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Planning and Regulation of Energy Networks

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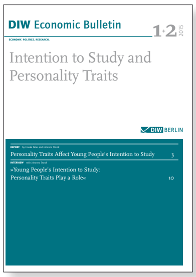

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Electricity Grids and Climate Targets: New Approaches to Grid Planning

By Robert Mieth, Richard Weinhold, Clemens Gerbaulet, Christian von Hirschhausen and Claudia Kemfert

Grid optimization, capacity increases, and grid expansion all play a key role in the development of the German power generation system. Thanks to transmission system operators' foresightedness with regard to grid investments, transmission expansion has not been an obstacle for Germany's energy transition to date. So far, grid expansion planning already accounted for German renewable energy targets, the nuclear phase-out, and the European Emissions Trading System. From now on, the planning framework also includes scenarios which explicitly account for German emissions reduction targets. The level of CO_2 emissions from power stations is to be cut to 187 million tons and 134 million tons by 2025 and 2035, respectively, compared with 317 million tons in 2013. Unlike last year's version of the scenario framework, the latest draft put forward by transmission system operators included a significant increase in lignite-based power generating capacities. In contrast, the version that has now been approved by the German government contains specifications for lignite-based power generation which, depending on the scenario, are five to seven gigawatts lower than the values set down in the draft.

Since 2011, development plans for the electricity transmission system in Germany have been drawn up in a newly structured iterative process involving both transmission system operators and the German Federal Network Agency (*BNetzA*), subject to regular public consultation procedures.[1] Every three years at the least, the annual Grid Development Plan (in German, Netzentwicklungsplan, NEP) is taken as the foundation for grid requirements planning in accordance with the Federal Requirement Plan Act (*Bundesbedarfsplangesetz*). This in turn is based on the draft scenario framework put forward by the transmission system operators, which contains various development scenarios for power generation capacities using different technologies as well as for electricity demands for a period of ten to fifteen years. Despite the increased transparency provided by the new process in comparison to previous approaches to grid planning, it, too, has been criticized.

The inclusion of climate target considerations in grid development plans has been the subject of recent debate. The authors of the present report, however, have long since stressed that grid expansion should not only be about securing supply but should also serve to help meet climate targets.[2]

So far, renewable energy targets and a–moderate–CO_2 price from the European Emissions Trading System (ETS) have already been reflected in the planning pro-

1 For details of the public consultation process, see "Neuer institutioneller Rahmen der Netzplanung" in C. Gerbaulet et al., Netzsituation in Deutschland bleibt stabil, DIW Wochenbericht, no. 20+21 (Berlin: 2013): 4.

2 See the joint statement by DIW Berlin and the Department for Economic and Infrastructure Policy of the TU Berlin: R. Ihlenburg et al., Stellungnahme zum Szenariorahmen 2025 des Netzentwicklungsplan Strom 2015 dated April 30, 2014 (Berlin: 2014): 4. See also L. Jarass, "Stromnetzausbau für erneuerbare Energien erforderlich oder für unnötige Kohlestromeinspeisung?," EweRK, Zeitschrift für Energie- und Wettbewerbsrecht, no. 6 (Nomos: 2013), as well as F. Flachsbarth et al., " Ein Netz für die heutige Welt oder für die Welt von morgen? Kommentierung des Szenariorahmens 2015," Öko-Institut (Freiburg: 2014): 7.

cess.[3] The current 2015 scenario framework, which was approved by the Federal Network Agency on December 19, 2014, now includes, for the first time, scenarios which explicitly consider the German government's targets for CO_2 emissions reductions for the energy sector. Unlike previous scenario frameworks, this version anticipates a faster phase-out of lignite-based power generation.

The modifications made by the Federal Network Agency are to be seen in the context of the current debate on energy policy in Germany. The government recently re-confirmed its commitment to cut greenhouse gas emissions in Germany by 40 percent over the reference year 1990. Its Climate Agenda 2020 sets down specific targets for CO_2 emissions reductions which are to be met by 2020; exactly how this will be achieved has yet to be specified.[4]

Energy Transition So Far Not Hindered by Grid Expansion

In connection with network development planning, it is often claimed that the speed of grid expansion defines that of the energy transition.[5] Yet neither the latest studies nor Federal Network Agency statistics have given any indication to date that this might be the case.[6] First, capacity increases, as well as grid optimization and expansion measures continue to be implemented.[7] Neither grid expansion (new and additional lines) nor upgrades to existing and new power lines have been subject to any major delays. Many additional sections of transmission lines are already in the final project stages and are expected to be completed in the near future.[8] The grid expansion plan is slightly behind schedule but will not impede the energy transition in the immediate future.

Second, over the past few decades, the German national grid, for reasons of historic development, was substantially expanded, such that, despite nuclear power phase-out and the increasing use of renewables, only minor redispatch measures were required. In 2013, the total intervention into power plant operation by transmission system operators amounted to 4.4 terawatt-hours;[9] this is equivalent to less than one percent of the total amount of electricity produced in this year. The number refers to both power- and voltage-related measures as well as related counter-trading activities. Redispatch measures were carried out during 232 days of the year 2013 with an overall duration of 7965 hours. Total costs for national redispatch amounted to around 133 million Euro. For the most part, redispatch was carried out within the area operated by TenneT as well as the border region between TenneT and 50Hertz Transmission.[10] Although detailed data for 2014 is not yet available, transmission system operators could also manage the grid situation in 2014 at all times, drawing on the established instruments.

Previous Scenario Frameworks and Network Planning with Large Share of Lignite-Based Power Generation

In the past, German grid development plans have foreseen extensive integration of lignite-fired power plants into the grid. Transmission system operators are legally obliged to provide a transmission grid that is able to cope with the market based dispatch as often as possible and to ensure reliable transport of that energy to end customers. This is said to facilitate and promote competition between the different power plant operators.

