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Is the German energy transition sustainable?

In 2011, Germany began a radical energy policy, or *"Energiewende"*, with the aim of completely abandoning nuclear power by 2022 and then achieving an 80-95% reduction in the country's greenhouse gas emissions by 2050. By this date, the country will therefore have to be producing its electricity almost completely without the use of gas, oil and coal, having replaced 80% of these sources with renewable energies.

Germany is a rich country with one of the most competitive industries in the world. Its environmental commitments have been clearly stated and *Energiewende*, which is widely discussed throughout the country, has so far seen strong support from the population, despite the expected increases in the price of electricity which, however, is already almost twice as expensive as in France. Germany therefore seems to hold the winning cards required to successfully implement its energy transition.

However, many difficulties need to be overcome if this energy policy is to succeed, such as the development of the national power grid, the cost and financing of the necessary investments, improved electricity storage techniques, the acceptability of the planned increases in the price of electricity or the financial difficulties experienced by solar panel manufacturers as a result of the sharp reduction in subsidies and competition from Asia. In addition, recent political dissent within the government regarding the measures implemented to achieve its stated goal has slowed down the federal decision-making process on this matter.

Finally, Germany's decision is not without consequences for its European neighbours. It is upsetting and weakening the supply and demand balance of the European energy system and putting some operators in a difficult position. The eyes of all energy world observers are therefore riveted on the changes taking place in Germany, because they will have significant consequences for the entire European Union, and even beyond. ■

THE CHALLENGES

After several changes of direction in a decade of energy policy, the Fukushima disaster acted as a catalyst for the German government, which has now decided to permanently withdraw from the nuclear industry, a choice that appears to be irreversible. Although nuclear energy accounted for only 24% of the electricity consumed by our neighbour before its phase-out, it will have to replace or refrain from consuming at least 150 TWh by 2022, whilst ensuring a secure supply and meeting its environmental commitments.

Abandoning nuclear energy represents only part of a wide-ranging package of measures designed to deliver the German energy policy or *Energiewende* by 2050. By this date, fossil fuels, coal, gas and oil will have practically disappeared from the energy mix in favour of renewable energy sources. This particularly ambitious action plan also provides for a significant decrease in energy consumption and an 80% to 95% reduction in greenhouse gas emissions by 2050.

What are the economic, technological and societal challenges Germany will have to face before it can deliver its successful energy policy? How does *Energiewende* fit into the European energy policy at a time when European cooperation in this field is becoming increasingly essential?

After making an initial assessment of the German energy mix and describing the *Energiewende* objectives (I), this policy brief provides an analysis of its impact on the electricity sector (II), examines the main difficulties to be overcome and therefore the chances of success of an energy policy based mainly on renewable energies (III), not to mention the question of costs (IV) and its consequences for its European neighbours (V).

THE AMBITIOUS GOAL OF *ENERGIEWENDE:* STOP USING NUCLEAR POWER AND ALSO, ULTIMATELY, FOSSIL FUELS

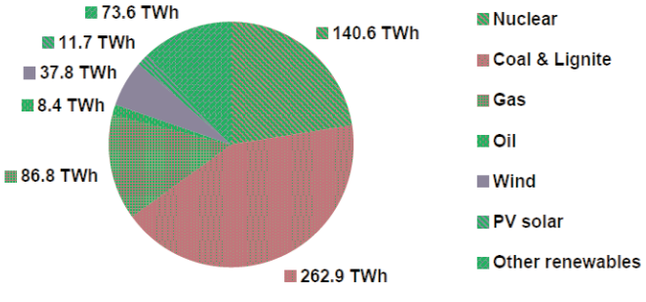
The present German energy mix is mainly based on fossil energies

Denser and more highly populated, Germany differs from France in its economic structure (the high added value of industry) and the composition of its energy mix. The share of coal in the Germany energy mix is still considerable and the gas share a little higher than in France for thermal and electrical applications, which results in significant greenhouse gas emissions (a German household emits more CO_2 than a French one: In 2010, the final energy consumption stood at 216 Mtoe[1], evenly distributed among the industrial, transport and residential sectors.

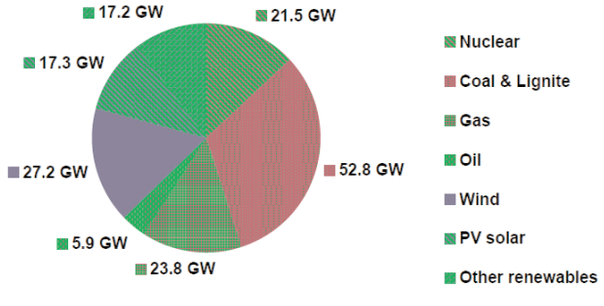
Pie chart 1

Power generation and installed capacities in Germany[2], 2010

Pie chart 1a - Power generation by sector



Pie chart 1b - Installed capacities by sector



Source: BMWi

(1) Million tons of oil equivalent. 1 toe equals 11.7 MWh.

(2) kW, MW and GW measure the power, i.e. the capacity of a facility. kW/h, MWh, GWh and TWh are units measuring the energy produced. A 1 MW power plant operating for 1 hour therefore produces 1 MWh.

The year 2011 is not really representative of the German electrical network, because it experienced a partial reduction in nuclear generation and growth in the production of renewables at the same time. In addition, the BMWi[3], which is responsible for producing the official energy sector statistics, has, to date, only supplied the 2011 data for renewable energies. In 2010, the last year before the phase-out, Germany produced 622 TWh of electricity, i.e. almost 15% more than France. Coal, which prior to 1973 accounted for almost three quarters of power generation, saw its share gradually reduced, but remains the major source of energy with 42%. Nuclear power, the second largest energy source, accounted in 2010 for almost 23% of production, for only 14% of capacity, with this type of energy serving as a base load supply[4]. Gas accounted for 13.5% of fossil fuel production, which represented 60% of the electricity mix in 2010.

Energiewende: very ambitious short- and medium-term objectives

As early as September 2010, the German government published a comprehensive action plan called the Energy Concept or *Energiekonzept,* defining the national energy guidelines[5] until 2050, as well as more than 140 measures:

- **Development of renewable energies**: renewable energies should account for 18% of the final energy consumption in 2020 and 60% in 2050. These percentages should respectively be 35% and 80% for power generation.
- **Reduction in energy demand**: for all the sectors and compared with 2008, it should be 20% in 2020 (primary energy) and 80% in 2050, 10% and 25% for electricity consumption and 20% and 80% for heat demand in buildings.
- **Increase in energy efficiency:** energy intensity[6] should decrease by 2.1% per annum.
- **A 40% reduction in greenhouse gas emissions** by 2020, 55% by 2030 and 80-95% by 2050 (in comparison to the 1990 level). In 2011, they were reduced by 24% (see later).

