10 Q & A on the German *Energiewende*

A contribution to the Japanese energy debate

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IMPRINT

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Preface

Energy systems worldwide are in a state of transformation. With the adoption of the Paris Climate Agreement in December 2015, the foundation for international climate policy has fundamentally changed. The decision to limit global warming to be well below to 2 °C can only be achieved if energy systems are completely decarbonized over the long term. Accordingly, the European Union has adopted ambitious goals to move toward a low-carbon economy and fully integrated energy markets. Furthermore, the G7 countries reaffirmed in May 2016 in Ise-Shima, Japan that they would strive to fully decarbonize their power systems, and China has become the world's largest renewable energy market. Germany is playing a prominent role in this transformation process, having adopted one of the most ambitious energy transition programs of all industrial nations – the *Energiewende*. With this long-term strategy – started more than a decade ago and invigorated after the Fukushima nuclear accident – the country has decided to fundamentally transform its power sector by phasing out nuclear and coal in favor of renewable energy.

Wind and solar energy form the backbone of the German *Energiewende*. Yet around the world, wind and solar are abundantly available and generation technology costs are rapidly decreasing. In 2016, renewable energy projects set low-cost records in countries around the globe, from Chile and Morocco to the United Arab Emirates and Denmark. Thus, many of the developments we currently see in Germany, and in other vanguard countries, are highly relevant for the rest of the world – including Japan. Comparing Germany and Japan is especially useful, as both countries, while geographically distant, have a comparably sized population, export-based economies and strong industries.

While the German approach is not unique worldwide, the speed and scope of the *Energiewende* are exceptional, and have attracted wide attention and debate in Europe and abroad. In Japan, however, there has been a growing tendency in recent years to report skeptically about the German *Energiewende* and see it as a failure.

Japanese energy and climate policy has undergone important change since the Fukushima disaster. A set of measures has been introduced to promote renewable energy development, encouraging particularly rapid growth in solar PV. However, the country is still facing several challenges that endanger the Japanese climate commitment while also impairing further renewable energy development. Against this backdrop, many lessons can surely be learned from the German experience with adopting renewables, both positive and negative. It is therefore crucial to provide an accurate and impartial overview of the progress of the *Energiewende*.

This document answers ten frequently asked questions in Japan about the German *Energiewende*. It aims to provide a current and accurate snapshot of the German experience. It focuses on the power sector, which many studies have shown will be crucial to decarbonisation.

We hope you enjoy reading it!

Patrick Graichen,
Executive Director of Agora *Energiewende*

Mika Ohbayashi,
Director of the Renewable Energy Institute

Content

Q1 **What is the German Energiewende?**

A The German Energiewende is a long-term energy and climate strategy that is based on developing renewable energy and improving energy efficiency. It involves a fundamental transformation of Germany's power system, including a shift from coal and nuclear to renewable energy. The Energiewende first started decades ago. A broad consensus has emerged on the need for this transformation.

The German *Energiewende*: a long-term energy and climate strategy

The German *Energiewende* (roughly, "energy transition") is a long-term strategy for the development of a low-carbon energy system that is based on renewable energy and improved energy efficiency. The *Energiewende* is an integrated policy that addresses all sectors of the economy. It is driven by four main political objectives: fighting climate change (through a reduction of CO_2 emissions), phasing-out nuclear power, improving energy security (through a reduction of fossil-fuel imports) and guaranteeing industrial competitiveness and growth (through indus-

Key German *Energiewende* targets — Table 1

		Status quo	2020	2025	2030	2035	2040	2050
Greenhouse gas emissions	Reduction of GHG emissions in all sectors compared to 1990 levels	-27 % (2016)*	-40 %		-55 %		-70 %	-80 – 95 %
Nuclear phase-out	Gradual shut down of all nuclear power plants by 2022	11 units shut down (2015)	Gradual shut down of remaining 8 reactors					
Renewable energies	Share in final energy consumption	14.9 % (2015)	18 %		30 %		45 %	min. 60 %
	Share in gross electricity consumption	32.3 % (2016)*		40 – 45 %		55 – 60 %		min. 80 %
Energy efficiency	Reduction of primary energy consumption compared to 2008 levels	-7.6 % (2015)*	-20 %					-50 %
	Reduction of gross electricity consumption compared to 2008 levels	-4 % (2015)*	-10 %					-25 %

AGEB (2016), BReg (2010), own calculations — * preliminary trial policies targeting technological, industrial, and employment development). This transformation of the economy is creating new business opportunities for German industry, but is not without its challenges. As part of the *Energiewende*, ambitious mid and long-term targets have been set in all energy sectors (power, heat, and transportation) reaching as far forward as 2050 (see Table 1). Reaching these targets will require a fundamental transformation of Germany's power system, including a shift from coal and nuclear to renewable energy, which must cover at least 80 per cent of Germany's electricity consumption by 2050. Reaching the long-term decarbonisation objectives in the other fossil-fuel intensive sectors (transportation, heating and cooling) will require progressive long-term electrification. Accordingly, the fundamental transformation of the power system is crucial.

The *Energiewende* first started decades ago and a broad consensus has emerged on its objectives and necessity

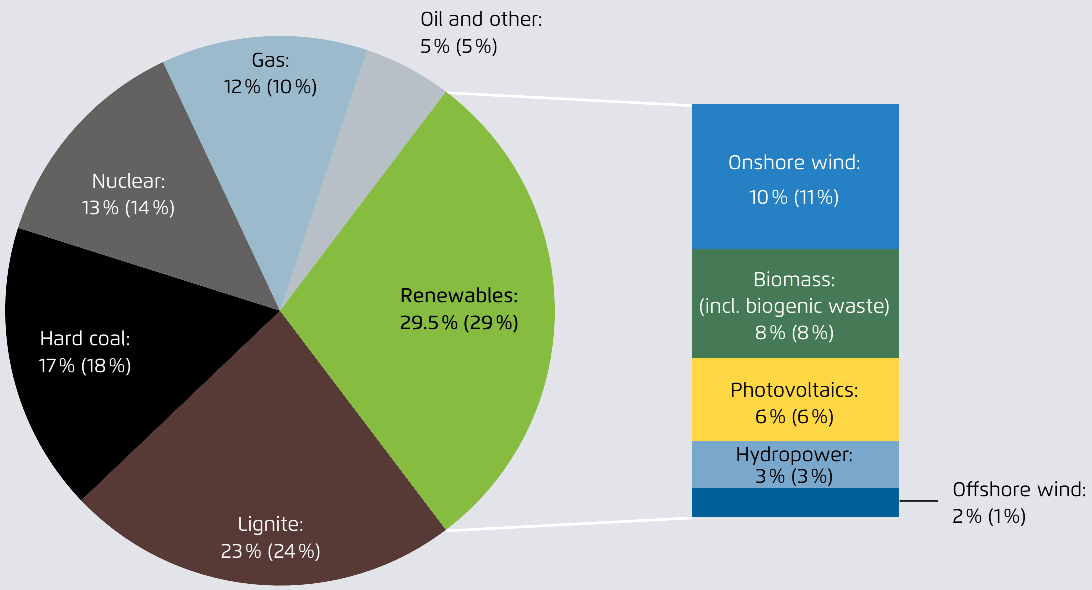
The *Energiewende* has its roots in public opposition to nuclear power, in the sustainable development movement, and in public support for action on climate change. A program to develop nuclear energy was launched in West Germany in the 1950s, although it faced heavy public opposition from the start. In the 1970s and 80s, a fierce anti-nuclear protest movement blocked development at potential reactor sites; several planned nuclear facilities were never realized. The Chernobyl disaster in 1986 was a first turning point in government policy. No new reactors were constructed in Germany after the accident. Then, in 2002, a first law was adopted to phase out nuclear energy by approximately 2022. Eight years later, in 2010, the government decided after a controversial debate to delay the nuclear phase-out until 2036. However, this decision was immediately reversed after the nuclear accident at Fukushima Daiichi in March 2011. In June 2011, the government reinstated the previous nuclear phase-out policy in an historic instance of cross-party support.

Major policies favoring energy efficiency and renewable energy development – including the Renewable Energy Act (EEG) – were adopted in the 2000s. In 2010, the German government adopted a long-term energy strategy calling for a renewables-based economy by 2050 (the so-called *Energiekonzept*). It included ambitious mid and long-term targets for developing renewable energy, improving energy efficiency, and reducing CO_2 emissions. This overall framework still prevails today. In the power sector, there is broad political consensus to shut down all nuclear power plants by 2022 and gradually increase renewables to at least 80 per cent of power consumption by 2050. The key debates in German energy policy concern the future role of coal and natural gas and the different policy options that are available on the road towards an economy based on renewable energy.

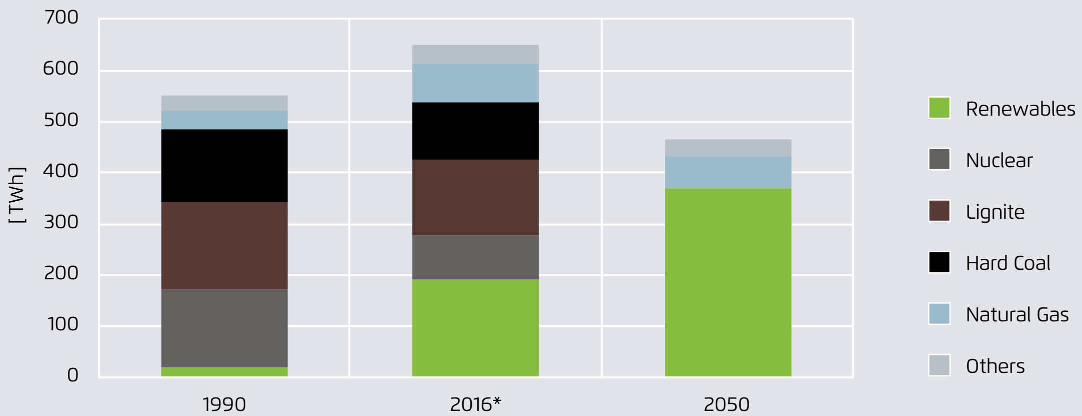
Q2 How is Germany progressing with its Energiewende?

A Renewable energy has become a key pillar of the power system. In 2016, renewables accounted for about 30 per cent of Germany's power production. After years of falling costs, wind energy and solar PV have become the backbone of the German power system transformation. Progress in the area of energy efficiency has been more moderate, as power consumption is only 4 per cent below its 2008 levels.

2016 German Power Mix (2015 data in brackets): Renewable energies produce 30 percent of German power and are by far the largest energy source — Figure 1



Gross electricity generation 1990, 2016 and 2050



AGEB (2016), BReg (2010), EEG (2014), own calculations — * preliminary

Renewable energy has become a key pillar of Germany's power system

Historically, power generation in Germany has been based on hard coal, lignite and nuclear. The German electricity mix has undergone significant diversification over the last twenty years, as seen in Figure 1. This evolution is characterized by:

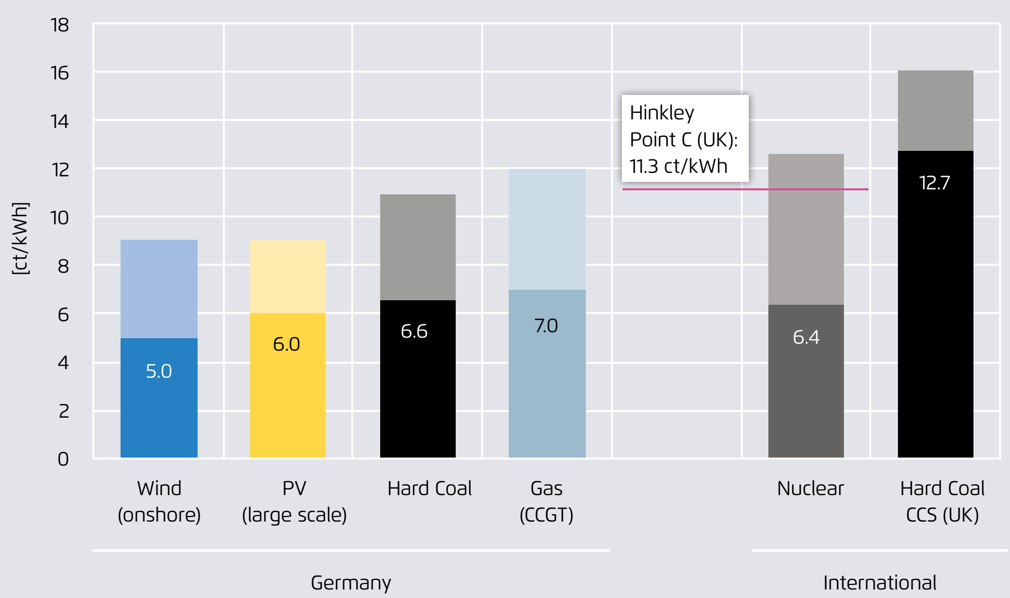
- → a substantial increase in renewable energy (from 3.6 per cent of the power production in 1990 to 29.5 per cent in 2016, corresponding to 32.3 per cent of national power consumption),
- → a progressive phase-out of nuclear power (13.1 per cent of domestic power production in 2016, down from 27.7 per cent in 1990),
- → continuous large-scale generation using lignite (23.1 per cent in 2016) and hard coal (17 per cent in 2016), with lignite power production remaining almost constant over the last twenty years and hard coal slowly declining. In 2016, declining power production from nuclear, hard coal and lignite (about –20 TWh compared to 2015 levels) was offset by an increase in production from renewables (+4 TWh) and natural gas (+16 TWh).
- → moderate decrease in power consumption over the last ten years (about -0.5 per cent annual average)

Since 2014, renewables have produced more electricity than lignite, evolving from a niche technology into a major pillar of the power system.