Owing to the extremely low prices for emissions allowances in recent years, the Emissions Trading System, the European Union's key tool for reducing CO_2 emissions, did not result in a shift away from lignite and hard coal toward the greener natural gas in Germany's energy sector. In fact, owing to their low power generating costs, lignite-fired power plants are almost invariably included in the market result, except for hours in which they are substituted by very high renewable feed-in. This is seen in the forecasts for 2024 resulting from transmission system operators' simulations.[11]

3 The reform of the European Emissions Trading System is currently being discussed in the European Parliament; this reform is based on a proposal by the EU Commission which was then adopted by the European Council in October 2014.

4 See German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety, Climate Agenda 2020 (Berlin: 2014): 28.

5 See the second draft 2014 Grid Development Plan: 120.

6 See Federal Network Agency monitoring reports, as well as F. Kunz et al., "Mittelfristige Strombedarfsdeckung durch Kraftwerke und Netze nicht gefährdet," DIW Wochenbericht, no. 48 (2013).

7 For example, the Power Grid Expansion Act (Gesetz zum Ausbau von Energieleitungen, EnLAG) passed in 2009 led to steps toward implementing more than 400 of 1,887 kilometers of power transmission lines.

8 See Federal Network Agency, EnLAG Monitoringbericht, Stand des Ausbaus nach dem Energieleitungsausbaugesetz (EnLAG) zum dritten Quartal 2014 (Berlin: 2014).

9 Bundesnetzagentur and Bundeskartellamt, „Monitoringbericht 2014." Bonn, 14.12.2014. See also https://www.netztransparenz.de/de/Redispatch.htm

10 Transmission system operator TenneT operates across an area stretching from Schleswig-Holstein and Lower Saxony to Hesse and Bavaria, while 50Hertz Transmission covers the northeastern region.

11 See the second draft 2014 Grid Development Plan: 53.

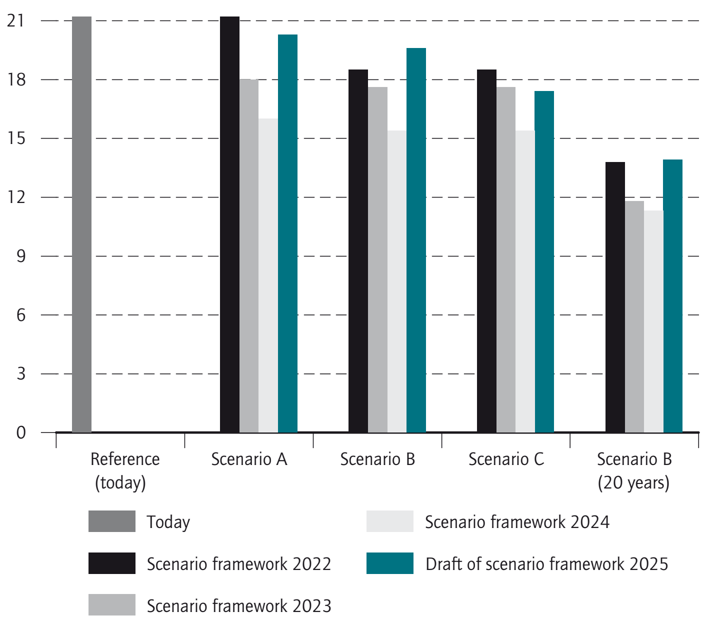
Draft 2025 Scenario Framework Envisaged Higher Lignite Capacities

All the scenarios in the draft 2025 scenario framework[12] put forward by transmission system operators on April 30, 2014 forecasted an increase in lignite-based capacity over the 2014 Grid Development Plan. Scenario A of the Grid Development Plan 2025 even included the construction of two new lignite-fired power plants in North Rhine-Westphalia (Niederaußem) and Saxony-Anhalt (Profen).[13] In addition, it was suggested that instead of assuming a service life of 50 years for all lignite-fired power plants across the board, the service life of these plants should instead be seen in relation to the duration for which open-cast mines have been approved. Compared to the values in the final approved scenario framework for the 2014 Grid Development Plan, this resulted in an increase in lignite-based capacity in the individual scenarios from 2.0 (scenario C) to 4.3 gigawatts (scenario A) for 2025, and 2.6 gigawatts for 2035 (see Figure 1). There was no consistent choice of power plant based on open-cast mine reserves and the assumptions made about extended service life were not comprehensible.

Figure 1

Lignite capacities in recent scenario frameworks

In gigawatts



Source: Bundesnetzagentur (Federal Network Agency).

The draft of the scenario framework 2025 foresees high lignite capacities.

Approved Scenario Framework with Emissions Reduction Targets and Less Lignite

The 2025 scenario framework, approved by the Federal Network Agency on December 19, 2014 contains two new scenarios in addition to the four used to date (see Table 1). In three of the scenarios, steps taken by the electricity sector to help meet Germany's climate targets are to be taken into consideration explicitly. As in the past, there are essentially three scenarios for a time frame of ten years (i.e., 2025), A, B, and C, with scenario B updated to cover 20 years (2035) as well.[14] What is new here is that development scenario B is shown in two versions, B1 and B2. In B1, the German government's climate targets will in all probability not be met. The B2 version, in contrast, contains mandatory emissions restrictions which are in line with the German government's emissions targets for the energy sector; in the three scenarios B2 2025, B2 2035, and C, the market simulations conducted by transmission system operators in their requirements planning must include a secondary condition which takes CO_2 emissions caps into account—a maximum of 187 and 134 million tons of CO_2 for 2025 and 2035, respectively.

Table 1

Overview of the new scenario structure

	Scenario for year:	
	2025	2035
Without emission limit	A, B1	B1
With emission limit	B2, C	B2

Source: Bundesnetzagentur (Federal Network Agency).

Scenario B is split up into two scenarios with and without emission limits.

In comparison to the draft submitted by transmission system operators, the lignite capacities approved by the Federal Network Agency for the 2015 Grid Development Plan were almost five (B 2035) to seven (C 2025) gigawatts lower (see Figure 2); the latter equates to a third

12 The draft proposal by transmission system operators is entitled Szenariorahmen für die Netzentwicklungspläne Strom 2015 (Scenario framework for grid development plans for electricity supply 2015). The version approved by the Federal Network Agency uses the title Szenariorahmen 2025 (2025 scenario framework).