After the Fukushima disaster, **these objectives were supplemented by a decision to accelerate the phasing out of nuclear power plants** (initially planned for 2036). A law was passed, stipulating that the eight reactors that had been shut down would not be restarted and that the remaining nine would be shut down by 2022. Several other documents redesigning the legal framework of the German energy sector were adopted by parliamentary bodies, such as the amendment to the Renewable Energy Sources Act *(Erneuerbare-Energien-Gesetz) of* 28 July 2011. All the ensuing measures strive to achieve these four ambitious previously determined objectives and mark a real "energy turning point" or *Energiewende.*

The nuclear energy phase-out is already half completed

Germany has always been one of the most reticent European countries with respect to the use of nuclear technology, despite its previous industrial experience in this sector[7]. The importance of the coal industry, the influence of certain philosophers[8] immediately after the war and the soviet nuclear threat[9] all contributed to the dawn of a powerful environmental movement in Germany that was opposed to civilian nuclear power. In 2001, under the Schröder (SPD-Green) government, this opposition culminated in the adoption of a first law providing for a nuclear phase-out (setting 2021 as the date when the last German nuclear power plant was to be shut down). A survey carried out in June 2011[10] showed that this opposition

(3) The BMWi, *Bundesministerium für Wirtschaft und Technologie*, Federal Ministry of Economics and Technology.
(4) A basic power plant is in almost continuous production, i.e. approximately 7000 hours a year. The shoulder load is used when there are no dips in power consumption (generally at night) and corresponds to an annual average use of several thousand hours. The peak load corresponds to the busiest few hundred hours of the year.
(5) For further information, see : http://www.bmu.de/english/energy_efficiency/doc/46721.php.
(6) Energy consumption required to generate one euro of GDP.
(7) European Commission (2010), "*Les Européens et la sûreté nucléaire*", special Eurobarometer report 324, March.
(8) Such as Hans JONAS in The Responsibility Principle. An ethic for the technological civilisation (1979) and Martin Heidegger before him in The Question of Technology (1953).
(9) One thinks, for example, of the stationing of SS20 missiles on German soil and the German pacifists' slogan *"Besser rot als tot"* ("Better red than dead").
(10) Ifop/*Le Monde* survey conducted between 21 and 27 June 2011.

was still strong, with 55% of Germans saying that they were against the use of nuclear energy, compared to only 17% in favour.

Whereas in certain neighbouring countries, the accident at Fukushima only revived the debate on this technology, it seems to have actually acted as a catalyst[11] in changing the mind of Chancellor Angela Merkel, who, only six months after having succeeded in passing a law extending the life of the seventeen German nuclear reactors, decided to expedite their closure. According to the BMWi, eight units were shut down in 2011[12], representing approximately 70 TWh of annual generation, i.e. 12% of the total power generation. The remaining nine units producing approximately 80 TWh a year will be shut down between 2012 and 2022. This decision, which was confirmed as being irreversible by minister Peter Altmaier on 16 August 2012, is interpreted as such by German industry[13] and the international community[14].

What is the difference between the Japanese and German situations?

It is very tempting to want to compare the energy and, more particularly, the nuclear policies of Japan and Germany. Although both these countries have in common the fact that they are technologically very advanced and have an extremely competitive industry which has led them to equip themselves with this type of energy in equivalent proportions (23% for Germany, 27% for Japan), they also share a distrust of atomic energy that has its roots in their respective histories.

Their situations are, however, different. Japan is an island, without its own energy resources, whereas due to its central geographical position, Germany is well connected to its European neighbours by electricity networks and gas pipelines. Japan has to import its oil, coal (27% of the power generation) and gas (28%) *via* LNG terminals at extremely high prices. These prices are now approximately 18 dollars/MBtu, as opposed to approximately 10 to 12 dollars in Western Europe, whereas the spot price in the USA is 2.5 dollars.

Shutting down nuclear production in Germany is a political decision taken at government level. Moreover, only 8 reactors were finally shut down (out of a total of 17) and their production accounts for only 10% of the total consumption, which could quite easily have been offset by thermal power generation (as before the phase-out, the German electricity system had considerable overcapacity), by exporting less electricity and through energy savings that were more easily achievable due to the present crisis and the extremely clement weather conditions in 2011.

In Japan, after the Fukushima disaster, the power plants were shut down one by one for scheduled maintenance and, before they could be started up again, had to wait for the green light from local authorities who saw in the situation an opportunity to open negotiations on topics not necessarily related to the safety of nuclear facilities. Almost 50 reactors[15] that previously produced an average of 300 TWh a year have now been shut down. The gas turbines power plants that, until then, were used for shoulder load operation, were able to operate as replacements for 115 TWh – emitting 50 Mt of CO_2 as they did so, but 15% to 20% of the consumption still had to be provided. To avoid power outages, the government launched a harsh authoritarian plan to reduce consumption by households and companies, which, as a result, saw their industrial production decrease by 13%, causing the first trade deficit that Japan had experienced since 1979. Meanwhile, the country was considering a new energy policy that was to be finalised during the summer of 2012 and aiming at a 15% share of electricity from nuclear sources in 2030, according to Environment Minister, Goshi Hosono's declaration of May 2012.

Initial feedback on the year 2011 shows a 32 TWh reduction in nuclear production due to the early shutdown of eight units during the year. As consumption had, at the same time, declined by 3 TWh as a result of the crisis, with electricity exports decreasing by 11 TWh (from 17 to 6 TWh between 2010 and 2011, source: ENTSOE), an increase in the production of renewable energies, whose capacities increased in 2011 (photovoltaic solar energy by 7.5 TWh and wind power by 9 TWh), provided the remaining 18 TWh. The proportion of fossil energies stayed roughly the same.

There is still uncertainty about the transient composition of the energy mix

Although it was possible to compensate for the shortfall in nuclear production in 2011, an additional 110 TWh will have to be found in 2022. At the moment, renewables do not seem

(11) Discussions about the energy mix were taking place on the German political and public scene long before Fukushima. The gas crises of 2008 between Russia and its neighbours (Belarus, Ukraine) had led the CDU government, in power since 2005, to amend the law on atomic energy in 2010 by extending the life of the German power plants, without formally casting doubt over the nuclear phase-out in the longer term.

