Understanding the *Energiewende*

FAQ on the ongoing transition of the German power system

BACKGROUND

Agora Energiewende

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IMPRINT

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FAQ on the ongoing transition of the
German power system

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Preface

Dear reader,

Energy systems worldwide are entering a phase of transformation. The European Union, for example, has adopted ambitious goals to move toward a low-carbon economy and fully integrated energy markets. Furthermore, the G7 countries declared in June 2015 that they would strive to fully decarbonize their power systems, and China has just 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, phasing out nuclear and coal in favor of renewable energy within the next four decades.

Wind and solar energy are the backbone of the German energy transition. Yet around the world, wind and solar are abundantly available and generation costs are rapidly decreasing. We therefore strongly believe that many of the developments we currently see in Germany are highly relevant for other countries in Europe and beyond.

While the German approach is not unique worldwide, the speed and scope of the *Energiewende* are exceptional, attracting wide attention and debate in Europe and abroad. This document answers some of the most frequently asked questions on the ongoing transformation of the German power system, delivering fact-based information. It focuses on the power sector, which many studies have shown will be crucial in this transition.
If you have further questions, remarks, or ideas, we look forward to your comments.

Sincerely yours, Patrick Graichen
Executive Director of Agora Energiewende

Key findings at a glance

1. **The German *Energiewende* is here to stay. Started in the 1990s, it is a long-term energy and climate strategy reaching as far forward as 2050.** It enjoys broad public support and is driven by four main political objectives: combatting climate change, avoiding nuclear risks, improving energy security, and guaranteeing competitiveness and growth.

2. **Wind energy and solar PV are the backbone of the German *Energiewende* and flexibility is the new paradigm of the power sector.** Wind and solar energy are now cost-competitive with conventional energy sources for new investments. These technologies, however, impact power systems, making increased system flexibility crucial. Fossil power plants currently deliver the needed flexibility; increasingly other options (demand side management, storage,…) will become more important.

3. **The *Energiewende* requires a structural change in the German energy sector, bringing new challenges and opportunities.** Given the transformative nature of the *Energiewende*, investment, growth, and employment are shifting towards new low-carbon sectors. Renewable energy and energy efficiency are providing several hundred thousand jobs, while jobs in the nuclear and coal sectors are declining. A broad consensus on the phasing out of coal is needed to accompany this restructuring process.

4. **The transformation of the power systems toward renewable energy is not only taking place in Germany but worldwide.** In 2014, for the third year running, worldwide investment in new renewable capacity exceeded investment in fossil-fuel power. Many other countries in Europe and beyond have set ambitious renewable energy targets. The challenges faced by Germany are therefore a preview of what is likely to occur in several other countries in the medium to long-term.

Contents

Executive summary

The German energy transition (*Energiewende*) is a long-term energy and climate strategy towards a low-carbon energy system based on developing renewable energy and improving energy efficiency. While many countries within the European Union share similar goals, the speed and scope of the German transition is unique. This ambitious industrial and societal transformation has garnered wide attention in Europe and abroad, and is often debated, analyzed, supported or criticized. This paper provides fact-based overview of the German *Energiewende*, focusing on the power sector. It explains the current status of the energy transition in Germany and outlines the challenges ahead. It is organized into seven sections; each answers a key question.

1. What is the *Energiewende*? Origins, current status, and future goals

Launched in the 1990s, the *Energiewende* includes ambitious targets reaching as far forward as 2050. While originally controversial in German politics, the *Energiewende* has gained broad political consensus across all parties since the 2011 nuclear accident in Fukushima. At its heart lie four main objectives: to combat climate change, avoid nuclear risks, improve energy security, and guarantee competitiveness and growth. The *Energiewende* is an integrated policy framework, covering all sectors of the economy, and includes targets and policy measures for CO_2 emissions reduction, renewable energy development, phasing out of nuclear energy, and improvement of energy efficiency. In recent decades, Germany has significantly diversified its electricity mix toward renewable energy (which grew from 4 percent of power in 1990 to 27 percent in 2014), including a sharp increase in citizen-owned projects. German politicians and citizens strongly support the *Energiewende*. Regular polls have consistently shown that more than 90 percent of German citizens are in favor of its goals.

2. Why does Germany rely on renewable energy? How can a power system be based on variable energy output?

Wind energy and solar photovoltaics form the backbone of the German *Energiewende*. Due to a dramatic price decrease in recent years, they are now mature technologies and cost-competitive with conventional energy sources for new investments. In 2015, generation costs in Germany ranged between 6-9 cts€/kWh for wind energy and 8-9 cts€/kWh for solar PV. Further cost reductions are expected. While there are additional costs for integrating these technologies into conventional power systems, they do not change the big picture. In Germany, even at high penetration rates, estimated integration costs range between 0.5 and 2 cts€/kWh.

With wind energy and solar PV representing the key technologies of the *Energiewende*, flexibility is the new paradigm of the German power system. Baseload capacities are no longer needed: power markets and power systems are now built around the variable renewable energy sources. Coal and gas fired power plants have become increasingly flexible, and a wide range of new "flexibility options" (demand-side management, grids, storage, power-to-heat, etc.) are progressively entering the system. Despite these high shares of variable renewables, the German power system is one of the most reliable in the world – power outages stand at less than 15 minutes per customer per year. Currently, Germany has a surplus of generation capacity and is – despite the phase-out of nuclear power – a net exporter of power to its neighbours; in 2014 it reached a new export record of 6 percent of its electricity consumption.

3. What are the costs and benefits of the German energy transition?

Current costs of supporting renewable energy (the so-called "EEG surcharge" paid by power customers) are quite high compared to other countries. The EEG surcharge has risen over the years and is currently set at 6.14 cts€ pro kWh (for a total of 21.5 billion euros in 2015). This reflects initial development costs of emerging technologies, especially solar PV in its early years of deployment. Future costs will be much more moderate. The EEG surcharge is expected to increase moderately until 2023, reaching about 7.20 cts€ pro kWh, and then to decline to 4.4 ct per kWh in 2035, when 60 percent of the power will come from renewables. On the other side, renewable energy deployment leads to lower wholesale market prices, partially offsetting the high EEG surcharge.

The *Energiewende* requires structural changes in the German energy sector. Given its transformative nature, investment, growth, and employment are shifting towards new low-carbon sectors. In 2013, the renewable energy industry alone accounts for about 370, 000 jobs. At the same time, jobs have been phased-out in other sectors of the economy. The development of renewable energy and energy efficiency has also a positive impact on the balance of trade, enhances energy security, and reduces CO_2 emissions. Between 2000 to 2014, about 220 billion euros were invested in renewable energy (in all sectors) in Germany. Due to aging energy infrastructure, new investments are necessary *per se*. In the decade to come, investments to transform the power sector alone are expected to reach about 15 billion euros per year.

4. Who pays for the *Energiewende* and how much?

Distributing the costs and benefits of the energy transition in a fair and transparent manner has become an important focus of the German energy political debate. Electricity prices for German households are among the highest in Europe (currently about 30 cts€/kWh). Due to the efficient use of electricity (and low use of electric heating) in Germany, however, the actual costs to households are comparable to countries with lower prices but higher consumption levels. Energy-intensive industrial consumers benefit from large exemptions on taxes and levies (including the EEG surcharge) to preserve their competitiveness in international markets. Low wholesale market prices ensure energy-intensive industries in Germany enjoy one of the lowest electricity rates in Europe. On the contrary, non-energy-intensive industries do pay relatively high electricity prices compared to other European countries. For these companies, however, energy represents only a small portion of their total costs. Thus far the high cost of renewable power has not harmed German industry.

5. Is Germany on track in meeting its CO_2 reduction targets? Is coal making a comeback?

Germany has ambitious mid and long-term national climate goals – namely, a 40 percent reduction in greenhouse gas emissions by 2020 (below 1990 levels), followed by an 80 to 95 percent reduction by 2050. In 2014, emissions were 26 percent below 1990 levels. The German energy sector – still dominated by coal – is the largest emitter (449 $MtCO_2$ in 2014). Renewable energy sources significantly reduce CO_2 emissions and more than compensate for the nuclear phase-out. But the current high competitiveness of coal compared to gas – in the context of a weak European Emission Trading scheme (ETS) – has a negative impact on Germany's CO_2 emissions. Therefore, the government decided in July 2015 to retire approximately 13 percent of Germany's oldest lignite power plants by 2020. To reach the 2030 targets and beyond, a consensus needs to be established on the gradual decrease of coal.

6. What are the upcoming challenges and policy decisions?

The German energy transition is a long-term industrial and societal transformation and will bring many new challenges and opportunities in the years to come. The development of distributed energy resources fundamentally transforms the traditional business model of energy utilities but also brings new business opportunities.

Important policy decisions and regulatory changes will continue to reshape the power system to integrate higher share of variable renewables and enhance the overall flexibility of the system. The primary challenges include: designing the new electricity market; implementing new measures to reduce CO_2 emissions; finding new, cost-effective methods to finance renewables and promote their market integration; strengthening cooperation with neighbouring countries and Europe as a whole; accelerating the necessary grid expansion. A coherent strategy and new business models must also be developed in order to leverage the potential of energy efficiency measures.