13 The power plant Profen was already included in the 2014 Grid Development Plan.

14 Under the third sentence of Section 12a (1) of the German Energy Industry Act (Energiewirtschaftsgesetz, EnWG), this describes the likely development in the next 20 years.

Table 2

List of lignite power plants in the confirmed scenario framework 2025

BNetzA-ID	Plant Name	Block Name	State	Comission-ing (Year)	Net Capacity [MW]	Net capacity in the confirmed scenario framework [MW]			
						Scenario A 2025	Scenarios B1 / B2 2025	Scenario C 2035	Scenarios B1 / B2 2035
BNA0081	Klingenberg	Klingenberg	Berlin	1981	164	164	164	0	0
BNA0183	Schwarze Pumpe	A	Brandenburg	1999	74	74	74	74	74
BNA0785	Schwarze Pumpe	B	Brandenburg	1981	465	465	465	0	0
BNA0786	KW Jänschwalde	A	Brandenburg	1982	465	465	465	0	0
BNA0787	KW Jänschwalde	B	Brandenburg	1984	465	465	465	0	0
BNA0788	KW Jänschwalde	C	Brandenburg	1985	465	465	465	0	0
BNA0789	KW Jänschwalde	D	Brandenburg	1987	465	465	465	465	0
BNA0790	KW Jänschwalde	E	Brandenburg	1989	465	465	465	465	0
BNA0914	KW Jänschwalde	F	Brandenburg	1997	750	750	750	750	750
BNA0915	HKW Cottbus	1	Brandenburg	1998	750	750	750	750	750
BNA0439	Buschhaus	D	Lower Saxony	1985	352	352	352	0	0
BNA0292	BoA 2	Neurath F	North Rhine-Westphalia	1959	118	0	0	0	0
BNA0313	BoA 3	Neurath G	North Rhine-Westphalia	1966	284	0	0	0	0
BNA0314	Niederaußem	A	North Rhine-Westphalia	1970	278	0	0	0	0
BNA0489	Niederaußem	B	North Rhine-Westphalia	1992	66	0	0	0	0
BNA0490	Niederaußem	G	North Rhine-Westphalia	1993	85	0	0	0	0
BNA0491	Niederaußem	H	North Rhine-Westphalia	1991	52	52	52	52	52
BNA0543	Niederaußem	K	North Rhine-Westphalia	2010	75	75	75	75	75
BNA0696	Neurath	A	North Rhine-Westphalia	1972	277	0	0	0	0
BNA0697	Neurath	B	North Rhine-Westphalia	1972	288	0	0	0	0
BNA0698	Neurath	C	North Rhine-Westphalia	1973	292	0	0	0	0
BNA0699	Neurath	D	North Rhine-Westphalia	1975	607	0	0	0	0
BNA0700	Neurath	E	North Rhine-Westphalia	1976	604	604	0	0	0
BNA0705	Weisweiler	G	North Rhine-Westphalia	1968	297	0	0	0	0
BNA0706	Weisweiler	H	North Rhine-Westphalia	1971	299	0	0	0	0
BNA0707	Weisweiler	E	North Rhine-Westphalia	1974	648	0	0	0	0
BNA0708	Weisweiler	F	North Rhine-Westphalia	1974	653	0	0	0	0
BNA0709	Niederaußem	F	North Rhine-Westphalia	2002	944	944	944	944	944
BNA0710	Niederaußem	D	North Rhine-Westphalia	1963	125	0	0	0	0
BNA0711	Niederaußem	E	North Rhine-Westphalia	1963	125	0	0	0	0
BNA0712	Niederaußem	C	North Rhine-Westphalia	1965	294	0	0	0	0
BNA0713	Frimmersdorf	P	North Rhine-Westphalia	1970	295	0	0	0	0
BNA1025	Frimmersdorf	Q	North Rhine-Westphalia	1965	312	0	0	0	0
BNA1026	Frechen / Wachtberg	Frechen / Wachtberg	North Rhine-Westphalia	1967	304	0	0	0	0
BNA1027	Goldenberg	F	North Rhine-Westphalia	1974	592	0	0	0	0
BNA1028	HKW Merkenich	Block 6	North Rhine-Westphalia	1975	592	0	0	0	0
BNA1401a	Goldenberg	E	North Rhine-Westphalia	2012	1 050	1 050	1 050	1 050	1 050
BNA1401b	Ville / Berrenrath	Ville / Berrenrath	North Rhine-Westphalia	2012	1 050	1 050	1 050	1 050	1 050
BNA0115	Lippendorf	R	Saxony	2000	875	875	875	875	875
BNA0116	Braunkohlekraftwerk Lippendorf	LIP S	Saxony	1999	875	875	875	875	875
BNA0122	Boxberg	N	Saxony	1979	465	465	0	0	0
BNA0123	Boxberg	P	Saxony	1980	465	465	0	0	0
BNA0124	Boxberg	Q	Saxony	2000	857	857	857	857	857
BNA1404	Boxberg	R	Saxony	2012	640	640	640	640	640
BNA0177	HKW Chemnitz Nord II	Block B	Saxony	1988	57	57	57	57	0
BNA0179	HKW Chemnitz Nord II	Block C	Saxony	1990	91	91	91	91	0
BNA0196	Schkopau	A	Saxony-Anhalt	1936	67	0	0	0	0
BNA0878	Schkopau	B	Saxony-Anhalt	1996	450	450	450	450	450
BNA0879	Deuben		Saxony-Anhalt	1996	450	450	450	450	450
	Plants < 50 MW				428	351	302	278	244
	Sum				**21 206**	**14 231**	**12 648**	**10 248**	**9 136**

Source: Bundesnetzagentur (Federal Network Agency).

Some big plants operating today are no longer considerd in the scenario framework.

of the total installed lignite-based generating capacity in Germany. One reason for this decrease is that the Federal Network Agency rejected the transmission system operators' proposal to calculate the service life of power plants on the basis of the periods for which open-cast mines have been approved.[15] Accordingly, lignite-fired power plants were removed from the list of power plants: all plans to build new power plants in Profen and Niederaußem in scenario A 2025 were abandoned and the service life of existing lignite-fired power plants reduced significantly (see Table 2).

