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In a Nutshell!

Why are Germany's CO_2 Emissions Only Falling Slowly Despite the Major Expansion in Renewable Energy Sources?

German National Academy of Sciences Leopoldina
acatech – National Academy of Science and Engineering
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In a Nutshell!

Although Germany is already producing over one third of its electricity from renewable energy sources, CO_2 emissions have only fallen by 17 per cent since 2000. There are four main reasons for this:

1. The share of renewable energy in the heat and transport sectors ist still low.
2. **Power generation from lignite remains high.** Electricity generated from this high-emission fuel has long been cheaper due to the lower CO_2 certificate prices than for other energy sources such as natural gas.
3. **Electricity from renewables is partly replacing low-CO_2 nuclear energy.** At the same time, generation from nuclear power plants has in part been replaced by fossil power plants for security of supply reasons.
4. **Germany is producing more electricity, ever more of which is being exported to foreign countries.** Highly volatile renewable generation capacity combined with a constantly high level of inflexible fossil electricity production result in low power prices which are attractive to other countries.

Germany has already been able to make more CO_2 emission savings in the power sector than in the heating or transport sectors. These savings are not, however, sufficient to meet the Paris climate targets.

Background

Germany has been able to reduce its total annual greenhouse gas emissions by 17 per cent since 2000 [1][2]. The energy sector has reduced its emissions by 16 percent in the same time and contributed roughly a third of the overall reduction. (see figure 1). It should be borne in mind that mild winter temperatures made a huge contribution to cutting emissions from 2017 to 2018 [3]. Energy sector emissions are essentially determined by power generation. However, against the background of the massive expansion of renewable energy sources, the reduction in emissions in the power sector would appear to be low. Why is this?

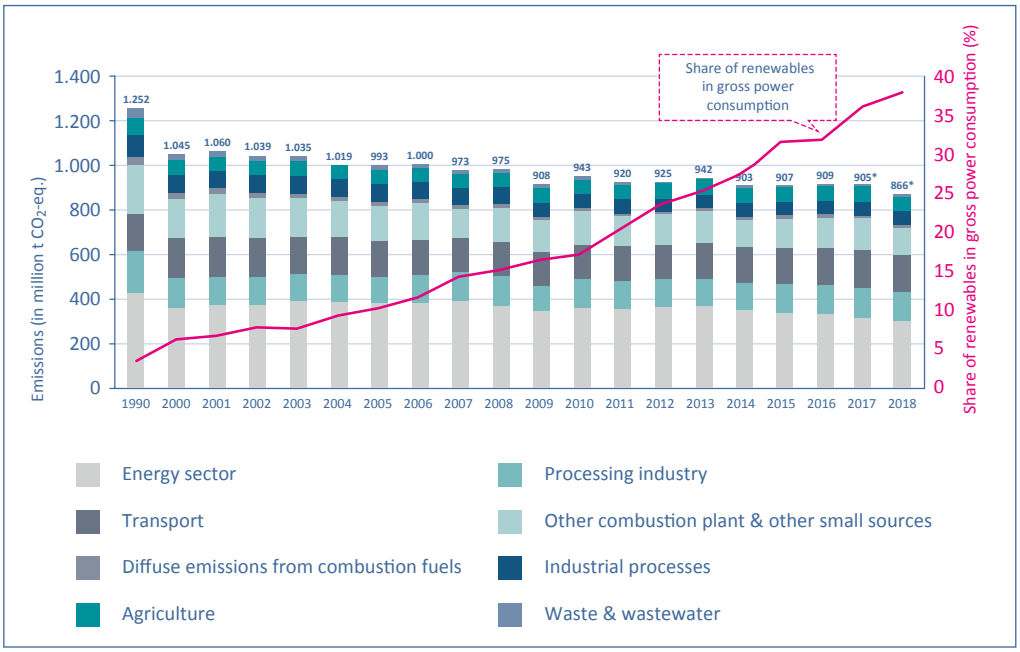

Figure 1: Annual greenhouse gas emissions from all sectors by category and share of renewables in gross power consumption (own presentation using data from [1][2][4]) *Estimate for 2017, 2018

Power generation from renewables plays a central role in restructuring the energy supply: it is essentially intended to supply low-emission energy to the power, heat and transport sectors. With a share of 37.8 per cent of gross power consumption in 2018, renewables have already become the most important energy sources in the power sector [4]. In the heating sector, their share is currently 13.9 per cent and only 5.6 per cent in the transport sector [4], so these sectors have considerable ground to make up.