7. Is Germany alone in its attempt to build a sustainable energy system?

The German energy transition is embedded in the wider European energy and climate policy framework designed to bring greater sustainability, energy security, and competitiveness to the continent. Many other European member states have equally ambitious short and long-term targets. Thus, the challenges faced by Germany provide a snapshot of those likely to occur in several countries in the medium to long-term.

Germany and its neighbours are strongly interconnected. Whatever happens in the German power market affects its neighbours and vice-versa. Stronger European and regional cooperation – especially on power market design and support schemes for renewable energy sources – can benefit everyone.

The transformation towards renewable energy is global: In 2014, for the third year running, worldwide investment in new renewable capacity exceeded investments in fossil-fuel power plants.

1. What is the *Energiewende*? Origins, current status, and future goals

The major findings at a glance:

- → Started in the 1990s, the *Energiewende* includes ambitious targets reaching as far forward as 2050. It is driven by four main political objectives: to fight climate change, avoid risks associated with nuclear power, improve energy security, and guarantee competition and growth.
- → The *Energiewende* is an integrated policy framework covering all sectors of the economy, including goals and policies to reduce CO_2 emissions, phase-out nuclear power, develop renewables and improve energy efficiency in the power, heating and transport sectors.
- → German politicians and citizens strongly support its goals: 85 percent of MPs voted for *Energiewende* policies in the Bundestag in 2011. In 2015, more than 90 percent of German citizens support its goals.
- → Germany has diversified its electricity mix over the past decades, including a sharp increase in citizen-owned renewables.

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

The German energy transition (*Energiewende*) is a long-term strategy towards a low-carbon energy system based on developing renewable energy and improving energy efficiency. The *Energiewende* is an integrated policy covering all sectors of the economy.[1] 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 competitiveness and growth (through industrial policies targeting technological, industrial, and employment development). It sets ambitious mid and long-term targets reaching as far forward as 2050 (see Table 1). The *Energiewende* is embedded in a wider European energy policy framework, designed to bring greater sustainability, competitiveness, and energy security in Europe (see section 7).

Strategies for this ambitious industrial and societal transformation were initiated in the 1970s, reinforced at the end of the 1990s, and again at the beginning of the 2010s. The *Energiewende* requires a fundamental transformation of the power system towards renewable energy, which must cover at least 80 percent of Germany's electricity consumption by 2050. The *Energiewende* is also based on improvements of energy efficiency in all sectors of the economy, and a progressive long-term electrification of fossil-fuel intensive sectors (transport, heating/cooling).

1 This paper focuses on the electricity sector only. In the coming years, Germany will also need to strengthen its policies in the heating and transport sector to reach its long-term Energiewende targets.

Key German *Energiewende* targets[2] — Table 1

		Status quo	2020	2025	2030	2035	2040	2050
Greenhouse gas emissions	Reduction of CO_2 emissions in all sectors compared to 1990 levels	-26.4% (2014)*	-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	12.4% (2013)	18%		30%		45%	min. 60%
	Share in gross electricity consumption	27.3% (2014)*		40 – 45%		55 – 60%		min. 80%
Energy efficiency	Reduction of primary energy consumption compared to 2008 levels	-9.1% (2014)*	-20%					-50%
	Reduction of gross electricity consumption compared to 2008 levels	-4.8% (2014)*	-10%					-25%

AGEB (2015), BReg (2010), own calculations — * preliminary

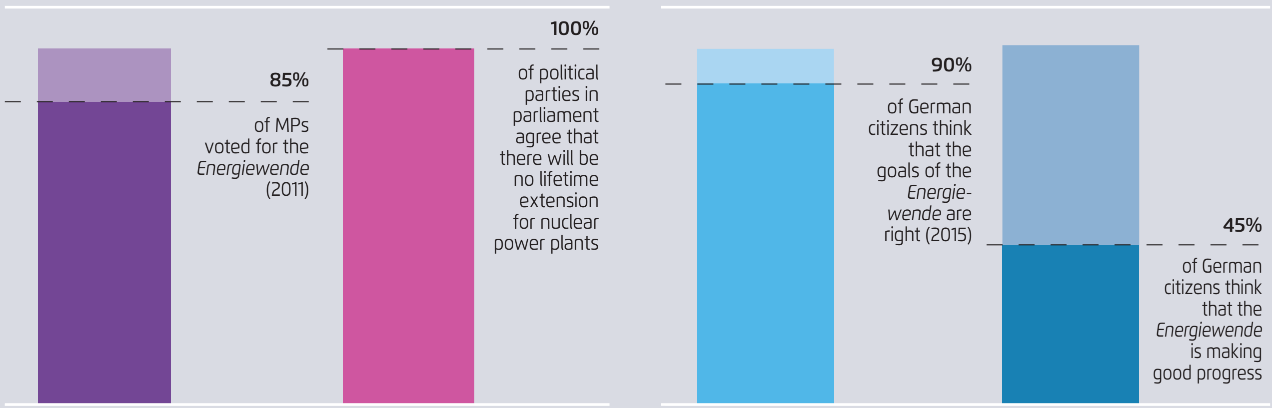
The *Energiewende* policies benefit from strong support within German politics and society: 90 percent of German citizen support its goals.[3] Only 45 percent of Germans, however, think the *Energiewende* is properly managed.

2 The Federal Ministry of Economics publishes periodically a monitoring report of the Energiewende, in order to analyse its progress towards these mid- and long-term targets. See BMWI 2014d.

3 BDEW, 2014a; AEE 2014

Political and public support for the Energiewende — Figure 1

Voting results in the Bundestag on Energiewende — Public opinion on Energiewende



German Bundestag (2011) — BDEW (2015a)

German Bundestag (2011), BDEW (2015)

1.2 The first *Energiewende* policies started decades ago: Since then a consensus has emerged on the ideal long-term electricity mix

Power generation in Germany was historically based primarily on coal and lignite, which comprised about 80 percent of total power generation in 1960. The 1970s oil crisis led Germany – as well as other Western countries – to adopt new energy policies to promote energy efficiency and energy mix diversification, and launch research into renewable energy sources.

The nuclear energy program launched at the end of the 1950s gained political momentum during the oil crisis, though it faced severe public opposition from the start.[4] From the mid-1970s to the mid-1980s, a fierce anti-nuclear protest movement strongly opposed potential nuclear sites; several planned nuclear power plants and nuclear fuel reprocessing plants were never realized. The accident at the Chernobyl nuclear power plant in 1986 amplified the already heated debate and intensified the perceived risks of nuclear power within German society. No more new reactors were constructed in Germany[5] after the accident. Two years later, about three quarters of the German population were opposed to nuclear power.[6] The political response was instantaneous: the emerging Green party called for an immediate shutdown of all nuclear power plants; the Social Democrats committed themselves to phasing out nuclear power; a Ministry of Environment and Nuclear Safety was created. But the ruling coalition CDU/CSU and FDP did not change its pro-nuclear stance.

At the end of the 1980s, a new issue became essential to energy policy: The need to tackle climate change gained cross-party consensus; the first climate *Enquete Commission* of the German Parliament unanimously voted to reduce greenhouse gas emissions by 80 percent by 2050. Chancellor Kohl called it the "most important environmental problem"[7] and gained broad support in the run-up to the 1992 Earth Summit in Rio de Janeiro.

These concerns were translated into policy during the 1990s: the first Climate Change Action Plan was adopted by the government in 1990; the first plan to support renewable energy introduced in 1991. Reunification lead to a complete restructuring of the East German power sector: the six East German nuclear power plants shut down; coal power plants were modernized. In 1997, the country signed the Kyoto Protocol, committing itself to a reduction of its greenhouse gas emissions by 21 percent until 2012 (below 1990 levels).

Major energy policy changes were introduced in the 2000s. The then-ruling coalition of Social Democrats (SPD) and the Green Party decided to phase out nuclear energy by around 2022, on the basis of an agreement between the government and the energy utilities (the so-called "nuclear consensus," approved in 2002, giving the 19 remaining nuclear power plants in Germany a lifetime of about 32 years). Strong policies favoring energy efficiency and renewable energy development – including the Renewable Energy Act (EEG) – were adopted. In 2003 and 2005, the first two nuclear power plants were shut down. The grand coalition of CDU/CSU and SPD which ruled from 2005 to 2009 continued this policy, adopting in 2007 a climate and energy policy package, targeting a greenhouse gases reduction by 40 percent in 2020 compared to 1990 levels; 14 additional laws and ordinances passed to promote renewables and energy efficiency in the heat, power and transport sector.

