German Nuclear Phase-Out Enters the Next Stage: Electricity Supply Remains Secure — Major Challenges and High Costs for Dismantling and Final Waste Disposal

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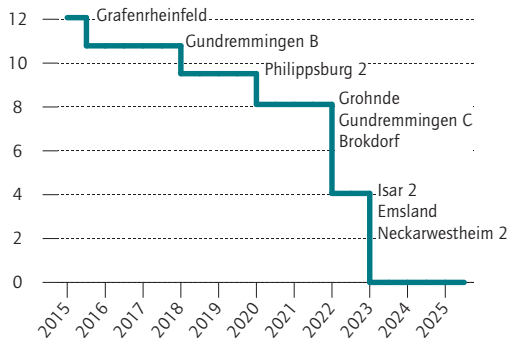
The June 2015 shutdown of the Grafenrheinfeld nuclear power plant marks the shift into a new phase of the energy transition, in which all nuclear power plants in Germany will gradually be shut down by 2022. But even with the end of the commercial use of nuclear power, the lights in this country will not go out: As DIW Berlin's calculations attest to, the electricity supply in Germany remains secure. It is even assumed that Germany will still export electricity in 2025. However, the real challenges – the dismantling of the nuclear power plants and the disposal of nuclear waste – have yet to come: The final disposal of the highly radioactive waste in a (yet-to-be-determined) repository will continue, in all likelihood, into the 22nd century. For the dismantling and final disposal, the estimated costs – which, so far, are not very reliable – are expected to be at least 50 to 70 billion EUR. As such, the 38 billion EUR of provisions set up by the nuclear power plant operators are unlikely to be sufficient to cover the expected costs. Given the major financial risks, DIW Berlin recommends that the provisions set up by the nuclear companies be promptly transferred into a public-law fund. For costs that go beyond the framework covered by the provisions, a reserve liability should be established.

After Chancellor Angela Merkel imposed a moratorium at short notice on March 14, 2011, in the wake of the nuclear disaster in Fukushima, the operating licenses for the seven oldest German nuclear power plants (NPP) as well as the Krümmel nuclear power plant were withdrawn in the same month.[1] According to the 13th amendment of the Atomic Energy Act, the operators of the eight remaining NPPs with capacities of twelve gigawatts (GW) must gradually remove them from the grid by 2022 at the very latest (Figure 1). This puts Germany in the same category as several European countries — among them Austria, Italy, Switzerland, and Sweden — that have decided against the continued civilian use of nuclear power. In a next step, the NPP in the Lower Fran-

1 Initially, the operating licenses were only withdrawn for three months; in summer 2011 they were withdrawn permanently.

Figure 1

Capacity development of nuclear power plants according to the Atomic Energy Act
In Gigawatt



Source: DIW Berlin based on the Atomic Energy Act from 28 August 2013.

The last nuclear power plant in Germany will shut down in 2022.

Figure 2

Nuclear power plants and nuclear waste disposal sites in Germany

Source: DIW Berlin.

The nuclear power plant Grafenrheinfeld will shut down in June 2015.

conian municipality of Grafenrheinfeld is being taken off the grid in June 2015.[2]

At the same time, the discussions in Germany concerning the storage of the nuclear waste are heating up. The planned deep geological repository is currently impossible due to the lack of an appropriate site for this kind of storage, and so, for the foreseeable future, the nuclear waste must be temporarily stored in the interim storage facilities close to the power plants themselves.[3] However, the operating licenses of these plants will expire by 2046, and even the intermediate storage containers (CASTOR) for fuel elements have an operating license of only 40 years.

In addition to the technical aspects of the final disposal, the economic challenges are increasingly coming into focus. The costs of the entire process, which is expected to continue into the next century, are not only very high, but also fraught with considerable uncertainties. There is mention of 50 to 70 billion EUR—which is nearly twice the value of the provisions that have been set up by the NPP operators.[4]

Impacts of the NPP shutdown on the energy industry are low

It is expected that the June 2015 shutdown of the Grafenrheinfeld nuclear power plant will create only minimal consequences for the energy sector. Both in Germany as well as in other European countries, there are sufficient reserves available on the electricity market to compensate for the loss of the 1,275-megawatt (MW) net output. Calculations show that around half of the reduced annual electricity production in Germany can be compensated for with five terawatt hours—mainly by coal, but also by lignite and natural gas. The difference will be provided from abroad.[5]

Even after 2022, by when all of the remaining nuclear power plants will have been shut down, the security of supply in Germany and in the neighboring countries will still be guaranteed, according to the current state of planning. In addition to the scenario framework for Germany, the scenarios concerning the capacity planning created by the European Transmission System Operators (ENTSO-E)—the so-called System Outlook & Adequacy Forecast (SOAF)—are used in the analysis. Accord-