Wind energy and solar PV are the backbone of the German energy transformation

Wind energy and solar PV are the two renewable energy technologies with the largest growth potential in Germany, far ahead of other renewables such as biomass, hydro power, marine energy or geothermal energy. The further growth potential of biomass is limited because of costs, land-used constraints

Range of levelized cost of electricity (LCOE) in 2016 — Figure 2



Agora Energiewende (2014), DECC (2013), enervis (2015), EDF, own calculations. The LCOE is a metric used to compare the generation costs (EUR/kWh) of different technologies, taking into account fixed and variable costs, as well as cost of capital (WACC). In general, feed-in tariffs are slightly higher than the LCOE, as energy producers usually include revenue margins in their calculations.

and sustainability concerns. Wind and solar PV have undergone considerable development, primarily thanks to the feed-in tariff system introduced by the German Renewable Energy Act (EEG) (see Q10). In recent years the costs of these technologies have dropped dramatically due to technological progress and economies of scale. Cost declines have been particularly dramatic for solar PV, which experienced a 80 per cent decline between 2005 and 2015. Wind energy and solar PV are now competitive with conventional energy sources for new investment: in 2016 generation costs in Germany stood at 5–9 cts€/kWh for wind energy and 6–9 cts€/kWh for solar PV (see Figure 2). Moreover, future cost declines are expected.

In 2016, the cumulative installed capacity of those two technologies exceeded 89 GW (onshore wind: 44.8 GW, offshore wind: 4.1 GW, photovoltaics: 40.4 GW), thus comprising approximately 15 per cent of national power consumption. At current growth rates, renewable energy sources will be able to more than compensate for the phase-out of nuclear by 2022.

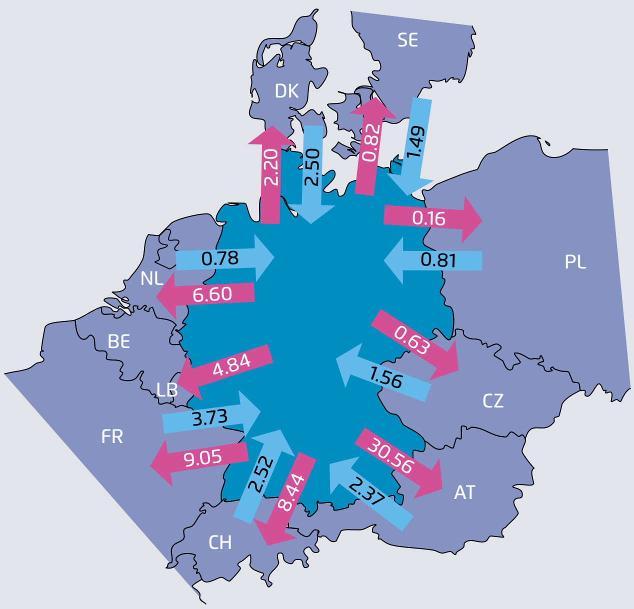
Q3 **Does Germany import nuclear and coal electricity from neighbouring countries to compensate for the nuclear phase-out?**

A No. Germany has been a net exporter of power to its neighbours since 2003, reaching a new export record in 2015. Renewable energy sources have more than compensated for the closure of nuclear power plants since Fukushima nuclear accident.

Germany is a net exporter of power to its neighbours, despite the nuclear phase-out

Germany has been a net exporter of electricity since 2003. This trend has accelerated since 2011, despite the definite close eight nuclear power plants in the wake of the Fukushima disaster. In 2016, Germany's net power exports reached 47.5 TWh, representing 8 per cent of national power consumption. Austria, France, the Netherlands are the main importers of power from Germany. Germany is a strong exporter because it has the second-lowest power prices in Europe after Scandinavia. These low prices are attributable to the rapid expansion of renewable energy, a competitive generation mix, stagnant power demand, and the current high competitiveness of coal power in the context of very low carbon certificate prices in Europe.

Trade flows with neighbouring countries 2016. Germany exported electricity primarily to Austria, France, Switzerland and the Netherlands — Figure 3



Exports: 63.3 TWh (2015: 97.8 TWh)
Imports: 15.8 TWh (2015: 36.9 TWh)
Balance: 47.5 TWh (2015: 60.9 TWh)
Traded electricity in TWh

Calculations based on ENTSO-E 2016; shown are commercial exchanges, not physical flows

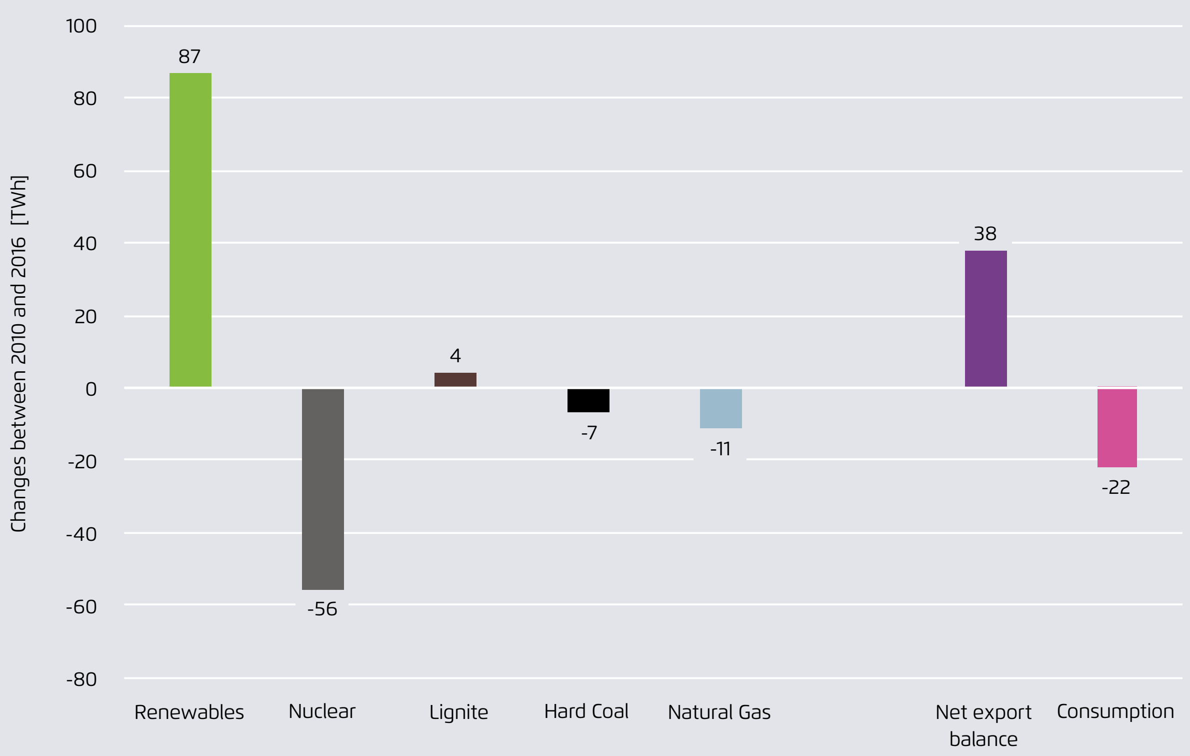
Growth in renewables has more than compensated for the closure of nuclear power plants since Fukushima

Between 2010 and 2016, power production from renewables increased by +87.2 TWh, while nuclear generation declined by –55.7 TWh. However, during this same period, coal power generation was almost unchanged due to low prices for CO_2 and coal, despite a concurrent fall in power demand (–22 TWh between 2010 and 2016). This has led to an increasingly wide spread between cheap coal and expensive natural gas. As a result, coal-power production levels are still very high (see Q5), despite a small drop from 2015 to 2016, contributing to historically high power exports.

Germany is a net exporter of electricity to France, and a net importer from the Czech Republic and Poland, but the volume of electricity traded with these two countries is relatively low

Germany is a net exporter of electricity to France (+5.3 TWh in 2016). This means that Germany sells more electricity to France than it buys from France (see annex for an explanation of power flows between European countries). Germany has a tendency to buy electricity from France over the summer, when demand in both countries is lower. But it sells electricity the rest of the year, especially in the winter, when demand is higher. However, the electricity does not necessarily transit directly through the German/French border, but may transit through the Netherlands/Belgium or Switzerland.

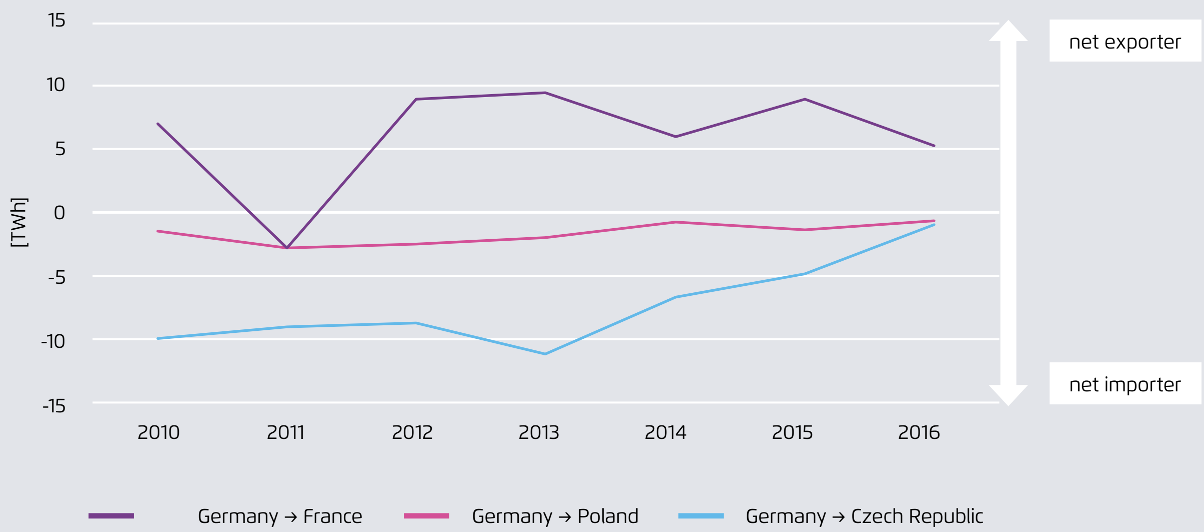
Change in electricity volumes, 2010-2016 * Figure 4



AG Energiebilanzen 2016 * preliminary

Yearly electricity trade (commercial flows) between Germany and Czech Republic, Poland and France from 2010 to 2016

Figure 5



ENTSO-E, own calculation

On its eastern borders, Germany is a net importer of electricity from Poland (+0.65 TWh) and the Czech Republic (+0.9 TWh). These imports are only partially attributable to the market-driven optimization of power flows (see details in the annex). The net trade balance with those countries in 2016 has decreased compared to 2010, before 8 nuclear power plants were shut down. Accordingly, the nuclear phase-out has not been associated with higher imports. In any event, the volume of electricity traded between Germany and its eastern neighbours is relatively low.