In 2010, the newly elected conservative-liberal coalition (CDU/CSU and FDP) adopted the *Energiekonzept*, a long-term energy strategy calling for a renewable-based economy by 2050. It included ambitious mid and long-term targets for the development of renewable energy, improving energy efficiency, and reducing CO_2 emissions. After a controversial political debate, the government also decided

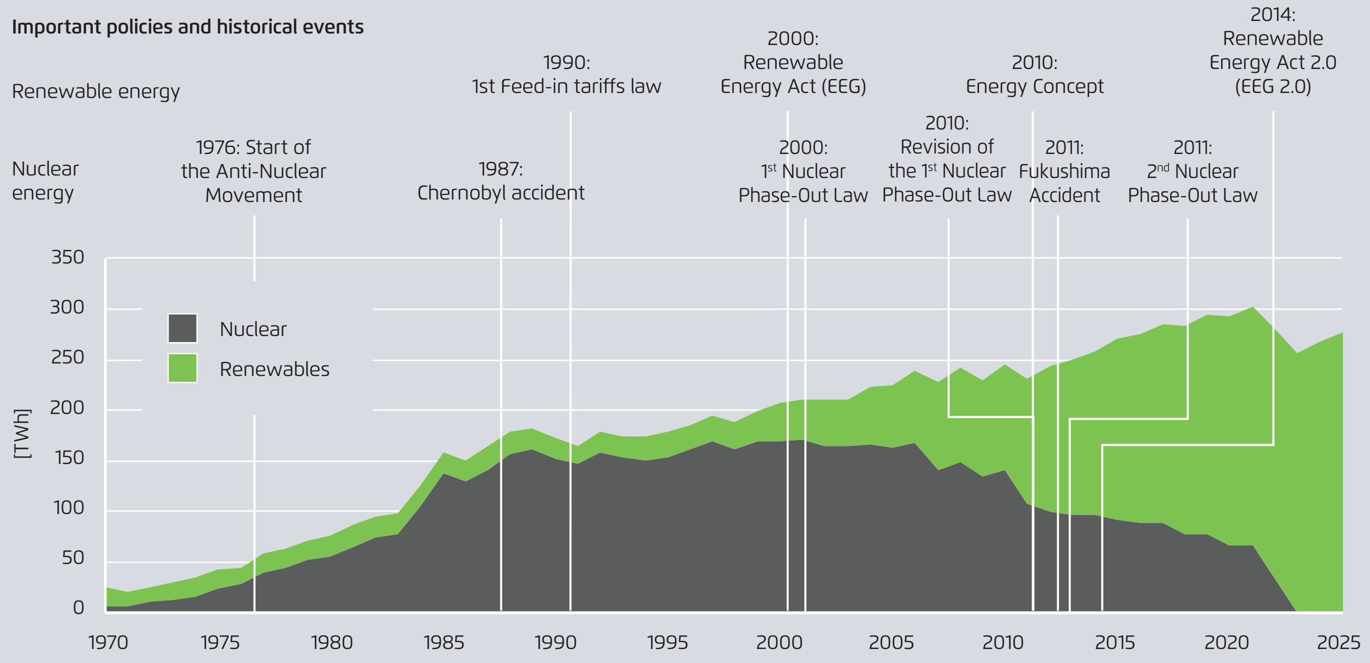
4 Mez and Piening, 2006.

5 A few reactors started operation after the Chernobyl accident, but the construction of these reactors had begun several years before the accident.

6 Jahn, 1992.

7 Huber, 1997.

Nuclear and renewable electricity generation and major political events, 1970 – 2025 Figure 2



AGEB (2015), AGEE (2015), BNetzA (2014), BNetzA (2015), Statistical Yearbook of the GDR (1973 - 1988), own calculations

within the Energiekonzept to extend the lifetime of existing nuclear power plants by eight to fourteen years, thus delaying the nuclear phase-out until 2036.

Six months later, immediately after the nuclear accident at Fukushima Daiichi in March 2011, the German government reversed its 2010 nuclear decision and reinstated the previous nuclear phase-out law passed in 2002. As part of this move, the seven oldest nuclear reactors were immediately shut down. The parliamentary vote on this renewed phase-out law in June 2011 gained an historic cross-party political support of 85 percent (see Figure 1). This decision was accompanied by further legislative measures aimed at accelerating the energy transition.

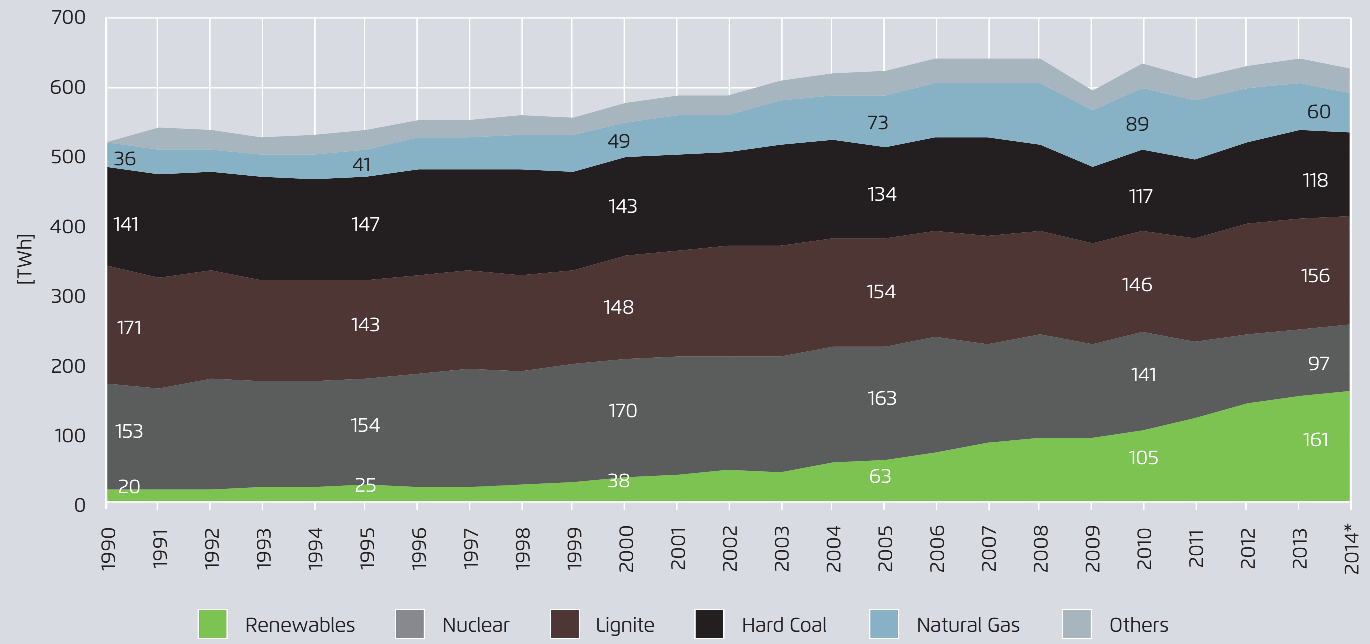
Today there is broad political consensus to shut down the last nuclear power plant by 2022 and gradually increase renewables to reach at least 80 percent of power production by 2050. The key debates in German energy policy concern the future role of coal and gas and the different policy options on the road towards an economy based on renewable energy.

1.3 Germany has diversified its electricity mix over the past decades, including a sharp increase of citizen-owned renewables generation

The German energy mix has undergone a significant diversification over the last twenty years, as seen in Figure 3. This evolution is characterized by:

→ a substantial increase in renewable energy (from 3.6 percent of the power production in 1990 to 25.8 percent in 2014 corresponding to 27.3 percent of national power consumption),
→ a progressive phase-out of nuclear power (15.5 percent of domestic power production in 2014, down from 27.7 percent in 1990),
→ continuous large production of lignite (24.1 percent in 2014) and hard coal (18.9 percent in 2014), with lignite power production remaining constant for the last twenty years and hard coal slowly declining.

Structure of gross electricity generation in Germany, 1990 - 2014 — Figure 3



AGEB (2015) — * preliminary

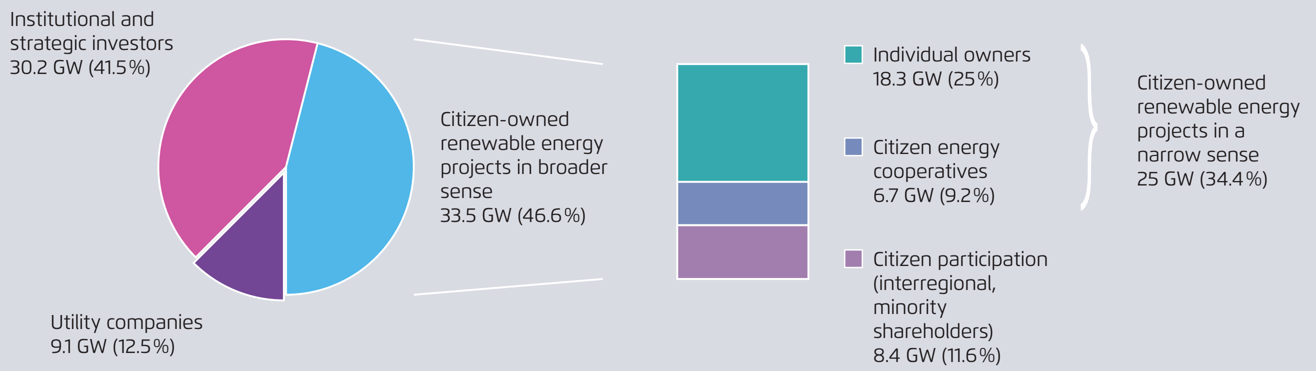
In 2014, for the first time renewables produced more electricity than lignite, evolving from a niche technology to a major pillar of the electricity supply. The two renewable energy technologies with the largest potential in Germany – wind and solar PV – have undergone considerable development, primarily triggered by the German renewable energy laws. At the current growth rates, renewable energy sources will be able to more than compensate for the nuclear phase-out by the year 2022 (see Figure 2). The share of gas (9.5 percent of power generation in 2014) has been rising slightly from 2000 to 2010. Since then, it has lost shares to coal generation (due to current market conditions, see section 5.2).