(12) To be precise, this decision involved only seven plants, as the eighth had already been scheduled to shut down.

(13) See also SIEMENS' announcement indicating its intention to completely withdraw from the nuclear industry (*Les Échos,* 19 September 2011).

(14) The plants will, however, remain in operating order for the next two years as a backup, if the thermal capacity were to prove insufficient to avoid blackouts in winter.

(15) Kansai restarted reactor 3 at the Ohi plant on 4 July 2012.

to be able to produce this amount of energy, for reasons that will be analysed below. Germany will probably only be able to count on limited energy imports, because some of its neighbours, such as Switzerland or Belgium are themselves anticipating an energy deficit. It would be risky to speculate on a 10% fall in energy consumption by 2020: this objective has just been deemed excessive by the new Environment Minister, Peter Altmaier[16], who spoke of the "gigantic efforts" required to achieve it. They can be compared with those currently required of the Japanese: the 15% forced reduction in consumption in the very short term is compelling them to make radical changes to their way of life. It will also be noted that in Germany, some efforts have already been made by upgrading all the ex-GDR's old reputedly energy-guzzling equipment[17].

Although the *Energiewende* objectives are clear, many issues regarding the practical way to proceed remain unresolved[18]: costs of such investments and their funding, technical issues related to integrating vast amounts of renewable energy into the grid, the country's energy dependence, a cohesive European energy policy, the acceptability of such a plan to the population, etc.

THE USE OF FOSSIL FUELS IS UNAVOIDABLE FOR ENSURING THE SWITCH TO ALTERNATIVE ENERGIES

There is no guarantee of achieving a supply and demand balance in the medium term and, in view of this risk, the German government believes that the use of thermal power generation (lignite-, coal- and gas turbines) will be inevitable[19] to compensate for the early closure of nuclear power plants, at least initially.

Coal and lignite have historically played a major role in power generation

Coal and lignite[20] play a very particular role in Germany, as they are national resources that have been providing the country with the raw material for its impressive industrial development for the last hundred and fifty years. Every year, 70 Mtons of coal are extracted from the German subsoil and 120 Mtons are used. The reserves are estimated at more than 40 Gtons. Coal mining has been subsidised for a long time and still receives State aid, which is intended to be continued until 2018. The expected need to resort to the use of more imported coal could slow down this industry, considered by the population to be highly polluting, but the fact that the management of power plants is often decentralised and that they run as CHP[21] works in their favour. As a sign of the current worldwide energy revolution, Germany has just imported coal from the USA, which is at present in the process of abandoning this energy in favour of gas (specifically unconventional gas[22]).

For lignite, the situation is a little different. Its resources appear to be inexhaustible and Germany extracts approximately 180 Mtons a year. Very large excavators are used in open pit mines to strip and backfill large quantities of ore over very wide areas. This type of operation makes crops and meadows unusable, sometimes permanently[23], and requires populations to be moved away, as is being done, for example, by the Vattenfall company in Lusace, in the Land of Brandenburg. Almost all this cheap fuel (less than 25 €/ton) is burned on site in power plants producing base load electricity and providing the most economical substitute for nuclear power plants.

(16) Peter Altmaier, interview given to *Bild am Sonntag*, 15 July 2012.

(17) Upgrading all the ex-GDR's highly polluting industrial facilities to conform to western standards has also allowed Germany to reduce its emissions by 24% since 1990 and keep its Kyoto commitments (- 21%). It is unfortunate that very detailed studies, such as that published in September 2011 by IDDRI and Global Chance *(Energy in Germany and France. An instructive comparison)*, do not include this major event in their analysis. Homes and domestic equipment were also upgraded to western standards. Moreover, the Germans were ahead of the French in buying more energy-efficient equipment, a phenomenon which was not taken into account in this study either.

(18) See, for example, the interview given to the AFP by Maria Van der Hoeven, Executive Director of the International Energy Agency (IEA), in September 2011.

(19) See the interview given to *Die Zeit* by the German Federal Minister for the Environment, 26 July 2012.

(20) Lignite is an intermediate rock between peat and coal.

(21) Combined Heat and Power : it increases the overall efficiency of the facility.

(22) Beeker (2011), "The unconventional gas: a North-American energy revolution not without consequences for Europe", *Policy Brief* no. 215, Centre for Strategic Analysis, March.

(23) In the Rhineland, out of 25,000 hectares mined, two-thirds have been returned to crop production.

The growing role of gas is forcing Germany to increase the security of its supplies

Gas enjoys a relatively good public image, as it burns cleanly and emits less CO_2 than coal or oil[24]. Combined cycle gas turbines (CCGT) have an excellent output and are a low capital investment, which makes them the ideal complement to intermittent renewable energies (back-up). In February 2012, Siemens was awarded the highly prestigious prize for innovation by *Wirtschaftsclub Rhein-Main* for its type SGT5-8000H CCGT. The latter holds the world record for best performance for this type of power plant (60.75%) whilst at the same time allowing rapid variations in power. The ten years of development and almost half a billion euros worth of investment required by this plant indicate the importance of this technology for our neighbour who has made it a preferred axis for development.

As the weak point of gas is its security of supply, Germany has successfully pursued a policy of openness and dialogue "*Annäherung durch Verflechtung*[25]" for many years with Russia, based on a policy of trust and interdependence[26]. As early as 1997, a project for the construction of a gas pipeline under the Baltic Sea was signed to link Germany directly with Russia[27]. In 2005, the work began and former Chancellor Gerhard Schröder was engaged by the Russian company Gazprom – in which E.ON holds a 6% share *via* its subsidiary RuhrGas – to chair the supervisory council of the Germano-Russian consortium responsible for building and operating this pipeline known as *North Stream*. The first line was completed in May 2011, two months after the Fukushima accident, and therefore simultaneously with the decision to abandon nuclear power, and the second is to be completed by the end of 2012. At the inauguration, Vladimir Putin declared: "The volume of gas supplied will be equivalent to the energy produced by eleven nuclear power plants."

The German company Wintershall (a subsidiary of BASF that is conducting exploration and drilling operations in Russia) has an interest in *South Steam*, another project linking Russia with Central Europe *via* the Black Sea, also bypassing the Ukraine, and expected to be commissioned in 2016[28], which does not stop RWE from being a member of the Nabucco consortium[29], a European project that is expected to connect Southern Europe directly to the Central Asian or Middle Eastern deposits *via* Turkey.

