The German *Energiewende* and its Climate Paradox

An Analysis of Power Sector Trends for Renewables, Coal, Gas, Nuclear Power and CO_2 Emissions, 2010 – 2030

ANALYSIS

Agora Energiewende

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An Analysis of Power Sector Trends for Renewables, Coal, Gas, Nuclear Power and CO_2 Emissions, 2010 – 2030

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Scope of this paper

Germany has decided to radically transform its power sector. Referred to as the *Energiewende*, the goal, adopted in 2010/2011, is to fully decarbonise the power sector by 2050 while phasing out nuclear power by 2022. The aim is to achieve by 2020 a 40 percent total reduction of greenhouse gas emissions below 1990 levels, and a total reduction of 80 to 95 percent by 2050.

As a result of this policy shift, Germany's power system will increasingly be shaped by renewable energy sources, most prominently wind and solar. According to national energy policy targets adopted by the current government, the share of renewables in meeting electricity demand is expected to reach 40 to 45 percent by 2025 and 55 to 60 percent by 2035. Indeed, this dynamic movement already began several years ago.

A quarter of Germany's 2013 power consumption was met by renewable energies. In that and previous years, electricity production from coal fired power plants rose significantly whereas the power generation of gas and nuclear plants decreased. Moreover, net electricity exports from Germany to its neighbours reached an all-time record.

This report reviews recent developments in the German power sector and links them to the key future energy scenario published by the government in 2011. We first summarise developments with respect to the deployment of renewable energies, followed by observations regarding the overall power generation mix and the development of electricity exports. The effects of the power sector trends for CO_2 emissions are discussed and linked to commodity price developments. Finally, this is put into the broader context of the 2030 scenarios that the government published in 2011. Based on these scenarios, we describe the pathway that the coal sector will face from now until 2030.

Key findings at a glance

1. **Germany is currently facing an *Energiewende* paradox: Despite an increasing share of renewable energy sources, its greenhouse gas emissions are rising.** The reason for this paradox is not to be found in the decision to phase out nuclear power – the decrease of nuclear generation is fully offset by an increased generation from renewables. Rather, the paradox is caused by a fuel switch from gas to coal.

2. **Due to current market conditions, German coal-fired power plants are pushing gas plants out of the market – both within Germany and in neighbouring countries.** Since 2010, coal and CO_2 prices have decreased, while gas prices have increased. Accordingly, Germany's coal-fired power plants (both new and old) are able to produce at lower costs than gas-fired power plants in Germany and in the neighbouring electricity markets that are coupled with the German market. This has yielded record export levels and rising emissions in Germany.

3. **If Germany is to reach its *Energiewende* targets, the share of coal in the German power sector has to decrease drastically – from 45 percent today to 19 percent in 2030.** Sharp decreases in generation from lignite and hard coal of 62 and 80 percent, respectively, are expected in the next 15 years while the share of gas in electricity generation will have to increase from 11 to 22 percent. This goes in line with the governments' renewables and climate targets for 2030.

4. **Germany needs a coherent strategy to transform its coal sector.** Such a strategy – call it a coal consensus – would bring power producers, labour unions, the government and environmental groups together in finding ways to manage the transformation.

Contents

Deployment of renewable energies

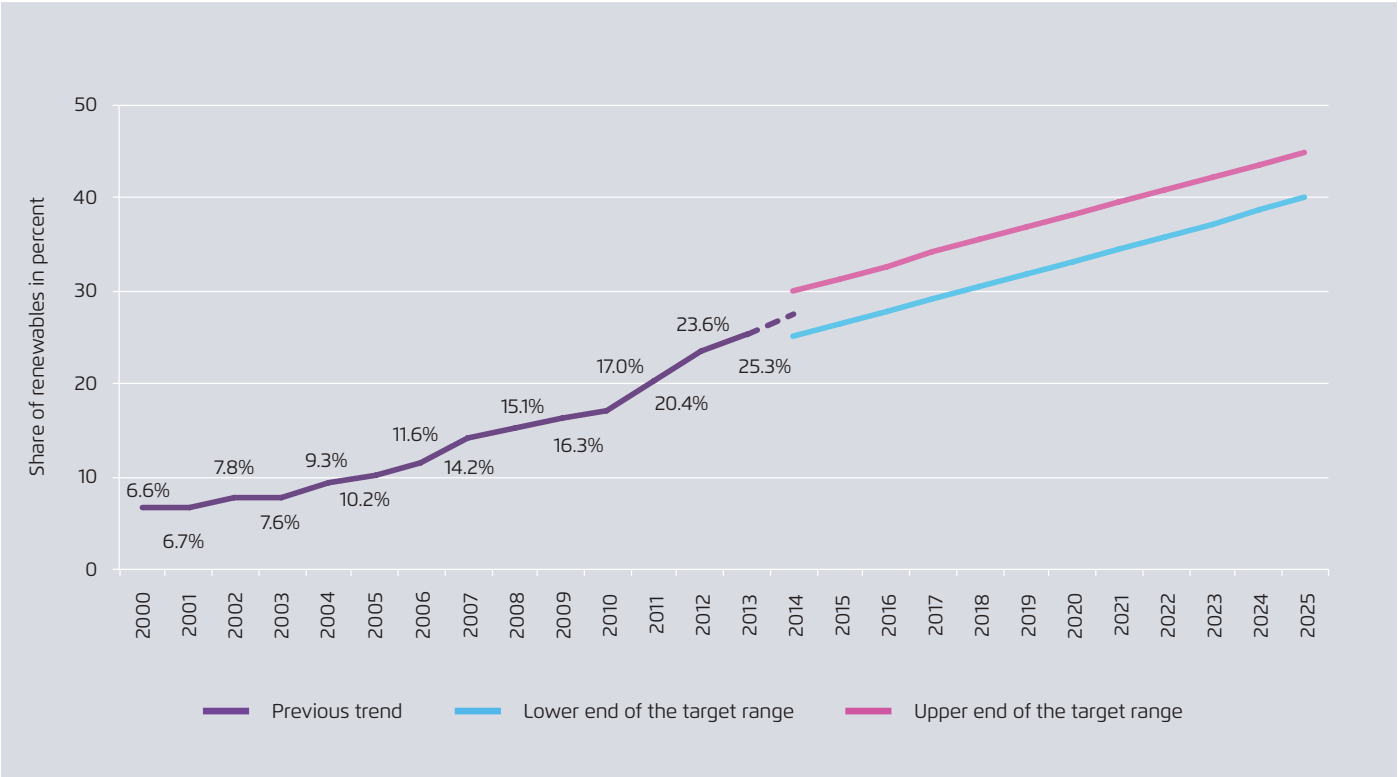
In 2013, the share of renewable energies in gross electricity consumption reached 25.3 percent, an all-time high.[1] A quarter of power consumption was met by wind, solar, hydro, bioenergy and geothermal power plants. Figure 1 illustrates the development from 2000 to 2013. The graph indicates the lower and upper bounds of the envisaged deployment of renewables in the electricity sector as specified in the coalition treaty of Germany's new governing coalition. As we can see, the share of renewables in gross electricity consumption is expected to reach 40 to 45 percent by 2025.

