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Short communication

Blown by the wind. Replacing nuclear power in German electricity generation

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ABSTRACT

Only three days after the beginning of the nuclear catastrophe in Fukushima, Japan, on 11 March 2011, the German government ordered 8 of the country's 17 existing nuclear power plants (NPPs) to stop operating within a few days. In summer 2011 the government put forward a law – passed in parliament by a large majority – that calls for a complete nuclear phase-out by the end of 2022. These government actions were in contrast to its initial plans, laid out in fall 2010, to expand the lifetimes of the country's NPPs.

The immediate closure of 8 NPPs and the plans for a complete nuclear phase-out within little more than a decade, raised concerns about Germany's ability to secure a stable supply of electricity. Some observers feared power supply shortages, increasing CO_2-emissions and a need for Germany to become a net importer of electricity.

Now – a little more than a year after the phase-out law entered into force – this paper examines these concerns using (a) recent statistical data on electricity production and demand in the first 15 months after the German government's immediate reaction to the Fukushima accident and (b) reviews the most recent projections and scenarios by different stakeholders on how the German electricity system may develop until 2025, when NPPs will no longer be in operation.

The paper finds that Germany has a realistic chance of fully replacing nuclear power with additional renewable electricity generation on an annual basis by 2025 or earlier, provided that several related challenges, e.g. expansion of the grids and provision of balancing power, can be solved successfully. Already in 2012 additional electricity generation from renewable energy sources in combination with a reduced domestic demand for electricity will likely fully compensate for the reduced power generation from the NPPs shut down in March 2011.

If current political targets will be realised, Germany neither has to become a net electricity importer, nor will be unable to gradually reduce fossil fuel generated electricity. Whether the reduction in fossil fuel use will be sufficient to adequately contribute to national greenhouse gas mitigation targets significantly depends on an active policy to promote electricity savings, continuous efforts to increase the use of renewables and a higher share of natural gas (preferably used in combined heat and power plants) in fossil fuel power generation.

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1. Introduction

Less than a week after the beginning of the nuclear catastrophe in Fukushima, Japan, on 11 March 2011, the German government ordered 8 of Germany's 17 existing nuclear power plants (NPPs) to stop operating for an initial 3-month evaluation period. These were the 7 oldest NPPs still in operation in Germany at that time plus the NPP 'Krümmel' in northern Germany, which had previously suffered from various technical problems. Two of these 8 NPPs had not been in operation since 2007 and 2009 respectively due to technical reasons. In the summer of 2011 a law came into force that finally terminated the operating licenses of those 8 plants, with an instruction for the remaining 9 NPPs to be closed down successively by the end of 2022. In making this decision, the government basically returned to the nuclear phase-out plan that had originally been implemented by a previous government in 2002 but had been modified by the current – then newly elected – government in October 2010, granting an average of 12 additional operating years to all 17 NPPs.[1]

The decision to shut down 8 NPPs immediately and to phase-out the remaining NPPs in the years to come raised concerns about Germany's ability to secure a stable supply of electricity. Critics warned of rising electricity prices and a considerable increase in Germany's fossil fuel based power generation, with related increases in CO_2 emissions. Some people also predicted that Germany would become a significant net importer of electricity from neighbouring countries, including nuclear electricity from France and the Czech Republic.

This paper does not aim to analyse what would have happened to CO_2 emissions and electricity prices if the decisions to extend the lifetimes of the existing NPPs had not been reversed after the Fukushima accidents. Rather, it attempts to provide (a) a preliminary assessment of the immediate changes brought about in the electricity market following the shut down of 8 NPPs in March 2011 and (b) a projection showing how the decrease in nuclear generation will be compensated for until 2025 and what effects this may have on electricity prices and CO_2 emissions.

2. Methodology

To analyse the short-term effects of the instant loss of around 40% of the country's nuclear power capacity, we take the electricity production of the year 2010 as a reference to reflect the typical electricity market situation in an annual period unaffected by the phase-out decision.[2] In 2010, 15 of the 17 nuclear power plants (NPPs) produced 141 TWh of gross electricity.[3] Official energy projections in 2010, which analysed the effects of the prolongation of nuclear lifetimes (BMWi, 2010; Nagl et al., 2011),[4] predicted similar levels of production until 2020. Renewables contributed 103 TWh in 2010. Net electricity exports were at 18 TWh, a level that had been relatively constant since 2006 (14–22 TWh/a).

Our comparison comprises three stages. Firstly, in Section 3 we examine the changes in the German electricity system with regard to both the short-term effects from 2011 to 2013, as well as the longer-term outlook to 2025 (a few years after the completion of the nuclear phase-out). For the second stage, we use the most recently available key energy scenarios and political targets in Section 4 to provide one 'optimistic' and one 'pessimistic' scenario on the replacement of nuclear electricity and its effects on CO_2 emissions until 2025. Finally, in order to evaluate the effects of the nuclear phase-out on electricity prices, we discuss in Section 5 the results of several modelling studies conducted in recent years. Section 6 concludes.

3. Changes in power generation due to nuclear phase-out

3.1. *Short-term effects until 2013*

Based on preliminary statistical data on power generation in 2011 (BDEW, 2011, 2012a; AG Energiebilanzen, 2012) and on the typical production over the previous decade of the nuclear power plants still in operation (IAEA, 2012), we estimate that the permanent shutdown of the eight NPPs in March 2011 resulted in a potential 'loss' of nuclear electricity generation of 32.5 TWh in 2011 and will result in a loss of around 41 TWh/a in both 2012 and 2013.[5] Relating the loss of nuclear power generation of the years 2012 and 2013 to actual electricity generation in 2010, this loss is equivalent to almost 30% of nuclear power generation and to about 7% of all electricity generation in Germany. After the permanent shutdown of the eight NPPs, the loss of nuclear power production was mostly compensated for by a combination of increased renewable electricity generation, reduced net electricity exports and reduced domestic electricity demand, as the following figure shows.

Electricity generation, net electricity exports and domestic electricity demand in Germany show typical seasonal patterns. Therefore the picture of what has changed in German electricity supply and demand since Fukushima becomes clearer when the same periods of different years are compared. This serves the purpose of eliminating seasonal effects, which can otherwise mask the de facto changes. Based

[1] For more details on Germany's nuclear policy before and after Fukushima, see e.g. Wittneben (2011), Jahn and Korolczuk (2012) or Bosman (2012).

[2] As levels of electricity generation, as well as net exports, traditionally fluctuate significantly on a seasonal basis it is important to either look at entire years instead of single months when comparing periods before and after the shutdown of NPPs or to compare a certain period of a year only with the same period of another year.

[3] Annual electricity generation from nuclear power in 2010 was at a similar level as in the years between 2007 and 2009 (135–149 TWh/a).

[4] Those scenarios of the study with lifetime extensions for NPPs predicted production levels of about 149 TWh for 2020 followed by a decline in later years.

[5] In this paper we use 2010 as the reference year for the analysis. In 2010, 15 NPPs had a gross production of 141 TWh (BDEW, 2011). 2 NPPs were out of operation throughout the entire year for technical reasons. Both of these are among the 8 NPPs that were permanently shut down in 2011.