On the other hand, our neighbour currently has no project for an LNG (liquefied natural gas) terminal in view, as the one planned for Wilhelmshaven has been blocked by local opposition, which limits the flexibility of its supply. Germany, however, could have large reserves of unconventional gas and the seventh of Minister Altmaier's ten priorities presented on 17 August 2012 is to organise a responsible debate on the use of fracking technologies. All these projects contribute to making Germany a gas "pole" at the centre of Europe[30] and this fuel is expected to play an important part in the decades to come.

Figure 1

The North Stream gas pipeline links Russia directly to Germany under the Baltic Sea

Source: http://europeorient.wordpress.cpm

The composition and production of fossil thermal energy will depend on a number of parameters

■ The fact that coal-fired power plants are no longer acceptable is prompting early demolition of the oldest units

According to a survey carried out by Forsa in April 2011, only 15% of Germans believe that coal-fired power plants should be built in the future as part of the new German energy project and 36% would support the use of gas turbines power plants. Many negotiations have taken place to enable the oldest coal-and lignite-fired power plants to be

(24) CCGT (gas) emits approximately 400 g of CO_2 per electrical kW/h produced, whereas a coal-fired power station emits between 800 and 1000 g according to its performance.
On the other hand, nuclear power and renewable energies do not emit CO_2.

(25) "Rapprochement through interdependence" in the words of Foreign Minister Herr Steinmeier.

(26) *Gas security in Europe: dependency to interdependency,* a report for the Centre for Strategic Analysis under the supervision of Christian Stoffaës, La Documentation française, May 2010.

(27) The fact that the gas pipeline bypasses Poland and the Baltic countries sparked anger in these countries.

(28) For a capacity of 63 billion m^3 of gas.

(29) It is expected to be able to transport 23 billion m^3 of gas.

(30) Countries such as the Czech Republic prefer to deal with Germany for their gas supply rather than directly with neighbouring producing countries such as Russia.

decommissioned in exchange for the construction of more modern plants (supercritical technology). Although they comply with the European Directives on pollutant emissions (sulphur and nitrogen oxides), between 14 GW and 30 GW of electricity capacity could be decommissioned ; this figure was provided by DENA and quoted in an IFRI study[31]. As shutting down a thermal unit is a matter for the operators, no accurate estimates of those that will still be connected to the grid in the next ten to twenty years are available.

- **Approximately 30,000 MW of fossil fuel-fired thermal power plants are under construction or planned**

In April 2012, the BDEW confederation[32] released a study on the renewal of the country's power generation plants in the post-nuclear era. Out of 84 power plants with unit power greater than 20 MWe that were expected to be built, at least 69 had at least passed the administrative instruction stage. In addition to the twenty-three offshore wind turbine farms, they include twenty-nine 12 GW combined cycle gas turbines and seventeen 18 GW coal- and lignite-fired power plants. Assuming 5000 shoulder load operating hours a year (probably from intermittent renewable energy), they will produce 90 TWh, making it possible to decommission the older units by 2020. It is more difficult to forecast the production of gas turbines power plants because a large number of them will be used to supplement renewable energies. They are likely to be smaller, operate between 1500 and 3000 hours a year and produce 18 to 35 TWh. For its part, the German government[33], expects that in 2020, production will be the same as that of 2010, in the region of 90 TWh.

THE DEVELOPMENT OF RENEWABLES, SPEARHEAD OF THE *ENERGIEWENDE*, FACES MANY CHALLENGES

The originality of the *Energiekonzept* is undoubtedly the highly voluntaristic plan for the development of renewable energies, dating from 28 July 2011. In fact, Germany is aiming at 80% wind, solar, biomass and hydraulic energy in its electricity mix in 2050, as opposed to 20% in 2011, with a 35% stage in 2020. The state of current technologies, their costs, the reduction in the number of available sites and public acceptability are all challenges to be met and make such significant growth problematic.

Renewable energies have experienced a decade of very strong growth, but apart from photovoltaics, they seem to be losing momentum.

The renewable energies policy established by the first Renewable Energy Sources Act (EEG) has, since it became law in April 2000, made it possible to double their production to 20% of the total power generation in 2011, but 38.2% of the installed power due to their reduced load factor. The growth in wind power has slowed in recent years, unlike photovoltaic solar energy which experienced strong growth in 2011 (+7.5 GW).

Although it does not have the advantage of particularly favourable wind regimes (1600 hours in 2011, as opposed to more than 2000 hours on average in France), Germany was among the first countries to develop onshore wind power, for reasons of cost[34] and quickly achieve a significant installed capacity. This capacity experienced only moderate growth in recent years and, in 2011, only 2 GW

Table 1
Installed capacity and generation of renewable energies in Germany (2011)

	Onshore wind	Offshore wind	PV solar	Biomass	Hydraulic	% RE
Installed capacity	29 GW	0.2 GW	25 GW	5 GW	4 GW	38.2%
Generation	46 TWh	0.7 GW	18 TWh	32 TWh	20 TWh	20.0%
Load factor	1585 h/year	3043 h/year	766 h/year	6019 h/year	4432 h/year	

Source: BMWi

(31) Deutsche Energie Agentur (German equivalent of the French ADEME), IFRI, Michel Cruciani (2012) *Development of the German energy situation,* March.
(32) Bundesverband der Energie und Wasserwirtschaft eV., which brings together industrialists and stakeholders from the energy and water sectors. For further details, please refer to www.bdew.de.
(33) In its National Action Plan for renewable energies.
(34) The purchase price of onshore wind power is 90 €/MWh. The price of electricity on the wholesale markets in Germany has remained between 50 and 60 €/MWh in recent years, but for a guaranteed base energy.

were put into service, mainly by replacing old turbines with new more powerful ones (a technique called "repowering"). The same year, the United States went from 40 to 47 GW and China from 45 to 63 GW. In fact, the equipment has already been installed on the best sites and the power system is finding it increasingly difficult to absorb this intermittent energy.

Encouraged by the policy of charging very high purchase prices (about 450 €/MWh until 2009), the German photovoltaic solar industry experienced significant expansion, which has accelerated even more in recent years. Installed capacity increased from approximately 5 GW to 25 GW in less than five years, which is the equivalent of almost 17% of the country's total electricity capacity, but accounts for only 3.1% of its consumption[35]. The productivity of solar panels in Germany also suffers from unfavourable sunlight conditions (on average, less than 1000 operating hours). The additional cost of this energy (see *below*) prompted the government to want to make a sharp, unscheduled reduction in its purchase price in March 2012[36]. But it is above all the fact that Chinese manufacturers have captured the market that has put a halt to the domestic industry, causing, since 2011, many bankruptcies amongst the former heavyweights of this sector, such as Solarhybrid, Solon, Solar Millennium, Sovello or even the pioneer, Q-cells.

