Climate Report
Research on the economics of climate change

cdc climat research | Caisse des Dépôts GROUP

N°7 • July 2011

German nuclear phase-out: Implications for the EU ETS

The disaster in Fukushima on March 11th 2011 led to a renewed questioning on nuclear power in a number of European countries, including Germany. On July 8th, the German Parliament approved the shutdown of all of the country's nuclear reactors by 2022. Given that nuclear electricity generation does not emit any CO_2, we expect this decision to increase German emissions from electricity generation from 324 to 468 $MtCO_2$ by 2020, which will lead to a rise in the price of European CO_2 allowances (EUA).

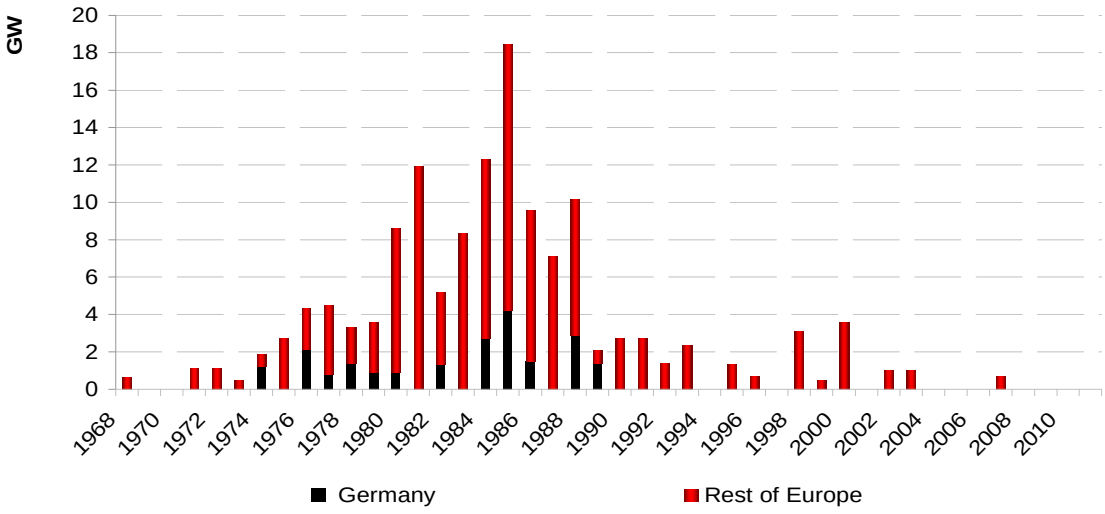
Background: nuclear energy in Europe and Germany

Ageing nuclear power plants at the heart of Europe's energy mix

The European Union is the world region where nuclear power has the largest weight in electricity generation. 143 out of 440 active nuclear reactors are located within its boarders and generate 27% of the region's electricity.

Most European nuclear power plants were built before 1990 (see Figure 1). The development of nuclear power then slowed, due to the fall in the price of fossil fuels and to the wariness towards atomic energy that emerged following the accident in Chernobyl. Given that around 25% of the installed generation capacity could reach the end of its life by 2020[1], the issue of whether to renew Europe's nuclear power generation capacity was still up for discussion.

Figure 1 - European nuclear power generation capacity broken down by start-up date