2 The plant's operator, E.ON, had originally scheduled May 31, 2015 as the shutdown date, as staying in operation until the legally determined end date of December 31, 2015 would have required the replacement of fuel elements and the payment of the nuclear fuel tax. An unexpectedly low utilization in the recent mild winter months has allowed E.ON to keep the plant in operation longer, and thus the closure was postponed to June 20, 2015. See: Bavarian Broadcasting (2015): *AWK Grafenrheinfeld bleibt bis 20. Juni am Netz* (Grafenrheinfeld NPP to remain on the grid until June 20), http://www.br.de/nachrichten/unterfranken/inhalt/akw-atomkraftwerk-grafenrheinfeld-laufzeit-100.html, retrieved May 13, 2015.

3 For an overview of previously accumulated radioactive waste and projected radioactive waste in Germany, see BMUB (2015): *Verzeichnis radioaktiver Abfälle. Kommission Lagerung hoch radioaktiver Abfallstoffe.* (Directory of radioactive waste. Commission for the Storage of Highly Radioactive Waste), K-MAT 13 p. 22.

4 See: Wille, Joachim (2015): *Experten warnen vor Milliardenkosten für den Staat: Bis ein Endlager gefunden, eingerichtet und befüllt ist, könnten noch 150 Jahre ins Land gehen* (Experts warn of multibillion-euro government expenditures: Until a repository is chosen, established, and filled, it could be another 150 years). Frankfurter Rundschau Online, April 20, 2015, downloaded April 24, 2015.

5 These and other model works were created in connection with the "Bavarian Energy Dialogue." See: Robert Mieth, Clemens Gerbaulet, Christian von Hirschhausen, Claudia Kemfert, and Richard Weinhold (2015): *Perspektiven für eine zukunftsfähige und preiswerte Energieversorgung in Bayern auch nach Abschalten der Atomkraftwerke* (Perspectives for a sustainable and affordable energy supply in Bavaria after the shutdown of nuclear power plants). Berlin, DIW Berlin Politikberatung Kompakt 97.

ing to the current capacity planning of the ENTSO-E, capacities of 367 gigawatts of conventional capacity are expected for Germany and the neighboring countries. In the context of the Central European electricity market, the electricity supply in Germany is secured even during peak load hours; in these few extreme hours, Germany becomes a net importer.[6]

The electricity price forecast for the wholesale market is highly dependent on the selection of carbon dioxide (CO_2) and fuel prices. A comparison of the ordered price duration curve[7] of the SOAF standard scenario as well as that of a scenario with reduced commodity prices[8] for the year 2025 indicates a slight increase in prices overall — the exact amount, however, is uncertain. The average prices shown vary from 34 to 47 EUR per megawatt hour (Figure 2). The CO_2 emissions would increase moderately depending on the scenario.

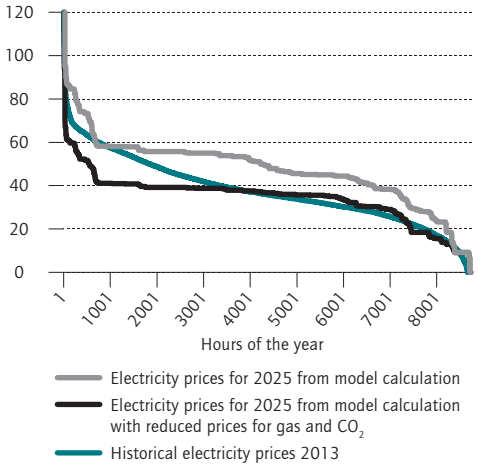
The next step: Dismantling the nuclear power plants

The shutdown of the nuclear power plants will be followed by the decommissioning and dismantling. The Atomic Energy Act allows for two approaches to dismantling: The first is "immediate dismantling," in which the dismantling of the power plant begins directly after the five-year post-operational period. Although this process generally takes about two decades, it can take longer and become more expensive if — as already seems to be the case — sufficient repository capacity for the radioactive waste is not established in time. In the second dismantling option — the so-called "safe enclosure" — the power plant is closed off for several decades and the control area, the nuclear reactor in particular, is not dismantled until after this time period.

One advantage of the immediate dismantling option is that the operational nuclear power plants' current staff and expertise can continue to be deployed. An argument in favor of the safe enclosure option is that the radioactivity decreases the most in the first decades following the shutdown, which simplifies the subsequent dismantling and potentially reduces the waste volumes. Internationally, immediate dismantling is the more common variant, and in Germany as well, the nuclear operators have chosen this variant.[9] A few other types of reactors are in safe enclosure.