Nevertheless, the anticipated successes in the power sector have not materialized: despite a more than sixfold rise in power output from renewables since 2000 [4], power generation is still responsible for around one third of German greenhouse gas emissions due to the combustion of fossil resources and the associated CO_2 emissions. While emission intensity has indeed fallen by around one quarter from 644 gram per kilowatt-hour to 474 gram per kilowatt-hour since 2000, annual CO_2 emissions at around 273 million tonnes are only just 17 per cent lower than in 2000 [5].

Reasons for High CO_2 Emissions in the Power Sector

1. Power generation from lignite remains high

Lignite power plants have the lowest marginal costs in the fossil power plant fleet. If an additional megawatt-hour of electricity is required at a point in time, it can be most inexpensively provided by coal-fired generation [6]. As a result, in particular lignite's share of German power generation has remained just about as high as ever in recent years. In 2018, 23 per cent of electricity was still being generated from lignite and 13 per cent from coal. Only around 13 per cent of Germany's power was obtained from the lower-emission, but still costlier natural gas [7]. Average emissions per generated kilowatt-hour in Germany are 374 grams for natural gas, 815 grams for hard coal and 1,142 grams for lignite [5]. Accordingly, while coal accounts for just one third of power generation, it is responsible for around 75 per cent of the power sector's CO_2 emissions.

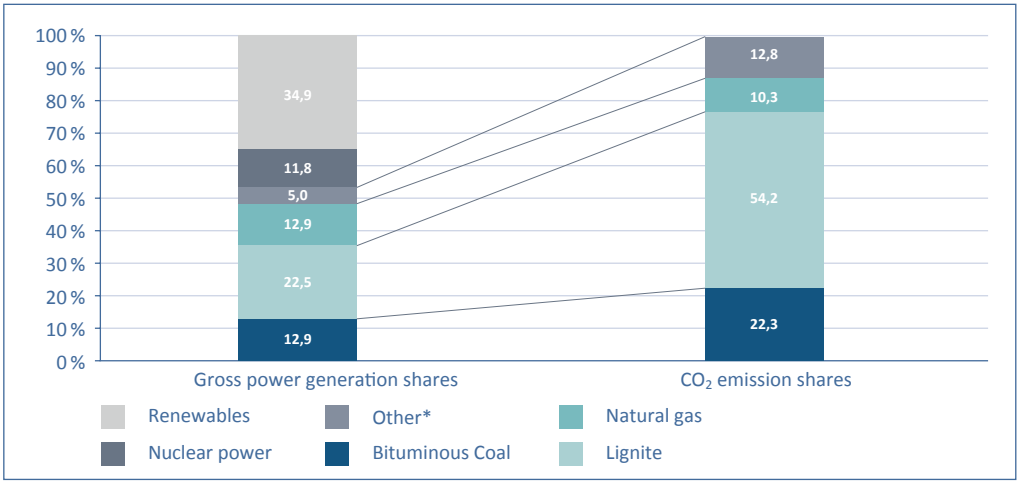

Figure 2: Gross power generation and CO_2 emissions from power generation by energy source, 2018 (own presentation using data from [5][7]) *incl. mineral oil and refuse incineration

The European Emissions Trading System (EU ETS), which is intended to make high-emission power plants costlier, for a long time had virtually no steering effect due to very low certificate prices. From 2013 to 2017, CO_2 certificate prices varied between three and eight euro [8]. It was thus still cheaper to produce electricity from coal rather than natural gas. As a result of the reforms to the ETS decided in late 2017, such as the Market Stability Reserve which applies from 2019, the price for certificates briefly rose in 2018 to 25 euro [8]. However, making lower-emission natural gas power plants competitive with coal-fired power plants would require a stable CO_2 price of at least 30 to 40 euro per tonne of CO_2 [6][9][10].

Short-term price fluctuations have so far had little effect on coal-fired power generation: coal-fired power plants occasionally continue to supply even when it makes no apparent economic sense, in extreme cases even when power trading prices are negative. In this case, the power station operators actually pay someone to take delivery of the electricity. There are technical and economic reasons for this: coal-fired power plants are relatively inflexible which makes quickly ramping up or down difficult and costly. In addition, many power station operators have long-term supply contracts with end customers which they fulfil irrespective of current trading prices. Some power plants also continue to be operated because they are obliged to supply balancing power.

Gas-fired power stations, in contrast, operate more flexibly and can respond more quickly to fluctuating power trading prices, but are currently still more expensive due to the lack of incentives [6].

2. Electricity from Renewables Filling in Gaps left by Nuclear Power

Since 2010, nuclear power generation has fallen by 65 terawatt-hours [7]. Over the same period, power generation from renewable energy sources has risen by 110 terawatt-hours [4]. On the balance sheet, renewables have thus replaced another low-emission technology for power generation which has thus had a smaller influence on CO_2 emissions.