As can be seen in Figure 1, the 2013 share of renewables in gross electricity consumption increased by 1.7 percentage points relative to 2012. Solar PV, biomass[2] and wind contributed to this increase (by 3.6, 2.9 and 2.7 TWh, respectively), whereas the generation of hydropower decreased slightly due to weather related circumstances (minus 1.3 TWh). Since 2000, wind power and biomass generation showed the highest average annual growth (3.4 TWh each), whereas annual fluctuations were significantly larger for wind power. One of the reasons for this was weather. Over the same time, solar PV generation rose on average by 2.3 TWh per year. The deployment of PV was particularly dynamic from 2010 to 2012, when the average annual increase

1 For this paper, data on electricity consumption and production is taken from AG Energiebilanzen (2014): *Bruttostromerzeugung in Deutschland von 1990 bis 2013 nach Energieträgern.* Based on version dated 7 February 2014. Data for 2013 is preliminary.

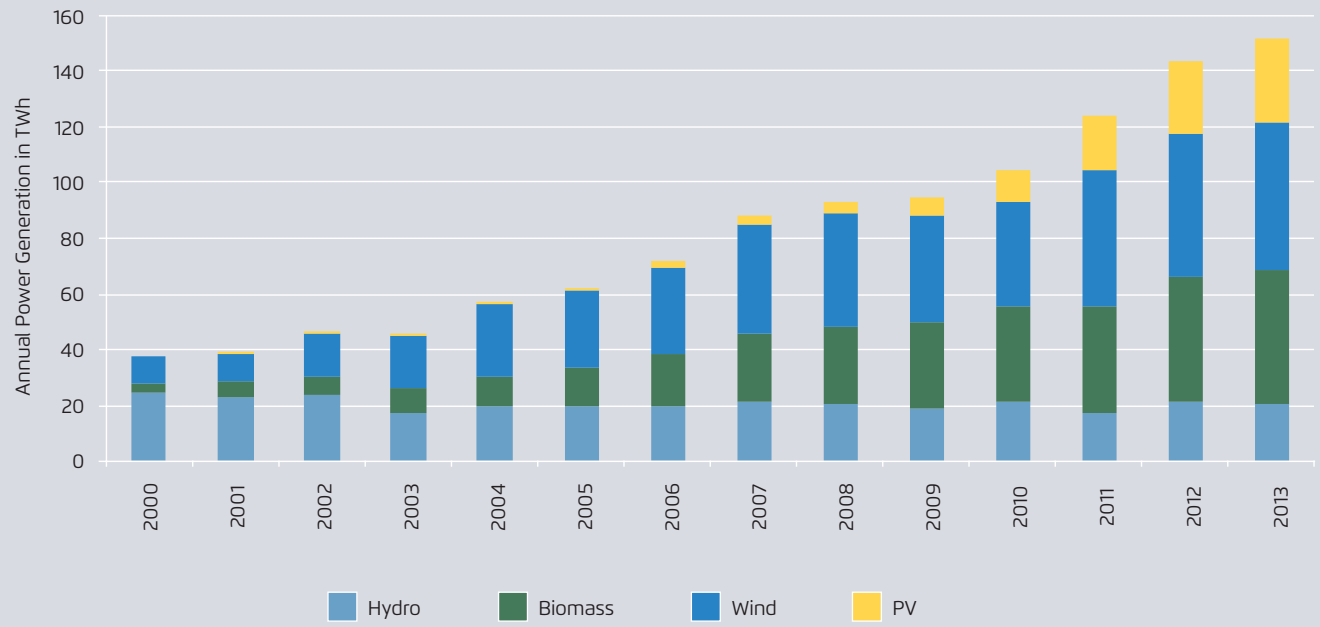
2 This includes the biogenic part of waste.

Share of renewables in gross electricity consumption and target path through 2025 — Figure 1



AG Energiebilanzen, own calculations

Annual power generation of renewable energy sources Figure 2



AG Energiebilanzen

in generation was 6.6 TWh. Figure 2 shows the development of renewable electricity generation from 2000 to 2013.

Evolution of the overall power generation mix

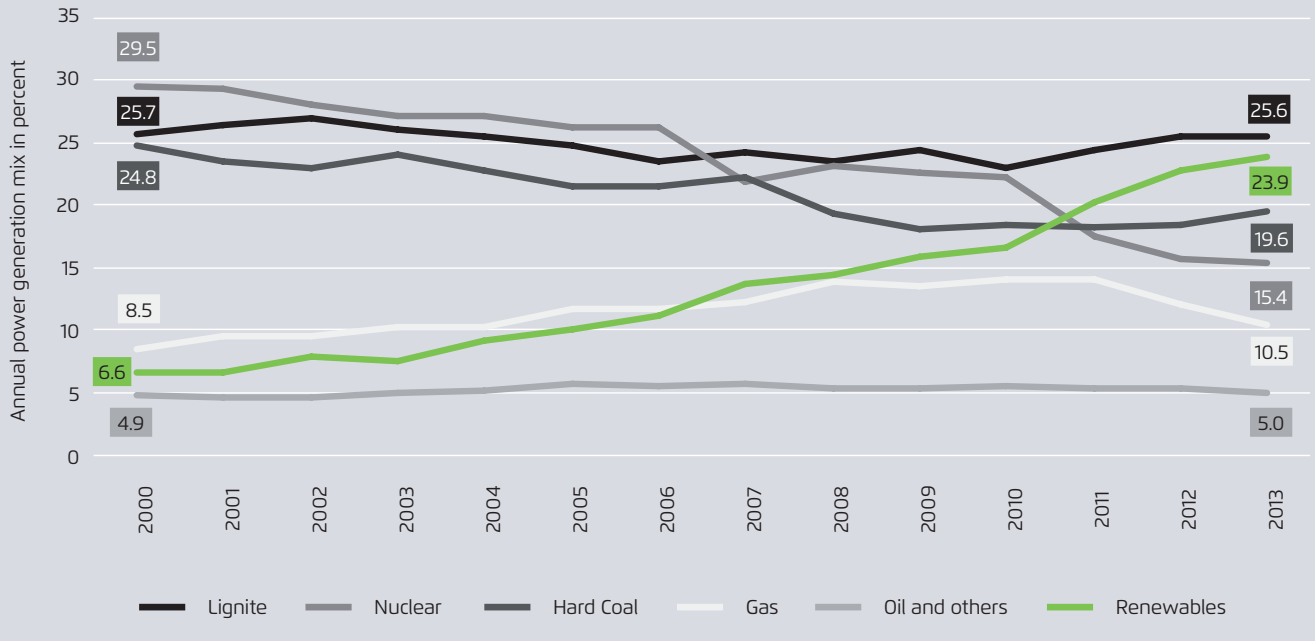
In line with the 2000 decision to phase out nuclear power (which was reinstated in 2011) – the share of nuclear energy in the power generation mix decreased from 29.5 percent in 2000 to 15.4 percent in 2013. Over the same period, the share of renewable power increased from 6.6 to 23.9 percent (see Figure 3).[3]

The share of gas in the generation mix grew from 8.5 percent in 2000 to 14.1 percent in 2010. Afterwards it decreased, falling to 10.5 percent by 2013. Generation in hard-coal-fired power plants amounted to 24.8 percent in 2000 and decreased to 18.5 percent in 2010. Since then, it has been on the rise, reaching 19.6 percent in 2013. Similarly, the share of lignite in the German power generation decreased slightly from 25.7 percent in 2000 to 23 percent in 2010 but increased to 25.6 percent in 2013. Figure 4 shows the total power generation mix in 2013.

The longer-term trends of Germany's power generation are illustrated in Figure 5. As we can see, the decline in nuclear generation is more than offset by the increase in generation from renewable energy sources. The graph also shows the recent increase in hard-coal- and lignite-fired generation. In fact, in 2013, the latter reached its highest level since 1990.

3 As Germany is a net exporter of electricity, the share of renewables in gross electricity consumption is higher than the share of renewables in electricity production.