Figure 3

Hourly wholesale electricity prices[1]
In Euro per Megawatt-hour



1 In descending order.

Source: DIW Berlin.

Fuel prices influence the development of the wholesale electricity price stronger than the nuclear phaseout.

The task of the century: The final disposal

Substantially more complex than the dismantling of the nuclear power plants is the search for long-term storage facilities for the radioactive waste.[10] This is largely due to the fact that the long-term, secure storage of highly radioactive waste has never been seriously addressed since the beginning of the German nuclear

6 In DIW Berlin's earlier model calculations, as well, it was shown that the current electricity system can cope with the loss of nuclear capacity. See: Kunz, Friedrich, et al. (2013): *Mittelfristige Strombedarfsdeckung durch Kraftwerke und Netze nicht gefährdet* (Medium-term electricity supply from power plants and grids not at risk). DIW Berlin Weekly Report 48-2013, pp 25–37. The calculations carried out in that instance include a detailed network modeling. A recent study conducted by the Central and Western European network operators for the period of 2020/21 also came to the conclusion that there are no bottlenecks in the German power grid. See: Pentalateral Energy Forum (2015): Pentalateral Generation Adequacy Probabilistic Assessment. Support Group Generation Adequacy Assessment, Final Report, March 5, 2015 online: http://www.bmwi.de/BMWi/Redaktion/PDF/G/gemeinsamer-versorgungssicherheitsbericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf, retrieved May 13, 2015.

7 In an ordered price duration curve, all 8,760 hourly wholesale prices from the course of one year are depicted in descending order.

8 This alternative scenario with reduced commodity prices assumes a price of 10 EUR (instead of 21 EUR) for each ton of CO_2 emitted and a natural gas price of 20 EUR (instead of 27 EUR) per megawatt hour (thermal).

9 Source: Operating companies' requests to the state authorities, see: atommuellreport.de; see: Sokoll, Jörg (2015): *Kernenergie: Erste Erfahrungen aus den Stilllegungen in Deutschland.* (Nuclear power: First experiences with decommissionings in Germany.) Energiewirtschaftliche Tagesfragen, Vol. 65, Issue 5, pp. 58–61.

10 This section as well as the next section of the weekly report are primarily based on a jurisprudential elaboration that arose in the context of joint research. See: Ziehm, Cornelia (2015): *Endlagerung radioaktiver Abfälle* (Final disposal of radioactive waste). Berlin, study commissioned by DIW Econ; printed in *Zeitschrift für neuen Energierecht (ZNER)* (Journal of New Energy Law).

program. Although the commercial use of nuclear power has been permitted in the Federal Republic of Germany ever since the passage of the Atomic Energy Act (AtG) in 1959, a safe option for the disposal of radioactive waste did not exist at that time. Only with the 1976 adoption of the Fourth Amendment to the Atomic Energy Act did the legislature establish a duty whereby the waste producers were ordered to remove the radioactive waste in an "organized" manner. Moreover, the law established henceforth the need for planning permission for a nuclear repository.

For the final disposal, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) is expecting a volume of around 190,000 cubic meters of low- and mid-level radioactive waste from German nuclear reactors. Along with other radioactive wastes, these are scheduled to be stored in the Konrad repository, which is currently being constructed.[11] Since the entire 303,000-cubic meter capacity of the Konrad repository has already been completely allocated, there is no space for the waste that is envisaged to be retrieved from the Asse II mine — an additional volume of about 175,000 to 220,000 cubic meters, according to the BMUB. To accommodate this waste, another repository would be needed; alternatively, the Konrad repository would need to be expanded. At present, the Federal Office for Radiation Protection (BfS) is making plans for an interim storage facility.

For the so-called "heat-generating waste" — which refers to the high-level radioactive waste that includes spent fuel elements, as well as the radioactive waste that originates from the reprocessing of irradiated nuclear fuel and is solidified in glass canisters — the BfS expects a waste volume of 28,100 cubic meters.[12] For this high-level radioactive waste, there is still no final repository, or even a planned repository site.[13] The only attempt to build such a repository for high-level waste took place in Gorleben, where the investigations of a salt dome to house such waste have been ongoing since 1979. A certificate of suitability based on geoscientific investigations, however, does not exist for the Gorleben salt dome. As well, no alternative locations have been examined more thoroughly thus far. The selection process of the 1970s, which ended with the selection of Gorleben, did not meet the necessary conditions.[14] So far, the costs of the Gorleben salt dome investigations have reached 1.6 billion EUR.[15]

The "Site Selection Law": A new beginning requires perseverance

During the course of the 2011 nuclear phase-out ruling, the issue of finding a suitable repository for nuclear waste also came back on the agenda. Subsequently, the Federal Parliament passed the Site Selection Act (StandAG) in 2013, which includes a transparent and scientific repository-selection process, as well as a comparison of potential sites involving extensive public participation. This organizational change represents a turning point in the decades-long history of the search for a repository is in Germany. Although the miners' investigation of the Gorleben salt dome stopped in 2012, the site is still being considered as one of the potential locations in the selection process, which is why the mine is currently being kept open.[16]

11 See: BMUB (2015): *Programm für eine verantwortungsvolle und sichere Entsorgung bestrahlter Brennelemente und radioaktiver Abfälle – Nationales Entsorgungsprogramm* (Program for responsible and safe management of spent fuel and radioactive waste – National Waste Management Program), draft from January 6, 2015, p. 10.

