2020.pdf?__blob=publicationFile&v=7 [accessed: 10.03.2021].

'Bundestag beschließt das Kohleausstiegsgesetz', https://www.bundestag.de/dokumente/textarchiv/2020/kw27-de-kohleausstieg-701804 [accessed: 30.08.2020].

Das Energiewirtschaftliche Gesamtkonzept. Konsequenzen eines beschleunigtes Atomausstiegs aus der Kernenergie in Deutschland, eine Studie der Prognos AG im Auftrag der vbw, April 2011.

'Deutscher Strom-Exportüberschuss geht zurück', *Handelsblatt*, 31.12.2020, https://www.handelsblatt.com/politik/deutschland/energie-deutscher-strom-exportueberschuss-geht-zurueck/26761454.html?ticket=ST-123457-9E4nU4KazwrICNvT6Cdb-ap4 [accessed: 20.01.2021].

Die Energiewende im Corona-Jahr: Stand der Dinge 2020. Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2021, Agora Energiewende, https://static.agora-energiewende.de/fileadmin/Projekte/2021/2020_01_Jahresauswertung_2020/200_AEW_Jahresauswertung_2020_WEB.pdf [accessed: 20.02.2021].

Die Nationale Wasserstoffstrategie, Bundesregierung, Juni 2020, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.pdf?__blob=publicationFile&v=20 [accessed: 20.12.2020].

Der Weg zur Energie der Zukunft – sicher, bezahlbar und umweltfreundlich, https://www.bmwi.de/Redaktion/DE/Downloads/E/energiekonzept-2010-beschluesse-juni-2011.pdf?__blob=publicationFile&v=1 [accessed: 28.12.2020].

Energie in Deutschland. Trends und Hintergründe zur Energieversorgung, BMWi, Februar 2013, p. 23, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/energie-in-deutschland.pdf?__blob=publicationFile&v=7 [accessed: 20.01.2021].

Energieverbrauch in Deutschland im Jahr 2020, Stand: 14. März 2021, Arbeitsgemeinschaft Energiebilanzen e.V., https://www.ag-energiebilanzen.de/ [accessed: 20.01.2021].

Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung, 28.09.2010, http://www.bundesregierung.de/Content/DE/_Anlagen/2012/02/energiekonzept-final.pdf?__blob=publicationFile [accessed: 28.12.2020].

Energiewende kostet, aber es lohnt sich. Dena-Chef Kohler: Atomausstieg ist bis 2020/2025 machbar. Konsequenzen und Kosten sind große Herausforderung. Akzeptanz der Bevölkerung nur mit ehrlicher Diskussion erreichbar, Deutschen Energieagentur (Dena), Presseinformation vom 18.04.2011.

Gesetz für den Ausbau erneuerbarer Energien (*Erneuerbare-Energien-Gesetz*, EEG), https://www.gesetze-im-internet.de/eeg_2014/BJNR106610014.html [accessed: 30.01.2021].

Feld, L.P. *et al.*, *Neustart in der Energiepolitik jetzt!*, Stiftung Marktwirtschaft, 2014, https://www.stiftung-marktwirtschaft.de/fileadmin/user_upload/KK-Studien/KK_58_Energiewende_2014.pdf [accessed: 10.01.2018].

Graichen, P., Hein, F., '10 Jahre nach Fukushima: Welche Folgen hat der Atomausstieg für die Energiewende?', Agora Energiewende, https://static.agora-energiewende.de/fileadmin/user_upload/10_Jahre_Fukushima_Agora_v4.pdf [accessed: 2.03.2021].

Janzing, B., 'Deutschland muss bald Strom importieren', *taz. die Tageszeitung*, 31.12.2020, https://taz.de/Deutschland-muss-bald-Strom-importieren/!5737103 [accessed: 20.01.2021].

Kędzierski, M., 'Niemcy: coraz większy zakres rozbudowy sieci elektroenergetycznej", *Analizy OSW*, 11.02.2021, https://www.osw.waw.pl/pl/publikacje/analizy/2021-02-11/niemcy-coraz-wiekszy-zakres-rozbudowy-sieci-elektroenergetycznej [accessed: 10.03.2021].

Kommission "Wachstum, Strukturwandel und Beschäftigung", *Abschlussbericht*, Beschluss vom 26.01.2019, https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/abschlussbericht_kommission_wachstum_strukturwandel_und_beschaeftigung_beschluss.pdf [accessed: 20.12.2020].

Löhr, M., *Energietransitionen. Eine Analyse der Phasen und Akteurskoalitionen in Dänemark, Deutschland und Frankreich*, Wiesbaden 2020.

Molo, B., 'Problem zapewnienia bezpieczeństwa energetycznego Niemiec w kontekście stopniowej rezygnacji z użytkowania elektrowni jądrowych', *Przegląd Zachodni*, No. 2 (347), 2013, pp. 69–89.

'Novelle des Bundesbedarfsplangesetzes', 12.02.2021, https://www.bmwi.de/Redaktion/DE/Artikel/Service/Gesetzesvorhaben/novelle-des-bundesbedarfsplangesetzes.html [accessed: 20.02.2021].