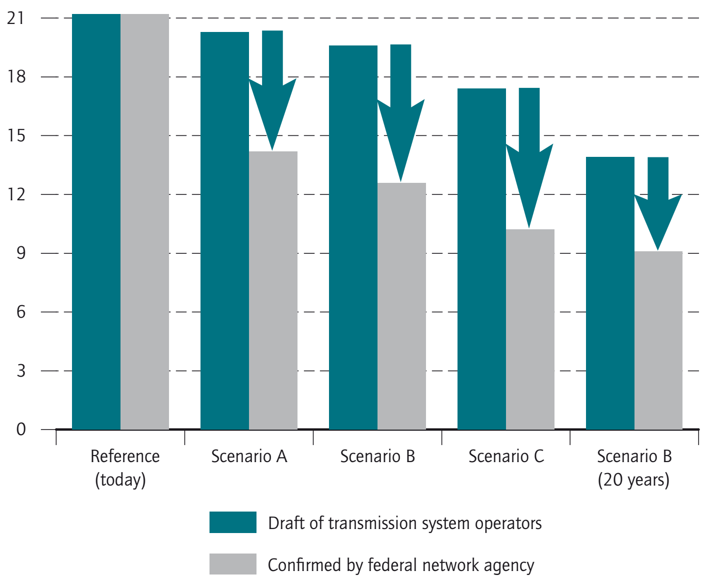
In light of this, the opening of new open-cast lignite mines, a decision justified by the need for lignite-based power generation, takes on new meaning, be it for the open-cast mining projects Jänschwalde-Nord, Welzow-Süd II, and Nochten II (Lausitz), Lützen and Pödelwitz in central Germany, or for the downsizing of the Garzweiler II open-cast mine in North Rhine-Westphalia.

In addition, according to the Federal Network Agency, future grid expansion planning in Germany will include capping methods that will apply an approximately three-percent cap to the rollout from onshore wind farms and solar power installations. This is in keeping with the provisions set down in the Ministry for Economic Affairs and Energy's Green Paper on the future development of the German electricity market, which underlines the lack of economy in expanding the national grid to accommodate "every last kilowatt hour of power generated."[16]

In the 2025 scenario framework approved by the Federal Network Agency, the agency used its regulatory powers to bring grid development in line with statutory provisions and social objectives for Germany's energy transition. For Germany's energy transition to be a success, grid development planning cannot be seen as an isolated entity—the acceptance of this is instrumental for the future of Germany's energy sector. In the medium term, further changes are needed in the methods used in grid development planning. This particularly means better harmonization with similar planning processes in Germany's neighboring countries.

Figure 2

Lignite capacities in the confirmed scenario framework 2015
In gigawatts



Source: Bundesnetzagentur (Federal Network Agency).

Lignite capacities were reduced by five to seven gigawatts depending on the scenario.

Conclusion

In their draft 2025 scenario framework, transmission system operators proposed an increase in lignite capacities over the 2014 Grid Development Plan; the reasoning behind this is new investments and also the fact that local lignite-based power generation is closely tied to available lignite reserves in Germany's open-cast mines. This was not consistent with the German government's target for the energy sector to cut CO_2 emissions by 40 percent over the reference year 1990 by 2020.

In contrast to the transmission system operators' draft, the 2025 scenario framework adopted by the Federal Network Agency on December 19, 2014 foresees substantially lower lignite capacities. In addition, it specifies emissions reduction constraints for three different scenarios for the transmission system requirements planning within the market simulation. According to these constraints, CO_2 emissions are limited to a maximum of 187 million tons and 134 million tons for 2025 and 2035, respectively. This would explicitly factor in

15 "Zudem ist die Wirtschaftlichkeit von Braunkohlekraftwerken im gegenwärtigen Marktdesign zumindest zu hinterfragen. " (Engl.: "In addition, in today's market design, the efficiency of lignite-fired power plants is highly questionable.") See Genehmigung Szenariorahmen 2025, Ref.:6.00.03.05/14-12-19, Szenariorahmen 2025 (Berlin: Federal Network Agency, 2014): 67.

16 See German Federal Ministry for Economic Affairs and Energy (BMWi) (2014): 27. At the moment, however, it is not yet possible to adopt this option actively into current grid development planning, since the provisions set forth in Sections 8, 11, and 12 of the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) state that transmission system operators must ensure that their networks have sufficient capacity to transmit, at any given time, the entire output from regenerative power generation. See Genehmigung Szenariorahmen 2025, Ref.:6.00.03.05/14-12-19, Szenariorahmen 2025 (Berlin: Federal Network Agency, 2014): 67

the CO_2 emissions targets of the German government for the energy sector.

The German network planning process will continue to draw on iteratively evolving scenario frameworks and respective Grid Development Plans, which result in a Federal Requirement Plan Act at least every third year. Actual planning and administration procedures should always be based on the latest Grid Development Plan, which currently is the NEP 2014. Actual changes in the scenario framework will be considered in the NEP 2015, which is to be approved by late 2015. The next revision of the Federal Requirement Plan is scheduled for 2016.

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FIVE QUESTIONS TO CHRISTIAN VON HIRSCHHAUSEN

»New Scenario Framework with CO_2 Emission Reduction Targets and Less Lignite«

1. Professor von Hirschhausen, in the context of energy transition, grid expansion has been a hotly debated topic. What is the actual planning process for the expansion of Germany's electricity transmission system? Since the revised German Energy Industry Act was adopted, planning for Germany's electricity system has been implemented in two key stages. The first stage consists of what is known as a scenario framework, involving discussions about the likely development of the power generation mix for the next ten or twenty years and determined by the German Federal Network Agency. These scenarios form the basis of the Grid Development Plans which, in turn, enter into force at least once every three years in the form of Federal Requirement Plans. The Bundestag adopted the first Federal Requirement Plan Act in 2013 and the assumption is that the next Federal Requirement Plan will be passed in late 2016 or early 2017.