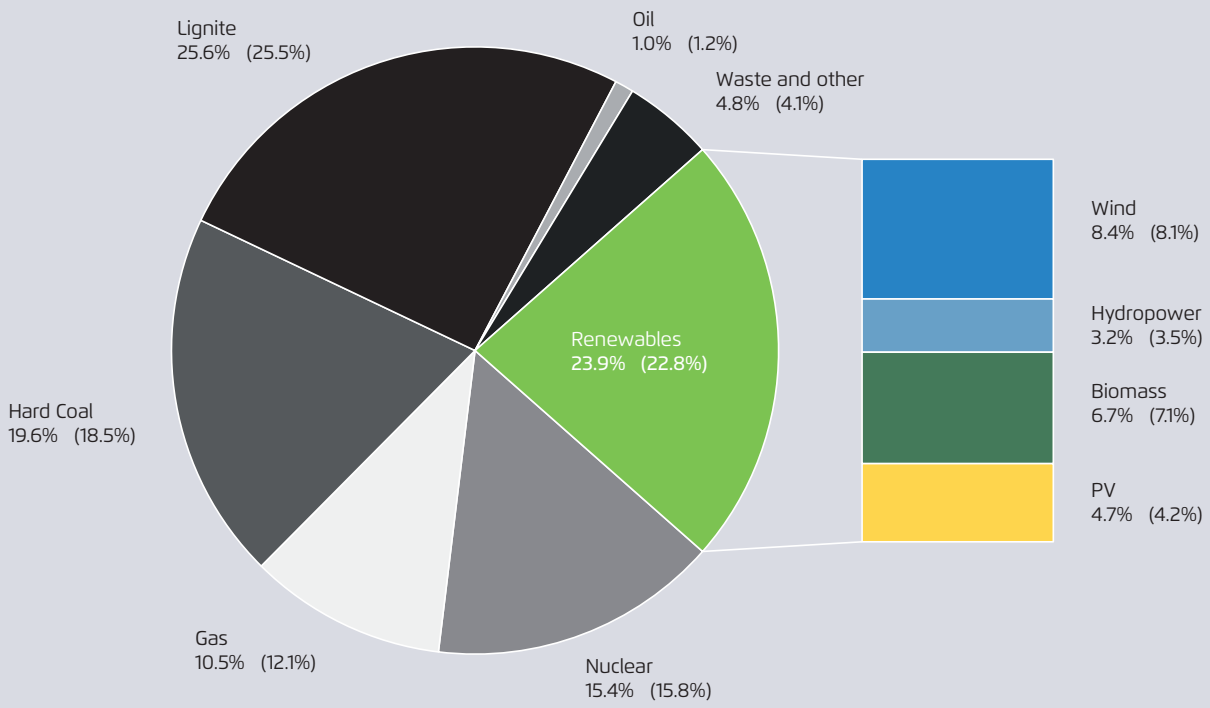
Annual power generation mix from 2000 to 2013 — Figure 3



AG Energiebilanzen, own calculations

Power generation mix in 2013 and 2012

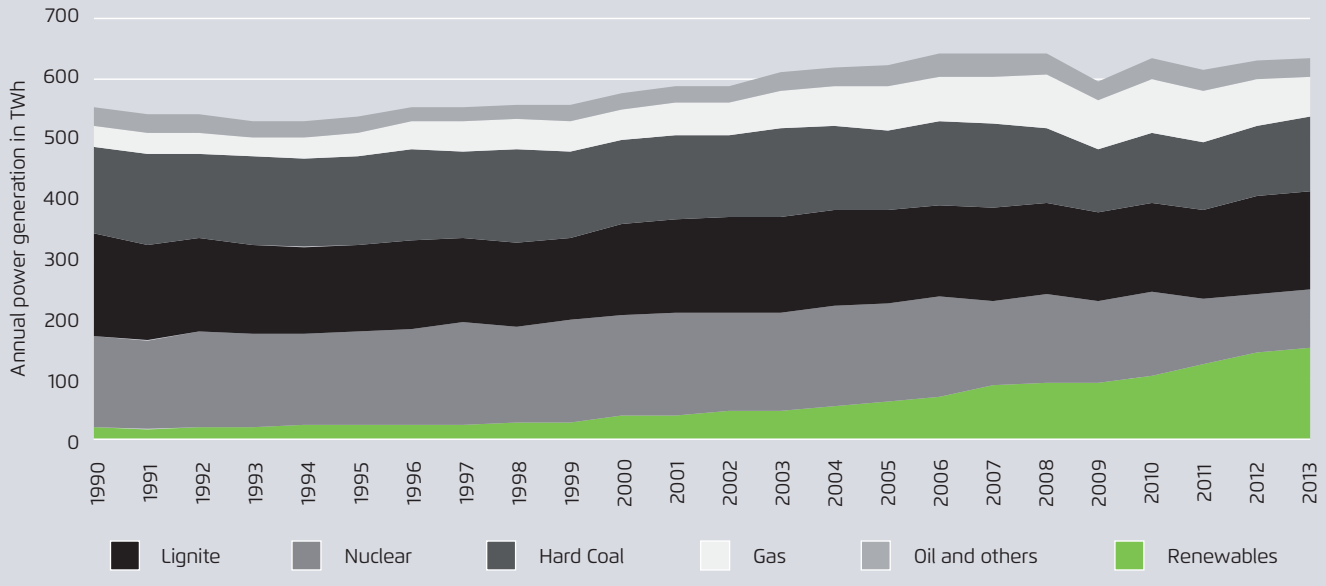
Figure 4



AG Energiebilanzen; numbers for 2012 have been placed in brackets.