As its hydraulics production capacities are virtually saturated, the country is also staking a lot on biogas for the power generation with CHP and expects to be producing an additional 10 to 15 TWh by 2020. However, this technique could suffer from the reported decrease in subsidies and raises the question of disputes over the use of land[37] also allocated to the production of biofuels and food crops, as the country had to import cereals in 2011 for the first time in twenty-five years[38].

The sea, a new prospect for the development of renewable energy?

Thanks to *repowering,* onshore wind power is likely to reach the predicted power of 35.8 GW in 2020, but will find it difficult to exceed this figure, which could bring its overall production to 55 TWh[39]. The production of photovoltaic solar energy is expected to continue to increase, but in a more limited manner (the federal government considers a growth limit of 2.5 to 3 GW per year to be sustainable). This growth might be stopped when the purchase price is reduced, as some experts think, especially in view of the fact that the prices of solar panels have reached a low point due to current production overcapacity.

A boost from new technologies and R&D is therefore essential. In the medium term, Berlin is counting on a huge deployment of offshore wind power. The objective for 2020 is to install 10 GW, i.e. 2000 giant 5 MW turbines that should produce 30 TWh. The fact that this volume is still insufficient was acknowledged by former minister Norbert Röttgen in March 2012, as at least 25 GW will be needed to meet the target of 35% production from renewables by that date. In the meantime, this technology will still have to prove that it can keep its promises, as only 220 MW were installed in 2011 and 600 MW are under construction in 2012 (source: BDEW). At present, the costs remain high[40] and no technological advances for increasing performance have been identified.

The integration of renewable energy into the grid is facing difficulties and energy storage technologies are still at the R&D stage

Although the law gives priority to the injection of renewable energies, wind turbines are subject to numerous forced shutdowns[41], as the energy they produce cannot be consumed, stored or transported to another place of consumption, due to congestion on the national electricity grid. The grid operators

(35) On 25 May 2012, the total photovoltaic power reached 22 GW, equivalent to half its electricity consumption, but only temporarily.

(36) This decision was not approved unchanged by the Bundesrat, which was anxious to safeguard jobs in the Länder.

(37) Information confirmed by the Energie Wirtschaft Institut of Cologne, which helped to draft the *Energiewende* scenarios (participation of Dr Dietmar Lindenberger in the CGEMP seminar in Paris on 22 June 2012).

(38) "Deutschland muss erstmals wieder Getreide importieren", *Westdeutsche Allgemeine Zeitung,* 9 January 2012.

(39) Based on the average load factor of onshore wind power in Germany in the last twenty years, or 1600 hours. It could be as high as 1800 hours in the future, thanks to *repowering.* For information, operating times are approximately 7000 hours for a base load nuclear or thermal power plant.

(40) The purchase price is 150 €/MWh in Germany. In France, CRE recently revealed costs of 220 €/MWh.

(41) *Le Monde* 30 October 2011.
In 2009, operators notified 285 forced wind turbine shutdowns over a period of sixty-five days; in 2010 this figure jumped to 1085 shutdowns over 107 days.

had to reimburse the producers 18 million euros in 2011 and 32 million euros in the first quarter of 2012 for "redispatching[42]", which illustrates the magnitude of this phenomenon.

The current priority is to strengthen the grid

The operators are therefore planning to build 4500 km of very high-voltage lines by 2020, in particular to carry energy from the wind turbine farms in the North Sea to the south of the country which will experience an energy deficit once the nuclear units have been shut down. At the end of May 2012, the BNetzA[43] assessed this programme at 20 billion euros, to which 25 billion euros would have to be added for the distribution grids (MV and LV). The grid operator Tennet announced that it was finding it difficult to raise the 5 billion euros it needed for its initial investment.

From a technological point of view, some challenges still have to be tackled. Technical difficulties related to the continuous transport of high-voltage direct current (HVDC, Siemens multi-point technology) are being experienced with respect to the connection of North Sea wind turbine farms. These uncertain conditions are delaying the work and penalising the operators (who are demanding compensation for their loss of income).

Finally, there appears to be a certain legal vacuum in Germany at present, with respect to offshore grids, which is slowing down their development. This was the reason given by RWE on 25 July 2012 for its decision to stop the project to build the world's largest offshore wind farm, Innogy Nordsee.

Renewable production is wrongly equated to "local" production, which creates the phenomena of the lines being rejected by the population

The German Länder and their inhabitants thought that the installation of renewable energy plants on their soil would allow them to regain the energy autonomy to which they are attached, as nuclear energy is renowned for being centralised. The reality is the opposite, as distributed energies, in particular wind turbine and solar energy, now require electricity grid densification and federal management. The inhabitants of the Land of Thuringia are a good example, because they do not understand that although the lines will be built on their soil, they will not be able to take advantage of the electricity, which will be transferred from the producer in the North to Bavaria, the consumer. Some people want to be sure that the electricity transmitted does not come from coal-fired power plants.

In view of these acceptability problems, the government has simplified and shortened the duration of the line construction procedures, which have constantly been blocked at local level. National and regional cooperation manifested by the Länder therefore appears to be an important condition for the success of a coherent countrywide energy plan.

In the longer term: investment in energy storage research

Technical solutions such as *smart grids*[44] and storage are encouraged by the government, but are far from being economically mature and are mainly being developed in niche markets. The research focuses on storing energy in compressed air in underground caverns, electrochemical batteries, and on the production of synthetic hydrogen and methane. These techniques are already very old[45], productivity is still low, costs prohibitive and economically viable solutions require technological breakthroughs.

They will therefore be closely followed by all the international stakeholders, as key components in the power systems of tomorrow. Meanwhile, as pumped-turbined energy storage facilities (STEP)[46] were the only ones currently offering an acceptable level of profitability, Germany planned to build some to provide almost 5000 MW (source: BDEW). Norway is highly admired for its significant hydraulic capacities prompting the deployment of new interconnecting cables in the North Sea.

(42) Source: E.ON – redispatching involves changing the demands on units when congestion occurs.

(43) Bundesnetzagentur, German Federal Network Agency.

(44) Also called "smart grids", they more accurately manage the injection of diffuse energy (such as photovoltaic) into the grid (voltage optimisation) and should eventually allow users to better control their consumption, particularly through the use of smart meters, although their development is still limited in Germany.

