Arthur D Little

The future of lignite power

A viewpoint on the "Energiewende" and its impact on lignite power

Content

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Acknowledgement for his support and valuable input: Michal Sladek (expert in lignite and hard coal generation Czech Republic)

Executive summary

The German Energiewende is the world's most ambitious program to transform the electric energy system of a country, with a goal of increasing energy efficiency and pushing the share of renewable energies, while stopping use of nuclear power and other fossil-fuel energy practices at the same time. The Energiewende's most significant impact is on the power generation and transmission segment: wind, solar PV and biomass/gas power production, fired by subsidies, currently have a 25.8% share of German gross power production, outnumbering other power plants. Through the merit-order market mechanism, power plants with the highest marginal cost will drop out of the market – currently oil, gas and older hard coal plants. Since 2011, ca. 8 GW of power plant capacity has had applications filed for final or temporary shutdown. Given the ambitious renewable targets of more than 40% by 2025, as defined in the coalition treaty of the German Federal Government, it is obvious that even base-load power plants could suffer from these developments. This means that after nuclear, the future of lignite will be the next big discussion on the energy agenda.

Lignite mining and power in Germany

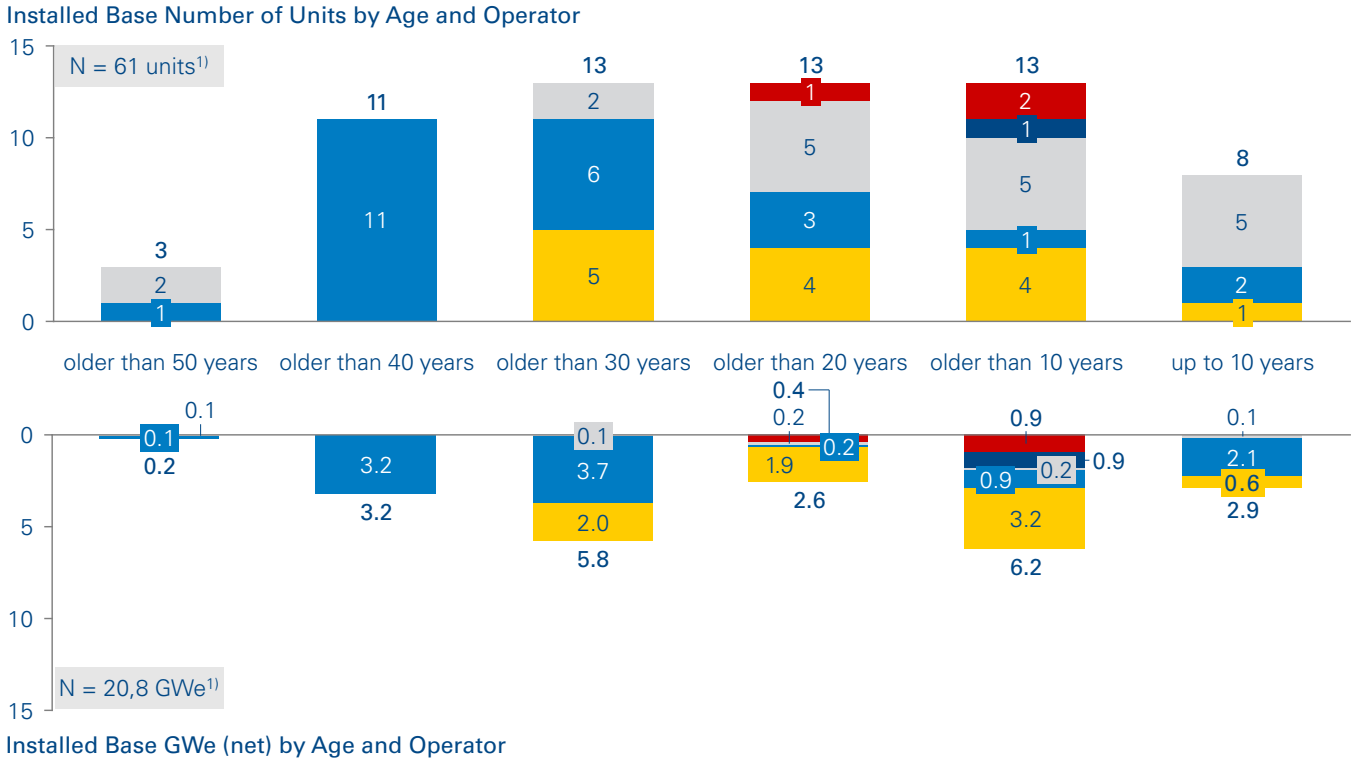
Lignite power plays a major role in Germany's power generation. Currently lignite power contributes around 25% to German gross electric power generation /1/. About 35 operating lignite plants with 61units (excluding units smaller than 10 MWe net capacity) were still operating in Germany at the end of 2014. A number of smaller units had been shut down in previous years. In total, lignite represented an installed power (net) capacity of ca. 21 GWe, used to the largest extent as base-load power /2/.