Annual power generation mix from 2000 to 2013

Figure 5



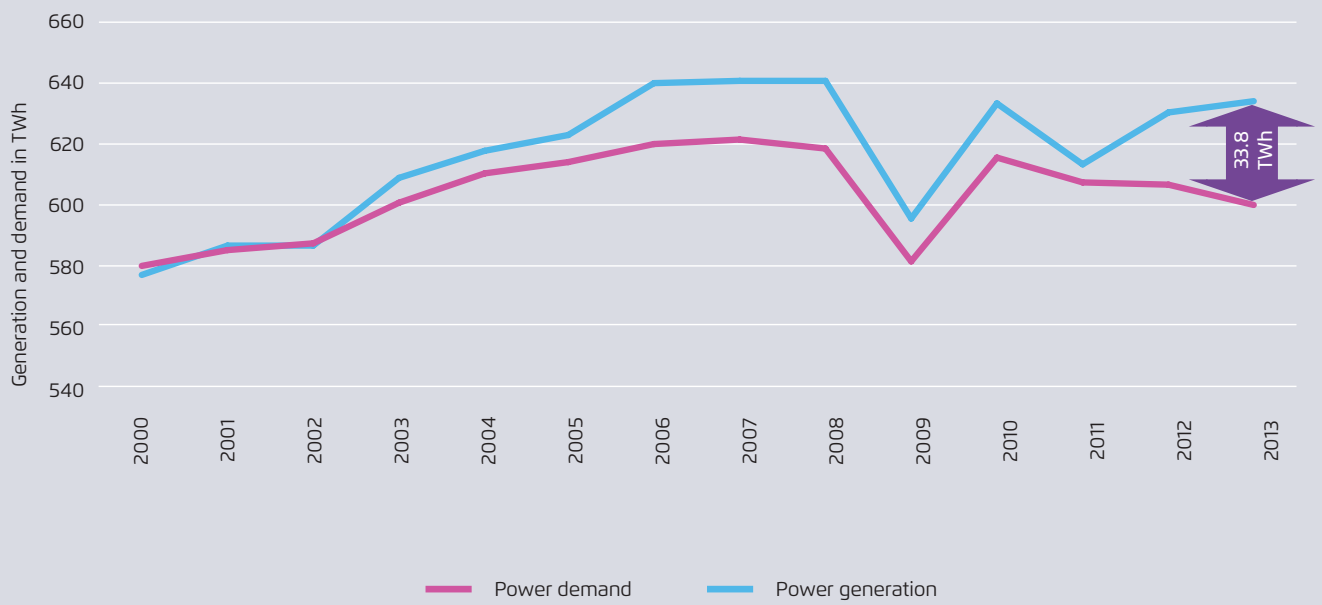
AG Energiebilanzen, own calculations

Power generation, domestic demand and electricity exchange

Besides these significant changes in its power generation mix, Germany has also experienced a rapidly rising trade surplus with its neighbours. As Figure 6 shows, Germany has been a net exporter of electricity ever since 2003. By 2013, almost 34 TWh of power were exported, corresponding to 5.3 percent of gross domestic power generation.[4] This development is the result of a slightly lower domestic power demand at home and of a constant (or slightly increasing) domestic power generation.

4 Taking into account commercial power exchanges, the net export position amounted to 41 TWh, as opposed to the physical net export position of 34 TWh. Physical exchanges comprise flows due to commercial transactions between the exporting and importing countries, transit flows (flows entering a specific country on one border and leaving it on another) and loop flows (unscheduled flows across borders arising from physical constraints in the transmission grid within a specific country). This results in differences between physical and commercial exports. For example, part of electricity exports from Germany to the Netherlands is not consumed within the Netherlands but flows through the Netherlands to Belgium and other elsewhere. All data on power exchanges is based on ENTSO-E: ENTSO-E, 2014. Data portal; and the transparency platform of ENTSO-E: entsoe.net.

Domestic power generation, demand and 2013 export surplus (physical flows) Figure 6



AG Energiebilanzen, own calculations

Figure 7 illustrates the commercial power exchanges of Germany and its neighbouring countries in 2013.[5] As we see, Germany exports power mainly to Austria (34.8 TWh), followed by the Netherlands (18.1 TWh) and France (12.5 TWh). Germany imports power mainly from Austria (18.4 TWh) and the Czech Republic (11.6 TWh). But Austria's imports from Germany nonetheless exceed its exports, yielding a net export surplus for Germany.

As illustrated in Figure 7, the Netherlands (18 TWh) and Austria (16.4 TWh) are the largest net importers from Germany. For these countries, increasing amounts of imports affect the domestic production levels significantly. For example, Austrian (physical) imports increased by 4.5 TWh from 2012 to 2013, while domestic gas-fired power production decreased by 3 TWh. Similarly, domestic power generation in the Netherlands, which is mainly based on gas-fired power plants, decreased by 4.4 TWh from 2012 to 2013.

5 Luxembourg is not included in the graph because data on commercial electricity exchanges is not available for it. Data for commercial exchanges is taken from ENTSO-E's transparency platform. Whenever available, final values for cross-border commercial schedules have been used. However, if these final values are not available (due to a publication lag), nominated day-ahead cross-border commercial schedules are used instead. Deviations of nominated values from final values show no underlying pattern. As such, in case of unavailability, nominated values are the best estimates for final ones.

Germany's commercial power exchanges in 2013 — Figure 7

ENTSO-E, own calculations

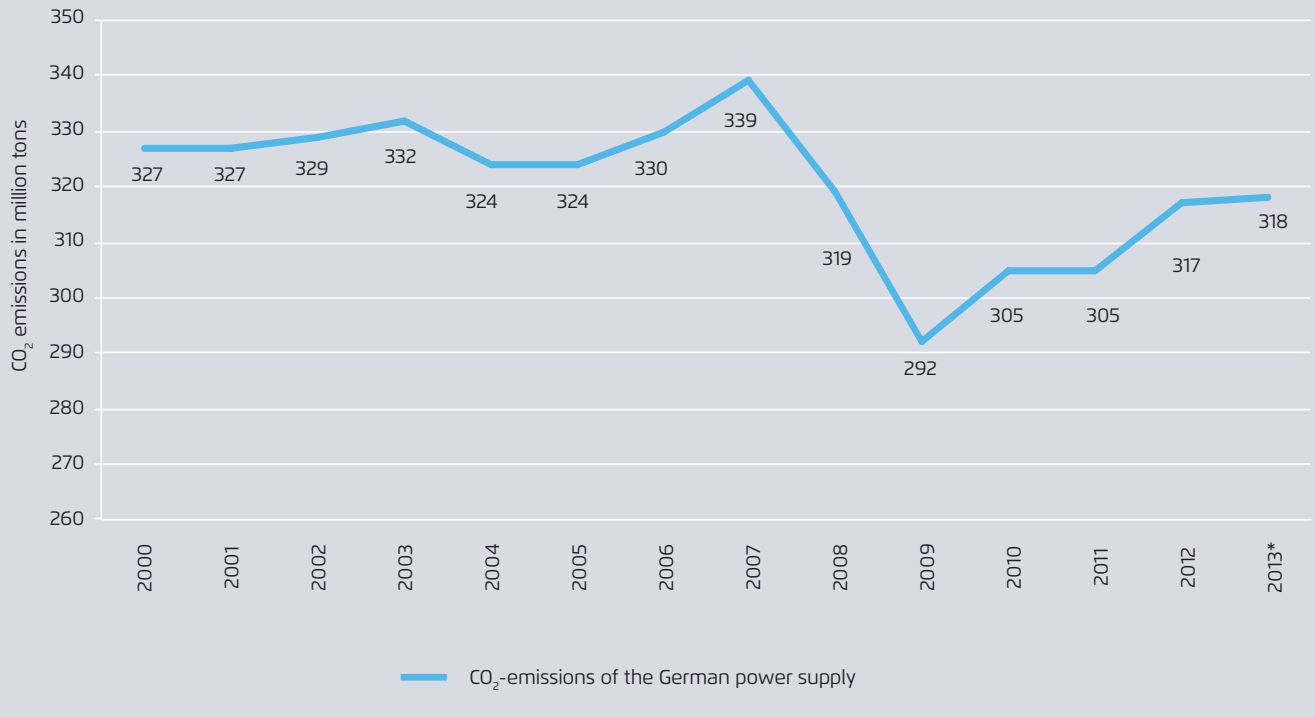
CO_2 emissions and the power generation mix

Although the share of renewable energies in the German power system has continuously increased since the year 2000, CO_2 emissions in the power sector have been on the rise since 2009 as well. Is Germany facing an *Energiewende* paradox?

As we have described in the above sections, electricity production from coal-fired power plants has risen significantly as has renewable generation, while the power generation of gas and nuclear plants has decreased. What is more, the increased competitiveness of Germany's coal-fired power plants precipitated strong growth in electricity exports. This is reflected in a rising carbon intensity of the domestic power generation mix.