12 Federal Office of Radiation Protection: Forecasts for future waste volumes, online: http://www.bfs.de/de/endlager/abfaelle/prognose.html, retrieved May 14, 2015.

13 See: Ziehm, Cornelia (2015, ibid, Part 1).

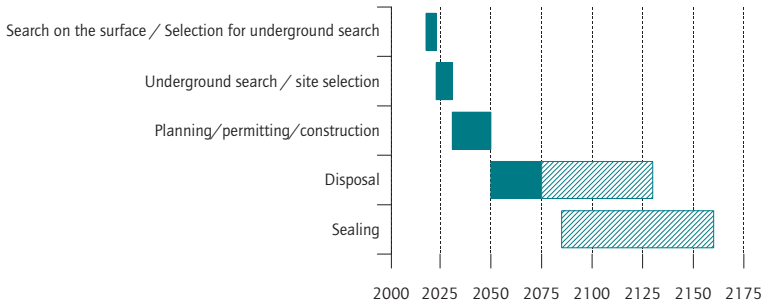
14 See: Ziehm (2015, ibid, p. 7).

15 See also: BMUB: http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Atomenergie/ einigung_offenhaltungsbetrieb_gorleben_bf.pdf.

16 The above-ground interim storage facility for highly radioactive waste still exists, but is no longer being filled. It currently contains 82 fuel elements, and 3,024 glass canisters of high-level radioactive waste that primarily originated from reprocessing. The location search will take place in Germany.

Figure 4

Schedule for the disposal of high-level radioactive waste (estimate)[1]



1 The begin of waste disposal in 2050 is an estimate. The actual timing is uncertain and might be delayed significantly.

Source: Endlagerkommission (Commission for the Storage of Highly Radioactive Waste, 2015): Prozesswege zu einer sicheren Lagerung hoch radioaktiver Abfälle unter Aspekten der Rückholbarkeit/Bergbarkeit/ Reversibilität, Papier der Vorsitzenden unter Einbeziehung von Kommentaren weiterer Mitglieder der AG 3, Kommission Lagerung hoch radioaktiver Abfallstoffe gemäß Paragraf 3 Standortauswahlgesetz, K-Drs./ AG3-12, 11. April 2015.

The waste disposal process will likely extend into the next century.

According to StandAG, the selection of underground sites to be investigated is scheduled to be completed by 2023. Accordingly, the final location decision shall be made by 2031. Therefore, only a few years remain for these steps to take place, after which comes the actual planning of the repository, the nuclear licensing procedures, possible judicial reviews of the site and commission decisions, and finally, the actual construction of the repository. It is already clear that a repository for high-level radioactive waste will not be ready before 2050. Despite these uncertainties, the currently convening *Commission for the Storage of High-level Radioactive Waste,* which was established through the Site Selection Act, has published an indicative timetable for the selection process and the final disposal process (Figure 3). It should be noted that unforeseen developments could push the duration of the final disposal process back by decades. The timeline of the ongoing process is associated with considerable uncertainties.[17]

Power plant operators' provisions: High demand for action

Pursuant to § 249 paragraph 1, sentence 1 of the German Commercial Code (HGB), the operators of NPPs set up provisions for unforeseeable liabilities arising from the dismantling of NPPs and the disposal of radioactive waste. At the end of the 2013 fiscal year, these provisions amounted to nearly 36 billion EUR (Table 1);[18] by the end of 2014, that amount had risen to about 38 billion EUR.[19] It is possible to distinguish between provisions for "decommissioning and dismantling" and provisions for "disposal."[20] Total amounts of provisions that were spent on specific tasks are likewise listed as payments made before 2013, and amount to around 2.7 billion EUR. With just under 22 billion EUR, the provisions for dismantling clearly exceed the provisions for disposal.

Although the operators of nuclear power plants set up the provisions, they are regularly redirected to the respective parent companies, where they are then used for other divisions. For the corporations, a comparatively low-cost financing source is therefore available for profitable investment opportunities.