Q4 Have electricity prices for German households risen due to the development of renewables?

A Partly Yes. As an early mover, Germany began developing renewables when they were relatively expensive, creating costs that will be borne by German consumers during years to come. However, this early commitment to renewables has contributed to their declining cost worldwide. Following years of increases, electricity prices for German households have been relatively stable since 2013, as new renewable plants are now comparable in cost to new conventional power plants. Furthermore, electricity bills in Germany are comparable to those in other industrialized countries, as German households are relatively more efficient and consume less electricity.

German electricity bills are comparable to those in other industrialized countries

German households pay about the same electricity bills as consumers in other industrialized countries (e.g. US, Japan) as they are comparably more efficient and consume less electricity, as shown in Table 2. However, German consumers do pay one of the highest electricity rates in Europe, currently about 0.30 €/kWh. Electricity is only more expensive in Denmark. On average, German households spend around 2.5 per cent of their total expenditure on electricity. A similar percentage was spent by German consumers on electricity in the 1980s, but a lower percentage was spent in the 1990s and 2000s (roughly 2 per cent of household expenditure). Low-income households in Germany are more affected by high electricity prices, which account for up to five per cent of household expenditures. Meanwhile, energy intensive industries in Germany pay one of the lowest electricity prices in Europe, benefiting from exemptions and falling wholesale electricity prices (see Q6).

Average household electricity bills in industrialized countries, 2014 — Table 2

	Annual household consumption in kWh	Electricity price in EURct/kWh	Annual electricity bill in EUR
Denmark	3,820	29.4	1,121
US	12,294	9.0	1,110
Germany	3,362	29.1	978
Japan	5,373	18.1	971
Spain	4,038	22.6	912
Canada	11,303	7.5	851
France	5,830	14.3	834
UK	4,143	17.3	717
Italy	2,485	23.3	580
Poland	1,935	15.1	291

Enerdata (2015), World Energy Council (2015), own calculations — * consumption data from 2013; electricity prices data from 2014

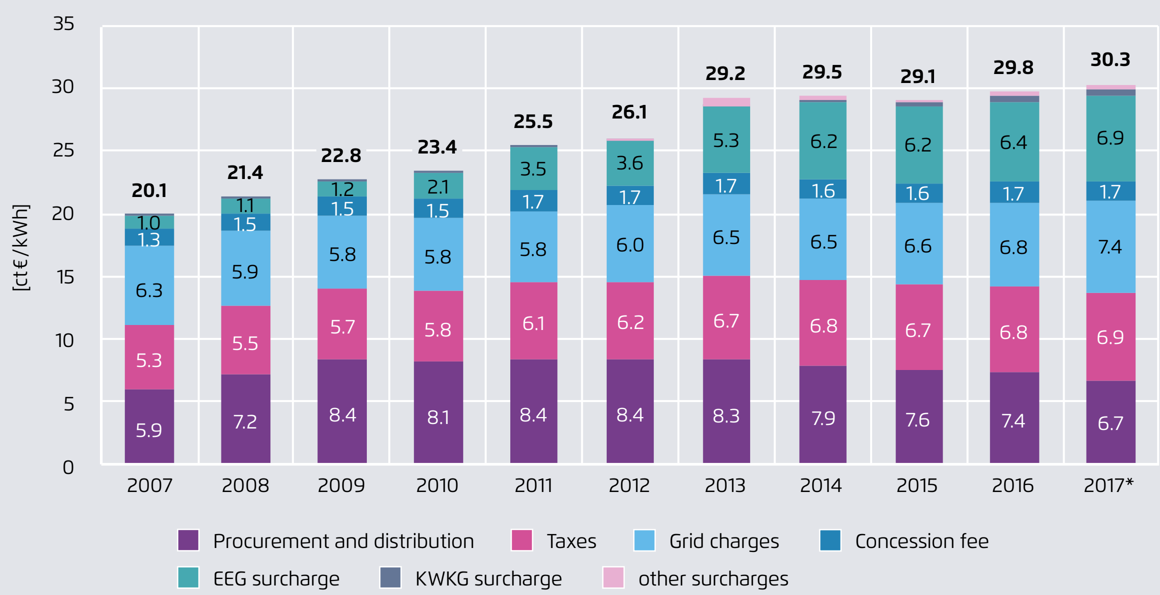
Following years of increases, electricity prices for German households have been relatively stable since 2013

As shown in Figure 6, power prices have increased by about 50 per cent since 2007 (in nominal terms), due to a continuous increase in almost all price components, including the levy for renewable energy, grid tariffs, and various levies and taxes. The "EEG surcharge," a fee that is added to power bills to finance renewable energy has risen continuously over the years and is currently set at € 6.88 cents per kWh (for a total of 24 billion euros in 2017). The EEG surcharge covers the difference between the cost of generating one kWh of renewable electricity (i.e. the feed-in tariff paid to the producers) and the revenues from selling this kWh on the wholesale market. The surcharge increased at a particularly fast rate between 2009 and 2013, due to a sharp increase in the deployment of solar PV when the costs of this technology were still very high. These "historic costs" will continue to be paid by German consumers in years to come as German law guarantees payment to solar PV producers for a twenty year period. On the other hand, renewable energy expansion has contributed to lower wholesale market prices, partially offsetting the high EEG surcharge (as shown in Figure 7). As an early mover, Germany invested heavily in renewables when they were still quite expensive. While this has created burdens for German consumers, it has contributed to falling technology prices worldwide, making it cheaper to develop renewables in other countries.

Electricity prices are expected to increase only slightly in the years to come

As depicted in Figure 6, household electricity prices have been relatively stable since 2013. Electricity prices are expected to increase only slightly in the years to come, as the major cost drivers belong to the past. The cost of solar PV has decreased significantly

Average household electricity prices for a 4-person household (3500 kWh annual use), 2007 – 2017 Figure 6

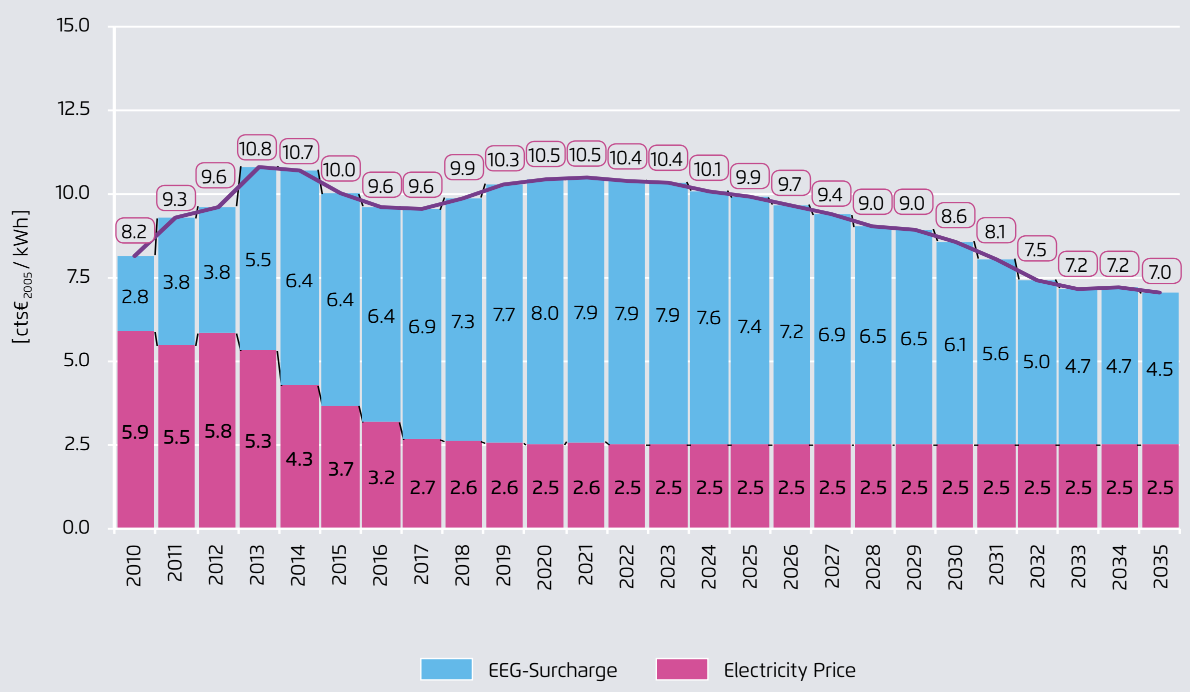


BNetzA 2016, * own estimates

in recent years (see Question 2) and will no longer be an important cost driver. Furthermore, the latest reform of the Renewable Energy Act (EEG 2017) has introduced a more competitive support system (based on auctions) in order to bring costs down even further (see Q10). The EEG surcharge is expected to increase only moderately in the years to come (see Figure 7). It is expected to reach a maximum of € 8 cents per kWh in 2020 and then decrease as consumers are no longer required to pay for the oldest (and most expensive) renewable capacity installed in the 2000s. The main reason for the continued increase until around 2020 is the development of offshore wind, a relatively expensive emerging technology. The EEG surcharge should decline to € 4.5 cents per kWh in 2035, when 60 per cent of power will come from renewables.

Sum of the electricity wholesale price (Phelix Base Year Futures) and the EEG surchage in cts€/kWh from 2010 to 2035

Figure 7



Ökoinstitut (2005), Agora Energiewende

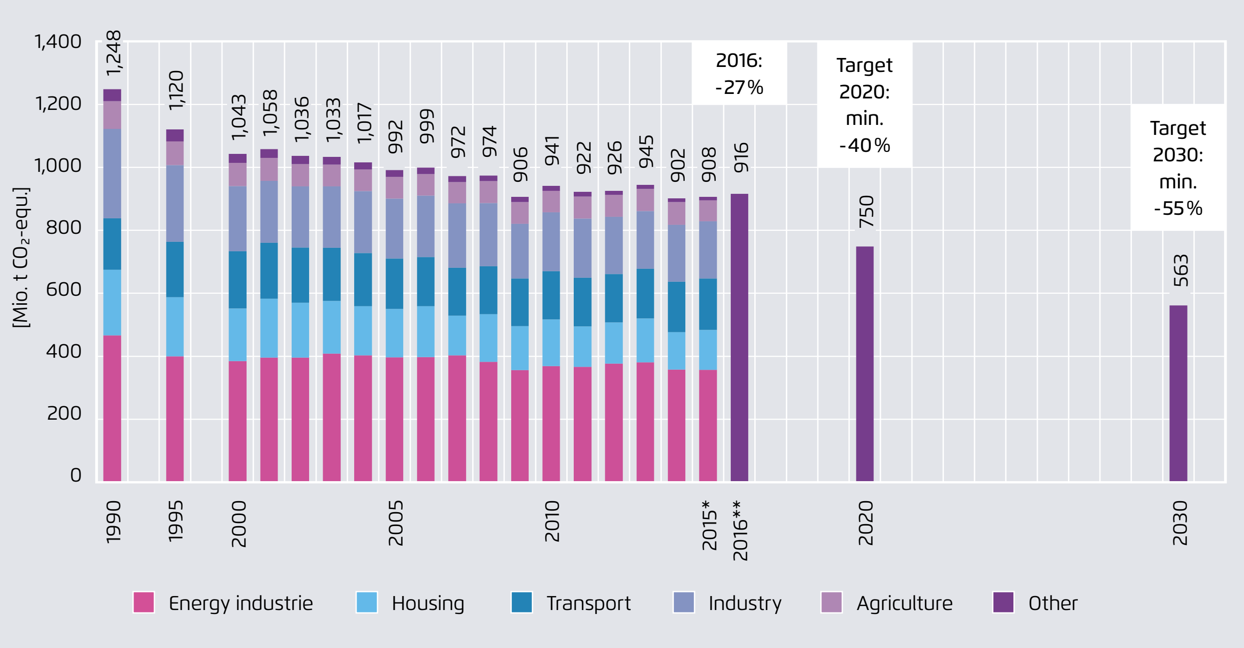
Q5 **Have German CO_2 emissions increased because electricity production from coal has risen?**

A Not really. In 2016, after declining for three consecutive years, coal-fired power generation and CO_2 emissions in the power sector were below their 2010 levels. However, German greenhouse gas emissions have slightly increased over the past three years, because of insufficient emission reductions in the heating, transportation and industrial sectors. Nevertheless, the strong competiveness of coal power has had a negative impact on Germany's overall CO_2 emissions. In order to meet its climate targets, Germany needs to gradually phase-out coal power.