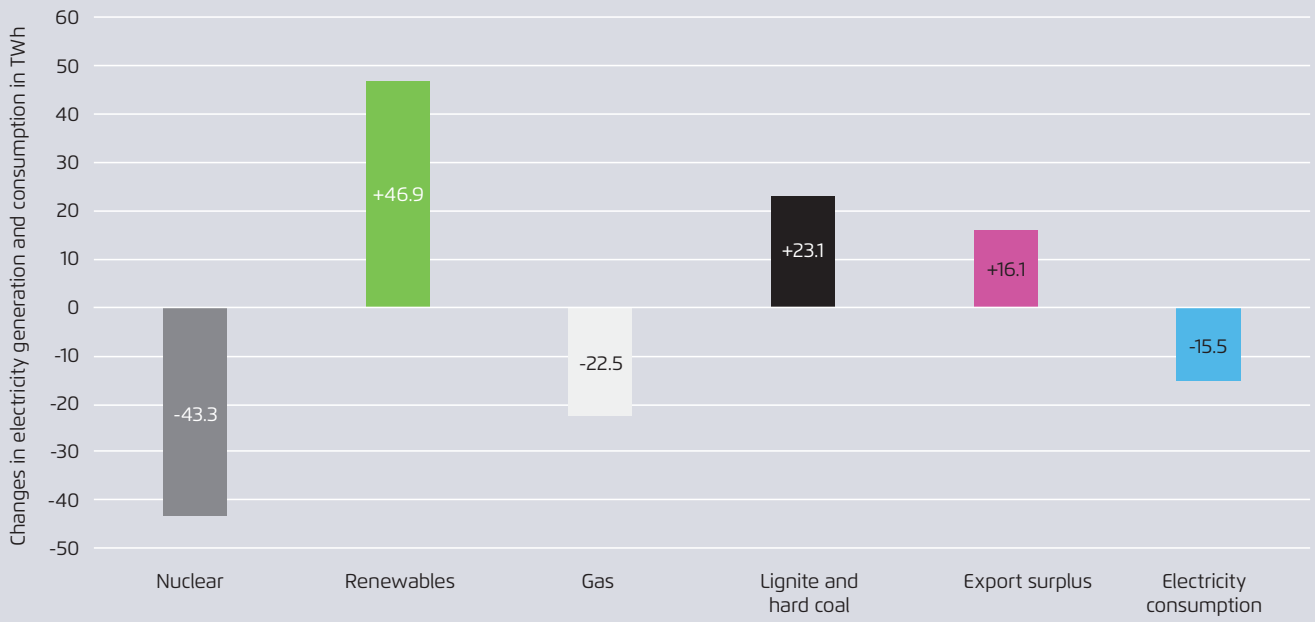
Specifically, lignite- and hard-coal-fired power plants increased their production from 2010 to 2013 by 23.1 TWh, of which 16.1 TWh came from lignite and 7 TWh from coal. Gas-fired generation dropped by 22.5 TWh, while physical exports grew by 16.1 TWh. Nuclear generation decreased by 43.3 TWh, and was offset by an increase in renewable electricity generation of 46.9 TWh.

CO_2 emissions from German power generation — Figure 8



Federal Environment Agency, *own estimates

Changes in electricity generation and consumption, 2010–2013 Figure 9



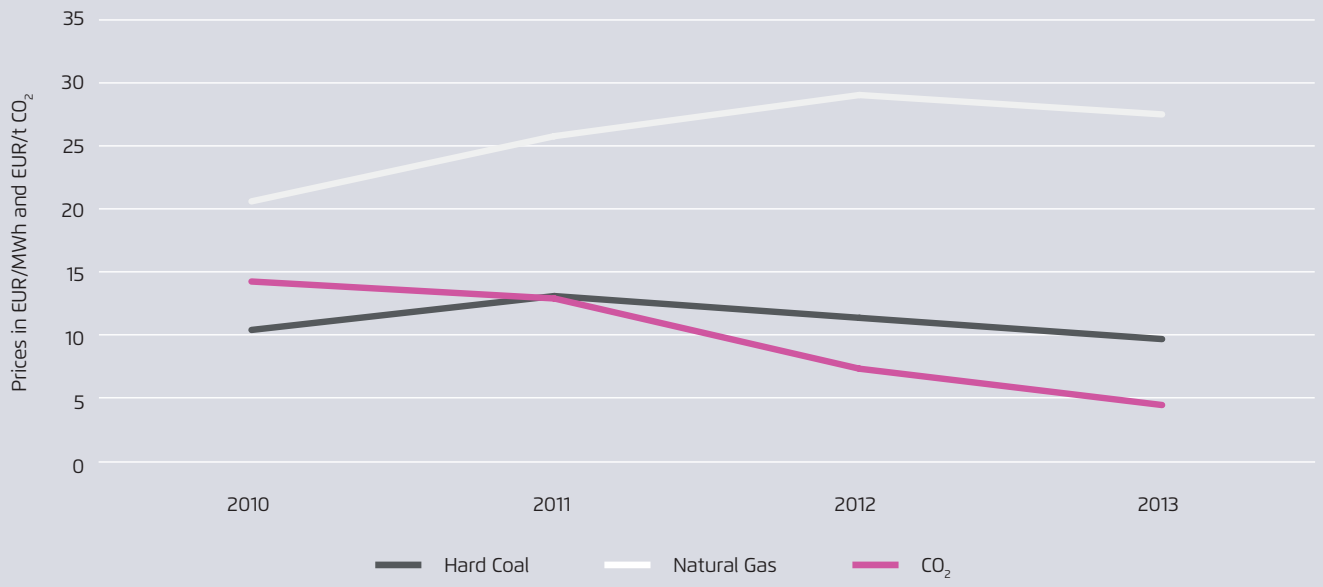
AG Energiebilanzen, own calculations

Figure 9 illustrates that a nuclear phase-out like the one implemented in Germany does not itself entail an increase in CO_2 emissions as long as it is offset by an equal rise in renewables. Indeed, the jump in CO_2 emission levels in the German power sector was caused by a fuel switch from gas to coal. Low CO_2 emission allowance cost and high gas prices often render gas-fired generation uneconomic. As shown in Figure 10, the spread between German border prices for natural gas and hard coal has widened since 2010, and in 2013 reached 18 euros/MWh. This gap has been amplified by continuously decreasing CO_2 prices, which in 2013 sank to 4 euros/MWh.

The increasing spread between gas and hard coal prices and the falling CO_2 price clearly affect the spread between the generation costs of hard coal plants and gas-fired power plants. As illustrated in Figure 11, old coal-fired power plants and new gas-fired power plants had similar generation cost levels (short-run marginal costs) in 2010 and 2011, amounting to some 45 euros/MWh.[6] However, the short-run marginal costs of coal plants decreased significantly in 2012 and 2013 (reaching some 33 euros/MWh for old hard coal plants), whereas the short run marginal costs of gas-fired plants increased, reaching 50 euros/MWh for new gas-fired plants.