2. What scenarios form the basis of the 2025 scenario framework? In this context, we have seen a major U-turn in the context of the German government's climate targets which, for the first time, feature in the 2025 scenario framework (planning for 2025 and 2035). The Federal Network Agency removed the construction of new lignite-fired power plants from the draft scenario framework and also—for the first time—specified sectoral climate targets for grid development. According to the framework, in 2025 the CO_2 emissions cap in the power sector will be 187 million tons compared with the current level of over 300 million tons. Even this is still relatively high when we consider the government's ambitious target of reducing overall CO_2 emissions by 40 percent by 2020. The electricity sector has very low CO_2 mitigation costs and could therefore make a more significant contribution toward meeting climate targets, compared to the transport or heating sectors, for instance, where it might be a lot more difficult to reduce CO_2 production.

3. Renewable energy sources such as wind or solar power are volatile and create feed-in peaks. How should or could the transmission network operators respond to this problem? Don't forget that the current discussion is about grid expansion for the next 20 years and there has been no serious transmission congestion to date. There are differing opinions as to exactly what the power system should look like in 2050. The most recent studies, such as that conducted by Agora Energiewende, indicate that the architecture of the future grid is relatively independent of the distribution of renewable energy sources, i.e., how renewable energy sources are spread across federal states actually has very little impact on grid expansion.

4. To what extent can grid expansion contribute to the achievement of the German government's climate targets? Grid development per se is obviously not a tool for tackling climate change. It is more a matter of scenario frameworks, which have been very carbon-intensive to date, needing to factor in the German government's climate targets. For the next decade, the expansion of the transmission network should not present any problems. The distribution networks face certain challenges such as smart grids and the flexibility required to integrate renewable energy sources, but, on the whole, the importance of the electricity grid as a topic of political debate is overrated. It is a difficult area, particularly when it comes to regulation, but it is certainly not something that would inhibit the speed of the energy transition in any way.

5. So the grid expansion will not determine speed of energy transition? Grid expansion is a technical and political topic. During the time of Franz Josef Strauß, a shortage of energy was used to secure society's commitment to nuclear power. Since the very first grid studies conducted by the German Energy Agency, dena, network expansion has never impeded the development of renewable energy sources (later termed "energy transition"). Grid expansion is important but it is not a constraint and consequently does not determine the pace of the energy transition.

Interview by Erich Wittenberg

No Barriers to Investment in Electricity and Gas Distribution Grids through Incentive Regulation

By Astrid Cullmann, Nicola Dehnen, Maria Nieswand and Ferdinand Pavel

Since early 2009, electricity and gas distribution in Germany has been subject to incentive regulation designed to ensure greater efficiency in electricity and gas grid operation. However, it remains to be seen how changes to the regulatory framework will affect the investment behavior of distribution system operators. Against this background, the present study empirically analyzes the investment activities of distribution system operators for the period from 2006 to 2012. The key questions are whether the introduction of incentive regulation in 2009 has had an empirically demonstrable impact on investment and whether this effect is due to the introduction of incentive regulation per se, or to its specific design. The findings show a positive effect on investment since the introduction of incentive regulation which, in particular, is determined by the specific design of regulation.

German electricity and gas grids have been subject to incentive regulation since early 2009 (see Box 1). Changes to the regulatory regime are to encourage distribution system operators to reduce their costs to an efficient level. It is currently being discussed, however, to what extent incentive regulation affects investment decisions. Against this background, the German Federal Network Agency (*BNetzA*), as the responsible regulatory authority, has captured data on the investment behavior of German distribution system operators based on a representative sample and commissioned DIW Econ and DIW Berlin to conduct a statistical analysis of this investment behavior. The main findings are summarized and discussed here.

The key finding of the analysis is that investments were not inhibited by the introduction of incentive regulation. Rather, an increase in investment was identified when incentive regulation was introduced. However, this effect is limited to certain years and cannot be explained by factors such as the obligation to connect decentralized power generation systems. Instead, it can be demonstrated that considerably higher levels of investment occurred in the base years which were used to determine the cost of capital.[1] This suggests that the effect of incentive regulation on investment in distribution grids is determined by its specific design. These kinds of investments include replacement investments, such as substituting power cables as part of regular investment cycles, and expansion investment in the grid itself which may be required when connecting new settlement areas or decentralized power generation systems.

Effect of Incentive Regulation on Investment so far Unclear

Compared to regulation aimed primarily at the profitability of grid operation, arguments against incentive regulation posit that it can reduce incentives to invest

1 This effect can be identified in all distribution grids but is much more pronounced in electricity grids than in gas grids.

Box 1

Incentive Regulation

One key feature of a grid-based energy supply is its sub-additive cost structure which allows a single provider to operate the necessary infrastructure at a lower cost than would be possible for multiple providers together (natural monopoly). As a result, distribution system operators are basically able to make monopoly profits. Consequently, so as to prevent welfare losses, it is useful to regulate grid-based energy supply. There are basically two types of regulation for natural monopolies: rate-of-return regulation and incentive-based regulation (price-cap or revenue-cap regulation).

In Germany, the rate-of-return approach was used prior to 2009. The competent regulatory authorities, i.e., the German Federal Network Agency and the state regulatory authorities, approved grid-use charges based on actual costs and permitted return on equity. In contrast, the introduction of incentive regulation from 2009 increased incentives for distribution system operators to reduce their costs and thus increase their efficiency. In advance of the regulatory periods, individual efficiency-based revenue caps were set by the regulatory authority which could only be changed minimally during the regulatory period (five years). The incentive for distribution system operators is to take steps to increase efficiency in order to generate additional profits for themselves. The principle is that efficiency gains are passed, at least partly, to final consumers in the following regulatory period.

The revenue cap is calculated based on a cost review. The costs of the distribution system operators are determined two years prior to the start of the regulatory period. The cost basis is the last complete financial year at that point in time. This year is called the base year. The cost situation in the base year is therefore crucial for determining the revenue cap for the following regulatory period and investments made in the base year are given special consideration.

since regulated companies participate more in the investment risks.[2] Furthermore, focusing on short-term efficiency potential supersedes long-term efficiency. Short-term efficiency targets may also be achieved at the expense of replacement investments and, consequently, supply quality (such as frequency and duration of supply interruptions).[3] Similarly, the impact of incentive regulation also encourages expansion investments.