Overall, about 50% of the installed lignite base is more than 30 years old. Some units in Germany have even operated since the 1930s, which confirms the robustness of the lignite power generation technology. Differentiated by owner, the two single largest operators of lignite plants are RWE Power and the Vattenfall Group, followed by E.ON and EnBW, which also still operate a few lignite plants. The remainders of smaller lignite plants are operated mainly by high-energy-consuming industrial companies (e.g. Pfeifer & Langen and Sachtleben Chemie).

The age and size structure of the lignite fleets varies significantly. RWE Power and the Vattenfall Group operate the newest fleets by average age of units. At the same time, RWE Power has the highest number of old plants in its fleet (40 years and older), in addition to two units that started commercial operations just two years ago. The average age of the individual units of the Vattenfall plants is 21 years, representing the newest plants in Germany (see figure 1). More than 3 GWe (net) capacity of Vattenfall's lignite fleet is produced in plants that are significantly newer than 20 years.

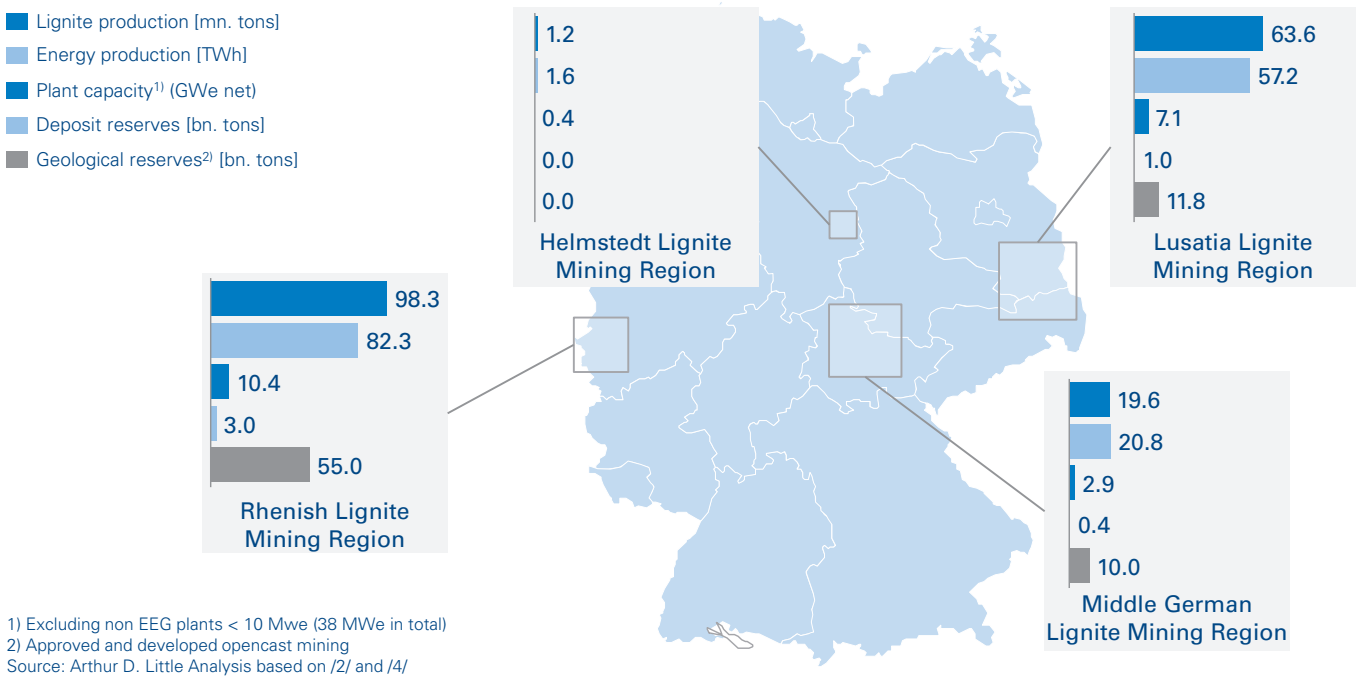
Lignite power production was between 146 and 161 GWh in the last decade. Plants recently achieved comparably high utilization