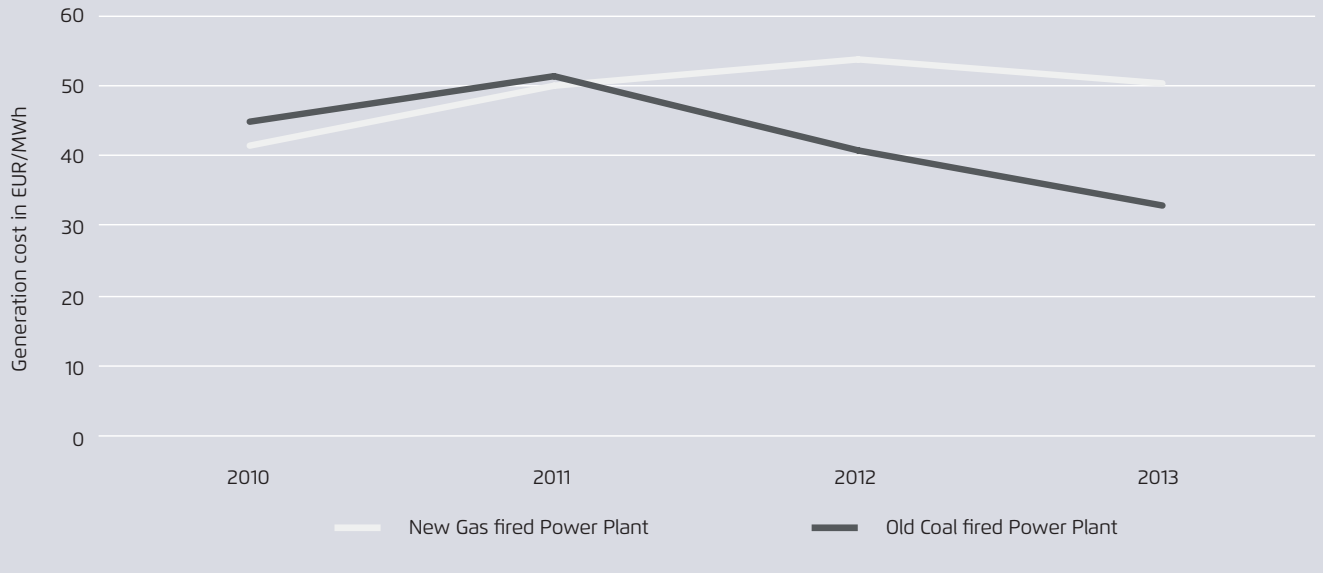
6 The assumed electrical efficiency rates are 57 percent for a new gas-fired power plant (CCGT) and 34 percent for an old hard-coal-fired power plant.

Annual average prices for hard coal, natural gas (both German border prices) and CO_2 emission allowances Figure 10



BAFA, EEX, own calculations

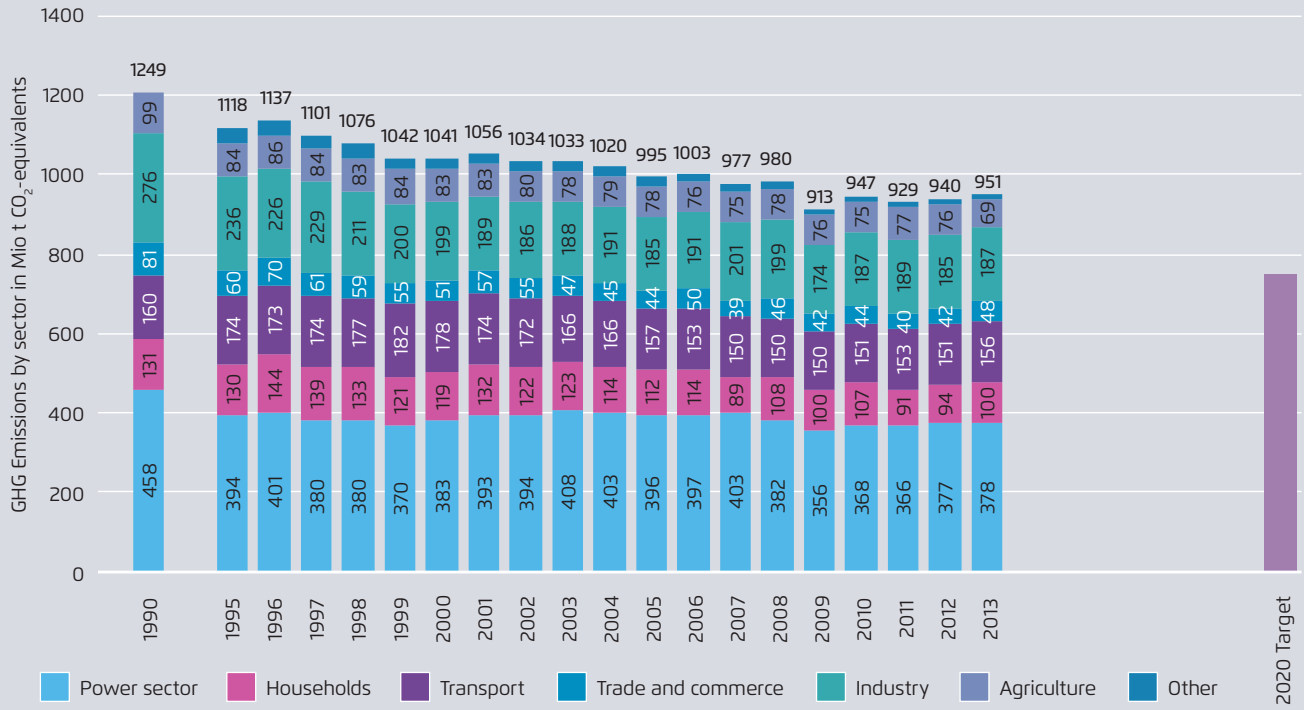
Short-run marginal generation costs of an old hard-coal-fired power plant and a new gas-fired power plant, 2010–2013 Figure 11



BAFA, EEX, own calculations. The assumed efficiency rates are 57 percent for new combined cycle gas power plant (CCGT) and 34 percent for old hard coal-fired power plants. New hard coal-fired power plants, which reach efficiency rates of 45 percent, have even lower short-run marginal generation costs (around 25 euros/MWh in 2013).

Greenhouse gas emissions in Germany from 1990 to 2013 and the 2020 target

Figure 12



Umweltbundesamt, own calculations

If these trends persist, Germany risks failing its 2020 climate target of reducing greenhouse gas emissions by 40 percent below 1990 levels. As we see in Figure 12, Germany has been quite successful in reducing its greenhouse gas emissions since 1990. It is often claimed that these are due to "wallfall profits", i.e. greenhouse gas reductions due to the economic restructuring in East Germany after reunification. While this partly holds true for the reductions from 1990 to 1995, the greenhouse gas trend from 1995 to 2011 can be attributed to active climate change policy across sectors. But a large part of the reductions since 1995 stem from the energy sector, which have shown rising emissions since 2011 – and is the major cause for the increase in overall German greenhouse gas emissions in 2012 and 2013.