In 2016, greenhouse gas emissions were 27 per cent below 1990 levels and the emissions of the power sector were below 2010 levels

Germany has adopted ambitious climate targets and aims to reduce its greenhouse gas emissions by 40 per cent in 2020, at least 55 per cent in 2030, at least 70 per cent in 2040 and by 80 – 95 per cent by 2050 (over 1990 levels). In 2016, greenhouse gas emissions were 27 per cent below 1990 levels (see Figure 8) and the emissions of the power sector were below 2010 levels. However, over the past three years, overall greenhouse gas emissions have slightly increased, because of insufficient emission reductions in the industrial, heating and transportation sectors. The German power sector – which is still highly dependent on coal – is the largest emitter, responsible for about 40 per cent of overall national greenhouse gas emissions (306 Mt CO_2 in 2016).

Greenhouse gas emission by sector, 1990 - 2016, together with reduction targets for 2020 and 2030 Figure 8



UBA 2016, own calculations * preliminary, ** own estimations

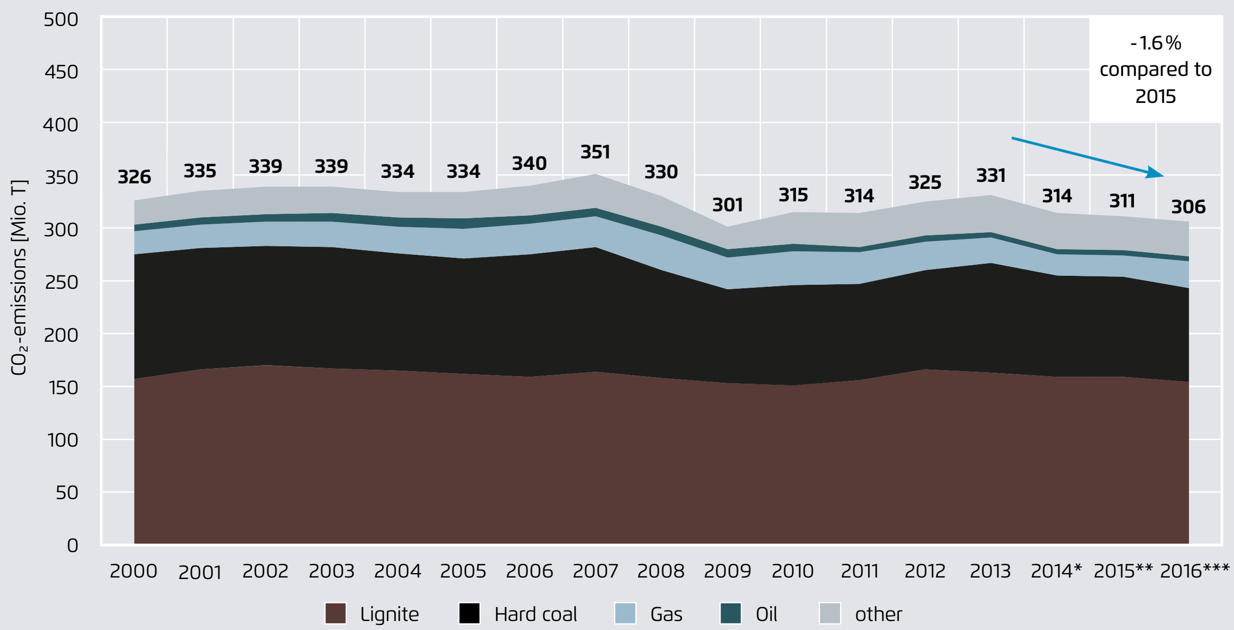
The decarbonization of the power sector is therefore essential for reaching climate targets.

The most recent investment decisions for new coal power plants in Germany were made about 10 years ago. One of those projects (Datteln 4) is still under construction, but otherwise there are currently no plans to build new coal power plants in Germany.

Since 2014, coal-fired power generation and CO_2 emissions in the power sector have been slightly declining

The CO_2 emissions of the power sector increased in 2012 and 2013, despite the development of renewables and increased energy efficiency (a counterintuitive development known as the "*Energiewende* paradox"). These high emissions are explained by the high competitiveness of coal power plants, which are still responsible for 40 per cent of total electricity generation in Germany. As a consequence of low coal and CO_2 prices (in the context of a weak European Emission Trading Scheme), coal-power production levels in Germany have been high, crowding-out less polluting natural-gas power plants, both in Germany and in neighbouring countries. This has led to high CO_2 emissions as well as historically high exports (with benefits for neighbouring countries, which profit from lower electricity prices). Since 2014, however, coal-fired power production and the CO_2 emissions of the power sector have been slightly declining (see Figure 9): renewables and reduced power demand are now also crowding out hard-coal power plants, leading to an overall decrease in domestic CO_2 emissions. Furthermore, in 2016, the decline of fossil fuel prices has favored gas power plants over old coal power plants, leading to a further decrease in CO_2 emissions. Thanks to the development of renewables, about 115 Mt of CO_2 emissions were avoided in the power sector in 2015. Nevertheless, power generation from lignite remains high and net exports are still strongly positive (see Q3).

CO_2 emissions in the power sector by energy source, 2000 - 2016 — Figure 9



UBA 2016 — (*preliminary, **Estimate UBA), ***own calculations

Germany needs to gradually phase-out coal power in order to meet its climate targets

The emissions of the power sector are expected to decline further in a business-as-usual scenario by about 40 Mt of CO_2 by 2020. However, this declining trend in the power sector is not sufficient to meet the 2020 reduction targets, leaving further reduction efforts necessary. A set of complementary policy measures have been adopted in order to close this gap, including the retirement of old lignite power plants (2.7 GW, about 13 per cent of old lignite power capacity in Germany). Once off the market, these plants will remain for four years in a "climate reserve" and will only be activated if there is a danger of a severe power shortfall. After four more years, the plants will be shut down completely.

Ultimately, there is no alternative to the phasing out of coal power if Germany is to fulfill its climate goals. In view of trends in the energy economy (including persistent low coal and CO_2 certificate prices), targeted action must be taken, as market-based instruments will not be sufficient. In order to reach the 2030 targets and beyond, a consensus on the gradual reduction of coal power must be established, together with power producers, unions, government, and environmental NGOs. The public debate on this issue has started in Germany. Agora *Energiewende* has contributed to this discussion by proposing a cost-efficient decommissioning plan for existing coal power plants. This plan foresees financial support for redeveloping affected mining regions.

Q6 **How has the German Energiewende impacted the domestic economy?**

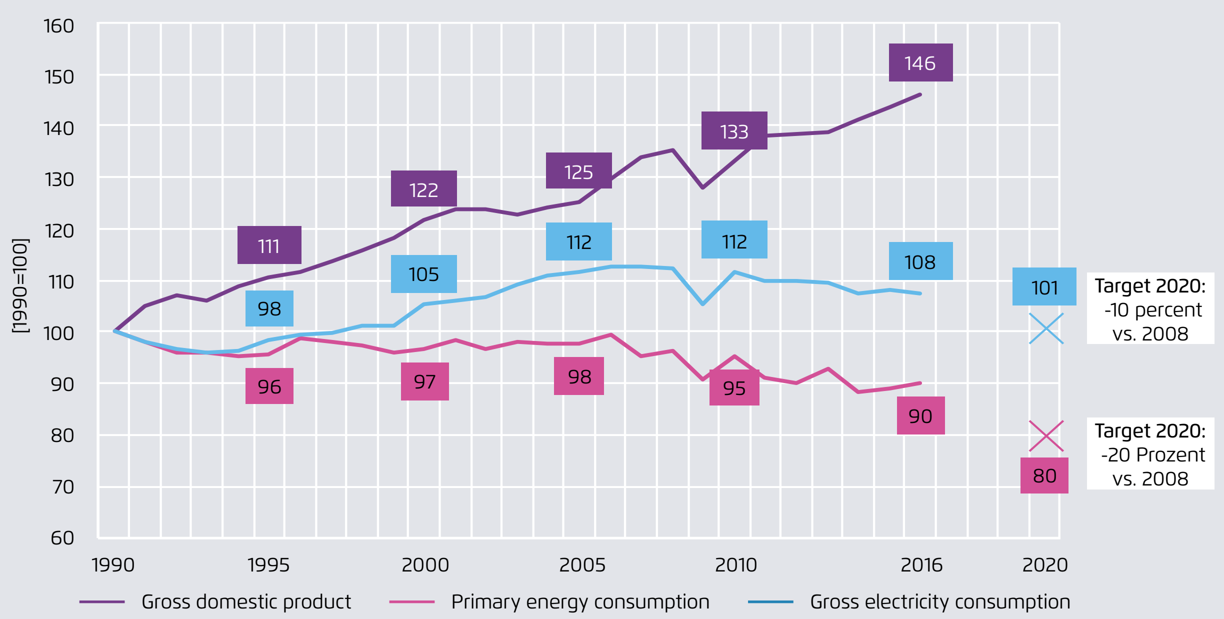
A Since 2008, the German economy has spent between 2.3 per cent and 2.5 per cent of annual GDP on its power system. Spending was similar in the mid-1990s but lower in 2000 (1.6 per cent). The development of renewable energy and promotion of energy efficiency have stimulated significant investment, encouraging employment and growth. However, given its transformative nature, the Energiewende is crowding out investment and employment in conventional energy sectors. Furthermore, energy intensive companies are shielded from rising power costs, in order to preserve their competitiveness and prevent industrial flight. Thanks to energy efficiency, Germany has successfully decoupled economic growth from energy consumption.

The development of renewable energy is contributing to German GDP growth, and, thanks to energy efficiency, Germany has decoupled economic growth from energy consumption

As a percentage of GDP, total spending in Germany on the power sector has not varied significantly over the last ten years. Since 2008, Germany has spent 2.3 per cent to 2.5 per cent of annual GDP on its power system, a level similar to the mid-1990s, but higher than in 2000 (1.6 per cent). In absolute terms, power system expenditures have risen (from about 60 to 70 billion euros annually) but this increase has been offset by higher GDP. The *Energiewende* is a process of socio-economic transformation and an important

Gross domestic product, primary energy, consumption and electricity production, 1990 - 2016 (indexed, 1990=100)

Figure 10



AG Energiebilanzen 2016; Statistisches Bundesamt, own calculations investment program, encouraging growth and innovation in new low-carbon sectors (renewable energy, energy efficiency, new energy services, and alternative transportation). Total investment in renewable energy across all sectors from 2000 to 2015 was 235 billion euros, corresponding to an annual average of 16 billion euros. These investments have contributed to German competitiveness in green technology while also supporting GDP growth. In the decade to come, investment in the power sector is expected to reach about 15 billion euros annually, 9–10 billion euros of which will be invested in new renewable capacity. Furthermore, Germany has managed to decouple economic growth from energy consumption (as can be seen in Figure 10).

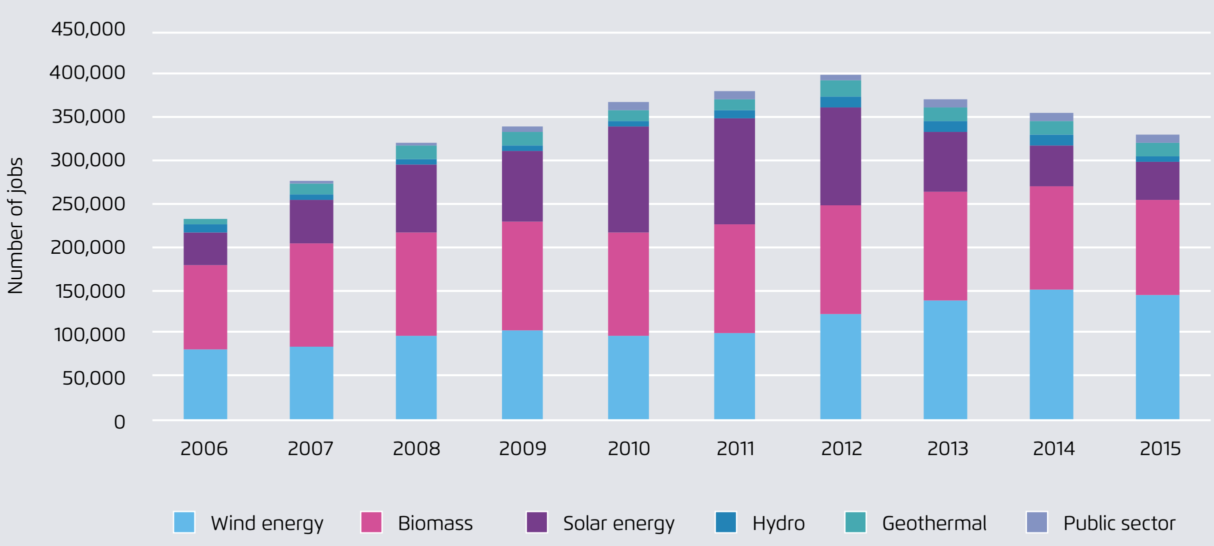
In 2015, the German renewable energy industry supported 330,000 jobs

The *Energiewende* has had an important impact on the employment structure of the energy sector. In 2015, the renewable industry alone accounted for approximately 333,000 jobs, twice as much as in 2004. The wind energy sector is the biggest employer (about 142,900 jobs in 2015) followed by the biomass sector (113,200 jobs). The German solar energy sector (42,200 jobs in 2015) experienced a profound restructuring between 2012 and 2015, losing about 70,000 jobs as a consequence of strong competition on the global market and slow-down of national demand (+1.2 GW installed capacity in 2016 compared to + 7.5 GW annual growth from 2009 to 2012). Nevertheless, the solar energy sector remains an important employer.