Figure 1: Installed lignite capacity in Germany by age



1) Excluding non EEG plants < 10 MWe (38 MWe in total)
Source: Arthur D. Little analysis based on /2/

Figure 2: German lignite plant and mining capacities



1) Excluding non EEG plants < 10 Mwe (38 MWe in total)
2) Approved and developed opencast mining
Source: Arthur D. Little Analysis based on /2/ and /4/

of 88%, with ca. 7.700 average operating hours /1/. The growth of 7% in lignite production between 2011 and 2013 was mainly due to the shutdown of ca. 6.3 GW nuclear power plant capacity after Fukushima /3/. Figure 2 shows the installed capacity of the operating lignite power plants and the corresponding mining capacities in 2014.

Lignite mines exist in Western Germany (Rheinland), and in Eastern Germany around Leipzig, Helmstedt and the Lausitz area. About 183 mn tons of lignite coal are exploited annually, and the existing or approved mines, with capacity of 4.4 bn. tons, have reach of ca. 25 years (at existing mining volumes). The economically feasible reserves of ca. 40 bn tons would ensure a supply for more than 200 years at current exploitation levels /4/.

For power plant operators and investors, especially of base-load plants such as lignite, several key questions arise from the German Energiewende:

1. How much residual base-load capacity is needed, and can base-load plants be operated profitably?
2. How sensitive are lignite power plants to changes in various external market drivers?
   a. Decreases in gas and hard coal prices
   b. Reductions in renewable technology prices (new build of mainly wind and solar PV)
   c. Rises in carbon emission prices
3. Which environmental and market regulation risks exist?
4. Which risks result from the political sphere and energy lobbying?
5. What are the conclusions and recommendations for lignite operators?

Many of these questions have been discussed in reports commissioned by the German government, energy industry associations, political parties, etc. in the course of the public consultation process. In this Viewpoint we rely on the *Energy Reference Forecast /5/,* which was prepared on behalf of the Federal Ministry for Economic Affairs and Energy. Further analyses were conducted based on, for example, the fundamental work on the *Transmission Grid Development Plan* which is prepared periodically by the German Transmission Grid Operators with participation of the Bundesnetzagentur /6/.

The analysis shows that lignite power is quite "robust" against changes in fuel and carbon prices, as well as environmental and market regulation, and the market mechanisms are well understood. Most open questions and risks result from politics and public opinion. These risks have to be targeted when whatever kinds of investment or lifetime extension decisions regarding lignite have to be made.

Lignite demand and its sensitivity

How much lignite capacity is viable and can be operated profitably?