The diversification of the power mix has also affected the ownership structure of power plants in Germany. In contrast to conventional thermal generation, renewable capacities are rather small-scale and deployed in a more decentralized manner. For the most part (with the exception of offshore wind energy) they are connected to the distribution network. Given favorable regulatory conditions and removal of administrative burdens since 2000, the majority of renewable projects are supported, financed, and owned by non-utility actors, namely private households, farmers, energy cooperatives, etc. (see Figure 4). In 2012, these citizen-owned projects accounted for 46 percent of all installed renewable capacity in Germany, while utilities only had a market share of around 13 percent. This unique ownership structure contributes significantly to the broad support of the *Energiewende* among citizens.

1.4 The Renewable Energy Act ensures continuous and sustainable growth of renewable energy

The development of renewable energy in Germany has been supported since the 1990s by a regulatory regime which guarantees reliable investment conditions for renewable energy producers through a fixed remuneration for twenty years (feed-in tariff) and priority access to the grid. Policy makers have continuously improved and adjusted this legal framework – the Renewable Energy Act (Erneuerbare En-

Installed renewable energy capacity broken down by ownership in Germany in 2012 — Figure 4



trend:research/Leuphana (2013)

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

ergien Gesetz, or EEG) – in order to encourage innovation, track technological development, and facilitate system and market integration of renewable electricity.

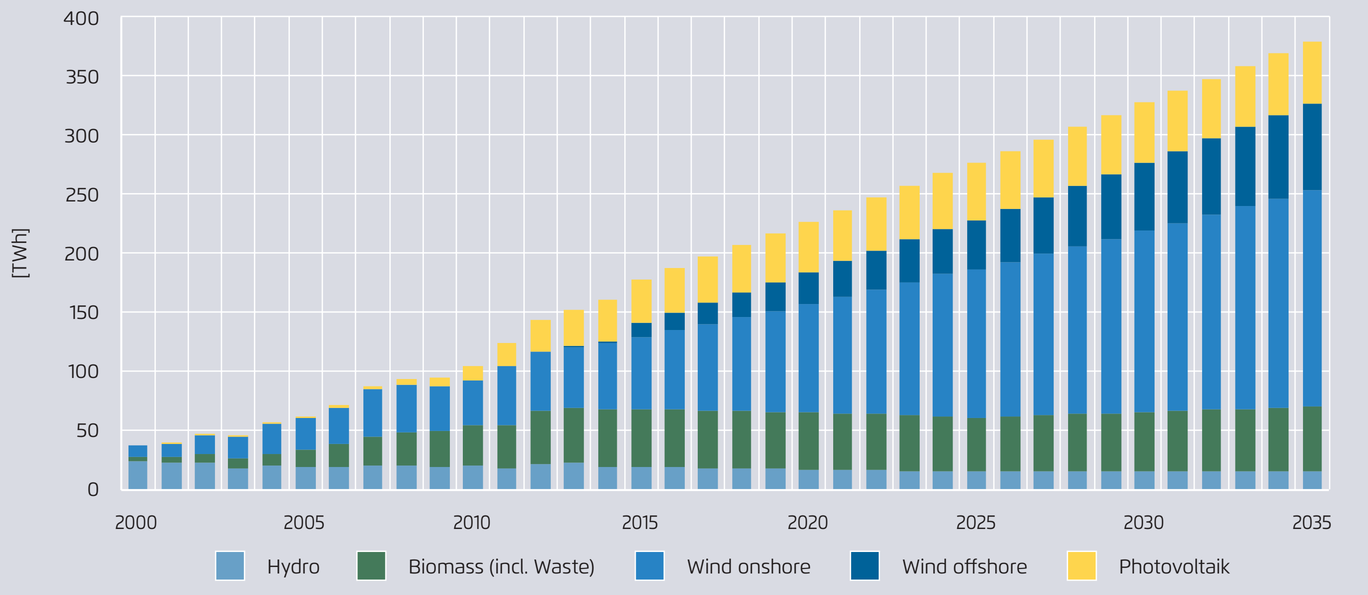
The most recent reform of the law in 2014 (EEG 2.0) paved the way for a sustainable growth of renewables. Ambitious mid-term targets have been introduced (40-45 percent of power consumption covered by renewables by 2025; 55-60 percent by 2035) together with annual capacity targets for each technology to make the roll-out of renewables more predictable (see Figure 5). This "expansion path" foresees a yearly capacity growth of +2500 MW of PV, +2500 MW of wind onshore, +800 MW of wind onshore and +100 MW of biomass. Feed-in tariffs are adjusted automatically depending on whether these technology-specific targets are met ("flexible cap"). The focus on the least expensive technologies – onshore wind and solar PV – ensures lowest cost for final electricity consumers (see section 2.1 and 3.3). The 2014 amendment also aimed at a more fair distribution of costs related to renewable energy development among different consumer groups. Prosumers[8] are now obligated to pay a small portion of the EEG surcharge and exemptions for energy-intensive industries have been slightly reduced (see also 4.3).

In line with the EU state-aid guidelines, the 2014 amendment of the German EEG law introduces several provisions to facilitate the market integration of new renewables installations: mandatory direct selling on the spot market; discontinuation of the feed-in support during periods of negative power prices (more than 6 consecutive hours);[9] and a pilot phase for auctioning 400 MW of large-scale ground-mounted solar PV. After a review of

8 Prosumers are consumers who generate locally part of the energy they consume (e.g. through rooftop PV panels).

9 However, this is only applicable for plants commissioned as of 2016. Exemptions apply to installations with a capacity of less than 500 kW and for wind energy installations with a capacity of less than 3 MW.

Gross electricity generation by renewables, 2000 - 2035 Figure 5



AGEE (2015), BNetzA (2014), BNetzA (2015), own calculations

* preliminary
2000 - 2014 historical data
2015 - 2035 own calculations based on BNetzA (2014)/BNetzA (2015)

this pilot phase, auctioning is to be extended or generalized to other technologies as of 2017.

2. Why does Germany rely on renewable energy? How can a power system be based on variable energy output?

The major findings at a glance:

- → Wind energy and solar photovoltaic are the backbone of the German energy transition. In recent years the costs of these technologies dropped dramatically. They are now competitive with conventional energy sources for new investments, with generation costs in Germany ranging in 2015 between 6-9 cts€/kWh for wind and 8-9 cts€/kWh for solar PV.
- → The costs of integrating renewables into conventional power systems exist but should not be overestimated. Integration costs of adding wind onshore or solar PV into the German system, even at high penetration rates, may range around 0.5 to 2 cts€/kWh.
- → Flexibility is the new paradigm of the German power system. Power markets and power systems will be built around the variability of power production from wind energy and solar PV.
- → No baseload capacities are needed any more – the fossil power fleet needs to become highly flexible. In addition, a wide range of other flexibility options exists (demand-side management, grids, storage, power-to-heat, etc.).
- → The German power system has currently a surplus of capacity and is one of the most reliable in the world.
- → Germany is – despite the phase-out of nuclear – a net exporter of power to its neighbours, reaching in 2014 a new export record of 6 percent of its electricity consumption.

2.1 Wind energy and solar photovoltaic experienced a massive cost reduction and are now the backbone of the German energy transition

Wind energy and solar photovoltaic have experienced massive technological development and cost reduction over the last two decades. Wind energy is now a mature and well-established technology, with an estimated installed capacity of 38 GW in Germany, 137 GW in Europe, and 370 GW world-wide.[10] Onshore windmills of 2-3 MW are standard today; in the 1990s their capacity reached only 170 kW. Solar photovoltaic experienced a massive price drop since 2006 (declining by 70 percent between 2005 and 2014, see figure 6) due to increased development and global consolidation of the world market. The current total installed capacity reaches 38 GW in Germany, 87 GW in Europe, and 177 GW world-wide.[11]

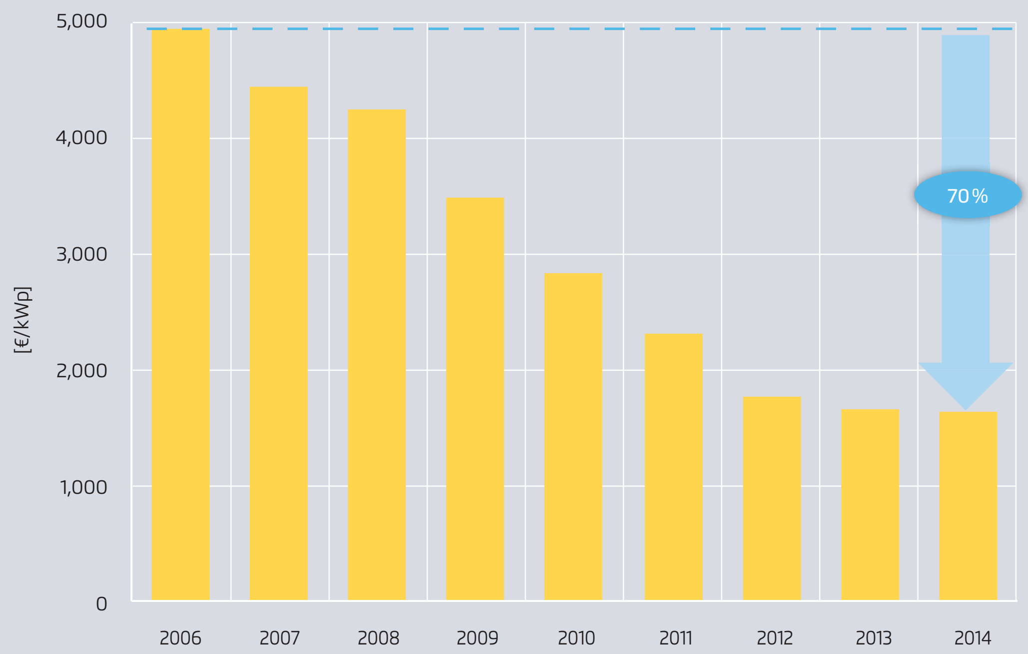
Today, wind onshore and solar photovoltaic are cost-competitive with all other newly built conventional energy sources (in terms of levelized costs of electricity generation, or LCOE), as seen in Figure 7. Furthermore, additional cost decreases can be expected, especially for solar PV, with LCOE ranging from 5.5 to 8 cts€/kWh by 2025.[12] What was in the past seen as a "technological bet" is about to become an economic rationale. Wind energy and solar photovoltaic are expected to contribute to about 215 TWh (or 36 percent) of the German power consumption in 2020 and 309 TWh (or 51 percent) in 2035 (see figure 3).