Conversely, focusing on cost reduction also compounds incentives to invest in cost-reducing technologies.[4] Incentive regulation can also be designed to specifically enhance investment incentives. For example, (replacement) investments are promoted by adjusting the revenue cap depending on supply quality. Similarly, incentives for expansion investments can be increased through investment measures that are fixed in the incentive regulation.[5]

In the context of the specific design of incentive regulations, investment barriers due to the time lag on investment returns are currently being discussed in the economic literature. It is argued that investment incentives may be weakened since some investments do not lead to corresponding adjustments of the revenue cap until the following regulatory period.[6]

Compared to the extensive theoretical literature on the effects of incentive regulation on investment incentives, there is only a small number of empirical studies on this issue. Recent international literature emphasizes that introducing incentive regulation and/or a departure from traditional rate-of-return regulation does not always lead to underinvestment in grid industries. Cambini and Rondi (2010)[7] show, for example, that the introduction of incentive regulation has had a considerable positive impact on investment for 23 of the largest energy suppliers in France, Germany, Italy, Spain, and the UK.

In summary, it can be stated that the effect of incentive regulation on investment behavior based on theoretical

2 B. Egert, "Infrastructure investment in network industries: The role of incentive regulation and regulatory independence," William Davidson Institute Working Paper (2009) no. 956.

3 See also C. Müller, C. Growitsch, and M. Wissner, "Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste GmbH (WIK), Regulierung und Investitionsanreize in der ökonomischen Theorie," IRIN Working Paper as part of the Arbeitspakt: Smart Grid-gerechte Weiterentwicklung der Anreizregulierung and P. Burns and C. Riechmann, "Regulatory instruments and investment behaviour," Utilities Policy 1 (2004): 211–219.

4 Egert, "Infrastructure investment."

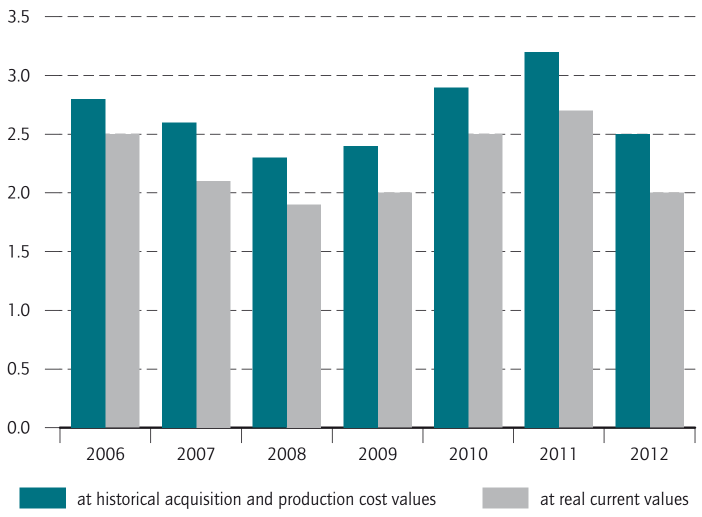
5 Certain grid investments are regulated separately through investment measures in accordance with Section 23 of the Incentive Regulation Ordinance (Anreizregulierungs-Verordnung, ARegV), primarily in the area of transmission networks. They are not subject to efficiency requirements, resulting in generally higher prices because they increase revenue caps even during ongoing regulation periods. See also Müller, Growitsch, and Wissner, "Wissenschaftliches Institut."

6 G. Brunekreeft and R. Meyer, "Netzinvestitionen im Strommarkt: Anreiz- oder Hemmniswirkungen der deutschen Anreizregulierung?," Energiewirtschaftliche Tagesfragen, no. 61 (2011): 40–43.

7 C. Cambini and L. Rondi, "Incentive regulation and investment: evidence from European energy utilities," Journal of Regulatory Economics, no. 38 (2010): 1–26.

Figure 1

Investment ratio of electricity distribution system operators
Mean values in percent



Source: German Federal Network Agency; Calculations by DIW Econ and DIW Berlin.

No decrease in investment ratio of electricity system operators after 2009 observable.

Figure 2

Investment ratio of gas distribution system operators
Mean values in percent

Source: German Federal Network Agency; Calculations by DIW Econ and DIW Berlin.

No systematic decrease in investment ratio of gas distribution system operators after 2009 observable.

considerations or technical correlations is not easy to determine and is also strongly affected by its specific configuration. Rather, complex and often contradictory interrelationships require a comprehensive econometric analysis of the investment behavior of distribution system operators based on representative data.[8]

Descriptive Analysis of Investment in Electricity and Gas Distribution

The key investment figure in the present study is the investment rate of the network operators. This indicates the amount of investment relative to current tangible fixed assets as a percentage, where

$$\text{Investment ratio} = \left(\frac{\text{Investments}}{\text{Fixed tangible assets}}\right) \times 100$$

Investments are calculated on the basis of the balance of acquisitions and disposals by investment groups and fiscal year as specified by the network operators. Acquisitions and disposals are assessed both in terms of historical acquisition cost and/or production cost, and at real current values. As a result, technical developments are taken into account that have an impact on the acquisition or replacement value of the fixed tangible asset.

The imputed investment rates of electricity distribution system operators at historical acquisition/production cost values and at real current values initially declined, and then, in 2008, reached 2.3 and 1.9 percent respectively, each rising by almost one percent by 2011, and then fluctuating at 2 and 2.5 percent respectively in 2012 (Figure 1).

The imputed investment rates of gas distribution system operators at historical acquisition/production cost values and at real current values initially declined from 2.5 and 2 percent respectively from 2006 to 2009 then rose slightly in 2010 and 2011, before falling again in 2012. Overall, the decline over the entire period is approximately 0.7 percent (Figure 2).