Firstly, it is questionable whether the current provisions are sufficient to satisfy the disposal obligations placed on operators. Secondly, the question arises whether the value of the provisions is guaranteed until the settlement date. The provisions are — just like equity and debt — bound up in physical assets. The upheavals in

17 Even the schedule for the relatively simple "Konrad mine" project for low- and mid-level radioactive waste has already experienced significant delays: Between the 1982 application for the planning approval of the low-level radioactive waste repository and the actual approval in 2007, 25 years elapsed. The Federal Office for Radiation Protection expects that the repository currently under construction will not be completed before 2022, and does not cite any concrete completion date.

18 Däuper and Fouquet (2014): *Finanzielle Vorsorge im Kernenergiebereich - Etwaige Risiken des Status quo und mögliche Reformoptionen* (Finance provisions in the nuclear sector - possible risks of the status quo and potential reform options), study conducted on behalf of the Federal Ministry for Economic Affairs and Energy, Berlin, December 10, 2014. Here: pp. 26/27.

19 Küchler and Meyer (2015): *Atomrückstellungen für Stilllegung/Rückbau und Entsorgung, Analyse der Rückstellungen Ende 2014 – Konzerne und einzelne Kraftwerke* (Nuclear provisions for decommissioning / dismantling and disposal, analysis of the reserves, end of 2014 - companies and individual power plants), *Forum Ökosoziale Marktwirtschaft* (Green Budget Germany), April 2015 www.foes.de/pdf/2015-04-FOES-kurzanalyse -Atomrueckstellungen-2014.pdf

20 Däuper and Fouquet (2014), ibid.

Table 1

Provisions for decommissioning and dismantling of commercial nuclear power plants and final disposal of nuclear waste in Germany[1]

In million Euro

	Owner's declarations to the BMWi Provisions for nuclear power 2013	Collection by Becker/Büttner/Held based on annual financial statements	Already paid amounts until 2013 (especially for directive "EndlagerVLV")	Sum of columns 2 and 3	There of decommissioning and dismantling	There of final disposal
E.ON	14,607	14,607	1,134	15,741	10,308	5,433
RWE	10,250	10,250	790	11,040	4,769	6,271
EnBW	7,664	7,664	570	8,234	4,515	3,719
Vattenfall	1,652	1,659	91	1,751	1,155	595
Kernkraftwerk Krümmel Gmbh & Co oHG	1,805	1,805	149	1,954	900	1,054
Total	35,878	35,985	2,735	38,720	21,647	17,072

1 As of 31.12.2013.

Source: Däuper, O., Fouquet, D. (2014): Finanzielle Vorsorge im Kernenergiebereich297 – Etwaige Risiken des Status quo und mögliche Reformoptionen. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie. Berlin, 10. Dezember 2014, 25 f.

For the tasks ahead 36 billion euros were provisioned in Germany by the end of 2013.

the energy market that have taken place in recent years have shown that the value and profitability of physical assets can change at short notice. For this reason, there is no financing security for the long-term commitments, in particular, in the area of radioactive waste management. If an operating company becomes insolvent, the parent company is liable for the subsidiary, provided that a control and profit transfer agreement exists, or a so-called unrestricted comfort letter[21] has been submitted. The experiences from recent years, however, show that even allegedly financially strong companies like automobile manufacturers, banks, or major energy companies (such as U.S. corporation Enron or Japanese electric utility Tepco) may be at risk of insolvency as well. If a nuclear power plant operator were to become insolvent, there would be an increased risk that the federal government and thus the taxpayers would have to bear the additional dismantling and disposal costs.[22]

Independent of any risk of insolvency, some large energy companies are trying to reorganize their company structures — presumably to achieve a limitation of liability for possibly high future payment obligations:[23] For example, in 2012 the Swedish Vattenfall Europe AG (*Aktiengesellschaft*, or joint-stock company) turned into Vattenfall GmbH (*Gesellschaft mit beschränkter Haftung*, or limited liability company) with a capital fund of only 500 million EUR. As announced, the E.ON Group will split up on January 1, 2016;[24] at present, it is unclear what exactly is going to happen with the provisions in the aftermath. Even though a direct liability with respect to the parent company for the enforcement of public liabilities does not appear to be categorically excluded in the case of corporate transformations, it is, however, by no means secure. In any case, it would only be possible under strict conditions and would only reduce the risks for taxpayers to a limited extent if the parent company were to become insolvent.[25]

Considerable uncertainties concerning the future costs of dismantling and disposal

When implementing major projects, planners are regularly faced with the problem that the development of future costs is more or less uncertain. With the dismantling of nuclear power plants, however, the situation is even more complex. For one, this has to do with a lack of experience; for another, it has to do with the strategic behavior of the nuclear companies, the non-transparency of information, and the absence of control possibilities for the public sector. The few experiences with the dismantling of nuclear power plants differ greatly and do not allow for generalized conclusions about future costs: For example, the costs and time investments expanded considerably during the dismantling of the former East German nuclear power plant in Greifswald,[26] but because this plant has a fundamentally different type of reactor, there is not much that can be learned from this experience. The costs of dismantling the older, smaller NPP in Würgassen (Baden-Württemberg, 640 megawatts) exceeded 1 billion EUR.[27] Again, it is unclear what these costs were made up of and whether they are representative of future dismantling costs at other power plants.