The *Energiewende* is crowding out investment and employment from conventional energy sectors in favor of renewable energy sectors

The development of renewable energy and energy efficiency has crowded out investment in conven-

Employment in the German renewable energy sectors from 2006 to 2015 — Figure 11



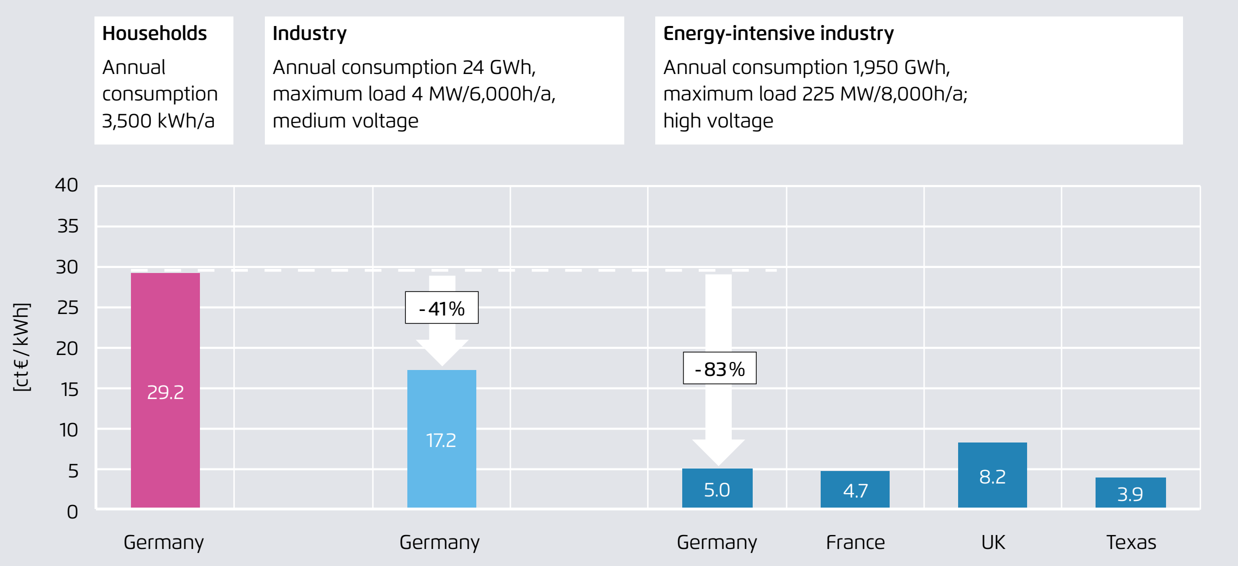
GWS/DLR/DIW/ZSW

tional energy (i.e. coal and nuclear), exerting negative effects on investment and employment in these sectors. Furthermore, increasing energy costs, while moderate, have reduced the purchasing power of German consumers and businesses, leading to lower spending and investment. These effects are nevertheless partially offset by increased exports for manufactured goods in the renewable energy sector. Furthermore, the development of renewables in combination with energy efficiency measures has led to a net reduction of fossil fuel imports. Estimates for 2015 indicate import savings of 8.8 billion euros from renewable energy development and 16 billion euros from energy efficiency. According to a study commissioned by the Federal Ministry for Economic Affairs and Energy, the net impact of the *Energiewende* on employment in Germany is moderately positive, with an annual net increase of 18,000 jobs up to 2020 in comparison to a scenario without the *Energiewende*.

Energy intensive companies are protected politically from rising energy costs, in order to ensure their competitiveness and prevent industrial flight

In recent years, the media has reported on some production site closures in Germany and reinvestment abroad, especially in the US. Such instances of industrial flight hinge on a wide range of factors, including proximity to new markets and labour cost differentials, and cannot be clearly attributed to historic or anticipated electricity price increases. However, in some sectors (for example, steel, aluminium, cement), electricity costs do in fact play a key role in firm competitiveness. The electricity prices paid by German industrial consumers diverge considerably, as varying exemptions on price components are granted depending on their consumption levels and exposure to international competition. While small German industrial consumers (consumption below 20 MWh) pay one of the highest retail prices in Europe, German

Average electricity prices for households and industrial consumers, 2013 — Figure 12



BNetzA (2014), Ecofys/ISI (2014)

energy-intensive industries pay one of the lowest. In fact, the energy intensive industries (steel, aluminium, cement) pay almost no taxes and levies (pro kWh consumed) due to exemptions provided to support their international competitiveness. They also purchase their electricity directly on the wholesale market, thus benefiting from lower prices. In 2016, about 2,140 companies in Germany – responsible for 20 per cent of national power consumption – benefited from those exemptions.

The rest of the German industrial sector pays relatively high electricity bills in comparison to the European average, but their energy costs are relatively insignificant in relation to revenues. 98.5 per cent of companies in Germany pay less than 6 per cent of their revenues in energy costs.

Q7 **Is security of supply in Germany threatened by reliance on renewables?**

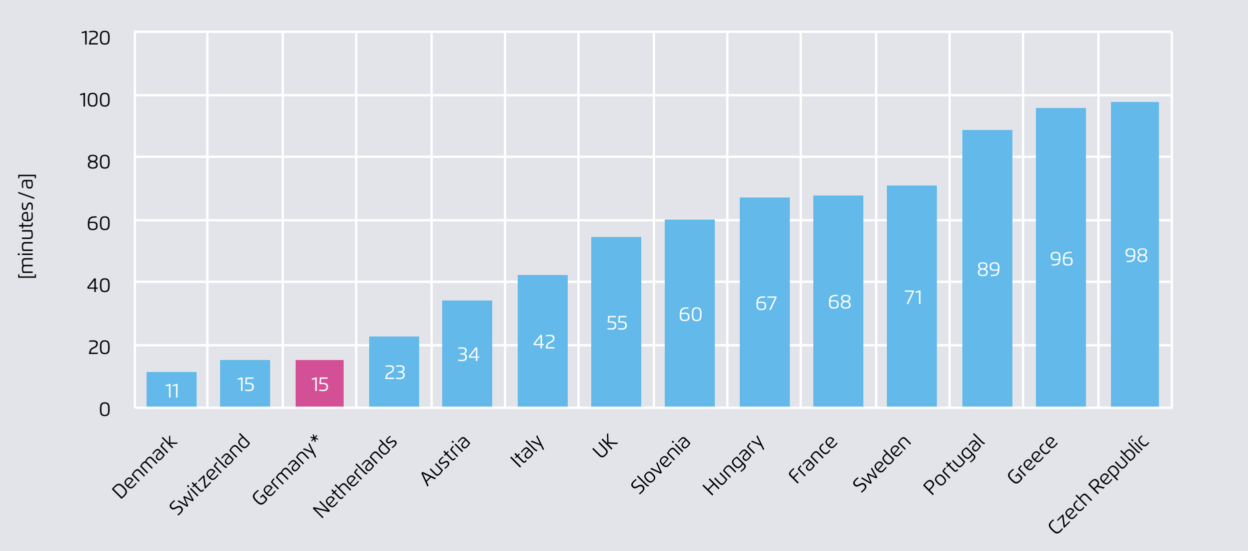
A No. Germany's electricity supply is stable despite a high share of renewables. The German power system is currently one of the most reliable in the world. The variable output of renewables is successfully managed with power system flexibility. The baseload operation of power plants has been significantly reduced, without damaging security of supply.

Electricity supply in Germany is stable despite a high share of renewables

Although renewables are currently responsible for 32.3 per cent of electricity consumption, the German power system is currently one of the most reliable in the world, with a very low level of unplanned capacity shortages (12.7 minutes in 2015; see Figure 13). By way of comparison, US capacity shortages were approximately 10 times higher. Some regional constraints on the grid – especially on the north/south axis – nevertheless make various active grid management measures necessary to ensure system stability, including the redispatch[1] of conventional generation and, as a measure of last resort, curtailment of variable renewables. Furthermore, increasing the level of interconnection between Germany

1 Redispatch is a means of resolving transmission congestion by changing generator output levels. By lowering the real power output of one or more power plants and at the same time increasing the real power output of one or more other power plants, it is possible to relieve congestion while keeping the total real power in the grid close to constant. Adjusting the output of generators that produce congestion could be a lower cost, faster solution for improving transmission flows than building new lines.

Unplanned System Average Interruption Duration Index (SAIDI, excluding exceptional events), 2013 Figure 13



CEER (2015)

* The German SAIDI index decreased to 13 minutes in 2015

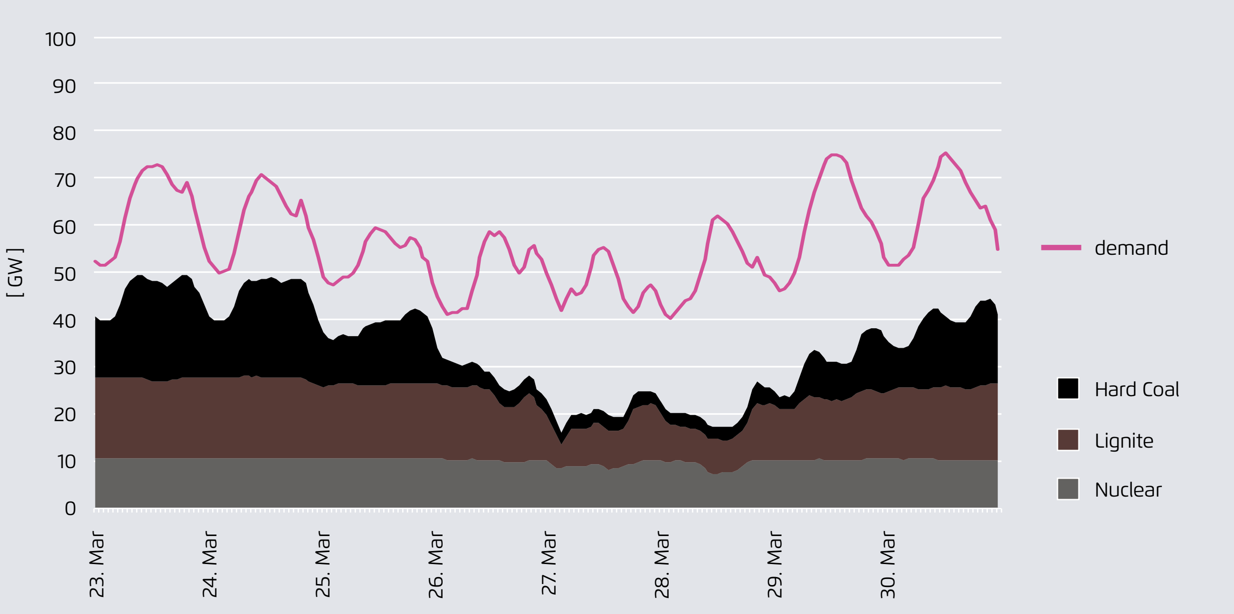
and its European neighbors has improved security of supply, while facilitating the incorporation of fluctuating renewables. Moreover, several reserves (capacity, grid and standby reserves) have been introduced to ensure supply security in "emergency situations". These reserves can be called upon to resolve electricity shortages or grid constraints. They are meant to address the political fears that an advanced energy-only market might be unable to guarantee security of supply needs. In addition to allaying fears, the grid reserve has the purpose of alleviating north-south grid congestion in Germany (see Q9).