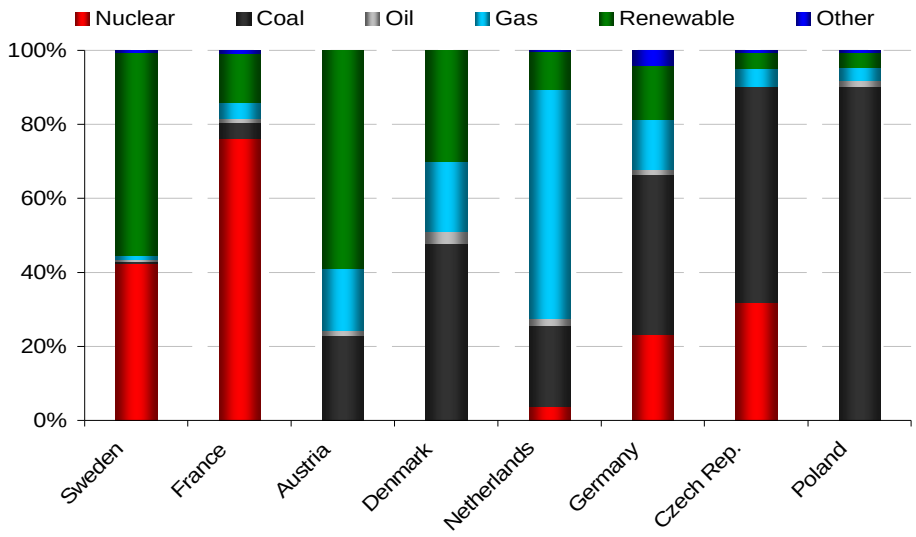


Source: PRIS-IAEA database

A revival of the industry had nonetheless been announced. The rise in the price of fossil fuels and the fight against climate change were expected to ensure the competitiveness of new reactors, which were more expensive, but were also safer and more efficient. Despite these factors, only 4 out of the 64 reactors currently under construction world-wide are located in Europe.

Nicolas Berghmans, Research fellow, nicolas.berghmans@cdcclimat.com

Figure 2 - Breakdown of electricity generation by primary energy source for Germany and neighbouring countries in 2008



Source: Eurostat

Lastly, it must be remembered that the importance of nuclear power in the energy mix varies widely in Europe, depending on the country. In this respect, Germany has a power generation among the most CO_2-emitting of the Western European countries, due to the significance of its coal consumption. However, the German electricity sector is less carbon-intensive than those of its Eastern neighbours (Poland and the Czech Republic).

Nuclear phase-out in Germany: an old chestnut

In Germany, a nuclear phase-out has been intensively debated for several decades. A strong anti-nuclear opinion has gradually developed in the country: in 2009, 52% of Germans wanted to see nuclear energy's share reduced in the future (compared with 34% in Europe), which makes Germany the most hostile European country to nuclear power among those hosting nuclear power plants on their territory[2]. In 2002, the ruling SPD-Green political coalition enacted a law planning a gradual exit from nuclear power in which the last nuclear reactor was meant to shut down in 2021.

The debate reappeared during the 2009 legislative elections. The Russo-Ukrainian crisis, which had caused a partial interruption in gas supplies to Western Europe, brought the issue of the security of energy supplies back to the forefront. In late 2010, the conservative (CDU/CSU) and liberal (FDP) coalition that won the elections decided to extend the life of the 17 reactors that were still active from 8 to 14 years, by amending the law on nuclear power. These extensions formed an integral part of the German strategy to reduce greenhouse gas emissions by 40% by 2020 compared with 1990. This strategy viewed nuclear energy as a "bridging technology" before renewable energies, which are currently more expensive[3], became widely available in the future.

News: Germany's "new" nuclear phase-out

A total phase-out by 2022

On March 11th of this year, a devastating tsunami struck the east coast of Japan, causing the cooling systems of three reactors at the Fukushima-Daichi power plant to fail, and the highest radioactive emissions since the Chernobyl nuclear disaster in 1986. In the wake of the incident, on March 14th, Chancellor Angela Merkel announced a three-month shutdown of seven nuclear reactors built before 1980 in order to enable safety checks to be carried out, as well as a moratorium on the 2010 law that extended the life of Germany's nuclear reactors. Although all Member States issued a call to strengthen safety checks in a

coordinated manner[4], and in some cases temporarily suspended their development programmes for new power plants, no other European country took the view that shutting down its reactors was necessary. Germany was also the only country to set up an "Ethics Committee" in March, in order to assess the social acceptability of exiting from nuclear power.

On May 30th this year, after receiving the report on the safety of its nuclear power plants and the Ethics Committee's report, the German Government suggested a gradual exit from nuclear power by 2022. The draft law of June 6th, which was adopted by Parliament on July 8th, sets out the terms and conditions of this change in energy strategy.

What does the draft law of June 6th say?

Since 2002, the German nuclear act has set out authorised amounts of electricity productions from January 1st 2000 onwards that correspond to a "normal" usage period of 32 years for each active reactor. These generation amounts are transferable, in whole or in part, from one plant to another, provided that the most recent plant of the two is the one that receives the production quota. It was therefore possible for a reactor to operate for more than 32 years if its output had been lower than forecast by the law, or if it had received from another reactor a share of its production quota. In late 2010, the life of the reactors was extended through an increase of these production quotas.