The development of investment rates provides an initial impression of the investment behavior of distribution system operators between 2006 and 2012. According to this first impression, investment rates have not decreased since the introduction of incentive regulation in 2009. Further, detailed statements on the underlying factors and the impact of incentive regulation can only be made on the basis of an extensive econometric analysis (multivariate regressions).

8 In particular, given the complex data requirements, this type of undertaking is only possible under the auspices of the Federal Network Agency as the competent regulatory authority.

Econometric Model Shows No Negative Effect of Incentive Regulation on Investment Behavior

The key objective of the econometric analysis is to determine whether the investment behavior of electricity and gas distribution system operators had altered significantly over time since the introduction of the incentive regulation in 2009. The investment behavior of the distribution system operators is analyzed using a suitable econometric model derived from academic literature (see Box 2).

An analysis was conducted here to determine the extent to which exogenous factors (independent variables such as the introduction of incentive regulation) impact the firm-specific investment rate (dependent variable).[9] The selection of independent variables to describe investment behavior and the heterogeneity of firms is heavily geared toward the cited literature on investment behavior (Cambini and Rondi, 2010[10]) and literature on efficiency comparisons between regulated energy supply firms (Farsi et al., 2004).[11] Since electricity and gas distribution system operators do not only differ considerably technologically but also in terms of the regulatory framework in the relevant markets, different investment models were developed for electricity and gas distribution system operators and separate estimates performed. Exogenous factors affecting our sample are shown in Tables 1 and 2. The investment rate in the previous period, gross domestic product (GDP) in the previous period, the size of the distribution system operator, the area of supply, and the number of connection points in the relevant voltage levels (medium voltage (MV) and low voltage (LV)) have emerged as the key parameters in describing investment behavior.[12] The relevant investment model is then gradually extended to analyze hypotheses pertinent to the investment behavior of distribution system operators in Germany.

Has the Investment Behavior Been Affected by the Introduction of Incentive Regulation in 2009?

The effect of the introduction of incentive regulation was tested using a dummy variable in the estimation equation which was given a value of one for the years 2009 to 2012 (dummy ARegV). As a result, the observation period was divided into two phases: i) the period before the introduction of incentive regulation and ii) the period after the introduction of incentive regulation.[13] The corresponding regression results for electricity supply firms are shown in Table 1.[14] The positive coefficient of the ARegV dummy is statistically significantly different from zero (at the ten-percent level). It may initially be assumed that the investment rate in the years after the introduction of incentive regulation is,

9 The investment rate is defined as the calculated investment rate based on investment at current new values. Investment volumes are not measured in absolute amounts in order to better separate the possible impact of exogenous factors from purely size effects.

10 Cambini and Rondi, "Incentive regulation and investment."

11 M. Farsi and M. Filippini, "Regulation and measuring cost efficiency with panel data models application to electricity distribution utilities," Review of Industrial Organization 25(1) (2004): 1–19.

12 The investment behavior of the gas distribution system operators is also considerably influenced by the geographical location of the system operators (former East or West German states).

13 Due to the dynamic structure of the investment model, however, it should be added that 2008 is the only year before the introduction of incentive regulation that can be considered in this regression.

14 The regression coefficient indicates how strong the link is between investment behavior and explanatory variable. If it is positive, then the corresponding variable has a positive effect on the investment rate. In addition, standard errors and p-values are given in order to check the statistical significance of the coefficient (*** significant at the one-percent level, ** five-percent level, and * ten-percent level).

Box 2

Methods

The starting point for the empirical analysis is a micro-econometric investment model with a dependent variable (the investment rate) and several independent variables (variables determining investment behavior in the current period, as well as control variables indicating the structural differences between electricity and gas distribution system operators). In micro-econometric literature on investment models[1] it is generally assumed that current investment behavior depends on that in the previous period. This dynamic must be taken into account in the estimation equation. The use of conventional estimation methods such as the ordinary least squares (OLS) or maximum likelihood (ML) methods may lead to an endogeneity problem and distorted estimation results. In dynamic models, therefore, investment behavior in the previous period is replaced (instrumented) by investment behavior from even earlier periods. The instrument variable estimation used in the present study to explain the investment behavior of distribution system operators is based on the principle of the generalized method of moments (GMM).[2]

1 G. R. Hubbard, "Capital market imperfections and investment," Journal of Economic Literature 36 (1998): 193–225. T. Lyon and J. Mayo, "Regulatory opportunism and investment behavior: Evidence from the U.S. electric utility industry," Rand Journal of Economics 36 (2005): 623–644.

2 R. Blundell and S. Bond, "Initial conditions and moment restrictions in dynamic panel data models," Journal of Econometrics 87(1) (1998): 115–143.

Table 1

Estimation results for electricity distribution system operators – Introduction of incentive regulation
Dependent Variable: Investment Ratio

Independent Variables	Coefficient	Standard Error	P-Value	Statistical Significance
Investment ratio of previous period	0.846	0.070	0.000	***
GDP of previous period	−5.112	1.179	0.000	***
Size of system operators	0.115	0.048	0.017	**
Area of supply at LV	0.060	0.027	0.027	**
Number of connection points at LV	−0.053	0.022	0.015	**
Geographical area at MV	−0.043	0.023	0.065	*
Number of connection points at MV	0.030	0.018	0.089	*
Constant	22.887	5.558	0.000	***
Dummy ARegV	0.104	0.062	0.091	*
Efficiency Value	0.939	0.380	0.014	**

*Note: Number of observations: 483. Number of distribution system operators: 99. Statistical significance at the *** 1-percent level, ** 5-percent level and * 10-percent level.*

Source: German Federal Network Agency; Calculations by DIW Econ and DIW Berlin.

The investment ratio of electricity distribution system operators is significantly higher after the introduction of incentive regulation.