(45) The two processes have been known for more than two centuries since the first water electrolysis was carried out on 2 May 1800 by W. Nicholson and Sir Carlisle, only a few days after the invention of the first electric battery by A. Volta.

(46) STEPs can store energy by pumping or turbining water contained in two different pools.

THE COSTS OF *ENERGIEWENDE* ARE AS YET UNDETERMINED, BUT THEY WILL GENERALLY BE VERY HIGH AND ULTIMATELY BORNE BY THE GERMAN CONSUMER

It is estimated that the cost of abandoning nuclear energy will be several hundred billion euros by 2020

The annual additional cost of renewable energies in power generation (the "*EEG-Umschlag*") was 13.8 billion euros in 2011, almost half of which was for photovoltaic solar energy. Total subsidies for photovoltaic solar energy (which, for information, accounts for 3.5% of the total power generation) are said to have already reached[47] 110 billion euros, whereas subsidies for wind power were 20 billion euros.

In September 2011, the German state-owned bank KfW, which was to help fund offshore wind power, published a more detailed study putting the amount of investment to be made by 2020 at between 350 and 415 billion euros for new generation capacity, line construction, possible electricity imports from abroad and investments in energy efficiency.

In May 2012, the grid operators estimated the bill for abandoning nuclear energy completely by 2022 at between 200 and 400 billion euros[48]. There have been very few economic assessments of the total switch to alternative energies, which is expected to result in 80% renewable energy in the 2050 electricity mix. A study[49] by professor Alfred Voß of the University of Stuttgart, mentions figures of over 2000 billion euros, a sum worthy of the financial efforts made within the framework of German reunification.

The energy companies, potentially weakened by the fact that their nuclear power plants are to be shut down, have little incentive to invest in new assets

These very high amounts are not necessarily incompatible with Germany's financial capacity. The German energy companies E.ON, RWE, EnBW and Vattenfall that were previously considered to be flourishing, saw their income drop in 2011. The most seriously affected were E.ON, which, in 2010, had posted a net profit of 5.8 billion euros for 2011 and finally announced a net loss of 2.2 billion euros and EnBW, which went from a 1.2 billion euro profit in 2010 to a loss of 800 million euros in 2011. These companies will also have to face the cost of the early decommissioning of nuclear power plants.

On the other hand, they will no longer have to bear the cost of taxes on nuclear power[50] (2.6 billion euros a year before the *phase-out)* and will certainly receive compensation from the federal government (they intend to demand a total of 15 billion euros before the Constitutional Court in Karlsruhe). The difficulties that may arise are more fundamental: investor confidence in the renewable energy sector has fallen, due to the fickleness of public policy, particularly in terms of the guaranteed feed-in tariff, and the profitability of combined cycle gas turbines and coal-fired power plants is adversely affected by their too short service life. The consequence of this situation is that RWE and E.ON both announced in August 2012 plans to axe ten thousand jobs.

The increase in electricity prices is threatening the competitiveness of German manufacturers that the government is seeking to protect

Replacing an amortised facility with low marginal generation cost (nuclear power) with other plants fired by gas, coal or renewable energies yet to be built can only

Table 2
Investments required for *Energiewende*

Investment sector	Amount (by 2020)	Source
Development of renewable electricity	144.6 billion €	BMU scenario 2010
Renewable heat	62 billion €	BMU scenario 2010
Energy efficiency improvement	130 - 170 billion €	GWS Institute
Grid development	9.7 to 29 billion €	Dena
Thermal power plants (10 GW to be built)	5.5 to 10 billion €	KfW bank
Total	351.8 to 415.6 billion €	

Source: KfW-Research (August 2011)

(47) Study by the RWI, Rheinisch-Westfälisches Institut für Wirtschaftsforschung, Essen.
(48) "Les Allemands évaluent le coût de l'abandon de l'atome", *Le Journal de l'environnement,* 31 May 2012.
(49) Prof. Dr.-Ing. Alfred Voß of the Institut für Energiewirtschaft of the University of Stuttgart, presentation to the Energy-Climate Chair, Paris, 11 October 2011.
(50) Tax created in 2010 as a compensation for the decision by Angela Merkel to extend the life of the 17 nuclear reactors.

increase the full generation cost. An increase in the price of power therefore appears to be inevitable. Energy-intensive and major manufacturing customers already enjoy a certain amount of tax relief (exemption from eco-tax, lower grid access costs, exemption from VAT) and therefore relatively low prices (52 €/MWh and 80 €/MWh respectively in 2011). According to a study by the Karlsruher Institut für Technologie (KIT), a 70% increase in these costs is expected by 2025, which will affect the competitiveness of large energy-consuming manufacturers, with the associated risks of a reduced trade surplus. The government therefore plans to grant them compensation, in particular to reduce the impact of the price of the CO_2 quotas on the price of electricity. The compatibility of these exemptions with the European regulations of its competitors remains to be assessed. Meanwhile, the textile industry federation, which does not currently benefit from exemption under the Renewable Energy Sources Act (EEG), has just announced that it plans to lodge a protest with the German Constitutional Court against the financial burden imposed on SMEs and individuals in order to support the switch to alternative energies.

The additional costs will ultimately be borne by the population who fully agrees with the reason for switching to alternative energies, but no longer at any price

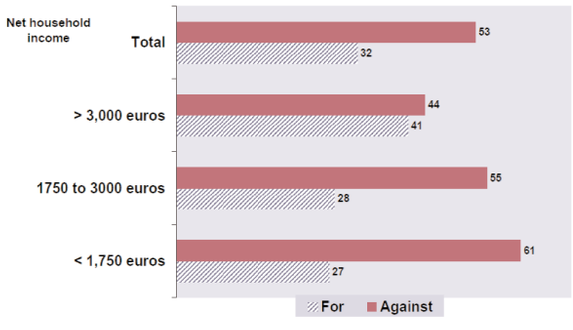
It is the domestic customers who will have to bear most of the additional costs of supporting renewable energies - which already amounted to 36 €/MWh in 2011 – *via* an increase in the price of electricity. At the end of 2010, it was already amongst the highest in Europe (244 €/MWh on average[51]), i.e. twice the average price in France (129 €). The KIT study mentions that by 2025, there will be even higher increases for manufacturers alone (at least +70%), which would result in a price bordering on 400 €/MWh!