10 As of End 2014. GWEC (2015).

11 As of End 2014. IEA (2014).

12 Fraunhofer ISE (2015).

Average system prices for new roof-mounted PV, 2006 - 2014 — Figure 6



BSW /2014)

Germany, along with other front-runner countries, supported at an early stage the large-scale technological development of solar photovoltaics, today reflected in the high electricity prices paid by German consumers (see section 3.3 and 4.2). If Germany would install today the overall photovoltaic fleet built before 2014 (more than 30 GW), German consumers would pay only about €60 to 80 billion (overnight costs), as opposed to the €180 billion that effectively has to be paid. Any country that starts to invest in these renewable energy technologies today can therefore benefit from past technological advances.

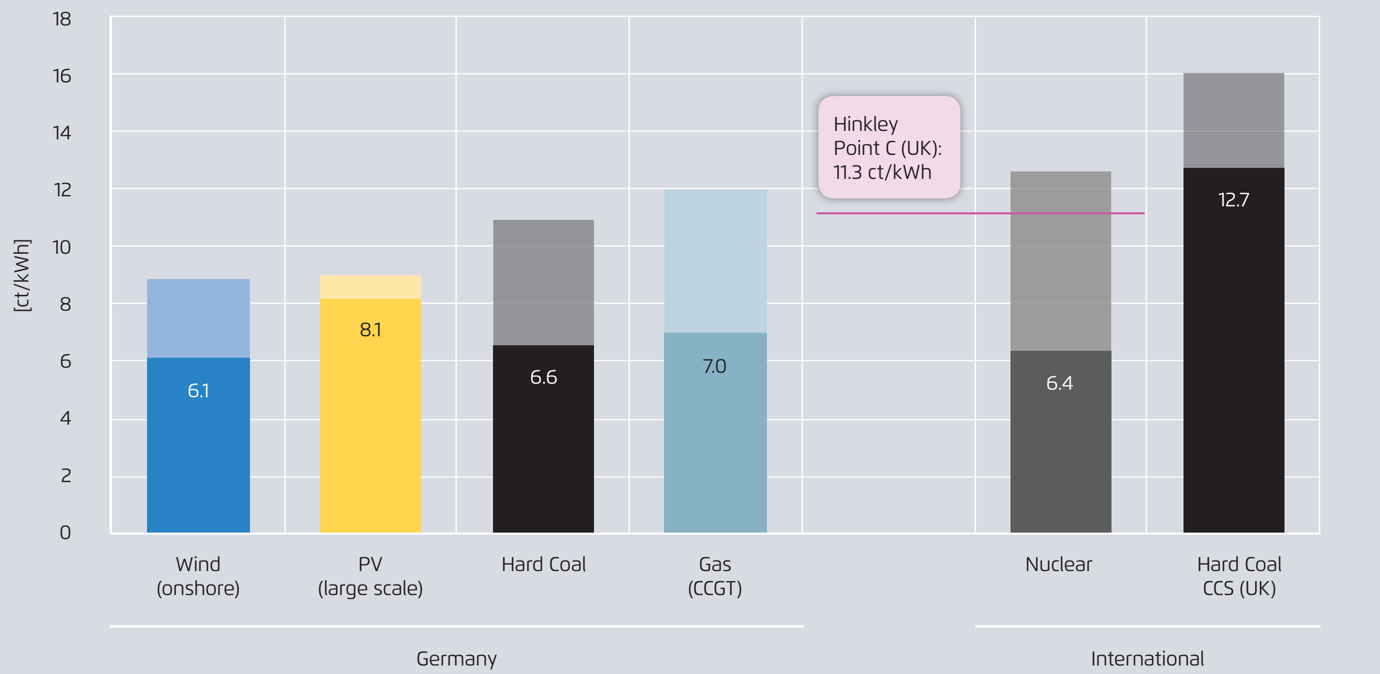
2.2 Flexibility is the new paradigm of the German power system: several options exist to facilitate integration of renewable energy

The characteristics of photovoltaic and wind energy are radically different from those of fossil fuel power plants. Wind energy and solar PV have variable output and provide electricity only when the wind blows and the sun shines. Given their short-term variability, they cannot be turned on according to the demand for electricity. Furthermore, they are characterized by high capital costs and virtually no operating costs. Once installed, wind and solar power plants produce electricity at almost zero marginal cost. Therefore, they change the utilization patterns of the conventional generation fleet, encouraging less baseload operation and more mid and peak operation.

These features fundamentally alter the power systems and power markets, which have to cope with highly fluctuating power generation. This new power system is characterized by enhanced flexibility to respond quickly to changes in variable generation and changes in the load. Baseload capacities will no longer be needed; fossil power plants will need to become very responsive (high ramping rates, short startup times and reduced minimum output).

In addition to flexible fossil power plants, several other flexibility options exist to incorporate variable energy sources

Range of levelized cost of electricity (LCOE) in 2015 — Figure 7



Agora (2014), DECC (2013), enervis (2015), EDF, own calculations

All numbers in EUR_{2015}

Assumptions:

Wind (onshore): Investment costs 1250 – 1500 EUR/kW, WACC 7 percent, technical lifetime 20a, Fixed O&M 35 EUR/kW/a, Variable O&M 0 EUR/MWh, FLH 2500 – 2000h

PV (large scale): Investment costs 800 – 900 EUR/kW, WACC 7 percent, technical lifetime 30a, Fixed O&M 17 EUR/kW/a, Variable O&M 0 EUR/MWh, FLH 1000h

Hard Coal: Investment costs 1500 – 1600 EUR/kW, WACC 12 percent, technical lifetime 40a, Fixed O&M 34 EUR/kW/a, Variable O&M 3 EUR/MWh, fuel 9 EUR/MWh, net-efficiency 45 percent, emissions-factor 0,336 t/MWh, FLH 4000 – 6000h

Gas (CCGT): Investment costs 700 – 900 EUR/kW, WACC 12 percent, technical lifetime 25a, Fixed O&M 19 EUR/kW/a, Variable O&M 2 EUR/MWh, fuel 22 EUR/MWh, net-efficiency 59 percent, emissions-factor 0,202 t/MWh, FLH 2000 – 4000h

Nuclear: Investment costs 4200 – 5000 EUR/kW, WACC 7-12 percent, technical lifetime 40a, Fixed O&M 90 EUR/kW/a, Variable O&M 1 EUR/MWh, fuel 3 EUR/MWh, net-efficiency 36 percent, FLH 6000 – 7500h

Hard Coal CCS: Coal IGCC with CCS and ASC with oxy combustion CCS, based on DECC (2013)

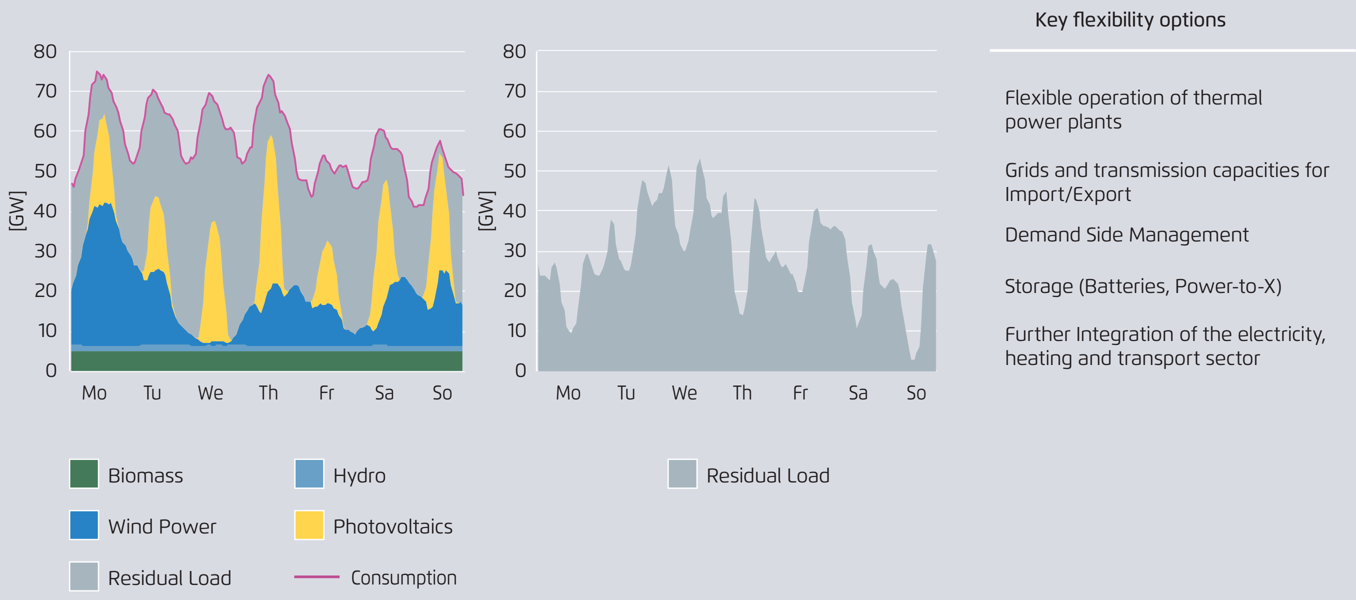
in the power system.[13] These include demand-side management, the expansion of (smart) grid infrastructure, bioenergy power plants, the temporary curtailment of wind and photovoltaic energy, new storage technologies, and new electricity demands from other sectors such as power-to-heat and electric cars.