The role of coal and gas in the German power mix through 2030

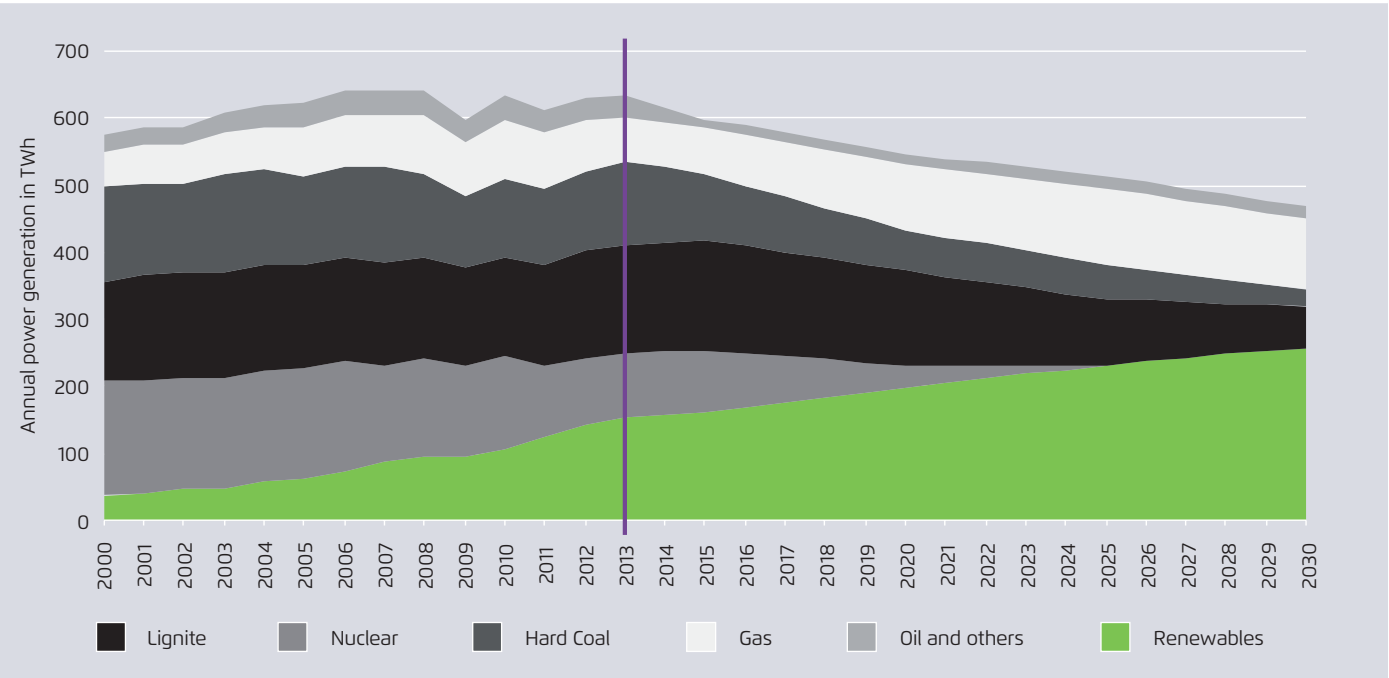
The analysis in the previous chapters has shown that despite significant deployment of renewable energies, German CO_2 emissions have increased due to increased coal-fired power production. How do these recent trends fit to medium- and long-term government climate and energy policy targets? As we mentioned at the outset of this paper, the goal is to fully decarbonise the power sector by 2050 while phasing out nuclear power by 2022. For the whole economy, the aim is to achieve a reduction of 80 to 95 percent by 2050, which implies, according to the national energy concept of 2010, a 55 percent reduction of greenhouse gas below 1990 levels by 2030. The recent CO_2 emission trends of the German power sector are clearly not in line with these emission reduction targets.

Figure 13 puts the recent power-sector developments into the broader context of the 2030 energy scenario "Szenario Ausstieg" – the nuclear phase-out scenario that the German Federal Ministry of Economics published in 2011 after the renewed decision to phase out nuclear power[7]. To achieve the 2030 outcome envisioned by Germany's climate and energy policy targets, the generation of lignite- and hard-coal- fired power plants has to decrease significantly from today's production levels. Specifically, lignite generation would need to decrease by 62 percent and hard coal generation would need to decrease by 80 percent relative to 2013. By 2030, generation from renewable energy sources would need to increase by 70 percent of 2013 levels and gas-fired

7 Data in this section is based on the nuclear phase-out scenario of Prognos/EWI/GWS (2011): *Energieszenarien 2011*.

Recent power generation developments (2010–2013) and prospective development (2015-2030) according to the energy scenarios of the German federal government

Figure 13



AG Energiebilanzen, Prognos/EWI/GWS, own calculations

generation would need to increase by 56 percent of 2013 levels to meet government targets. If these targets were achieved, CO_2 emissions in the German power sector would decrease by 60 percent of 2010 levels.

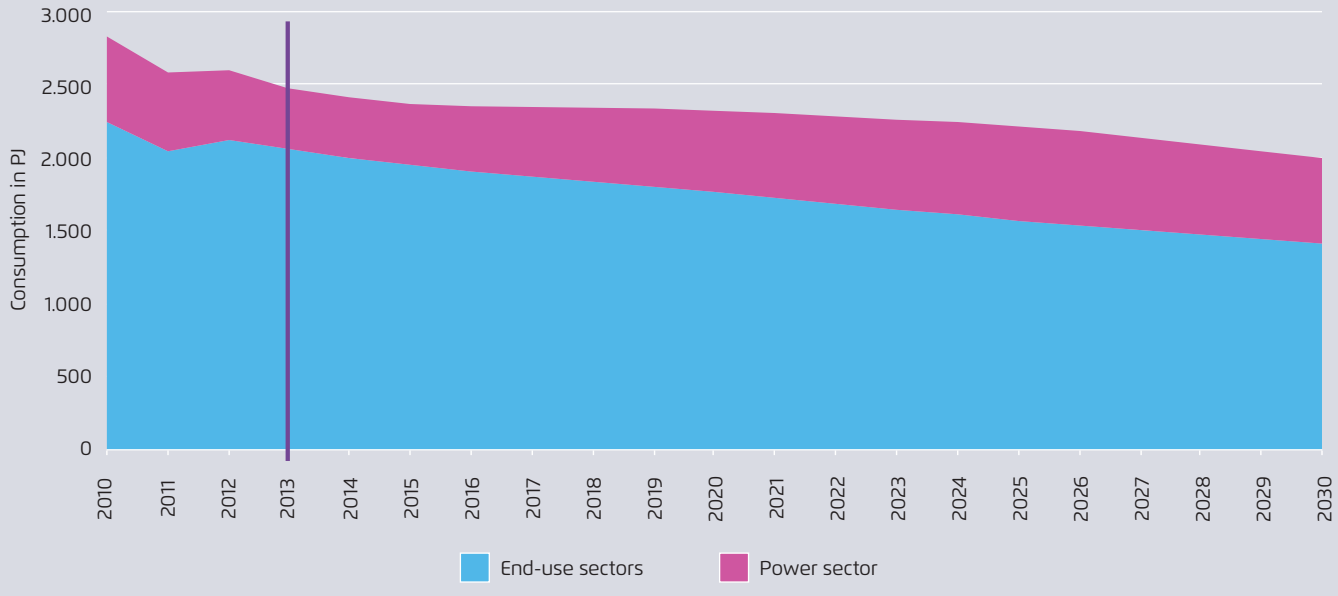
Again, in the energy concept scenario gas-fired generation is expected to increase its market share from 11 percent in 2013 to 22 percent in 2030. This means that the consumption of natural gas of the power sector would increase by 45 percent from 2013 to 2030 (a 27 percent increase from 2012 to 2030). This increased use of gas in the power sector will be offset by the decreased use of gas in the end-use sectors thanks to energy efficiency measures. The latter will decrease their gas consumption by some 35 percent from 2012/2013 to 2030. Given the higher energy consumption of end-use sectors compared with the power sector, overall German gas consumption is projected to decrease by some 23 percent from 2012/2013 to 2030 (see figure 14).

Based on the above scenario, the share of renewables in the 2030 power generation mix would amount to 55 percent, followed by gas with 22.3 percent. Lignite would have a share of 13.2 percent, while hard coal would be at 5.4 percent. Oil and others would amount to 4.1 percent (see figure 15). The significant changes in the power production mix illustrated in Figures 13 and 15 result partly from assumed increases of fossil fuel prices but mostly from a dramatic increase of the price for CO_2 emission allowances, which are expected to reach (in nominal terms) 54 euros/t CO_2 in 2030. The accompanying price developments are depicted in Figure 16. It is clear that the current price developments for CO_2 emission allowances are not in line with the assumptions of the official German energy scenario, which are projected to yield a 60 percent CO_2 emission reduction of the power sector by 2030.

To meet the government's climate targets, there are two policy options: Either quickly fix the emissions trading scheme such that it yields high price signals for the required fuel switch in the power sector, or adopt additional strategies and measures to accompany the emissions trading scheme that address the role and relationship of coal and gas in the power sector.