In 2011, most Germans were willing to pay more for their electricity to support the switch to alternative energies[52], but recently a change of attitude has been noted among consumers. In fact, according to a TNS Emnid survey for *FOCUS* magazine[53], only 48% of Germans would accept an increase of up to 20 euros[54] in their electricity bill, and only 9% would accept an increase of more than 20 euros. Conversely, 41% of Germans do not agree with a price increase. According to another survey conducted by the *Frankfurter Allgemeine Zeitung*[55], 73% of the respondents still agree with the government's decision to withdraw from the nuclear industry by 2022, whereas 16% are opposed to it. On the other hand, 54% of those questioned say that they are not willing to pay more for the deployment of renewable energies. Amongst those earning less than 1750 euros a month, 61% of those questioned were opposed to any increase.

Bar chart 2

German public opinion in response to the increase in energy prices

Source: Institut für Demoskopie Allensbach / FAZ.



German households are wondering about the exact cost of switching to alternative energies, fearing that the bill will be too high for the consumer to absorb, especially because of the support needed for renewable energies through the Renewable Energy Sources Act (EEG)[56], which already accounts for 15% of their monthly bill[57]. Predictions by the grid operators forecast that this tax could increase by 40%, from 36 €/MWh to 50 €/MWh in 2012. Thus, according to the Institute for Future Energy Systems (IZES), a typical household of four persons would support the switch to alternative energies at a cost of

(51) Source: Eurostat, press release of 29 June 2011.
(52) Survey conducted by Forsa for Germanwatch on a panel of 1005 German citizens on 6 and 7 April 2011.
(53) Alexander Wendt, "Zu teuer: Immer mehr Deutsche lehnen *Energiewende* ab", *Focus,* 17 June 2012.
(54) Based on the average consumption of a German household of two or three people, i.e. 3500 kWh per year and € 70 per month. An increase of € 20 would correspond to a 30% increase in the electricity bill.
(55) Prof. Renate Köcher, "Schwierige Wende", *Frankfurter Allgemeine Zeitung,* 20 June 2012.
(56) Tax equivalent to the CSPE (Contribution to the Public Electricity Service) in France.
(57) Alexander Wendt, "Die grosse Illusion", *Focus,* no. 25, 18 June 2012.
(58) Thibault Madelin, "L'Allemagne s'interroge sur le financement de sa transition énergétique", *Les Echos,* 21 August 2012.

210 € per year, as opposed to 150 € at the present time[58]. This inevitably raises the question of the development of fuel poverty among certain population categories[59]. Aware that electricity price considerations had previously been far too often evaded and putting the question of costs and acceptability by the population back at the heart of the decisions, the new Environment Minister, Peter Altmaier, said in July 2012, that his priority in terms of energy was now to keep the price of electricity affordable for consumers[60]. Moreover, on 15 October next, he has to present measures for funding renewable energies and their effect on household bills[61].

ENERGIEWENDE IS THE RESULT OF A SOVEREIGN DECISION NOT WITHOUT RISK TO THE EQUILIBRIUM OF THE EUROPEAN ENERGY POLICY

Power flows intensify, putting the European system under stress

The German decision to exit prematurely from the nuclear industry was a sovereign decision, but one which stirred up trouble[62] on the European scene, because it is not without consequences for the neighbouring countries. In particular, it changed the supply and demand balance throughout Europe, as reported by the French electricity transmission system operator RTE with respect to France. Basically, during windy and/or sunny periods, excessive "intermittent"[63] energy crosses borders, whilst power plants in neighbouring countries take over when climatic conditions are unfavourable, as German shoulder load power plants are not adequate for load following.

The flows can be reversed several times a day and increase exchanges over lines of heavy European transport by causing congestion, including on the national grids of neighbouring countries[64] including France. Already on 4 November 2006, a simple incident on a line in the North of Germany while the wind turbines were operating at full capacity resulted in a general *blackout* throughout Europe, which was fortunately quickly under control. The BNetzA itself acknowledged as early as April 2011 that the safety rule known as "n-1[65]" could no longer be observed once the eight nuclear units had been shut down. The voices of European grid operators (Belgian and Dutch in particular) are beginning to be raised to ensure that Germans pay for the stability of the grid they are providing them with.

Where production is concerned, the thermal power plants on the Continent are facing large power variations. Load following has reduced their output and the equipment is ageing faster due to unwanted stoppages/startups, as noted by the Spanish.

Shoulder and peak load power plants are losing profitability, which is penalising the European energy companies

More generally, the competitiveness of shoulder and peak load power plants is jeopardised by shorter operating times. In fact, renewable energies generate intermittent production which is therefore consumed as a priority, causing "haphazard[66]" consumption of conventionally produced energy, due to their intermittent nature. Paid for *via* purchase prices, they do not come within the scope of the electricity markets but bring down the average prices per MWh, which raises the question of the compatibility of this form of subsidy with the *"market design"*.

Negative prices per MWh: an anomaly due to the priority injection of renewable energies into the grid

The intermittence of renewable energies can oddly generate negative prices on the electricity markets. In Germany, this occurred on 17 days in 2010, 15 days in 2011 and 6 days in the first quarter of 2012. The phenomenon recently spread to France: 5 days in 2011 and 2 days at the beginning of 2012. It is due to the fact that the production of renewable energy takes precedence on the grid[67] and that it is more cost-effective for a producer to pay a consumer to use it than to bear the costs of shutting down/starting up his thermal power plants and wear them out prematurely. From the economic point of view, renewable energy which has a marginal generation cost of zero should not be offered on the market when prices are negative (and therefore less than the generation costs). The electricity exchange EPEX also notes episodes where peak prices were lower than basic prices, another anomaly due to the same causes.

(59) In 2011, 120,000 households in North Rhine-Westphalia had their power cut off, because they could not pay their electricity bills.
(60) Interview with Peter Altmaier, "Ich kämpfe für bezahlbare Strompreis", *Passauer Neue Presse,* 11 July 2012.
(61) Aline Brachet, "Allemagne : le ministre de l'Environnement présente les dix priorités de la politique énergétique", AEDD, newsletter no. 14544, 23 August 2012.
(62) Hubert Védrine, "La décision de l'Allemagne sur le nucléaire perturbe la France", *Les Échos,* 6 December 2011.
(63) Indicates energy that would be lost if not used (wind, solar, run-of the-river hydraulic energy, etc.).
(64) The countries mainly affected are the Netherlands, Poland, Austria, Switzerland and the Czech Republic.
(65) This standard rule defines the maximum admissible risk level for power outage in the grid.
(66) This term, borrowed from town planning, indicates breaks in the continuity of production of conventional plants.
(67) In economic terms, the marginal cost of wind or solar energy is zero and in the event of negative prices on the market, these methods of production should be avoided.