As of today, the German power system offers abundant technical potential for flexibility (much higher than the actual demand for flexibility).[14] Nevertheless, efficient market incentives need to be designed to translate the flexibility needs into market prices and leverage this technical potential in the most cost-efficient way (see section 6.1). The

13 Agora 2013

14 BMU 2012, BMWi 2014c

Gross electricity generation and residual load in Germany in a sample week in April 2022 with 50% renewables — Figure 8



Own calculation

occasional occurrence of negative prices on the wholesale market reflects the inflexible response of the conventional generation in the current power market. These negatives prices (i.e. producers pay the consumers for buying their electricity) can occur during specific hours with high renewables feed-in and low demand. During these hours, the power plants prefer to run at a low level (as a response to other technical or economic incentives) instead of shutting down. These negative prices have risen in 2013 (up to 64 hours), but have been stable in 2014 (also 64 hours, even though the renewable generation has increased), demonstrating some improvement in the flexible response of conventional generators. Nevertheless, further technical and regulatory progress is necessary in order to cope with the continuous growth of renewable energy production.

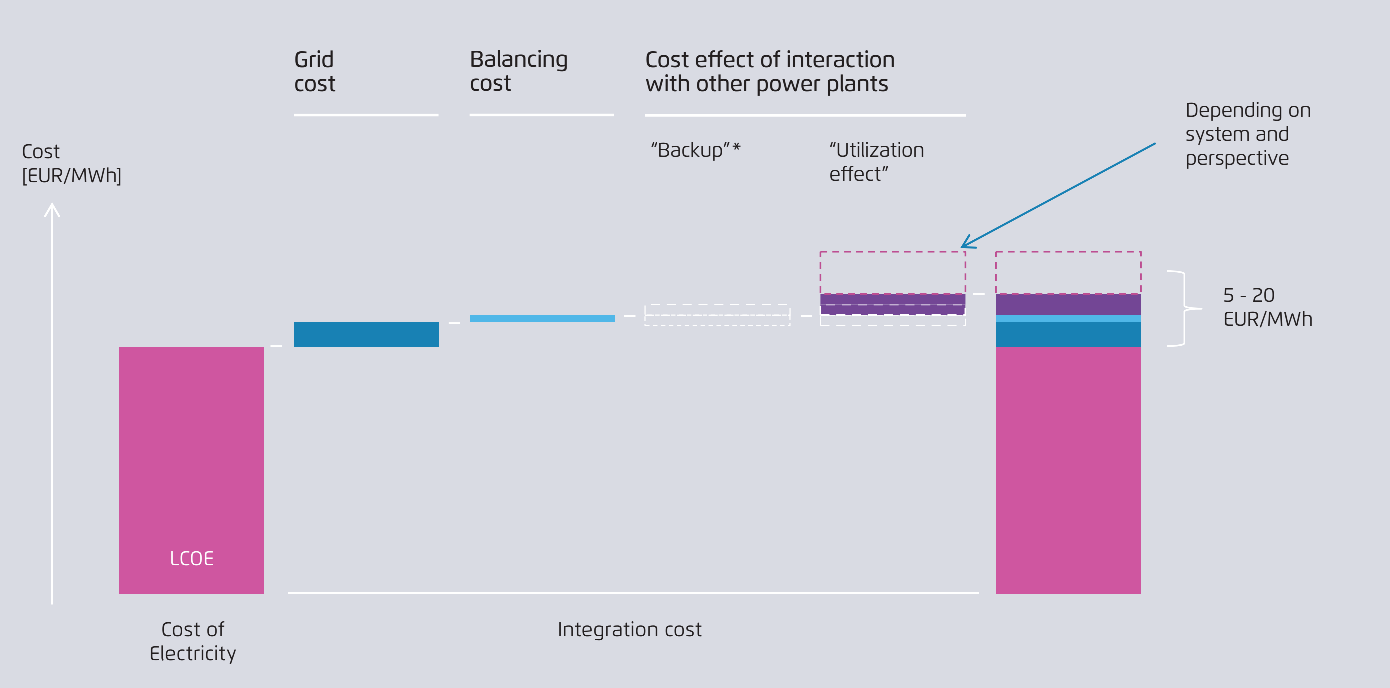
2.3 The cost of integrating renewables into conventional power systems exist but must not be inflated

The specific features of wind energy and solar PV (fluctuating output, forecast errors and spatial distribution of renewable resources) brings specific economic effects on the power system, sometimes referred as "integration costs," which are not captured by the generation costs. The definition and the range of these integration costs are controversial among academics and policy advisers. They depend on the power system and the perspective considered.

Integration costs for grids reinforcement (consequence of the spatial distribution of renewables) and balancing (consequence of the forecast errors) are better defined and small. For the German power system, these costs are often quantified with values around 5 to 13 euros/MWh,[15] even at high shares of renewables. Costs effects of the fluctuating output

15 Agora (2015b)

The integration costs of variable renewable energy — Figure 9



Agora Energiewende (2015) — *included in "utilization effect"

and its interaction with the residual generation fleet are more difficult to quantify. There is debate whether these effects can (and should) be considered as "renewable integration costs"[16] and how the value of backup power plants or lost revenues from conventional generators can be quantified. In the case of 50 percent wind and solar power in Germany, the range of these effects can be estimated between -6 and 13 euros/MWh,[17] with typical values around 0 to 10 euros/MWh (average costs). As a result, integration costs of adding wind onshore or solar PV into the German system may range around 5 to 20 euros/MWh (average costs).

16 Some argue that renewable energy are alone responsible for these costs. Other consider these costs as overall transformation costs of the energy systems that shouldn't be associated exclusively with renewable energy.

17 Negative values could be expected in the case of very high CO_2 prices. In that case, integrating renewables would diminish the use of CO_2 intensive – and therefore expensive – coal-fired power plants, leading to overall integration benefits.

From a system perspective, given the steep price drop in solar and wind power plants in recent years, the integration cost of these technologies do not substantially change their overall competitiveness. A greenfield power system, for example, consisting of 50 percent newly built wind and solar combined with 50 percent newly built gas fired power plants would generate power production cost of around 70 to 80 euros/MWh (including integration cost).[18]

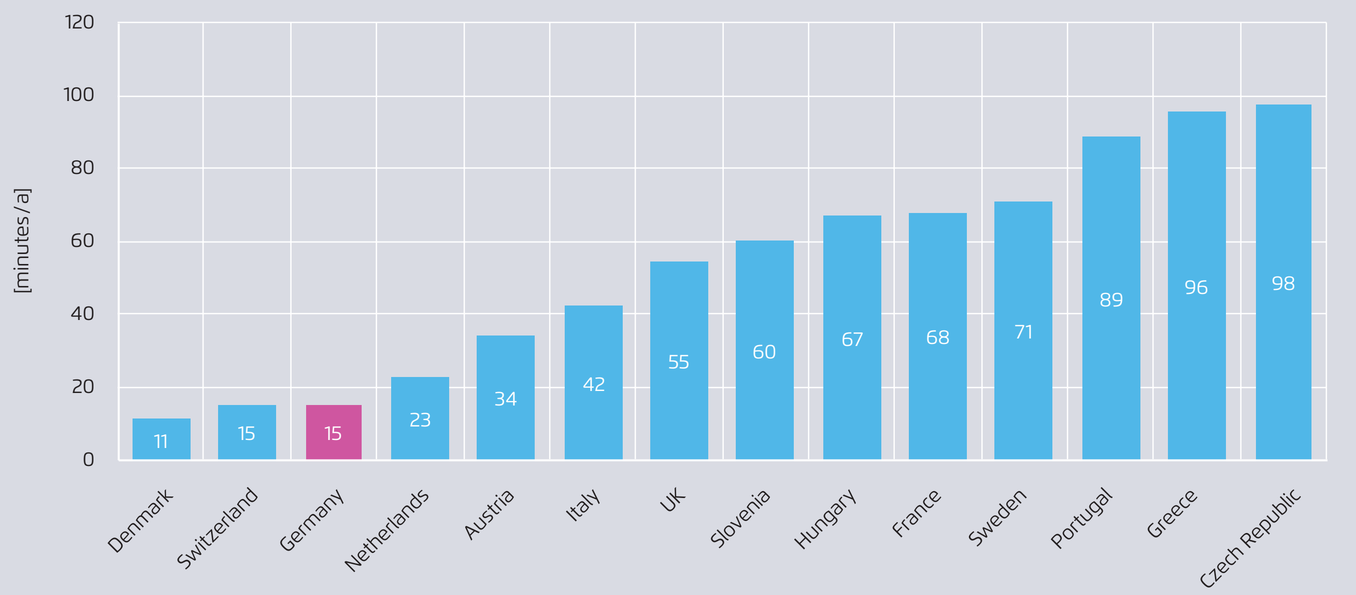
2.4 The German power system is reliable and currently distinguished by sufficient available capacity and high exports