However, the balance sheet also shows that Germany's gross power consumption declined from 622 terawatt-hours to 595 terawatt-hours between 2007 and 2018, while power generation rose from 640 terawatt-hours to 646 terawatt-hours over the same period [7][11]. While output from fossil fuel-fired power plants did indeed decline, it did not match the expansion of renewables. One reason for this is that some of the output from nuclear power plants was replaced by higher utilization of some of the existing, high-emission coal-fired power plants which continue to be operated in spells with little wind and sun and to ensure security of supply (system services). Completely making up the shortfall in power generation from nuclear power with lignite would result in the emission of an additional 74 million tonnes of CO_2 per year [5][7].

The trend shows, however, that Germany can in any event replace the low-CO_2 nuclear power plants in volume terms without having to produce additional coal-generated power (see Figure 3). In the absence of further power storage systems, highly flexible power plants and flexible power consumption, coal-generated power will remain part of the power mix.

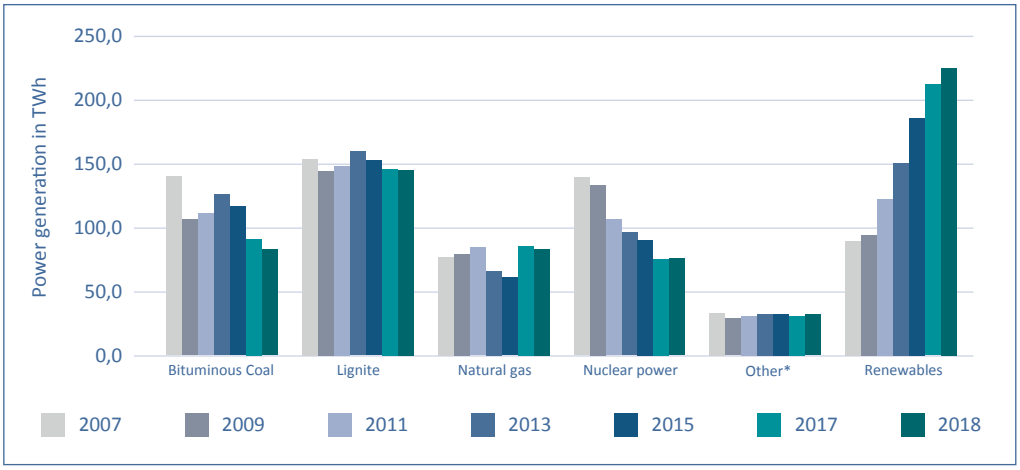

Figure 3: Power generation by energy source, 2007-2018 (own presentation using data from [7][11]) *including mineral oil and refuse incineration

3. High Levels of Power Generation and Exports

In 2017, Germany generated around 646 terawatt-hours of electricity [7] , some 83 of which were exported to other EU countries, while only 32 terawatt-hours were imported (see Figure 4). No other EU country supplies as much power to other Member States as Germany. This is because the additional, sometimes wildly fluctuating power generation from renewable energy sources can temporarily result in high levels of supply. Since some of the fossil fuel-fired power stations can only be operated **inflexibly** and some power plants continue to be operated even when there are high levels of supply of electricity from renewable sources in order to **ensure security of supply**, power trading prices drop as a result. This makes it attractive to other countries to import inexpensive electricity from Germany. Demand from foreign countries moreover prevents power prices from falling still further and making power generation from lignite and coal entirely unattractive. Accordingly, the additional renewable energy sources in the power mix have so far resulted in almost no reduction in generation from fossil energy carriers.

The export surplus of around 51 terawatt-hours in 2018 was three times as high as in 2010 [7]. In line with the "polluter pays" principle, all the emissions arising from power generation are included in Germany's CO_2-balance while the receiving countries' emission balances are unaffected. While it is true that exports cannot be directly associated with the individual generation technologies, if it is assumed that the exported power corresponds to the average German energy mix, some 25 million tonnes of CO_2 can be attributed to exported power in 2018, which is an increase of 17 million tonnes over 2010 [5][7].