The draft law suggests abolishing the generation amounts awarded in late 2010 and setting explicit limit shut-down dates for each reactor. The seven reactors stopped since mid-March5 will be shut down immediately, together with the Krümmel reactor, which was shut down in 2009 following repeated breakdowns. The cut-off dates for the nine remaining reactors will be staggered until December 2022. It should be noted that the unused6 production quotas awarded to the eight reactors already shut down can be transferred to reactors that are still active, which should enable them to operate until their cut-off date.

While reaffirming its 2020 targets for GHG emissions (-40% compared with 1990), for renewable energies development (35% of the electricity used in 2020) and for energy efficiency (-10% less electricity used compared with 2008), the draft German law amends or creates seven other pieces of legislation aimed at accelerating the country's energy transition7. The building and renovation of renewable energy installations and the development of the electricity network will be made easier by more flexible administrative procedures and increased feed-in tariffs. A plan to assist the development of efficient thermal fossil fuel power plants will also be included, although their generation capacity will be limited to 10 GW, and access to subsidies will be banned for the four major German electric companies. Although the maintaining of the original target for electricity from renewable sources leads us to believe that Germany will offset its nuclear electricity by electricity from fossil fuels, the aimed acceleration in the deployment of renewable energies should allow those energies to play a role.

In terms of energy efficiency, strengthening the system for granting preferential loans for building renovation is the only issue still under discussion, as the Federal Government and the Länder disagree on the financing conditions. Finally, all the income generated by Phase III EUA allowance auctions will go to the German climate fund, which has been set up in order to fund the development of renewable energies and energy efficiency policies8.

Analysis: Implications for the EU ETS

In 2010, 22.6% of the electricity generated in Germany was from nuclear power. The shutdown of the eight nuclear reactors deprives Germany *de facto* of 7 GW, i.e. 37% of its nuclear generation capacity[9].

There are two short-term options to replace nuclear electricity: an increase in the electricity generated by power plants in Germany, or recourse to electricity imports from neighbouring countries. In the longer term, the coming on line of new production capacity will need to be taken into account.

Emissions will increase by 2020

In the short term, Germany can only make up for the "lost" nuclear electricity generation through combustion thermal power plants or electricity imports. Renewable electricity generation installations are already running at full capacity and their output can only be increased by investment over the long term. Our estimates are based on replacing the "lost" German nuclear electricity output for 2011-2013 with the current German fossil-fuel mix, using an emission factor of 0.88 tCO_2 per MWh, based on the 2010 data provided by the Association of German Utility Companies (see Appendix 1).

We have introduced variations to this emission factor from 2014 onwards, depending on the gradual substitution of nuclear power by new investments. New investments fully offset the lost nuclear power generation from 2020 onwards under all three scenarios.

We have drawn up three scenarios for replacement technologies:

- a "high emissions" scenario, where nuclear electricity is replaced by electricity from coal-fired power plants;
- an "average emissions" scenario, where combined gas turbines make up the shortfall;
- a "low emissions" scenario, where 50% of the replacement electricity is from renewable sources, and 50% is from combined gas turbines.

The emission factors selected for these new installations are 0.795 tCO_2 per MWh for coal-fired power plants and 0.398 tCO_2 per MWh for gas, which correspond to the best available technologies.

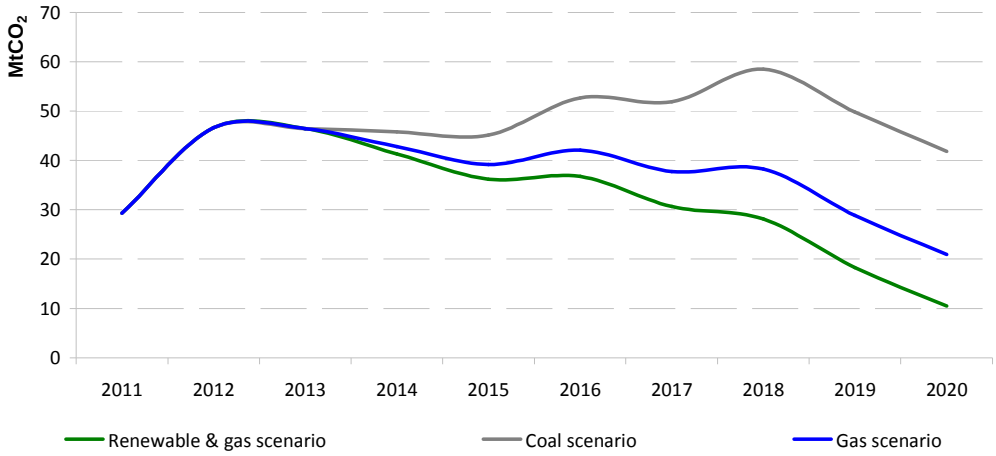
Table 1 - estimated CO_2 emissions caused by the exit from nuclear power