These facts are particularly striking in Germany, but as a result of European market coupling, lower prices impact all the neighbouring countries: part of the energy companies' production is therefore under-remunerated. Core assets which are already largely depreciated (nuclear, hydro, or even lignite or coal in Germany) are therefore worth less. In the case of shoulder and peak load power plants (in particular gas turbines, but also sometimes coal-fired plants), the combination of lower market prices per MWh, the shorter service life of these plants, the priority afforded to renewable energies and the high price of gas means that operators' assets are no longer sufficiently remunerated and that some operators even find themselves in financial difficulty[68]. This is doubtless the cause of the problems experienced by Poweo's Pont-sur-Sambre power plant. E.ON has also stated that three of its gasturbines power plants, with a total power of 1461 MW, were not cost-effective and that it intended to shut them down[69].

The supply and demand balance during transition peaks and tense grid situations is weakened

Unlike nuclear power plants that have to be withdrawn from the grid, renewable energies – predominantly wind power – do not provide guaranteed energy and cannot be included in transition peak estimates (and tense situations in general, such as those where wind strength is not as expected). The presence of so-called *back-up* resources, generally combined cycle gas turbines, is therefore necessary to ensure the electricity supply and demand balance under all circumstances. As the conditions of the electricity markets described above no longer guarantee the profitability of certain existing assets, they cannot *a fortiori* guarantee that of new peak and shoulder load facilities (the *"missing money"* problem).

There is a serious problem of under-investment in these plants in Germany, as well as in other countries, including France, which also have to reckon with the planned decommissioning of the oldest (coal- or fuel-fired) thermal power plants that could also provide some of the *back-up.* For fear of a *blackout* during the coming winter (2012-2013), the BNetzA has asked for them to remain operational. This decision is however a matter for the producers, causing them to enter into negotiations with the BNetzA. In 2011, the latter had already paid for *Stadtwerke* in the South of Germany and Austria to provide reserve capacity. Some operators, such as E.ON in the case of its Baravian gas turbines, are trying to get compensation by legal means for being forced to keep their plants available. More institutional mechanisms therefore need to be put in place, such as requiring operators to maintain guaranteed production capacities. This is the solution that France has chosen, as these commitments could be traded on a capacity market, which would avoid each producer having to hold their own assets. An obligation to retain guaranteed means of production would put renewable energies at a disadvantage and increase their cost, which probably explains why the Federal Minister for the Environment, Peter Altmaier, once again rejected their deployment on 16 August 2012.

The European countries must coordinate their switch to alternative energies

It is, however, in Europe's interest to strengthen its cooperation, as it is large enough to ensure the liquidity necessary for this type of market. On 6 June 2012, Philipp Rössler called[70] for a coordinated energy policy between Germany and its neighbours. The call must be heard and it would be advantageous if a dialogue were initiated, as a matter of priority, on:

- the consequences of the development of renewable energies on the economic profitability of shoulder and peak load power plants;
- the completion of the internal energy market which requires the provision of incentives for investments in production and a smooth integration of renewable energies;
- the European dimension of a possible peak load capacity obligations market.

(68) The E-Cube consulting company assesses that the losses for CCGT operators in France will amount to 900 million euros in 2030; these losses should logically be charged to the producers of intermittent renewable energies (study reproduced in Enerpresse, 13 July 2012).

(69) *Financial Times Deutschland,* 14 May 2012.

(70) Berlin appelle à coordonner sa sortie du nucléaire avec ses voisins, *Le Monde* 5 June 2012.

CONCLUSION

With its Energiewende, Germany, "the model top-of-the-class pupil" of the European economies, which has accumulated considerable technological know-how and financial reserves, is heading for a new type of energy future. If successful, this will put Germany in a position of energy independence and climate neutrality and ensure that it is strongly placed to sell the technologies it has developed. Its energy policy deserves attention and research in fields such as renewable energies, energy storage, carbon capture, smart grids and energy efficiency and can be a source of inspiration for our own policies.

In the short term and even if they continue to export electricity throughout the year, the accelerated closure of the nuclear power plants and an increased intermittent production of wind and photovoltaic energy will force the Germans to rely heavily on their European neighbours' power systems to ensure their production/consumption balance: such a fast decision is therefore not "exportable". The European energy companies (including German ones) will find themselves having to bear part of the risk associated with this unilateral decision, which deserves compensation, since their operating margins are reduced. Increased coordination between all the stakeholders (governments, producers, consumers, suppliers, grid operators, etc.) is desirable, so that they can each benefit from or bear the consequences of their choices in a fair and just manner.

In the medium term, i.e. by 2020, since current technologies do not allow very large amounts of electricity to be stored in an economically acceptable manner, the potential of renewable energies will be limited. Because Germany was concerned about its energy security, it planned to build thermal power plants to burn its domestic energy, coal and lignite, and directly negotiated its gas supply with Russia, which does not exactly lead to a europeanisation of its energy policy. The issue of CO_2 emissions, which is beyond the scope of this Policy Brief, has been little discussed, but it will be interesting to see how Germany will solve its climate equation after shutting down its nuclear units and achieve the goals it has set itself.

In the longer term, in other words after 2030, the success *of Energiewende will be based* on the development of technologies still in their infancy that require technological breakthroughs to become economically viable.

Finally, this great plan would not be possible without the consent of the population. Although there is still a wide consensus in society in favour of the Renewable Energy Sources Act, German public opinion is becoming less enthusiastic about the idea of a marked increase in the price of electricity, whilst remaining overwhelmingly opposed to nuclear energy. The challenges are many and the coalition government has had serious disagreements about how to overcome them, which, in May 2012, forced Chancellor Angela Merkel to take direct control of the energy switching process.

The changes in German energy policy that may take place in the coming months will therefore have to be closely analysed, as they will have repercussions for the entire European Union, making consultation between all its Member States even more necessary than ever.

Key terms: energy policy, Germany, *Energiewende*, nuclear power, renewable energies, climate change, European energy policy.

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LA NOTE D'ANALYSE

Étienne BEEKER,
with the contribution of Clélia GODOT[71]

[71] This Policy Brief has been carefully proofread by Gilles BELLEC, Michel BENARD, Joël HAMELIN, Jan Horst KEPPLER, Claude MANDIL, Jacques PERCEBOIS, Dimitri PESCIA and Jean SYROTA and the preparatory work was carried out by Johanne BUBA.

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Press centre:
Jean-Michel Roullé,
Communications Manager
01 42 75 61 37 / 06 46 55 38 38
jean-michel.roulle@strategie.gouv.fr

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