The German power system is currently one of the most reliable in the world and unplanned capacity shortages remain on a very low level. The time when electricity is unavailable adds up to an average of 15 minutes per year (see Figure 10).[19] Sufficient generation adequacy exists (i.e. sufficient

18 Prognos (2014)

19 Bundesnetzagentur 2014

Unplanned System Average Interruption Duration Index (SAIDI, excluding exceptional events), 2013 Figure 10



CEER (2015)

resources are available for meeting demand at all times, even in critical situations), with reserve capacity margins expected to increase (from +5.5 GW in 2013 to +12 GW in 2016).[20] Some regional constraints on the grid – especially on the South-North axes – have however made it necessary to establish a temporary capacity reserve for Southern Germany that would be called upon in times of an electricity shortage situation in Southern Germany.[21]

Moreover, increasing interconnection within Europe has improved security of supply while facilitating the incorporation of fluctuating renewables. Germany and its neighbours, particularly those within the Pentalateral Energy forum[22], have developed new methods to assess resource adequacy in a dynamic way and on a regional scale.[23] This new approach lowers the cost of achieving a reliable power system and mitigates the need for flexibility, as national scarcity events do not occur exactly at the same time among the different interconnected countries. Accordingly, the joint peak load of Germany and its electric neighbours is lower by at least 10 GW in 2015 (20 GW in 2025) than the sum of national peak loads taken individually.[24]

Germany is a net exporter of electricity since 2003, as seen in Figure 11. This trend has accelerated since 2011, despite the definite closure of eight nuclear power plants after Fukushima's accident. German power exports hit a new record in 2014 at 35.5 TWh, representing 5.7 percent of the national power consumption. This situation is the result of both the rapid expansion of renewable energy and the current high competitiveness of coal (see also section 5.2).

20 BNetzA 2013, 2014a, 2014b

21 BMWi 2014c

22 The Pentalateral Energy Forum (PLEF) comprises seven countries (Austria, Belgium, France, Germany, Luxembourg, the Netherlands and, as an observer, Switzerland).

23 Moving away from a purely national and static perspective on security of supply.

24 Consentec, r2b (2015)

Net electricity exports from Germany to its neighbours (physical flows), 2000-2014 Figure 11

AGEB (2015), own calculations *preliminary

3. What are the costs and benefits of the German energy transition?

The major findings at a glance:

- Given the transformative nature of the *Energiewende*, investment, growth, and employment are shifting towards new low-carbon sectors.
- In 2013, the renewable energy industry alone accounts for approximately 370,000 jobs. At the same time, jobs have been phased-out in other sectors of the economy.
- The development of renewable energy and energy efficiency has a positive impact on the trade balance, enhances energy security, and reduces CO_2 emissions.
- Between 2000 to 2014, about 220 billion euros were invested in renewable energy (in all sectors). Due to aging infrastructure, new investments are necessary per se. In the decade to come, investments in the transformation of the power sector are expected to reach about 15 billion euros per year.
- Current costs of supporting renewable energy (the so-called "EEG surcharge") are quite high compared to other countries. The EEG surcharge, which has risen over the 2000s, is currently set at 6.14 cts€ pro kWh (for a total of 21.5 billion euros in 2015). This reflects historic development costs of emerging technologies, especially solar PV in its early years of deployment.
- Future costs will be much more moderate. The EEG surcharge is expected to grow at a moderate pace until 2023, reaching about 7.6 cts€ pro kWh, before declining to 4.4 ct per kWh in 2035.
- Renewable energy deployment leads to lower wholesale market prices, partially offsetting the increased EEG surcharge.

Assessing the overall costs and benefits of the *Energiewende* is extremely difficult given the scale of the project, its dynamic and long-term nature, and the lack of comprehensive data. Several economic factors can be evaluated[25] but they are intertwined in a complex way. They also do not necessarily reflect exclusive costs and benefits of the energy transition itself, as they may be related to other drivers. New investment in the power system, for example, is necessary due to aging energy infrastructure and cannot be attributed to the energy transition alone. This section focuses on several macroeconomic indicators regularly discussed in the public debate: employment, investments, fossil fuel imports, cost of the renewable energy surcharge, and wholesale market prices. This analysis is not exhaustive.

3.1 Given the transformative nature of the *Energiewende*, investment, growth and employment are shifting towards new low-carbon sectors.

The *Energiewende* is a process of socio-economic transformation and an important investment program, leveraging growth and innovation in new low-carbon sectors (renewable energy, energy efficiency, new energy services, and alternative transportation). About 220 billion euros were invested from 2000 to 2014 in renewable energy (in

25 E.g. employment level (gross or net), investments in renewable energy capacities, benefits of fuel savings, costs of renewables and grid roll-out, etc.

all sectors). In the decade to come, investment in the power sector is expected to reach about 15 billion euros annually, including 9-10 billion euros invested in new renewable energy capacity.[26] These investments contribute to the development of the German greentech sectors.[27]

The *Energiewende* also has an important impact on the job structure of the energy sector.[28] In 2013, the renewable industry alone accounted for approximately 370,000 jobs, twice as much as in 2004. The wind energy sector is the biggest employer (about 140,000 jobs in 2013) followed by the biomass sector (93,000 jobs).[29] The German photovoltaic sector (56,000 jobs in 2013) experienced a profound restructuring between 2011 and 2013, losing 45,000 jobs as a consequence of strong competition on the global market (accelerating the cost reduction of this technology, see 2.1). But despite the loss of employment in this sector, the sustained demand of solar PV in Germany (2 GW growth in 2014) still brings important added-value on the national level.[30]

Given its transformative nature, the *Energiewende* impacts other sectors of the German economy. The development of renewable energy and energy efficiency has crowded out the conventional energy sectors (i.e. coal or nuclear industry), with negative effects on their investment and employment structure ("substitution effect").[31] The energy cost increases related to the development of renewables have been moderate (see section 4). They have nevertheless reduced the purchasing power of certain German consumers and business (with the exception of energy-intensive industries, as explained in section 4.3), leading to a reduction of their spending and investments ("budget effect"). This effect is partially compensated by a net reduction of fossil fuel imports (see section 3.2) and new exports development for manufacturing goods ("trade balance effect"). The combination of these three effects have both direct and indirect impacts on the structure of employment.

According to a study commissioned by the Ministry of Economics,[32] the net result of the energy transition on employment is moderately positive, with a yearly net increase of 18,000 jobs up to 2020 (in comparison to a scenario without the *Energiewende*).

3.2 The development of renewable energy has positive impacts on trade balance, import dependency, and CO_2 emissions

The German economy relies strongly on energy imports (with the exception of lignite, which is extracted nationally). In 2013, Germany imported about 87 percent of the hard coal consumed, 87 percent of the gas consumed, and 98 percent of the oil consumed (see Figure 12).[33] This fossil fuel dependency represents a net trade deficit of about 90 billion euros in 2014, including 60 billion for crude and refined oil, 23 billion euros for natural gas, and 3.6 billion euros for hard coal. The replacement of fossil fuel by renewables energies, as well as energy savings measures (as embodied by

26 PWC (2014).

27 Environmental and resource efficient technology, including renewable energy, energy efficiency, waste and water management.

28 For an overview of different perspectives on how the energy transition affects jobs and businesses, see, for example, CLEW (2015).

29 including 68,000 jobs for the provision of biomass and biofuels.

30 47 to 72 percent of the added-value of German PV is still rooted locally, through installation and maintenance jobs, among others. Furthermore, the German industry is still well-positioned in the upstream of the PV chain (for example in manufacturing silicium).

31 The decrease of employment in the coal and mining industry started in the 1990s with the collapse of mining activities in the GDR after reunification and the progressive end of subsidies allocated to German hard coal. The rationalization process triggered by the liberalization of the power sector since the 1990s has induced further job losses.
According to the nuclear federation (Atomforum), the German nuclear industry counted about 40,000 jobs before 2011, including 8,000 jobs operating in the nuclear power plants and 32,000 jobs associated to the nuclear industry (manufacturers, suppliers, and R&D). About 75 percent of the jobs in nuclear power plants are maintained during the closing-down phase of the power plants (DIW ECON 2014) which is expected to last 15 to 20 years after the final shutdown of the power plants.

32 O'Sullivan, M., D. Edler, et al. (2014). This evaluation of job growth is made in reference to a scenario "without the energy transition." This net yearly jobs growth is similar to the one found in sectors like the chemical or manufacturing industry.

33 BMWi (2014b)

the *Energiewende* strategy), have a positive impact on the trade balance. In 2013, about 8 billion euros of energy imports have been saved, including about 4 billion euros savings in the power sector.[34] This strategy reinforces national energy security and brings down German CO_2 emissions: 152 $MtCO_2$ have been avoided in 2014, including 110 $MtCO_2$ in the power sector, as a result of the development of renewable energy.