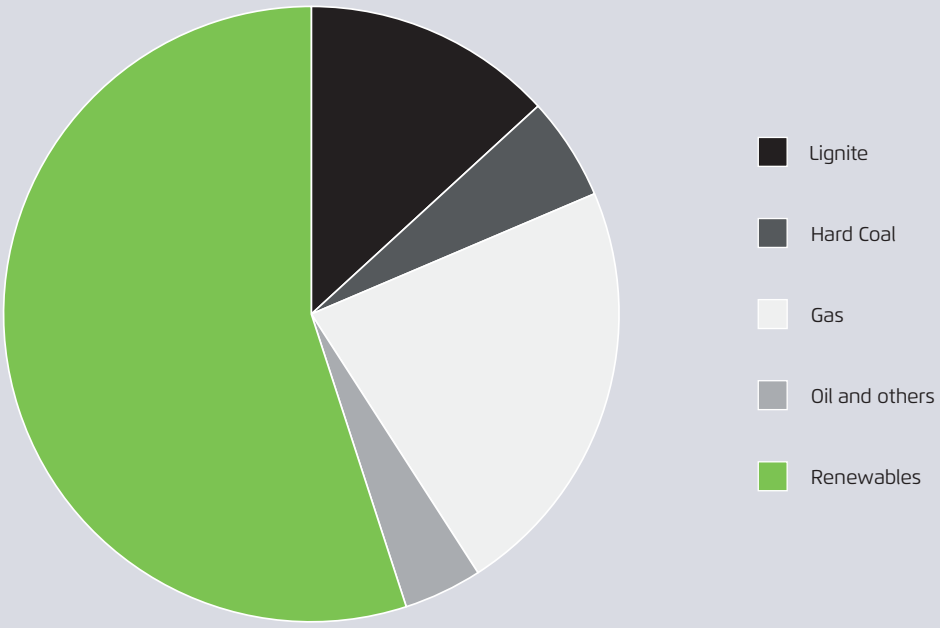
Natural gas consumption of the power and end-use sectors according to the energy scenarios of the German government

Figure 14



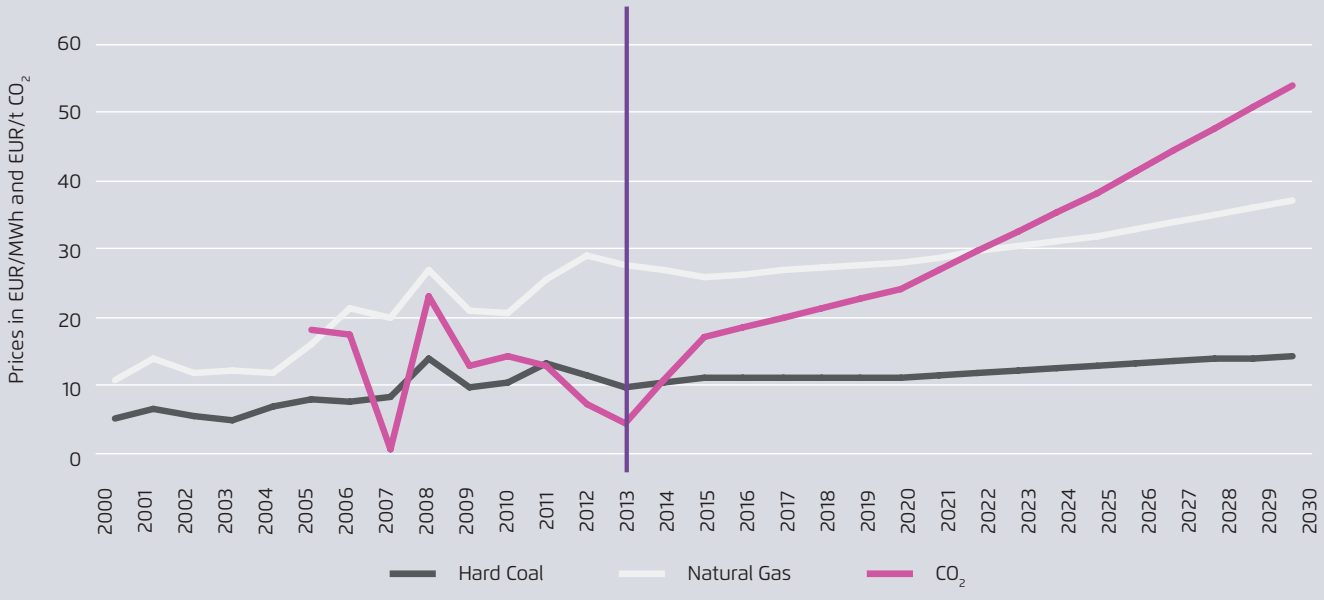
Energiebilanzen, Prognos/EWI/GWS, own calculations

2030 power generation mix according to the energy scenarios of the German government Figure 15



Prognos/EWI/GWS, own calculations

Recent commodity price developments for hard coal, natural gas, CO_2 (2000–2013) and assumptions in the energy scenarios of the German government (2015-2030) (all prices nominal) Figure 16



BAFA, EEX, Prognos/EWI/GWS, own calculations

Conclusion

This report has reviewed recent developments in the German power sector and linked them to Germany's official energy system scenario prepared in 2011 for the Federal Ministry of Economics. This scenario is in line with the overall climate and energy policy goals of Germany and the European Union, including the full decarbonisation of the power sector by 2050 and the phase-out of nuclear power by 2022. The power system will be shaped more and more by renewable energy sources, most importantly wind and solar photovoltaics. Already, the domestic power system has shown dynamic developments in recent years, though the power sectors' CO_2 emissions still fall short of Germany's broader climate targets.

In 2013, a quarter of German power consumption was met by renewable energies. At the same time, electricity production from coal-fired power plants rose significantly while power generation from gas and nuclear plants decreased. Specifically, gas power plants faced a competitive disadvantage due to low CO_2 and high gas prices. The increased competitiveness of coal-fired power caused strong growth in electricity exports and yielded record export levels.

These developments describe an *Energiewende* paradox: Despite Germany's increasing share of renewable energy sources, its greenhouse gas emissions are rising. Since the decrease in nuclear generation has been fully offset by an increased deployment of renewable electricity sources, the paradox must result from the switch from gas to coal, made possible by very low coal and CO_2 emission allowance prices combined with high gas prices.

The current developments contrast sharply with the overall trend that the energy sector will have to take until 2030 if the *Energiewende* targets are to be met. Assuming the government achieves its goal to increase renewables by 2035 to 55 to 60 percent of production, coal generation will have to decrease considerably over the coming years. Indeed, the scenarios prepared for the Federal Ministry of Economics show that the path to the 2050 goal of an 80 to 95 percent reduction in greenhouse gases requires a 2030 power mix that consists of 55 percent renewables, 22 percent gas and 19 percent coal (lignite and hard coal). This in turn implies that, from 2013 to 2030, lignite generation will have to drop by 62 percent and hard coal fired generation by 80 percent.

To achieve these targets, Germany needs a coherent transformation strategy for its coal sector. A new Coal Consensus that brings together power producers, labour unions, the government and environmental groups to manage the transformation would be the best way forward.

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Zusammenhang von Strombörsen und Endkundenpreisen
Studie von Energy Brainpool

038/04-A-2014/EN

How do we accomplish the *Energiewende*? Which legislation, initiatives, and measures do we need to make it a success? Agora Energiewende helps to prepare the ground to ensure that Germany sets the course towards a fully decarbonised power sector. As a think-&-do-tank, we work with key stakeholders to enhance the knowledge basis and facilitate convergence of views.

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