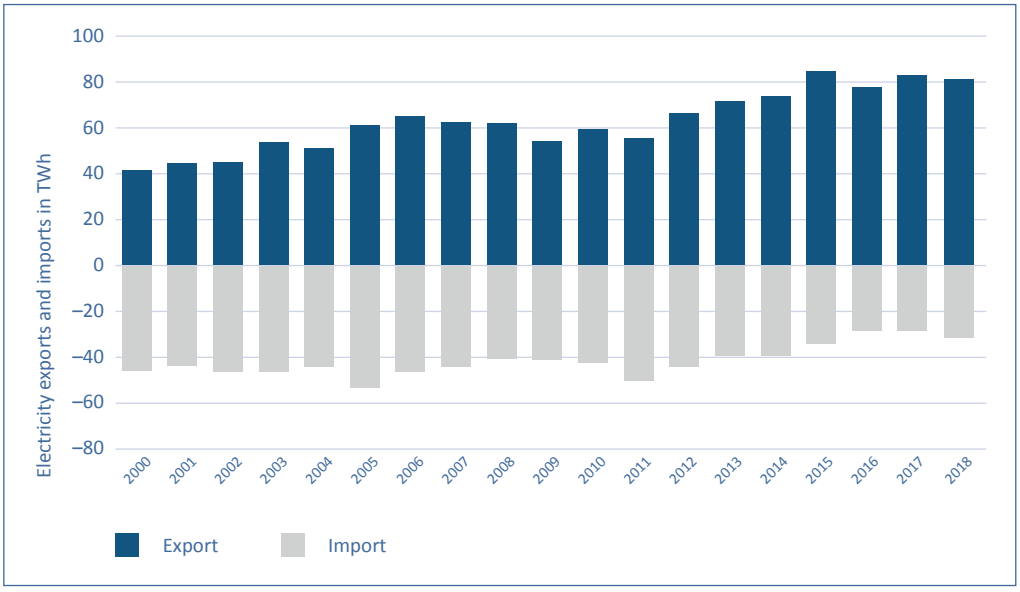

Figure 4: Power export and import trends in Germany, 2000-2018 (own presentation using data from [7][11])

Going Deeper:

What might the power supply look like in 2050? The **ESYS Position Paper** ***"Flexibility concepts for the German power supply in 2050. Ensuring stability in the age of renewable energies"*** describes various possibilities.

The **ESYS Position Paper** ***"Coupling the different energy sectors – options for the next phase of the energy transition"*** discusses how to provide climate-friendly options for the entire energy system comprising power generation, heating and transport.

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Contributors

ESYS-Board of Directors:
Prof. Dr Dirk Uwe Sauer (RWTH Aachen), Prof. Dr Christoph M. Schmidt (RWI – Leibniz Institute for Economic Research), Prof. Dr Carl Friedrich Gethmann (University of Siegen), Prof. Dr Karen Pittel (ifo Institute), Prof. Dr Indra Spiecker genannt Döhmann (Goethe University Frankfurt), Prof. Dr Eberhard Umbach (acatech)

ESYS-The Project Office:
Dr Berit Erlach, Achim Eberspächer, Dr Ulrich Glotzbach, Christoph Stemmler, Dr Cyril Stephanos, Julika Witte

The Academies' Project "Energy Systems of the Future"

The „Energy Systems of the Future" (ESYS) initiative is the strategy chosen by acatech – National Academy of Science and Engineering, the German National Academy of Sciences Leopoldina and the Union of the German Academies of Sciences and Humanities to provide impetus for the debate about the challenges and opportunities presented by the energy transition in Germany. Over 100 experts from science and research are working together in the Academies' Project in interdisciplinary working groups to formulate options for implementing a secure, affordable and sustainable energy supply.

The „In a Nutshell!" format

The compact „In a Nutshell!" publication format communicates scientific findings from the project in order to explain live issues relating to the energy system which are often raised in public debate without any solid scientific foundation. Graphs and diagrams illustrate the textual content. „In a Nutshell!" is published under the authors' responsibility and was drawn up by a group of ESYS members.

Contakt:

Dr Ulrich Glotzbach
Head of Project Office "Energy Systems of the Future"
Pariser Platz 4a, 10117 Berlin, Germany
phone: +49 (0)30 206 30 96-0 | e-mail: glotzbach@acatech.de
web: energiesysteme-zukunft.de/en

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German National Academy of Sciences Leopoldina
Jägerberg 1
06108 Halle (Saale)
Phone: +49 (0) 345 47239-600
Fax: +49 (0)345 47239-919
E-Mail: leopoldina@leopoldina.org

Berlin Office:
Reinhardtstraße 14
10117 Berlin

acatech – National Academy of Science and Engineering
Karolinenplatz 4
80333 München
Phone: +49 (0) 89 520309-0
Fax: +49 (0) 89 520309-9
E-Mail: info@acatech.de

Berlin Office:
Pariser Platz 4a
10117 Berlin

Union of the German Academies of Sciences and Humanities
Geschwister-Scholl-Straße 2
55131 Mainz
Phone: +49 (0) 6131 218528-10
Fax: +49 (0) 6131 218528-11
E-Mail: info@akademienunion.de

Berlin Office:
Jägerstraße 22/23
10117 Berlin