We believe that lignite exploration and power generation will stay at current capacity and output until at least 2025. The main reason is its competitive cost and robustness against changes in gas and carbon prices, as well as higher growth in renewable new builds. Lignite power plant capacity will stay at a high level until 2030 at least, which implies retrofits and new builds. Full-load hours will remain at a high level, which implies a comparably profitable operation.

Table 1: Lignite power generation capacity, production, full-load hours compared to renewables capacity

Year	2012	2020	2025	2030	2040	2050
Renewables capacity in GWe	75.3	113	124	138	146	172
Lignite capacity in GWe	21.2	22	19	19	16	5
Lignite production in TWh	160.9	156	143	140	104	31
Lignite full-load hours	7,057	7,205	7,503	7,443	6,662	6,401

Source: EWI/et al (2014), Energy Reference Forecast /5/

How sensitive are lignite plants to changes in various external drivers?

Lignite coal power plants compete in the merit-order with hard coal and gas plants. In the merit-order curve they are positioned as a "low-production-cost" increment, right next to nuclear generation.

Costs of renewables influence renewable generation capacity, and thus reduce the residual load. Also, besides nuclear, high carbon dioxide emissions of lignite power make lignite sensitive to changes in carbon prices. In order to understand how sensitive lignite is to changes in external market drivers, the corresponding sensitivities must be understood.

A recent energy forecast prepared by a consortium of EWI, Prognos and GWS analyzed the sensitivities of a realistic medium- to long-term energy scenario regarding carbon emissions and other drivers. The sensitivities are not actual forecasts, but an indication of how much lignite will be influenced by changing market drivers. The tables below explain major drivers:

In a realistic scenario of increasing gas prices in a range of 15%, as well as increasing prices for hard coal by ca. 30%, until 2050, lignite exploration and power production would benefit considerably, and lignite production would be expected to rise significantly (see table 2).

Table 2: Sensitivity increase of fuel prices compared to reference scenario on lignite production

Year	2020	2025	2030	2040	2050
Increase of gas price	+12%	+12%	+15%	+14%	+16%
Increase of hard coal price	+32%	+31%	+31%	+31%	+31%
Lignite production change	0	+3%	+18%	+56%	+194%

Source: EWI/et al (2014), Energy Reference Forecast /5/

In the opposite scenario of decreasing gas prices and hard coal prices (in a range of 15% and ca. 30%, respectively), lignite production appears to be quite robust. No significant change would be expected in a long-term perspective until 2050 (see table 3).

Table 3: Sensitivity decrease of fuel prices compared to reference scenario on lignite production

Year	2020	2025	2030	2040	2050
Increase of gas price	-15%	-15%	-13%	-15%	-14%
Increase of hard coal price	-31%	-32%	-32%	-32%	-32%
Lignite production change	-3%	-3%	-3%	0	0

Source: EWI/et al (2014), Energy Reference Forecast /5/

Assessing further sensitivities, lignite generation is shown to also be robust against a 20% drop in renewable technology cost and lower gas prices, compared to the reference scenario. In the reference scenario, lignite production will also remain stable under these conditions until 2050 (see table 4).

Table 4: Sensitivity of renewable cost compared to reference scenario on lignite production

Year	2020	2025	2030	2040	2050
Renewable technology cost	-20%	-20%	-20%	-20%	-20%
Lignite production change	0	-1%	-2%	-5%	-16%

Source: EWI/et al (2014), Energy Reference Forecast /5/

The most impactful external driver for lignite generation is the price of carbon emissions after 2030. The reference scenario assumes an increase in carbon price from 12 EUR/t in 2020 to 91 EUR/t in 2050. Under these conditions, lignite production is expected to fall by 30% (see table 5).

Table 5: Sensitivity of carbon price compared to reference scenario on lignite production

Year	2020	2025	2030	2040	2050
Carbon price (EUR/t CO_2)	12	30	48	78	91
Lignite production change	0	-2%	-5%	-27%	-31%

Source: EWI/et al (2014), Energy Reference Forecast /5/

The sensitivity analysis indicates that, due to its low marginal cost, lignite is robust against several changes in market drivers in the energy-only market. In the current German market regime, lignite power will remain price competitive to changes in external drivers, such as increases in share of renewables and carbon emission certificates. Only in a scenario of a steep price increase in carbon certificates lignite production would be expected to fall significantly.