The variable output of renewables is managed with power system flexibility. The baseload operation of conventional power plants has been significantly reduced

Wind turbines and photovoltaic power plants are variable sources that provide electricity only when the wind blows and the sun shines. This variability necessitates fundamental change in the power system and power markets, which have to cope with highly fluctuating feed-in. As variable renewables currently represent 18 per cent of power consumption in Germany, conventional power plants (i.e. nuclear and coal) have to respond flexibly to rapid changes in power supply and demand. At present, the German power system offers abundant technical potential for flexibility (much higher than the actual demand for flexibility). As shown in Figure 14, conventional power plants are already being operated in a flexible manner to manage variable feed-in. During the depicted example week in March 2016, the baseload operation of nuclear and coal power plants was significantly reduced while RES generation was high. Several other flexibility options exist to incorporate variable energy sources into the power system. These include, for example, demand-side management, the expansion of grid infrastructure (including smart grid solutions) and, in the long-term, expanded storage

Power generation from nuclear, hard coal and lignite power plants and demand in Germany, 23 to 30 March 2016

Figure 14



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capacities. This paradigm shift will become increasingly important as Germany moves towards more than 50 per cent renewables by 2030.

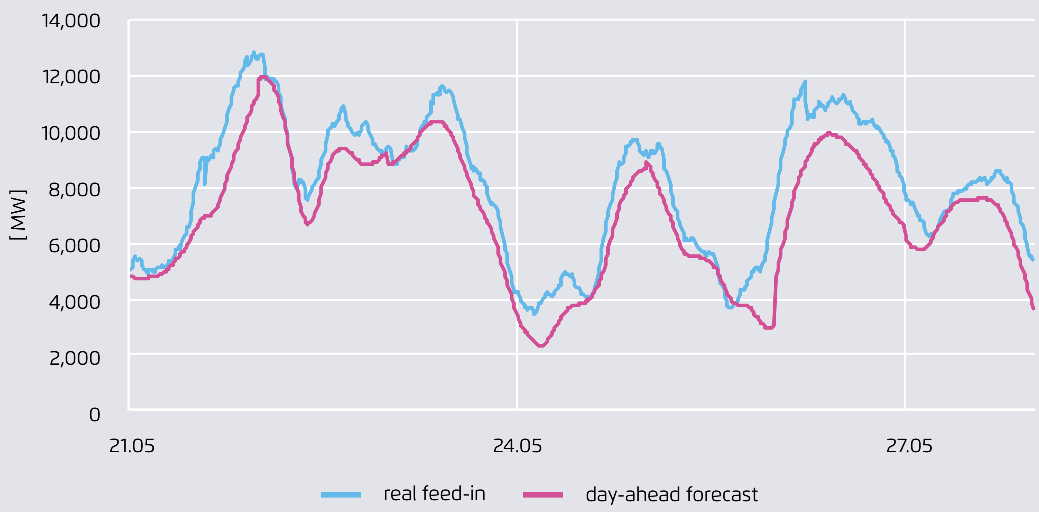
Against this backdrop, incentives to promote market efficiency are being redesigned within the scope of new electricity market legislation. Market prices need to reflect the benefits of flexibility, in order to leverage technical potential in the most cost-efficient way. Furthermore, a priority must be given to the gradual phase-out of inflexible baseload supply.

Improved forecasting, highly responsive control systems and flexible markets enable the integration of a high share of renewables, even in extreme situations

The German power system has already experienced several extreme situations in connection with the variable feed-in of renewables. On the 8th of May 2016, renewable energies covered up to 86.3 per cent of German electricity demand with large share of photovoltaic and wind energy. Yet variable output must not be confused with uncertain output, as the forecasting of wind and PV generation has made significant progress, as can be seen in Figure 15.

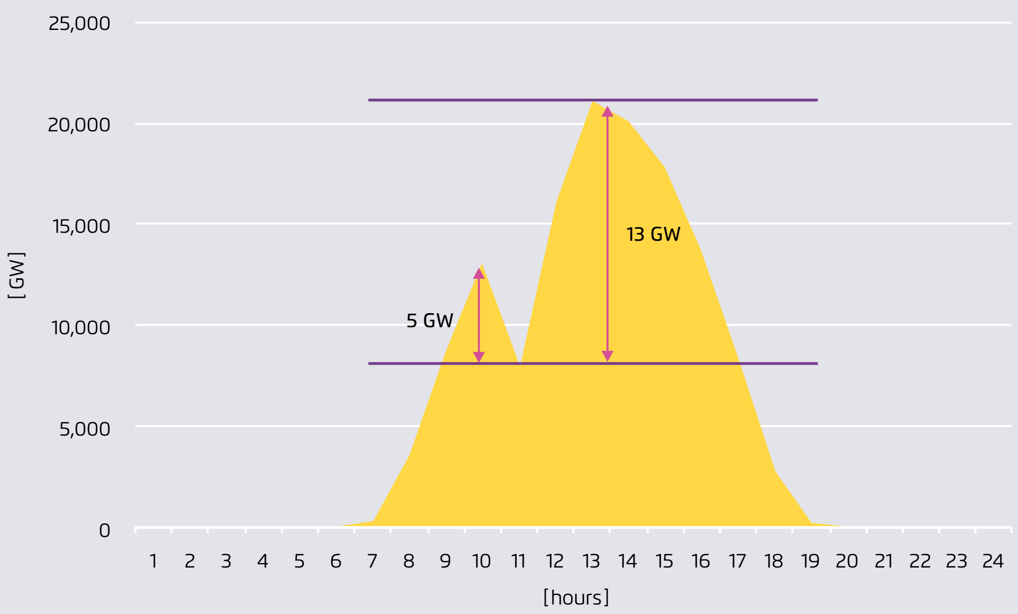
A good example of an extreme situation is the solar eclipse of 20 March 2015. Due to the eclipse, electricity production from solar PV dropped by 5 GW within 65 minutes, and ramped up again by 13 GW within 75 minutes, as depicted in Figure 16. To manage the impact of the solar eclipse, transmission system operators across Europe coordinated system operations ahead of and during the event. Furthermore, flexibility was traded on short-term markets. As a result, electricity supply remained stable during the hours of the eclipse. While such steep fluctuations in feed-in are unusual today, they will occur more frequently in 2030, when roughly 50 per cent of electricity will be produced by renewables.

Difference between day-ahead wind energy forecast and real feed-in
(week in May 2015 in the North-East of Germany) Figure 15



50 Hertz

Solar power production in GW during the solar eclipse on March 20, 2015 — Figure 16



Agora Energiewende (2015)

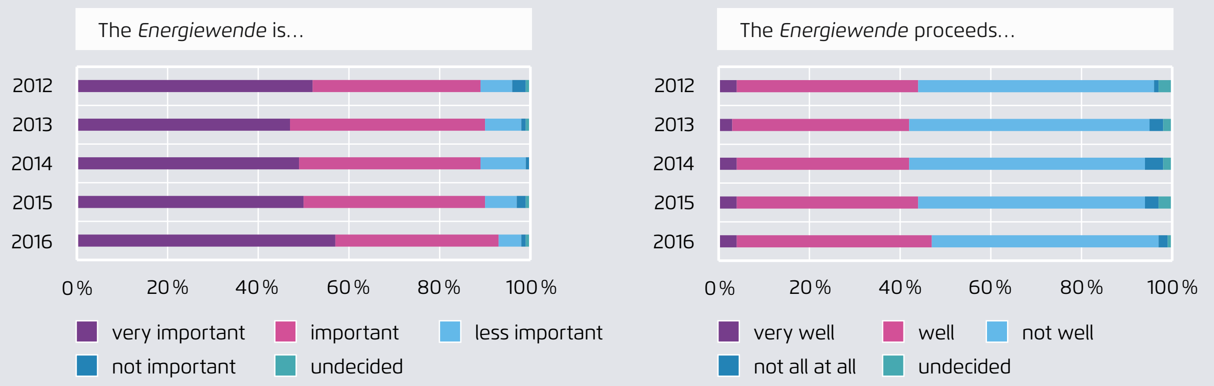
Q8 **Are German citizens and the business community supportive of the Energiewende?**

A German citizens strongly support the Energiewende. However, only about 50 per cent of Germans think the Energiewende is properly managed. The German business community has partially taken up the challenge of the Energiewende, which brings both risks and opportunities.

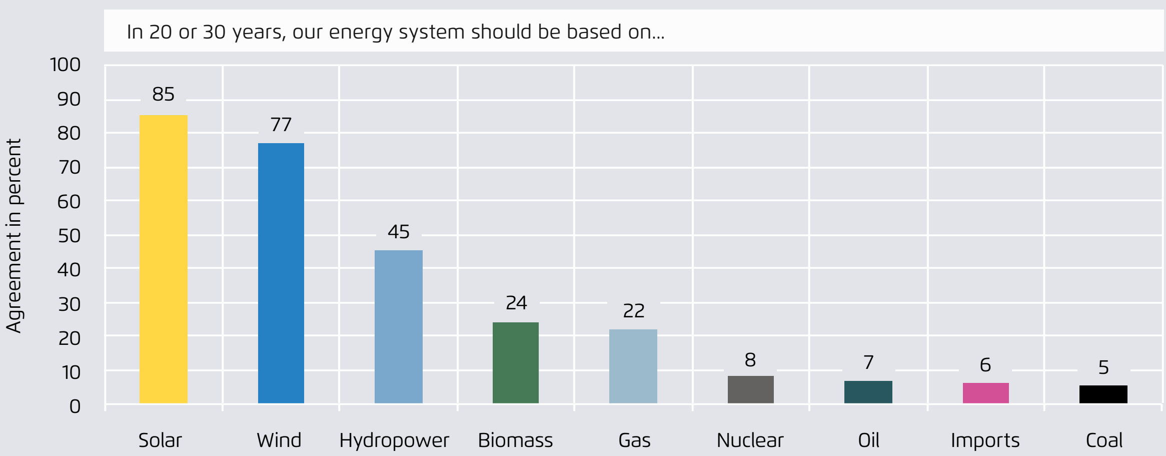
German citizens strongly support the goals of the *Energiewende*

The *Energiewende* encompasses much more than the technical transformation of energy infrastructure. It is a large-scale economic and ecological project motivated by scientific insights and ethical considerations. Germany's citizens have a strong desire to phase-out nuclear power and transform the way energy is supplied and consumed. There is a strong consensus in favor of renewable energy and more decentralized production, which together could foster the "democratiza-

Public opinion about the *Energiewende* — Figure 17



Forschungsgruppe Wahlen, comissioned by BDEW 2016



Bundespresseamt 2015, quoted from zeit.de and phasenpruefer.de tion of the energy system". Clearly, the *Energiewende* is having far-reaching economic and societal impacts.

Opinion polls show that Germany's citizens strongly support the *Energiewende*. More than 90 per cent of German citizens agree that the *Energiewende* is important or very important. Furthermore, the vast majority of German citizens are in favor of wind and solar as the key pillars of the energy system (see Figure 17). Some 48 per cent of Germans think the *Energiewende* is making good progress. For 55 per cent of German citizens, the expansion of renewable energy is too slow.