Year		2011-2012	2013-2020	2020
Electricity generation to be replaced (TWh)		86	468	53
Average emission factor for the replacement electricity generation (tCO_2 per MWh)	Coal scenario	0.88	0.84	0.80
	Gas scenario	0.88	0.63	0.40
	Renewable & gas scenario	0.88	0.53	0.20
Additional emissions ($MtCO_2$)	**Coal scenario**	**76**	**392**	**42**
	Gas scenario	**76**	**296**	**21**
	Renewable & gas scenario	**76**	**248**	**10**

The electric generation to be replaced is estimated according to load factors for each reactor presented in Annex 2. The pace of new investments penetration will remain the same over the period between 2014 and 2020: 1/7th of the "lost" electricity generation will be offset by the new technology in the first year, 2/7ths in the second, etc.

In the last two years of Phase II of the EU ETS, the resulting additional emissions are expected to amount to 76 $MtCO_2$, i.e. an increase of 13% in the German electricity sector's emissions, using 2010 as a benchmark. In Phase III, the amounts vary between 248 to 392 $MtCO_2$, depending on how the replacement technologies develop. Overall, the exit from nuclear power is expected to create between 324 and 468 $MtCO_2$ up until 2020, increasing the demand for European CO_2 allowances.

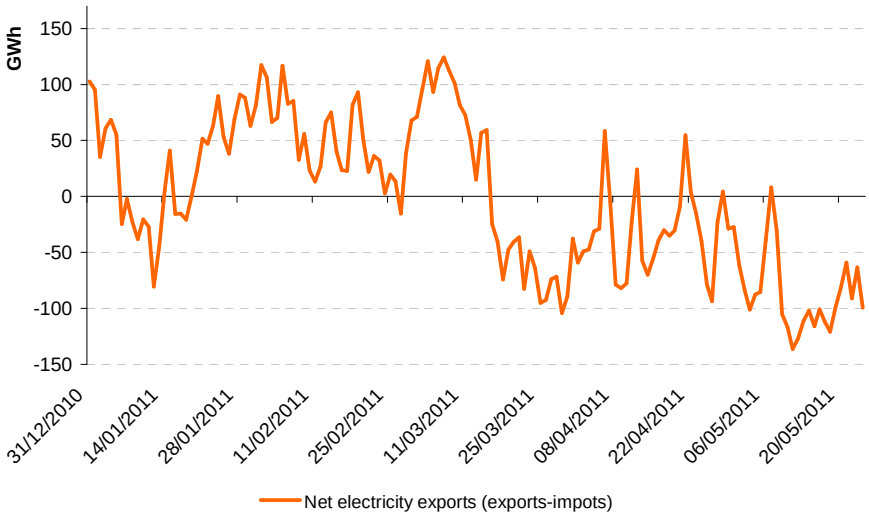
Figure 3 - Additional emissions by year based on various scenarios



Taking into account electricity imports

Germany's interconnection capacity with its neighbours is around 15 GW. It can import up to 6 GW from the French electricity grid, and 3 GW from the Netherlands on an ongoing basis. Since the shutdown of the seven reactors in mid-March, Germany's position in the international electricity market has switched from that of a net exporter to the rest of Europe to that of a net importer (Matthes *et al*., 2011). A comparison between Germany's net exports in 2011 and 2010 shows that the German grid was able to access an additional 3.2 GW[10] on average for the period between March 19th and May 25th 2011, either through importing electricity generated abroad, or through reducing its exports. Compared with the net loss of nuclear capacity, which amounted to 5.2 GW excluding the Krümmel and Brunsbüttel reactors, which had already been shut down, Germany would therefore have been able to offset two thirds of its lost production by altering the structure of its cross-border exchanges.