Which environmental and market regulation risks exist?

Environmental regulation exists for power generation and mining. Lignite power generation is regulated regarding emissions, like all other fossil power plants. Emission regulation is focused on SO_2, NO_X, dust, etc., as ruled in the emission protection order (BImSchV). A recent amendment to the BImSchV has tightened the target for these emissions, which impacts dust emissions of existing large plants (>300 MW) and new plants. We do not expect major challenges for existing and new lignite plants to meet the new emission targets.

Lignite energy producers in Germany have steadily invested into new technologies to reduce emissions of pollutants and raise the efficiency levels of their plants. RWE Power AG, for example, has invested into technologies in Niederaußem to build the world's most modern lignite plant with an optimized plant technology called BoA *(Braunkohlekraftwerk mit optimierter Anlagentechnik)*. Vattenfall has tested carbon capture store (CCS) technologies at its lignite plant Schwarze Pumpe, but has terminated this pilot program. This decision was taken in light of public opposition to carbon storage, as well as the negative impact of this technology on the efficiency level of the plant, which hence reduced profitability. Still, according to the Intergovernmental Panel on Climate Change, carbon capture technologies will remain a viable option to meet carbon emission targets /7/.

In December 2014 the Federal Ministry for Economic Affairs and Energy and the Federal Ministry for the Environment launched a program to close the carbon emission 2020 gap: the "Climate Action Programme 2020". This program will ensure that Germany meets its 40% carbon emission reduction target by reducing it by another 5 to 8 percentage points – in absolute terms, 62 to 78 mn tons CO_2 equivalent. Out of these, the electricity sector will contribute 22 mn tons. The Federal Ministry for Economic Affairs will draw up a concept for distributing these 22 mn tons as a mitigation commitment across the entire fleet of power plants in Germany. A "swift reform" of the European *Union Emissions Trading System* (EU ETS) is demanded to reduce the current excess liquidity and set sufficient economic incentives to invest into climate action.

Carbon emissions are regulated by the emissions trading system. Additional carbon emission targets are explicitly excluded as long as the emissions trading system is applied, according to EU law (European directive IED). Additional carbon reduction targets beyond the emissions trading system are seen as difficult to implement /8/.

Lignite mining is regulated through a license approval process for new exploration or changes in existing mines, while the operation of the mines is supervised by public authorities based on an operating license. A lignite mine receives a general license in the beginning, and then needs frame operating plans for the exploration of further areas within the mine. In the past all applications for operating licenses have been approved, occasionally delayed by lawsuits. We expect no significant risks for the exploitation of existing mines within the limits of the general license.

This view might be different for newly planned mines, which could gain much more public and political attention and resistance. Here we expect increasing opposition from environmental groups and political influence from left and green parties. Examples from other large capital investment programs in Germany confirm this view, such as E.ON's hard-coal plant new-build project, Datteln 4, and cases from the infrastructure sector (such as Stuttgart 21), which are struggling to get approval for needed licenses.

A further opportunity that is also a risk stems from changes in the market design and introduction of a "capacity market". In a capacity market, power plant operators are paid a fee for the availability of generation capacity. This will ensure that there is always capacity, even in times when solar and wind feed-in are lacking. For a power plant operator, a capacity payment is a kind of "flat-fee" revenue that compensates for the risks of lacking residual load. Whether this is an advantage for lignite plants depends on the capacity market model. In selective capacity markets, fossil plants with high carbon emissions, such as lignite, are excluded from the market. In an unrestrictive capacity market, all plants can apply for the capacity mechanism. The current federal government has not introduced capacity-market mechanisms. We expect this decision to last at least until the end of this legislation term, since the government aims to avoid additional financial burdens on energy consumers through another fee on the electricity bill or rising renewables charges.