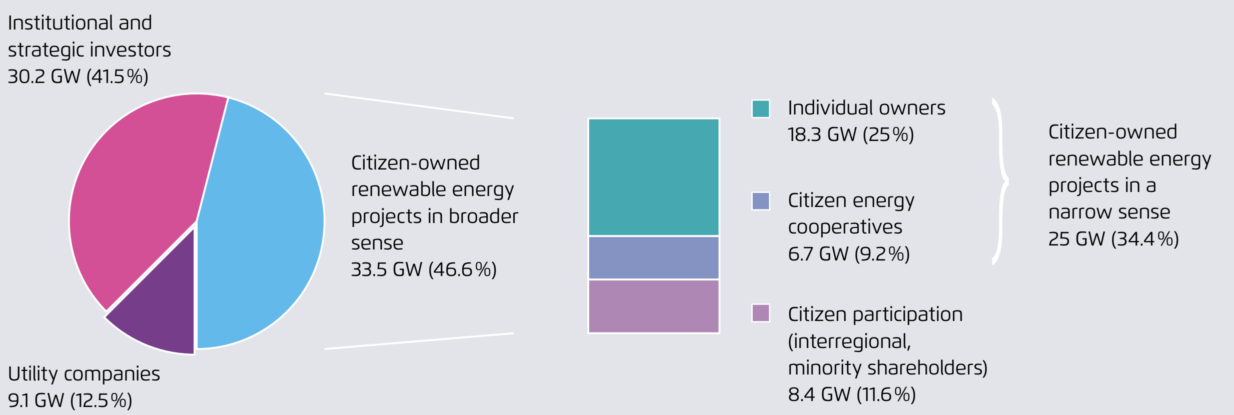
The *Energiewende* is ushering in a dramatically different energy economy – characterized by decentralized generation and a wide variety of actors

Currently, about 1.5 million photovoltaic systems and 26,000 wind turbines are installed in Germany. In contrast to conventional thermal generation, this renewable capacity is deployed in a highly decentralized patchwork of small-scale facilities. This diversification of the power mix has affected the ownership structure of power plants in Germany. A large share of these renewable energy systems were financed and are currently owned by non-utility actors, including households, farmers, and energy cooperatives. In 2012 (latest data available), such citizen-owned projects accounted for 47 per cent of all installed renewable capacity in Germany, while utilities only had a market share of around 13 per cent. This unique ownership structure is one reason for the broad support enjoyed by the *Energiewende*.

The German business community has partially taken up the challenge of the *Energiewende*, which brings both risks and opportunities

The German business community is has been broadly supportive of the *Energiewende*, as it offers new business opportunities. However, some stakeholders, especially industrial companies, fear energy cost increases that would undermine their international competitiveness. The German government has addressed these concerns by granting tax exemptions to energy-intensive industries. The stance taken by large utility companies on the *Energiewende* has evolved significantly over the last ten years. Historically, the business models of large utilities have relied on centralized production at fossil-fuel and nuclear plants and growing electricity demand. Renewable energy was perceived as a "niche technology". However, with the rapid development of distributed RES, stagnant power demand, and the impending phase-out of nuclear power, utilities are being forced to revise their business models.

Installed renewable energy capacity broken down by ownership in Germany in 2012 — Figure 18



trend:research/Leuphana (2013)

* not counting pumped storage power plants, offshore wind, geothermal energy, biowaste

Q9 **What is the current status of the north–south transmission grid expansion?**

A Upgrading the electricity grid is crucial for the future of Germany's power system. An estimated 8,000 kilometers of new transmission lines need to be installed by 2025, yet only 700 kilometers have been built to date. To ensure the reliable operation of the grid in Southern Germany, a grid reserve is activated when congestion prevents sufficient electricity flow from Northern to Southern Germany. New regulations aim to accelerate and better coordinate grid expansion.

Upgrading the electricity grid is crucial for the future of the German and European power systems

The rapid development of renewable energy, especially wind energy in the Northern Germany close to the coast, as well as the progressive phase out of nuclear power, has left Germany with a mismatch between the location of power generation and the location of its consumption. To address this problem, Germany's north–south transmission lines need to be expanded. This expansion will additionally support European market integration, e.g. by avoiding loop flows, especially with Germany's eastern neighbors (see Annex).

The Federal Requirement Plan Act Grid Expansion Plan (NEP) sets forth the expansion and reinforcement measures required over the next ten years to ensure the stable and reliable operation of the grid. The latest plan foresees around 8,000 kilometers of new transmission lines (comprising 43 individual projects). As of 2016, only 700 kilometers had been built.

The low-voltage distribution grid must also be expanded and reinforced, as a large share of onshore wind and PV are directly connected to the distribution grid. In Germany, local resistance to expansion measures has led to numerous construction delays. Building consensus at the local level through enhanced dialogue with a variety of stakeholders will be essential for improving public acceptance for grid expansion projects.

In order to ensure reliable grid operation in Southern Germany, a grid reserve is activated when congestion occurs on the north–south axis.

A grid reserve was enacted into law in 2012. It provides extra power when congestion prevents the flow of enough electricity from north to south. In this way, it ensures reliable grid operation in southern regions. The grid reserve consists of power plants in southern Germany and in neighbouring countries that would otherwise be non-operational or shut down.

For winter 2016/17, the Federal Network Agency has set aside 5.4 GW for the reserve. By winter 2018/19 this figure is expected to fall to around 1.9 GW on account of newly constructed power lines, including in particular the Thuringia Electricity Bridge.

New regulations aim to accelerate and better coordinate grid development

Energy regulation reforms adopted in 2016 (EEG 2017 and the new Electricity Market Act) have introduced various instruments to accelerate grid development and better coordinate grid planning and renewables expansion. The new regulations seek to address the ongoing delays to grid development. The new legislation provides three answers to the challenges facing the grid.

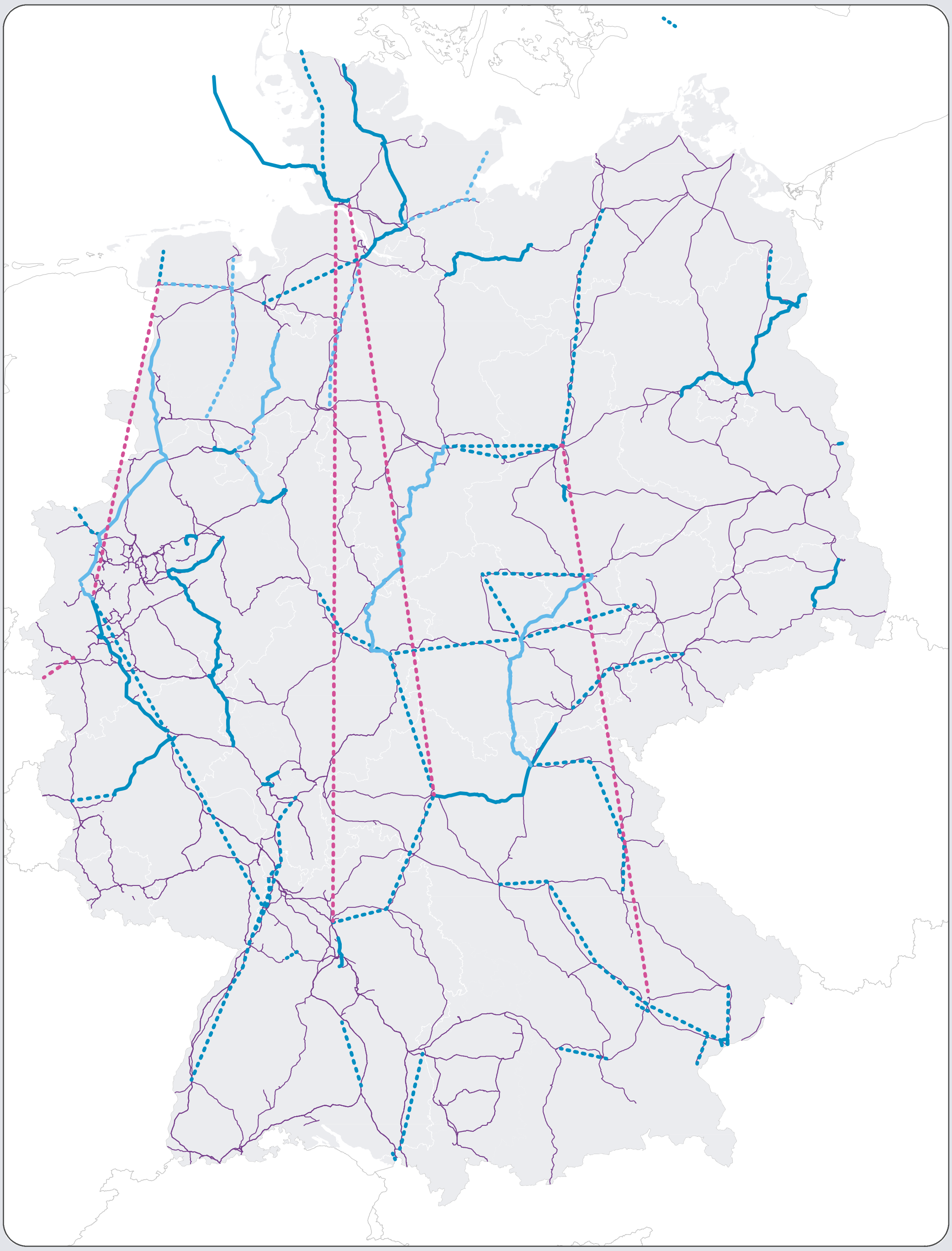
1. **Expansion of underground powerlines**
   The current Federal Requirement Plan Act stipulates the installation of underground power lines

in order to increase popular acceptance for expansion measures. High-voltage DC transmission lines must now be run underground instead of via transmission towers. In addition, AC grid expansion projects now have the option of underground installation in select areas. The main advantage of underground lines is lower visibility, which increases popular acceptance and may in some cases avert legal efforts to block development. However, the use of underground power lines can – depending on the specific location, cable length, soil consistency and transmission technology (AC or DC) – lead to considerable additional costs compared to transmission towers.

2. Peak shaving: an instrument for grid planning
The Electricity Market Act has introduced a new instrument for grid planning called "peak shaving". Previously, grid expansion followed the premise that the grid should absorb every kWh produced. This meant that the infrequently occurring feed-in peaks from wind turbine or PV were responsible for dimensioning the grid expansion. This approach, referred to as "until the last kilowatt hour", is neither fair for residents affected by new power lines nor economically efficient. The new approach now in place allows transmission system operators to curtail up to 3 per cent of annual renewable output in their grid requirement calculations. This reduces the cost of grid development by about 20 per cent. This grid expansion principle makes more economic sense for the overall power system.

3. Limits for additional onshore wind turbines in grid expansion areas
Transmission systems in some regions of Germany are currently under significant strain. In these areas, grid congestion, throttling-down measures such as redispatching and feed-in management for renewable energy installations are increasingly common. A new review instrument has been introduced in the new Renewable Energy Act (EEG 2017) to limit the creation of additional onshore wind turbine in places where the transmission grids are nearly overloaded.

Power line projects listed by the Federal Requirement Plan Act and the Power Grid Expansion Act — Figure 19



Agora Energiewendie; based on Bundesnetzagentur (2016)

Q10 **Why did Germany reform the Renewable Energy Act (EEG) and introduce an auction system?**

A The latest amendment of the German Renewable Energy Act (EEG) in 2016 aim to pave the way to higher shares of renewables, both at a steadier pace and at lower cost. The new system, based on auctioning, introduces more competition to the process of granting guaranteed remuneration to renewable energy producers. Because the German renewable energy sector is already sufficiently mature and competitive, this new system should bring further costs decreases while enabling the improved integration of renewables into the power system. It will, however, have major implication for a large part of the energy industry.

The Renewable Energy Act (EEG) has ensured the continuous and sustainable growth of renewables

Since the 1990s, the expansion of renewable energy in Germany has been promoted with various regulatory tools, most notably with the German Renewable Energy Act (EEG). It guarantees reliable investment conditions to producers of renewable electricity. The German Renewable Energy Act (EEG) has been continuously modified over the years. Each new set of rules has sought to stimulate innovation, to speed up technological development and cost degression, and to improve the integration of electricity from renewables into grid and market. Thanks to this support scheme, the share of renewables in power consumption has grown continuously, from 6.5 per cent in 2000 to 32.3 per cent in 2016, and renewables have become a mature market. With each new set of EEG rules, the mid and long-term targets have been raised (see Figure 20).

In 2016, the German government amended the Renewable Energy Act, the EEG 2017, as well as other important energy regulations. The core change to the Renewables Energy Act is that support for renewable energy projects will now be mostly determined by market mechanisms, by means of an auction system, rather than being fixed by the government through the feed-in tariff system. According to the German government, this new auction system will ensure that the expansion of renewables proceeds at a steady and controlled pace and at low cost. The EEG 2017 entered into force in January 2017.

While the German government sees the new legislation as a fundamental and indispensable requirement for the successful continuation of the *Energiewende*, others fear a slowdown or even a failure of the country's transformation efforts. While the new regulations will change little for consumers and the economy as a whole, they will have major implications for large parts of the energy industry.