Cost estimates from the energy industry itself are, however, only very roughly comprehensible — or not comprehensible at all. Such is the case in a study by Arthur D. Little, which estimates average dismantling costs of 930 EUR per kilowatt of installed capacity. Foreign cost estimates, which by their very nature are also subject to large uncertainties, can only provide a rough estimate due to differences in technical and institutional frameworks (for example, with regard to authorization procedures). In Switzerland, the dismantling costs are estimated at 962 EUR per kilowatt.[28]

There is therefore the risk that the provisions the nuclear operators have allocated for dismantling and decommissioning — which currently amount to just under 22 bil-

21 A parent company pledges with an unrestricted comfort letter to provide daughter firms with enough financial resources to be able to meet all financial obligations.

22 See: Däuper and Fouquet (2014, ibid, page 8f.), who likewise doubt that the state puts a high priority on debt claims. A similar problem is currently arising in the banking sector with the obligation of the member states to create reserves, which could be required in the process of bank liquidation, see ECB (2015):. Monthly Bulletin, Vol. 66, No. 6, June.

23 See also: Hermes, statement delivered as part of the expert consultation of the German Parliament on March 4, 2015, committee documents 18 (9) 372, as well as Irrek, in: Wirtschaftswoche from December 6, 2014

24 The "new" E.ON will take over the areas renewable energy, customer services, and the distribution network operators. The conventional business with nuclear, coal, and gas power plants as well as global energy trade, exploration, and production will be transferred into a new business called "Uniper."

25 Nawarotzky and van Beuningen (2015): *Einstandspflicht eines Unternehmens für* öffentlich-rechtliche *Verbindlichkeiten eines Tochterunternehmens nach Maßgabe des Gesellschaftsrechts* (Purchase price payment obligation of a company for public liabilities of a subsidiary in accordance with company law), elaboration of the Scientific Service of the German Parliament), WD 7-3000 - 283/14, Berlin, February 25, 2015. p. 6 and the following.

26 Estimated costs of 4.2 billion EUR, see: http://www.heise.de/newsticker/meldung/Nach-dem-AKW-Abbruch-Atom-Entsorger-stellen-sich-neu-auf-2073185.html.

27 See: Neue Westfälische online from October 25, 2015: *„Rückbau des AKW Würgassen nach 17 Jahren abgeschlossen - Kosten von mehr als einer Milliarde Euro"* ("Decommissioning of the Würgassen nuclear power plant completed after 17 years – costs in excess of 1 billion euros"). http://www.nw.de/lokal/kreis_hoexter/beverungen/beverungen/11276380_Rueckbau-des-AKW-Wuergassen-nach-17-Jahren-abgeschlossen.html.

28 See: Küchler, S. et al. (2014): *Atomrückstellungen für Stilllegung, Rückbau und Entsorgung - Kostenrisiken und Reformvorschläge für eine verursachergerechte Finanzierung*. (Nuclear provisions for decommissioning, dismantling, and disposal - cost risks and reform proposals for a polluter-pays-principle financing). Study conducted on behalf of the *Bund für Umwelt und Naturschutz Deutschland* (Friends of the Earth Germany). Online: http://www.bund.net/fileadmin/bundnet/pdfs/atomkraft/140917_bund_atomkraft_atomrueckstellungen_studie.pdf. Retrieved on May 8, 2015.

Table 2

Selected financing models for decommissioning and waste disposal in other European countries

	Switzerland	Finland	Sweden
Costs to be covered	Decommissioning and Dismantling of commercial reactors and intermediate storage, disposal of nuclear waste	Decommisisoning and dismantling of commercial and research reactors; disposal of nuclear waste	Decommisisoning and dismantling of commercial and research reactors; disposal of nuclear waste
Estimated total costs	CHF 20.65 bn ~4,000€/kW installed capacity	EUR 2.3 bn ~800€/kW installed capacity	SEK 123 bn ~1,300€/kW installed capacity
Financing	Yearly contibution by power plant operators; capital income (ex ante)	Yearly contibution by power plant operators; capital income (ex post)	Contribution per kWh produced plus fixed amount for decommissioned nuclear power plants; capital income (ex post)
Volume	2013: CHF 5.28 bn; ~1,200€/kW installed capacity	2013: EUR 2.27 bn ~800€/kW installed capacity	2013: SEK 51.4 bn ~500€/kW installed capacity
Guidelines for investments strategy	Adequate return and financial security → diversified portfolio	Financial security and liquidity → Government bonds and serial bonds	Financial security and liquidity → primarily swedish guarantees
Average yearly nominal rate of return	Decommissioning fund (since 1985): 4.6% Disposal fund (since 2002): 2.4%	No average values available 2012: 1.7%; 2013: 0.8%	Since 1996: ~5%