Which risks result from the political sphere and energy lobbying?

Lignite mining, as well as power generation, have been subject to criticism, resistance, protest and legal intervention for at least 40 years (for the Western German mines and power plants). Major opposition stems from environmental groups (BUND, Greenpeace and many other interest groups) and political parties, mainly the Green Party *(Die Grünen)*, the Left Party *(Die Linke)* and, selectively, the Social Democrats *("Sozialdemokratische Partei Deutschland")*.

We do not expect further anti-coal/anti-lignite political action at federal level until 2017, the end of the current parliamentary period. The "Climate Action Programme 2020" is hard to implement and could lead to lengthy lawsuits. In the end, it could settle on an easy-to-bear compromise. The main objective of the government, mainly the Minister of Economic Affairs and Energy, is to limit the cost burden of the *Energiewende* on businesses and consumers in the short term /9/.

This could change if a new red/left/green coalition emerges after the 2017 election. The Green Party, in particular, is targeting elimination of coal-fired power generation. After the exit from nuclear, a fundamental raison d´être of the party, an "exit from coal" is the next programmatic step. Even under a more coal-/lignite-hostile federal government, a "lignite exit" – comparable to the "nuclear exit" – would be hard to achieve under current constitutional and legal conditions. There is no "lignite law" like the atomic law, which sets clear permissions and rules for operating plants. The main legal levers for influencing the existence of non-nuclear power are the carbon emission regime, taxes and subsidies. Although the carbon emission scheme is not in the hands of the federal government, subsidies and taxes are, but these possibly need to be aligned with European legislation.

Further political stakeholders to consider are the federal states with lignite power: Nordrhein-Westfalen, Sachsen-Anhalt and Sachsen. Tax payments and jobs in lignite power are an important economic factor for these states, as they are facing tightened budget conditions. Lignite is, from a national perspective, a "regional or even local issue": besides the carbon emissions, only few people are immediately affected, and those who, are familiar with it. It is hard to make this a deciding topic before elections or a major political stake for a politician.

Conclusions and recommendations

The Energiewende allows lignite power to exist under economically viable conditions, at least until 2030 – probably far beyond that date. Besides the manifold proclaimed benefits of lignite, such as low cost, security of supply and grid stabilization impact, it has an economic justification. Nevertheless, there is no reason for the stakeholders "to relax".

The further trajectory of the Energiewende might make sudden and unexpected turns, be they the global or European economy, commodity fuel prices, technology innovation, etc. Although lignite is quite robust against market-driver changes, extreme developments, especially in carbon prices, must be considered. Lignite power plant and mining operators must therefore regularly update their long-, medium- and near-term scenarios, be they related to the markets, political or public sphere.

Although the regulatory risks for lignite operators are moderate, close monitoring and influencing of regulatory development is recommended. This is because regulation (emissions, environment), taxes, subsidies, etc. are the main levers for politics to influence lignite power. Regulatory monitoring, strategy and management are key to staying ahead of the developments and proactively shaping the framing conditions.

Public and political opinion regarding lignite are mostly local or regional issues. Nevertheless, continuous and carefully prepared stakeholder management, especially communication, is essential. Lignite being an essential but temporary element of the Energiewende could be a key message. Lessons could be learned from the nuclear industry, which, for far too long, was overconfident of its existence.

If lignite operators have clear commitment to this energy source and do their "homework" regarding changes in market drivers and the public domain, there is a fair chance that lignite will continue to exist for many decades in Germany. Residual risks remain.

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The cover picture shows a bucket-wheel excavator digging for lignite in a surface mine at sunset in the Rhenish Lignite Mining Region. Bucket-wheel excavators are amongst the largest vehicles ever constructed. RWE Power's "Bagger 293" for example weighs 14,200 (metric) tons and is capable of moving 240,000 cubic metres of overburden every day. It is 225 meters long and a little less than 100 meters tall.

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