Figure 4 – German net daily electricity exports since January 1st 2011

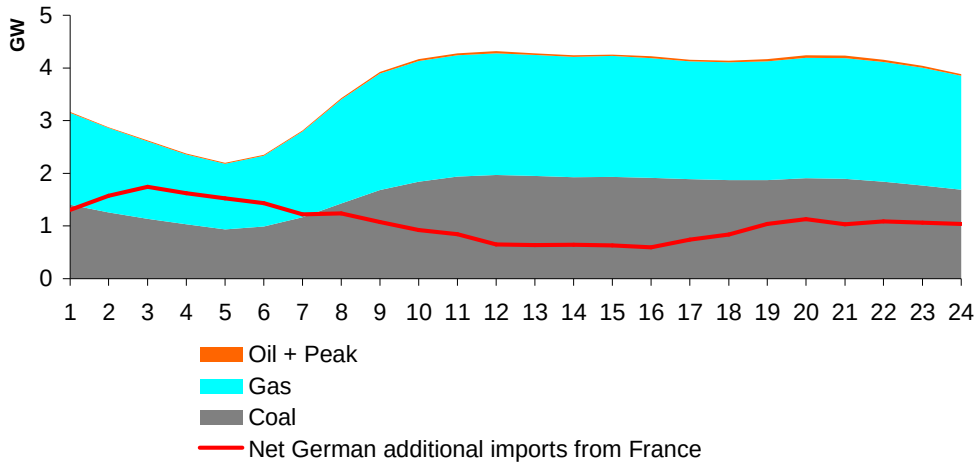


Source: ENTSOE transparency

Although Germany can import electricity from other countries, this does not necessarily mean that the increase in forecast CO_2 emissions will be lower. It all depends on the power plants that will be used to meet German demand. Electricity power plants are typically started up according to their marginal generation costs, in ascending order, i.e. the last power plants to be brought online are usually thermal power plants that emit CO_2. In France, an increase in the demand for electricity from Germany will therefore lead to an increase in the electricity

generated by gas, oil or coal-fired power plants, if France's nuclear reactors are already running at full capacity. Figure 5 shows that the additional demand on French power plants from Germany compared with 2010 is usually covered by the generation of electricity from fossil fuels[11].

Figure 5 - Average hourly additional net German imports from France and French CO_2-emitting electricity generation (working days only)



NB: Net additional imports = Net 2011 imports - Net 2010 imports (period between March 19th and May 25th)

Source: ENTSOE transparency, RTE

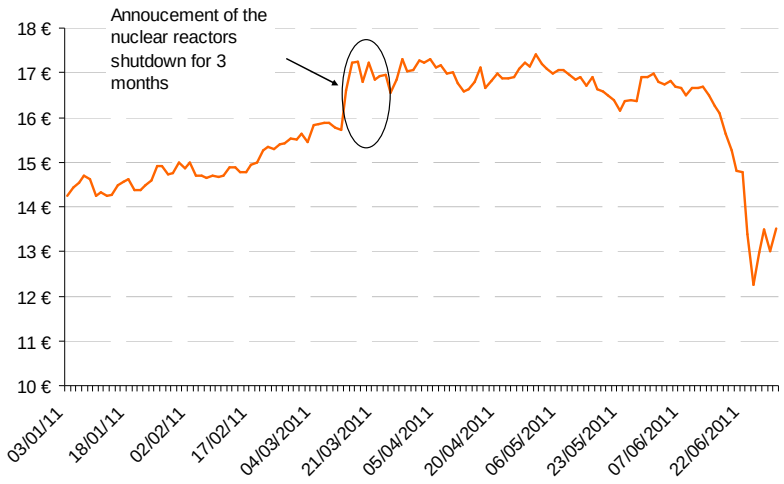
When compared with hourly generation by fuel-type in France between March 19th and May 25th, only 20% of the additional electricity imported from France by Germany can be considered as nuclear electricity. Meanwhile, a change has also been observed in the trade balance with the Czech Republic and Poland (Matthes *et al., 2011*), where the electricity mix are more carbon-intensive than in Germany (see Figure 2). Finally, the winter period is expected to lower the availability of nuclear electricity, due to higher electricity demand.

While there is evidence that the shutdown of the reactors in mid-March has altered the electricity exchange balance in Europe, the contribution made by nuclear electricity generated outside Germany towards replacing the electricity "lost" in Germany appears limited. Recourse to the international electricity market is therefore not expected to mitigate the increase in CO_2 emissions to any great extent, but rather to contribute to their geographical dispersal, with the increase in generation split across the European countries that interconnect with the German grid.