'Power plant list', 19.01.2021, Bundesnetzagentur, https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/SecurityOfSupply/GeneratingCapacity/PowerPlantList/PubliPowerPlantList_node.html [accessed: 20.01.2021].

Wege zur 100% erneuerbaren Stromversorgung, SRU Sondergutachten, Sachverständigenrat für Umweltfragen, Berlin 2011, https://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2008_2012/2011_07_SG_Wege_zur_100_Prozent_erneuerbaren_Stromversorgung.pdf?__blob=publicationFile [accessed: 2.03.2021].

Westphal, K., Dröge, S., Geden, O., 'Die internationalen Dimensionen deutscher Wasserstoffpolitik', *SWP-Aktuell*, No. 37, Mai 2020, https://www.swp-berlin.org/fileadmin/contents/products/aktuell/2020A37_Wasserstoffpolitik.pdf [accessed: 20.12.2020].

Wyzwania dla bezpieczeństwa energetycznego Niemiec w kontekście wycofywania energii jądrowej i węgla
Streszczenie

Artykuł koncentruje się na głównych wyzwaniach bezpieczeństwa energetycznego (rozumianego jako bezpieczeństwo dostaw energii) Niemiec w kontekście rezygnacji z wykorzystywania energii jądrowej i węgla do produkcji energii elektrycznej. W związku z wycofywaniem energii jądrowej do produkcji energii elektrycznej wyrażano obawy dotyczące utrzymania określonego poziomu bezpieczeństwa dostaw energii. Na podstawie wybranych składowych bilansu energetycznego ukazano, że w okresie 2011–2020 nie wystąpił deficyt w dostawach energii elektrycznej, czy – szerzej – nie odnotowano „luki w systemie elektroenergetycznym". Omówiono kwestię stabilności systemu elektroenergetycznego Niemiec w perspektywie krótkookresowej, tj. w związku z jednoczesną rezygnacją z energetyki jądrowej i węglowej, jak również instrumenty utrzymania bezpieczeństwa dostaw energii w dłuższej perspektywie czasowej.
Słowa kluczowe: Niemcy, bezpieczeństwo energetyczne, odejście od energetyki jądrowej, odejście od węgla

Challenges for German Energy Security in the Context of Nuclear and Coal Phase-Out
Abstract

The article focuses on the main challenges of Germany's energy security (understood as security of energy supply) in the context of abandoning the use of nuclear energy and coal to produce electricity. Concerns about the maintenance of a certain level of security of energy supply have been expressed in connection with the phase-out of nuclear energy for electricity production. On the basis of selected components of the energy balance, it was shown that in the period 2011–2020 there was no deficit in electricity supplies or, more broadly, there was no "gap in the power system". The issue of the stability of the German electricity system in the short term, i.e. in connection with the simultaneous abandonment of nuclear and coal energy, as well as instruments for maintaining the security of energy supply in the long term, were discussed.
Key words: Germany, energy security, phase-out of nuclear energy, phase-out of coal

Herausforderungen für die Energiesicherheit Deutschlands im Kontext vom Kernenergie- und Kohleausstieg
Zusammenfassung

Der Artikel konzentriert sich auf die Hauptherausforderungen der deutschen Energiesicherheit (verstanden als Sicherheit der Energieversorgung) im Kontext der Abkehr vom Strom aus Kernenergie und Kohle. Im Zusammenhang mit dem Ausstieg aus der Kernenergie zur Stromerzeugung wurden Bedenken hinsichtlich der Aufrechterhaltung eines bestimmten Sicherheitsniveaus der Energieversorgung geäußert. Anhand ausgewählter Komponenten der Energiebilanz wurde gezeigt, dass im Zeitraum 2011–2020 kein Defizit bei der Stromversorgung oder allgemein keine „Lücke im Energiesystem" bestand. Die Frage der kurzfristigen Stabilität des deutschen Stromnetzes wurde diskutiert, d. h. im Zusammenhang mit dem gleichzeitigen Kernenergie- und Kohleausstieg, sowie Instrumenten zur langfristigen Aufrechterhaltung der Energieversorgungssicherheit.
Schlüsselwörter: Deutschland, Energiesicherheit, Kernenergieausstieg, Kohleausstieg

Вызовы энергетической безопасности Германии в контексте отказа от ядерной энергии и угля

Резюме

В статье рассматриваются основные вызовы энергетической безопасности Германии (прежде всего безопасности энергоснабжения) в контексте отказа от использования ядерной энергии и угля для производства электроэнергии. В связи с отказом от использования ядерной энергии для производства электроэнергии, сохраняется обеспокоенность по поводу возможности поддержания надлежащего уровня безопасности энергоснабжения. На основе анализа отдельных компонентов энергобаланса в исследовании показано, что в период 2011–2020 гг. не было дефицита и перебоев в поставках электроэнергии. В статье были также рассмотрены вопросы касающиеся стабильности энергосистемы Германии в краткосрочной перспективе, т.е. в связи с одновременным отказом от ядерной и угольной энергетики, а также указаны инструменты поддержания безопасности энергоснабжения в долгосрочной перспективе.

Ключевые слова: Германия, энергетическая безопасность, отказ от атомной энергетики, отказ от угля