Source: DIW Berlin, based on Küchler, S. et al.(2014): Atomrückstellungen für Stilllegung, Rückbau und Entsorgung – Kostenrisiken und Reformvorschläge für eine verursachergerechte Finanzierung, Studie des Forums öko-soziale Marktwirtschaft im Auftrag des Bund für Umwelt- und Naturschutz. Berlin, Oktober 2014.

lion EUR — are not sufficient. The cost assumptions that the nuclear power plant operators use as a basis for their provisions have not been made public. As well, the very different amounts of the specific provisions in the four companies affected suggest uncertainty and a great variance of costs: For example, the energy company RWE accounts for only 600 EUR of dismantling costs per kilowatt of nuclear capacity. For Vattenfall, however, this figure stands at 1,400 EUR per kilowatt.[29]

Even more uncertain are the costs of the long-term storage of the nuclear waste that is produced during the dismantling process. A fundamental cost analysis is only possible once a site for high-level waste has been chosen. After analyzing available literature, Green Budget Germany (FÖS) assumes the costs will range from EUR 15 to 27 billion in an average scenario.[30]

Because the state of science and technology is continually developing, the requirements emanating from the nuclear law and thus the cost of dismantling may ultimately be higher than expected. As well, the provisions that have been set up most likely include no risk premiums to cover the potential costs of any necessary recoveries of radioactive waste, or redevelopments of the repositories after their closures.[31] The costs of the site selection process as well are to be borne proportionally by the waste producers. In particular, the investigation of areas that come into consideration as well as the above- and underground explorations of sites, including the respective safety investigations, have to be refinanced.[32]

A public fund as a suitable instrument

Internationally, there have been varying experiences with the creation of nuclear funds; the level of financial preparedness also differs greatly. In Switzerland, for example, costs of up to 4,000 EUR per kilowatt of installed

29 See: Küchler, et al. (2014, p. 12).

30 For example, in 2012 the French Court of Auditors raised the original estimate of the final disposal costs from 14–16 billion EUR to 35 billion EUR; in England, the cost estimates for the dismantling and cleanup of the nuclear sites increased from 57 billion British pounds (2004/05) to 104 billion British pounds (2012/13); see: *Länderberichte in Brunnengräber*, et al., (2015, ibid).

31 See: Meyer, B. (2012): Rückstellungen für Rückbau und Entsorgung im Atombereich – Analyse und Reformkonzept. Zeitschrift für neues Energierecht, 3/2012, 239.

32 Ziehm (ibid, p. 26) additionally criticizes the fact the total sum does not include costs that the nuclear power plant operators would likewise have to bear according to the polluter pays principle: This refers to the proportional costs for the safe closures of the Morsleben repository (approximately 2.2 billion EUR) and the Asse II repository, for which the total level of costs is still unknown.

power plant capacity are assumed, but only 1,200 EUR per kilowatt have been put aside in the nuclear fund. In Finland, the nuclear fund only covers a small portion of the expected costs (Table 2).[33] Therefore, there is a major risk in these countries that the difference in costs must be borne by the general public.

At present, different organizational models for the financing of dismantling and final disposal are being discussed in Germany. Various reasons are given in favor of establishing a public-law fund. Maintaining the status quo, in which the NPP operators alone are responsible for financing the unknown dismantling costs in the future as well, appears to make little sense due to the many unresolved issues, which include not just the level of costs, but the liability issues in cases of insolvency, as well. Moreover, the Federal Administrative Court has made it clear that the mere creation of provisions within the companies responsible is not sufficient to ensure the financing of decommissioning and post-closure obligations.[34]

Even the proposal for two separate funds — one for decommissioning and dismantling, the other for final disposal — appears risky given the uncertainties in both areas. For example, the creation of a private-law fund by the energy companies for dismantling and decommissioning, and a public-law fund for the final disposal, has occasionally been proposed.[35] It is a prerequisite of this proposal that the dismantling costs are possible to predict. However, since both technical as well as procedural issues — and therefore the expected costs, as well — are very uncertain, there would be the risk that the fund turns out to be too small, and the remaining costs either have to be transferred to the repository fund or end up being paid for by the public sector (as in the case of bankruptcy).