Upward pressure on the EUA price

German (or European) thermal power plants that have increased their short-term generation are mostly included in the EU ETS. Greater use of these plants will therefore increase the demand for allowances, and put upward pressure on the European price for a tonne of CO_2. When the seven reactors were shut down in mid-March, the December 2011 EUA price soared by €1.29 per tCO_2 (see Figure 6). A survey of analysts published in *Point Carbon* showed that they were expecting an average EUA price of €43.00 in 2020, in the event of an early shutdown of the German nuclear reactors, compared with €35.00 if the German reactors were started up again and run as planned before Fukushima[12]. Through an increase in the price of emission rights the European trading scheme will encourage offsetting the additional emissions resulting from the German nuclear phase-out by additional abatement in other installations included in the EU ETS, thus reducing its environmental consequences.

Figure 6 – EUA price for delivery in December 2011 since the beginning of the year



Source: ICE

Next steps: new German energy strategy and the impact on discussions regarding the EU ETS

Germany combined its decision to exit from nuclear power with a review of its energy policy drawn up in late 2010 which is mainly intended to accelerate the development of renewable energies. Nonetheless, the security of supply to the grid and the political will to refrain from importing electricity will result in an increase in the German electricity sector's CO_2 emissions over the short and medium term, and put upward pressure on the price of European allowances. It is unlikely that Germany will backtrack, given that there is now a broad political consensus on this issue. When considering the future of the EU ETS, two points deserve to be highlighted:

1) Germany is the first country that has clearly set out what it will do with the allowance auction income from 2013 onwards. By dedicating most of that income to energy efficiency and renewable energy policies, the country is acknowledging the important role that the carbon market can play in financing an energy transition.

2) Germany's new energy strategy is a priori unlikely to be followed by other Member States. Switzerland and Italy have undoubtedly given up their plans to build new reactors, but their programmes were intended to deliver new capacity after the end of Phase III of the EU ETS in 2020. The strengthening of safety requirements could result in delays; however, many European countries have reiterated their intention to continue their nuclear programmes (including France, the United Kingdom, the Czech Republic and Poland).

The upward pressure on emissions from the electricity sector is therefore likely to remain limited, and represent less than 50% of the 500 to 800 million EUAs that the Commission has suggested setting aside. This amount, which is mentioned as part of its roadmap for moving towards a low-carbon economy by 2050 published in March 2011 was meant to enable the EUA price to be maintained by scrapping the Phase II surplus. Moreover, the fall in the price recorded in June, which was, among other things, the result of the publication of an energy-efficiency directive proposition, has more than offset the price surge seen in mid-March. At a time when questions are being asked about the appropriateness of the EU ETS emission ceiling for the EU's long-term strategy by 2050 (-80% of GHG emissions by then), the German exit from nuclear power should not be a disruptive factor in current discussions regarding the EU ETS' contribution to the achievement of the European environmental goals.

Further reading:

- *Bode (2009) "Nucs down in Germany – prices up in Europe?" Energy Policy 37,7, pp. 2492-2497*
- BDEW, Energiedaten: *http://www.bdew.de/internet.nsf/id/DE_Energiedaten*
- *PRIS database on the IAEA website: http://www.iaea.org/programmes/a2/*
- *ENTSOE-transparency : http://www.entsoe.net/home.aspx*
- *Eurostat, electricity generation data: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database?_piref458_1209540_458_211810_211810.node_code=ten00087*
- *Matthes et al. (2011) "Atomstrom aus Frankreich? Kurzfristige Abschaltungen deutscher Kernkraftwerke und die Entwicklung des Strom-Austauschs mit dem Ausland", Öko-Institut : http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/KKW-Ausstieg%20und%20Stromimporte%20v5final.pdf*
- *Draft law of June 6th on Germany's exit from nuclear power: http://www.bmu.de/energiewende/doc/47467.php*
- *RTE, generation data: http://fondation.rte-france.com/lang/fr/visiteurs/vie/telecharge.jsp*

Annex 1 – CO2 emissions for each kind of fossil-fuel electricity generation process in Germany

Fossil fuel	2010 generation (TWh)	Emission factor ($MtCO_2$/MWh)	Average usage hours (2007)	Replacement mix share
Lignite	140.5	1.21	6,000	30.73%
Coal	147.0	1.03	6,000	29.37%
	84.5	0.50	3,170	35.78%
Oil	7.5	0.76	1,500	4.12%
		Replacement mix emission factor		**0.88**

Source: BDEW Energiebilan 2010. The share of the replacement mix is adjusted according to the availability of each type of power plant, calculated on the basis of the average usage hours supplied by BDEW.