Table 2

Estimations results for gas distribution system operators – Introduction of incentive regulation
Dependent Variable: Investment Ratio

Independent Variables	Coefficient	Standard Error	P-Value	Statistical Significance
Investment ratio of previous period	0.844	0.156	0.000	***
GDP of previous period	−0.043	0.454	0.340	
Size of system operators	0.239	0.113	0.035	**
Former East German States	0.198	0.107	0.063	*
Area of supply	−0.069	0.267	0.010	**
Number of exit points	0.170	0.057	0.003	***
Constant	0.326	0.590	0.580	
Dummy ARegV	0.083	0.088	0.350	
Efficiency Value	−0.740	0.740	0.318	

*Note: Number of observations: 309. Number of distribution system operators: 63. Statistical significance at the *** 1-percent level, ** 5-percent level and * 10-percent level.*

Source: German Federal Network Agency; Calculations by DIW Econ and DIW Berlin.

In case of the gas distribution system operators there is no significant influence of incentive regulation on the investment ratio.

on average, significantly higher than in the period prior to its introduction.

Also, the influence of a firm-specific efficiency value was tested. This was calculated for each distribution system operator on the basis of benchmarking methods in the first regulatory period.[15] The firm-specific efficiency value has a positive correlation with the rate of investment. From this estimated finding, it follows that electricity distribution system operators which were assessed as relatively efficient before the start of the incentive regulation have a higher average investment rate.[16]

Unlike for power distribution system operators, there is no indication of any significant influence of the ARegV dummy on gas distribution system operators (see Table 2). Apparently, their investment behavior has not been affected by the change in the regulatory regime. This finding is maintained even if the efficiency value from the first regulatory period is also taken into account. This has no significant effect on the investment rate either. Consequently, investment behavior is not significantly adversely affected by introducing incentive regulation.

Are Investment Decisions Heavily Affected by the Design of the Incentive Regulation?

It was also examined whether specific legal requirements and standards affect investment behavior in the observation period. The revenue cap and the associated initial level of costs also play a major role in the design of incentive regulation.

Costs from the base year are used to determine the initial level for the revenue cap in the relevant regulation period. Consequently, investments made in the base year are given special consideration.[17]

A dummy variable given the value one in the base year should determine whether there has been a base year effect on the investment behavior of the distribution system operators, since the investments were treated separately for the purposes of cost verification.

The estimated findings for the electricity distribution system operators shown in Table 3 suggest that the ARegV dummy loses its relevance when taking into account the base year effect. In contrast, the coefficient of the base year is positive and statistically significant.

15 See S. Seifert, "Effizienzanalysemethoden in der Regulierung deutscher Elektrizitäts- und Gasversorgungsunternehmen," DIW Roundup, no. 40 (DIW Berlin, 2014).

16 However, the impact direction of the two parameters cannot be clearly determined. On the basis of these findings, it is not possible to conclude, for example, that a lower efficiency value prevents investment and therefore moderate specifications to reduce inefficiencies are required.

17 The base year for the first regulatory period (2009–2012 for gas distribution system operators and 2009–2013 for electricity distribution system operators) was 2006, and for the second regulatory period, the base year was 2011 (for electricity distribution system operators) and 2010 (for gas distribution system operators).

This leads to the conclusion that the previously observed positive effect of introducing incentive regulation is primarily due to increased investment in the base years. Therefore, it is, in particular, the design of incentive regulation that explains the investment behavior of distribution system operators.

Overall, the base year effect identified in the regression model corresponds to the development of investment behavior described previously. In this respect, the result of the regression model is not surprising. Rather, the level of investment and the investment rates suggest that these were higher, not only relative to 2008 (as evidenced by the regression analysis), but also relative to previous years (since 2006 at least). In addition to a base year effect attributable to incentive regulation, other developments, particularly the expansion of decentralized power generation systems under the German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz, EEG*) could have caused the increase in investment. Nevertheless, decentralized production rose continuously in the observation period, both in terms of the number of plants and installed capacity (installed capacity from 2009 actually rose by over ten percent annually). In contrast, investment and investment rates in 2012 fell to the levels they were in 2009 and earlier. Even when the changes in decentralized power generation are taken into account, as part of an in-depth econometric analysis, the existence of a base year effect is reaffirmed.

A significant base year effect is identified for gas distribution system operators when the introduction of the incentive regulation (ARegV dummy) is not taken into account. On the basis of these findings, the existence of a weak base year effect can therefore be determined for gas distribution system operators. However, it is not as pronounced as for electricity distribution system operators.

Conclusion

Electricity and gas distribution system operators in Germany have been subject to incentive regulation since 2009. It has been hotly debated how grid replacement and expansion investments have developed under the new regulatory framework. The present *Economic Bulletin* uses econometric methods for the first time to analyze investment behavior by electricity and gas distribution system operators in Germany separately. The main finding of the study is that investment behavior has not been adversely affected by the introduction of incentive regulation. For electricity distribution system operators, the analysis shows a significant positive relationship between the introduction of the incentive regulation and the investment rate of distribution system operators. Further analysis shows that this effect is due to the design of the regulation, since it uses significantly higher investments in the base year to determine capital costs. In summary, the analysis shows that investment incentives have been compounded by the introduction of incentive regulation. This is of particular relevance to the challenges arising from the energy transition, such as the further expansion of renewable energy sources.

Table 3

Estimations results for electricity distribution system operators – Design of incentive regulation

Dependent Variable: Investment Ratio

Independent Variables	Coefficient	Standard Error	P-Value	Statistical Significance
Investment ratio of previous period	0.835	0.068	0.000	***
GDP of previous period	0.018	0.024	0.453	
Size of system operators	0.096	0.048	0.045	**
Area of supply at LV	0.060	0.029	0.039	**
Number of connection points at LV	−0.054	0.023	0.019	**
Geographical area at MV	−0.025	0.021	0.231	
Number of connection points at MV	0.024	0.019	0.192	
Constant	−0.165	0.067	0.014	**
Dummy base year	0.205	0.065	0.002	***
Dummy ARegV	0.021	0.076	0.784	

*Note: Number of observations: 483. Number of distribution system operators: 99. Statistical significance at the *** 1-percent level, ** 5-percent level and * 10-percent level.*

Source: German Federal Network Agency; Calculations by DIW Econ and DIW Berlin.

Investment decisions are significantly influenced by the design of incentive regulation.

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