Therefore, the formation of a single public-law fund appears to be the appropriate solution: Since the business model of the traditional utility companies continues to be threatened and further losses are foreseeable, this fund should be established as quickly as possible.[36] The nuclear waste producers should be required to supplement this fund in order to cover the following: the additionally required costs that are not covered by the current provisions, including a realistic "cost-increase factor"; an appropriate risk reserve; and the anticipated costs of the site selection process. Also needed is an additional reserve liability to cover additional costs that will be incurred in the future.

Summary and economic policy conclusions

The June 2015 shutdown of the Grafenrheinfeld nuclear power plant marks the transition into the next step of the restructuring of the German electricity system. At the same time, this should in no way be considered an "exit" from nuclear power — rather, it should be viewed as an "entrance" into the economy of dismantling and, in particular, of final disposal.

DIW Berlin's calculations show that the electricity supply in Germany will be secure even after the shutdown of the nuclear power plants. The shutdown of the Grafenrheinfeld NPP is unlikely to have any negative effects on the German power system. The elimination of the net capacity totaling 1,275 MW will be compensated for by the currently ample excess capacity. Based on the scenario framework of the German and European TSOs, the model calculations also show that further closures of the remaining eight nuclear power plants by 2022 will not lead to supply bottlenecks in Germany or in neighboring countries. On the contrary, it is expected that Germany will still be able to export electricity in 2025. At that point, by far the largest part of the electricity supply will be covered by renewable energy sources. The peak load amounting to 84 gigawatts in Germany would be — as it already is today — secured with the framework of the Central European electricity market. The electricity prices and emissions will increase only slightly.

However, the shutdown of the Grafenrheinfeld nuclear power plant points toward far more complex challenges, namely the safe dismantling of NPPs and the long-term storage of nuclear waste — and at a time when it must be taken into account that the formerly financially strong NPP operators are facing increasing difficulties in fulfilling their obligations. With regard to the

33 See: Küchler, S. et al. (2014): *Atomrückstellungen für Stilllegung, Rückbau und Entsorgung - Kostenrisiken und Reformvorschläge für eine verursachergerechte Finanzierung* (Nuclear provisions for decommissioning, dismantling, and disposal - cost risks and reform proposals for a polluter-pays financing). Study conducted on behalf of the *Bund für Umwelt und Naturschutz Deutschland* (Friends of the Earth Germany). Online: http://www.bund.net/fileadmin/bundnet/pdfs/atomkraft/140917_bund_atomkraft_atomrueckstellungen_studie.pdf Retrieved May 8, 2015.

34 See: The statements of the Federal Administrative Court on the financing of waste landfills, as well as the discussion with Ziehm on this topic (2015, ibid, p. 27).

35 For example, there is a report on this recommendation commissioned by the BMWi, see: Däuper and Fouquet (2014, ibid).

36 See also the request from Schleswig-Holstein, Hesse, Rhineland-Palatinate: *Entschließung des Bundesrates zur Insolvenzsicherung der Rückstellungen für Stilllegung, Abbau und Entsorgung im Atombereich* (Resolution of the German Federal Council on the insolvency insurance of the provisions for decommissioning, dismantling, and disposal in the nuclear sector), Federal Council document 280/14, as well as the Federal Council's decision from October 10, 2014, plenary session 926 of the Federal Council. For a more detailed description of the public-law fund model, see: Hermes, statement delivered as part of the expert consultation of the German Parliament on March 4, 2015, committee documents 18(9)372.

dismantling of the NPPs, there are still no reliable cost estimates. All the same, the "immediate dismantling" immediately following the power plant shutdown would be preferable to the so-called "safe enclosure" option, in which the actual dismantling is put off for three to four decades.

Even today, six decades after the first commercial usage of nuclear power in Germany, there is still no repository — or even a planned location for a repository — for the high-level radioactive waste. The Site Selection Act presents the opportunity for a new attempt that is earnest and supported by broad sections of civil society. This, however, will require a special political commitment, because the dismantling and final disposal involves a time scale that is unusual in politics: from several decades to centuries. So it can be assumed from a current perspective that the final disposal of nuclear waste will come to an end in the first half of the 22nd century, at the earliest.

Particularly urgent demand for action prevails with regard to the security of the provisions set up by the NPP operators for dismantling and disposal. Firstly, these reserves are not protected against insolvency, and NPP operators might try to dodge the financial responsibility — for example, through corporate restructurings. Secondly, it is already foreseeable at the present that the current accumulated provisions, which amount to around 38 billion EUR, will not be enough to cover the costs. Therefore, provisions should be promptly transferred into a public-law fund. For the additional costs that are expected, a reserve liability should be provided.

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