Annex 2 – German nuclear reactors ranked by planned shutdown date

Reactors in service at the beginning of 2010	Net output (MW)	Commission date	Load factor*	Estimated shutdown date (2010 Law)	Shutdown date (draft law of June 6th)
BIBLIS A	**1,167**	**26/02/1975**	**84%**	**Jan-20**	**Mar-11**
NECKAR 1	**785**	**01/12/1976**	**93%**	**Jan-19**	**Mar-11**
BIBLIS B	**1,227**	**31/01/1977**	**82%**	**Mar-20**	**Mar-11**
BRUNSBUTTEL	**771,**	**09/02/1977**	**76%**	**June-21**	**Mar-11**
ISAR 1	**878**	**21/03/1979**	**89%**	**June-19**	**Mar-11**
UNTERWESER	**1,345**	**06/09/1979**	**84%**	**July-20**	**Mar-11**
PHILIPPSBURG 1	**890**	**26/03/1980**	**89%**	**mai-20**	**Mar-11**
KRUMMEL	**1,346**	**28/03/1984**	**0%**	**July-09**	**Mar-11**
GRAFENRHEINFELD	1,275	17/06/1982	87%	Mar-27	**Dec-15**
GUNDREMMINGEN B	1,284	19/07/1984	80%	Aug-27	**Dec-17**
GUNDREMMINGEN C	1,288	18/01/1985	80%	Apr-28	**Dec-21**
GROHNDE	1,360	01/02/1985	90%	July-30	**Dec-21**
PHILIPPSBURG 2	1,392	18/04/1985	86%	Dec-29	**Dec-19**
BROKDORF	1,410	22/12/1986	85%	Dec-30	**Dec-21**
ISAR 2	1,400	09/04/1988	84%	Nov-31	**Dec-22**
EMSLAND	1,329	20/06/1988	87%	Nov-32	**Dec-22**
NECKAR 2	1,305	15/04/1989	87%	Dec-33	**Dec-22**

**Load factor = Volume generated over a period t (MWh/net output (MW) * number of hours in period t). The load factors used in the estimate were derived from the output volumes allocated to each reactor in late 2010 for 8 or 14-year extensions.*

Source: CDC Climat, based on the draft law of June 6th amending the law on the peacetime use of German nuclear power and the PRIS-IAEA database

[1] Assuming a 40-year life for all nuclear reactors.

[2] Special *Eurobarometer* 324 on "Europeans and Nuclear Safety", March 2010, European Commission. Only Austria (66%) and Greece (65%) are more hostile than Germany on this issue, although neither country has any nuclear power plants on its territory.

[3] Energy *Concept: for an Environmentally Sound, Reliable and Affordable Energy Supply*, German Environment Ministry, September 2010.

[4] See the European Council of March 24th and March 25th 2011.
[5] Between now and September, the Federal Electricity Grid Agency can decide to keep some of these reactors in reserve, in order to remedy a potential winter electricity shortfall.
[6] Together with an allowance granted to RWE as compensation for the closure of the Mülheim-Kärlich nuclear plant after a few months.
[7] See: http://www.bmu.de/energiewende/doc/47465.php
[8] Initially, the fund was meant to be financed by a tax on nuclear fuel, which was opposed by German electricity generators. The contribution of the auction income will offset the loss of revenue from that tax following the early closure of the nuclear reactors.
[9] The Krümmel power plant, which was shutdown since July 2009, was not included in this calculation; although its final decommission was included in the recent decisions, it can be considered as a consequence of its repeated faults.
[10] This outcome may be partly due to other factors than the shutdown of the German nuclear plants (e.g. a difference in the increase in electricity demand in Germany compared with other countries).
[11] Only bilateral exchanges between France and Germany are considered here.
[12] "German nuclear report to boost prices: analysts", *Point Carbon*, May 25th 2011.