The most important elements of the newest Renewable Energy Act (EEG 2017)

EEG 2017 reaffirms the objectives of renewable energy development in Germany. Like the former Act (EEG 2014), it calls for a rise in the share of renewables in gross electricity consumption from 32.3 per cent in 2016 to 40–45 per cent by 2025, to 55–60 per cent by 2035, and to at least 80 per cent by 2050. EEG 2017 also stipulates the annual new capacity to be added for individual technologies.

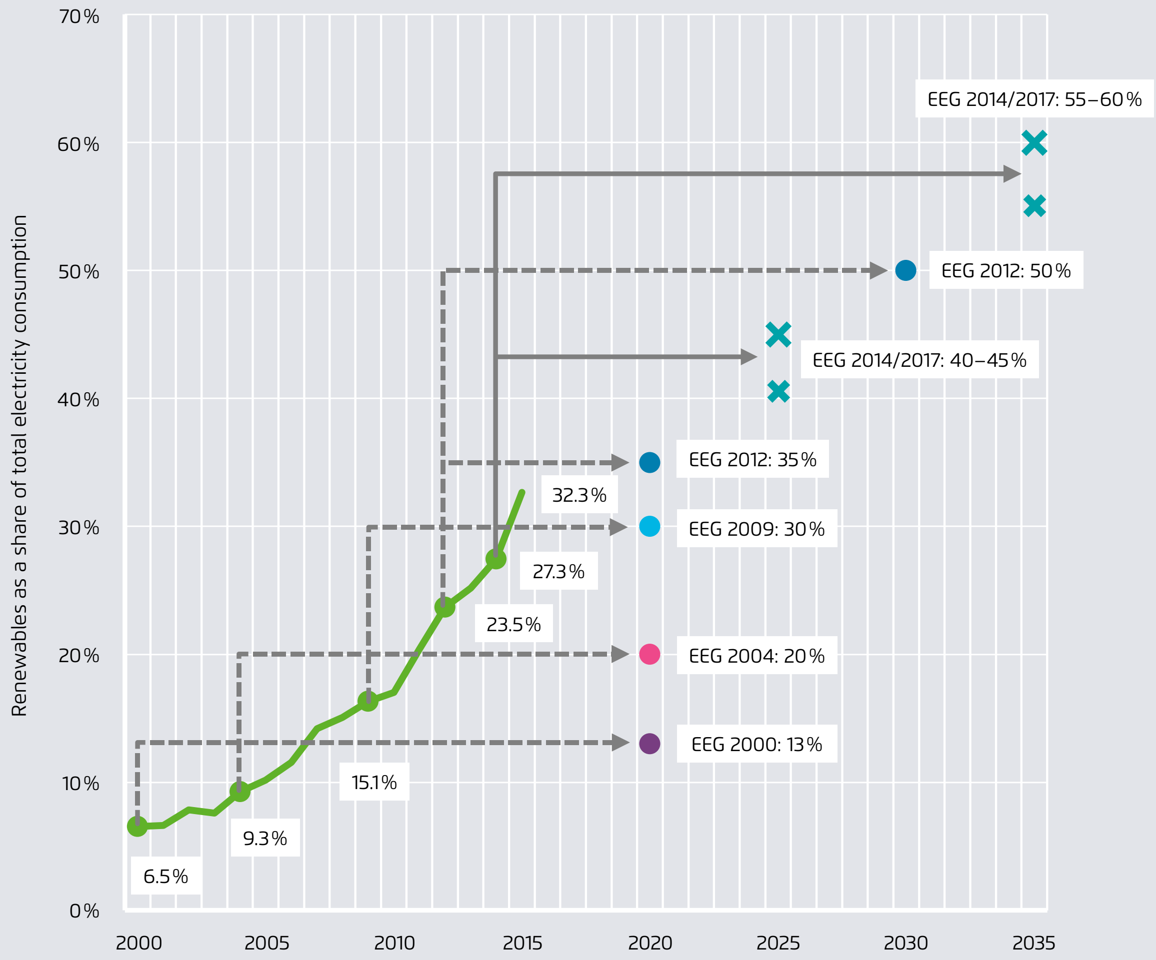
Starting in 2017, a competitive auction system will be the main instrument for financing large wind energy, photovoltaic and biomass projects. Funding for renewables will be determined by competitive bidding for a market premium that will be guaranteed for a period of 20 years from the start of energy production. The details of this auction mechanism were developed after a pilot phase for solar PV in 2015 and 2016. The auction system covers onshore and offshore wind farms and solar power installations with an installed capacity of over 750 kilowatts, as well as biomass plants with an installed capacity of over 150 kilowatts. The feed-in tariff system has been preserved for small installations. Consequently, the private operators of small rooftop PV installations are practically unaffected by the new auction system. However, the German government assumes that more than 80 per cent of future added capacity will be put to tender.

Various instruments have been introduced to better coordinate planning for grid and renewables expansion (see question 9). The new regulations will also affect the choice of location for new facilities. For many years now, large numbers of new wind turbines have been erected in Northern Germany, despite a lack of grid expansion on the north–south axis. Starting in 2019, wind turbine expansion in Northern Germany is likely to slow considerably. Instead, more wind turbines will be added to Central and Southern Germany.

EEG 2017 explicitly acknowledges the role of citizen-owned renewable energy facilities. In past years, the rise of renewable energy has been mostly driven by new actors generating electricity in a decentralized way (see question 8). The future of the *Energiewende* thus depends on the existence of smaller players. Given what's at stake, there has been much passionate discussion about how to maintain a diversity of players in the power system. EEG 2017 takes this into account by making it easier for small onshore wind projects owned by citizens to access the auction system. In the event they win the tender, they also receive the highest market premium that was bid in the auction. This special rule is designed to compensate for the structural disadvantages that energy cooperatives have relative to institutional investors. Whether the new regulations suffice to keep these small actors in the game (the new EEG is the first EEG to explicitly define them) will only be clear after the first auction rounds have been concluded.

Share of renewable energy in gross electricity consumption and the targets of EEG 2000, EEG 2004, EEG 2008, EEG 2012, EEG 2014, and EEG 2017

Figure 20



StromEinspG 1991
Introduction of a fixed feed-in tariff for renewables

EEG 2000
Goal: To double renewable capacity by 2010; fixed feed-in tariff with degressive payment amounts; feed-in priority; privileged grid access

EEG 2004
Goal: 20 % renewables by 2020; Adjustment of feed-in tariff

EEG 2009
Goal: 30 % renewables by 2020; Adjustment of feed-in tariff; rules to limit feed-in volumes

EEG 2012
Goal: Minimum 35 % renewables by 2020, min. 50 % by 2030, min. 65 % by 2040, min. 80 % by 2050; adjustment of feed-in tariff; introduction of a voluntary market premium model

EEG 2014
Goal: 40-45 % by 2025, 55-60 % by 2035; min. 80 % by 2050; introduction of a mandatory market premium model for large plants; technology goals for wind and PV; pilot auctions for PV

EEG 2017
Goal: 40–45 % by 2025, 55–60 % by 2035; min. 80 % by 2050; introduction of calls for tender for large plants, with exemption for citizen energy initiatives

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Conclusion

The Energy Transition in Japan – Learning from Germany

It has already been almost six years since the major earthquake off the eastern coast of Japan and the resultant nuclear accident at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant in March 2011. Many people have become more interested in energy issues since the earthquake and the nuclear accident. In addition, the amount of media reporting on energy issues has doubled since the accident as compared with the five years before these events. However, energy policies in Japan still do not have a clear focus.

On 4 November 2016, the Paris Agreement entered into force less than a year after it was adopted at COP21. Japan ratified the agreement four days after this date. This means that an energy transition towards a decarbonised energy system is also needed in Japan – because otherwise the goals of the Paris Agreement cannot be met.

Initial steps have already been taken. Adopted in 2012, the Feed-in Tariff system (FiT) has dramatically increased renewable power. However, the installed capacity mostly consists of solar PV (approx. 43 GW at the end of 2016). Wind power, which has been the most competitively priced energy in many countries in the world, does not fully benefit from FiT, and its capacity still remains at only around 3 GW. Moreover, the high initial tariff caused the surcharge to increase. Consequently, the Japanese government has decided to adopt an auction system for large-scale solar PV instead of FiT. In addition, the government still has to solve the issue of grid connection for renewable energy with the major utilities that monopolise power generation and the grid. The introduction of unlimited curtailment without compensation for variable renewable energy such as solar and wind makes it hard to invest in new renewable projects.

The government launched an Electricity System Reform after the earthquake disaster. In April 2016, the "full liberalisation of the electricity retail market" began to allow households to choose between power companies. In 2020, major utility companies plan to unbundle their power generation and transmission/distribution. However, this reform lacks consistency. The decision by the Japanese government at the end of 2016 to establish a market to trade mainly nuclear power and coal – or "baseload" power sources – does not correspond to modern market structures. Baseload power production is a concept that is becoming obsolete in Europe and the United States as it is not compatible with integrating more wind and solar into the power system.

The current construction plan for new coal-fired power plants that will add capacity of 23 GW in Japan is also a serious problem. If these plants are constructed and start operation as planned, the target set by the government – an 80% reduction of GHG emissions by 2050 — will not be achieved.

Around the year 2000, solar and wind power had only a share of less than 1% of power production in both Germany and Japan. By 2016, however, this share had increased to 18% in Germany but remained at about 5% in Japan. However, Japan gets much more sunlight than Germany and has long coastlines with an abundant source of wind power. Indeed, Japan is one of the few countries that has both advanced industry and rich renewable energy sources, including not only solar and wind but also geothermal, hydropower and bioenergy. The difference in renewable energy deployment between Germany and Japan is solely the result of the differences in energy policies pursued in the two countries.

What should be changed in Japanese energy policies, and how should these changes be achieved? This booklet provides an unbiased overview of German energy policies, and also offers plenty of valuable suggestions for analysing the energy transition.

In order to encourage the implementation of an energy transition in Japan, we would like as many people as possible to read this booklet. In this way, we hope to initiate a lively debate on the path that Japan might take towards achieving a decarbonised power system.

Patrick Graichen,
Executive Director of Agora Energiewende

Mika Ohbayashi,
Director of the Renewable Energy Institute

Annex

The market-driven optimization of power plant production is the key driver of energy flows between Germany and its neighbours. Physical and commercial flows may differ because of internal grid constraints within countries.

The import and export of electricity between European countries is driven by an hourly market-driven dispatch of power plant production. If during one hour it is cheaper to import electricity from a neighbouring country rather than to produce it domestically, then the market will encourage commercial flows from the cheaper to the more expensive country. This doesn't mean that the country importing power has a deficit in generation capacity.

Measuring the flows between several interconnected countries is nevertheless challenging, as those commercial flows (resulting from the trade between consumers and producers) may differ from the physical flows (the path followed by the electrons according to the laws of physics). These differences reflect internal grid constraints within countries, and can potentially lead to unplanned physical flows (so-called transit flows or loop flows).

Due to constraints on the German transmission system, surplus power produced in the north, largely from wind turbines, can lead to unplanned power flows through the grids of Germany's neighbours, and particularly through Poland and the Czech Republic, in order to reach Southern Germany. Over the last few years, these unplanned flows have led to a decrease in power exchange between Germany and Poland. This loop flow issue has been provisionally solved by establishing a virtual phase-shifter (binational re-dispatch mechanism) that has been followed by the introduction of physical phase-shifters on the German–Polish and German–Czech border.

Looking solely at the physical flows between Germany and France, we may conclude that Germany is importing from France, as the electricity does indeed flow from France to Germany. This assessment is nevertheless wrong, as those flows mostly represent transit through Germany from France to Switzerland (and sometimes to Italy).

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Das Potenzial für Photovoltaik-Speicher-Systeme in Ein- und Zweifamilienhäusern, Landwirtschaft sowie im Lebensmittelhandel

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Konzept zur schrittweisen Dekarbonisierung des deutschen Stromsektors (Lang- und Kurzfassung)

Der Klimaschutzbeitrag der Stromsektors bis 2040
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How do we contribute to energy transitions, especially in Germany and Japan?

Agora Energiewende develops scientifically based and politically feasible approaches for ensuring successful energy transition in Germany, Europe and worldwide. We see ourselves as a think-tank and policy laboratory, centered around dialogue with energy policy stakeholders. Together with participants from public policy, civil society, business and academia, we develop a common understanding of energy transitions, its challenges and courses of action.

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