3.3 Current costs of supporting renewables include large historic development costs; future costs will be moderate

The cost of renewable energy development is often linked to the so-called EEG surcharge. This EEG surcharge is paid by end-consumers through an increase of their electricity bill. Some industrial consumers receive partial or nearly full exemptions from this payment to preserve their competitiveness in international markets (see section 4.1 and 4.3).

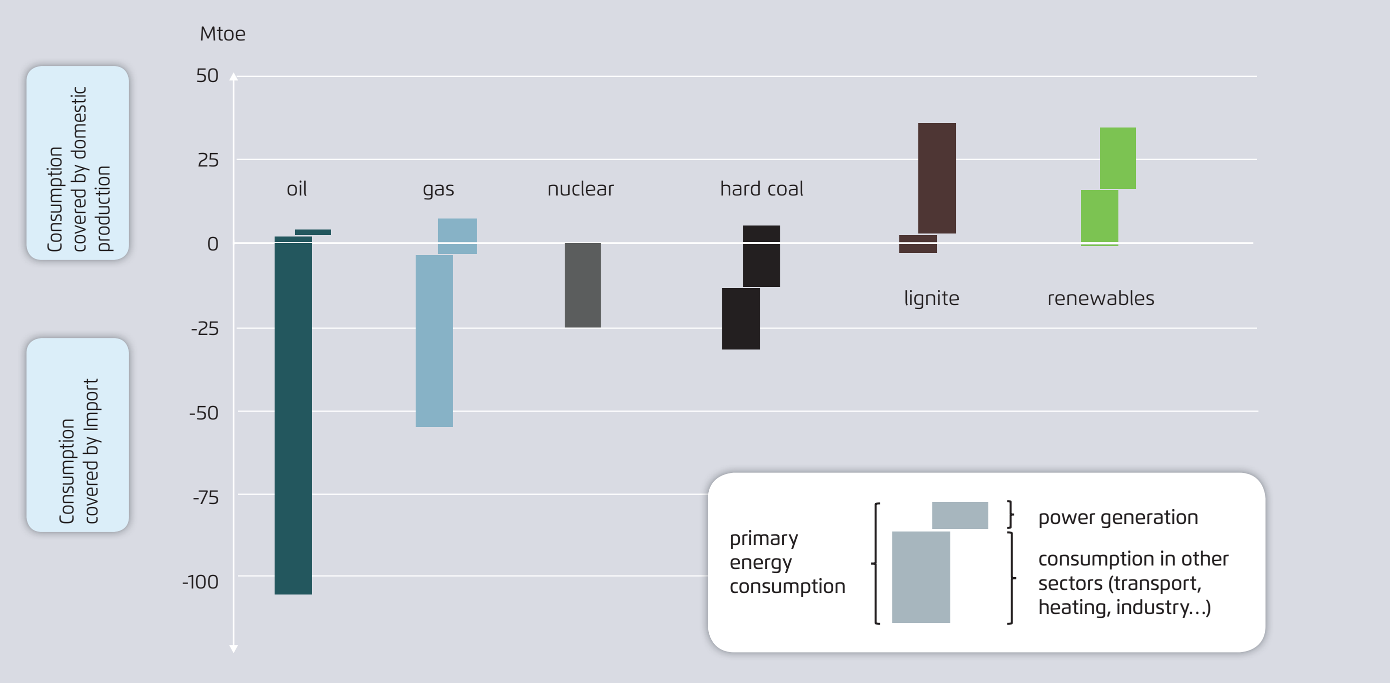
34 O'Sullivan, M., D. Edler, et al. (2014)

The EEG surcharge covers the difference between the cost of generating one unit of renewable electricity (i.e. the feed-in tariff paid to the generators) and the revenues from selling this unit on the wholesale market. In 2015, the EEG surcharge amounts to 21.5 billion euros, i.e. 6.14 cts€ per kWh, declining for the first time (22.4 billion euros in 2014).[35]

The EEG surcharge has risen continuously since 2000, especially between 2010-2013, due to a sharp increase in installation rates of solar PV at times when the costs of this technology were still very high. Altogether 25 GW of new capacity was installed in Germany during these four years,

35 The costs of supporting renewable energy (which are effectively promoted through indirect subsidy policies) must be put in perspective with the level of subsidies which benefit fossil-fuels (especially in circumstances when the negative external effects of burning fossil-fuels is not reflected in prices, e.g. low or no CO_2 prices). For comparison purpose, the worldwide subsidies for fossil fuels amounted to US$ 550 billion in 2013 only – more than four times the subsidies that were spent for renewables (IEA 2014).

Primary energy consumption by sources in Germany, 2014 — Figure 12



AGEB (2015)

about half of the world market at that time,[36] stimulating global competition and leading to a sharp decrease of the generation costs of this technology (see section 2.1). These "historic costs" will continue to be paid by German consumers over the years to come as the German legislation guarantees payment to solar PV producers for a twenty year period. But given the decrease of prices, solar PV will not be an important cost driver anymore.

With the 2014 reform of the EEG law focusing on the most mature technologies (wind onshore and solar PV), the EEG surcharge is expected to increase only moderately over the years to come (see Figure 14). It should reach a maximum of 7.6 cts€/kWh in the years 2022-2023 and then decrease when consumers no longer must pay for the oldest (and most expensive) renewable capacity installed in the 2000s. The main reason for the continued increase through 2023 is development of offshore wind, a relatively expensive emerging technology (twice as expensive as onshore wind).

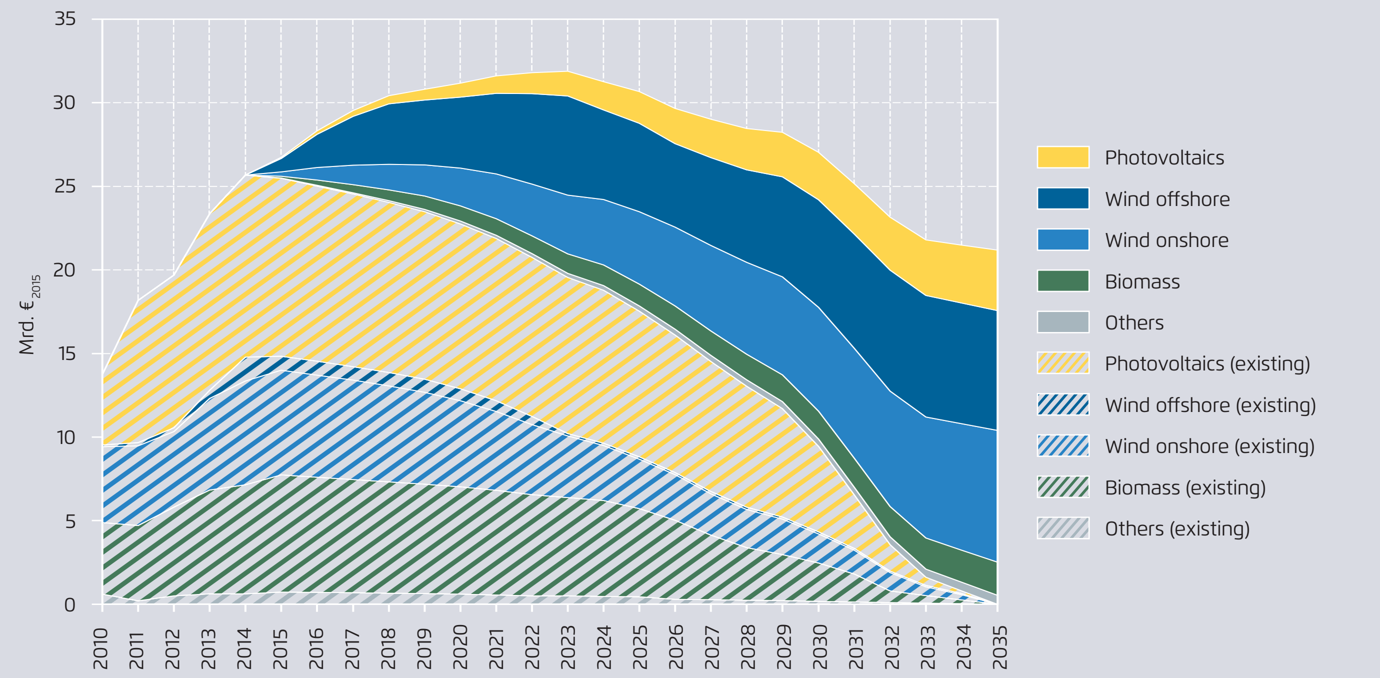
36 The massive deployment of these technologies increased the average payment for each kilowatt-hour of renewable electricity. In the year 2000, when renewable energy support focused largely in wind onshore and hydropower, average payments per kilowatt-hour amounted to 8.5 ct/kWh. By 2012, the average EEG payment had increased to 22.95 ct/kWh.

3.4 Renewable energy deployment lowers wholesale market prices, partially compensating the increasing in the EEG surcharge

The development of the EEG surcharge does not capture the comprehensive cost of renewable energy generation, as it is calculated in reference to wholesale market prices. Since wholesale electricity prices have declined over the last years, this has in turn contributed to a mechanical increase of the EEG-surcharge.[37]

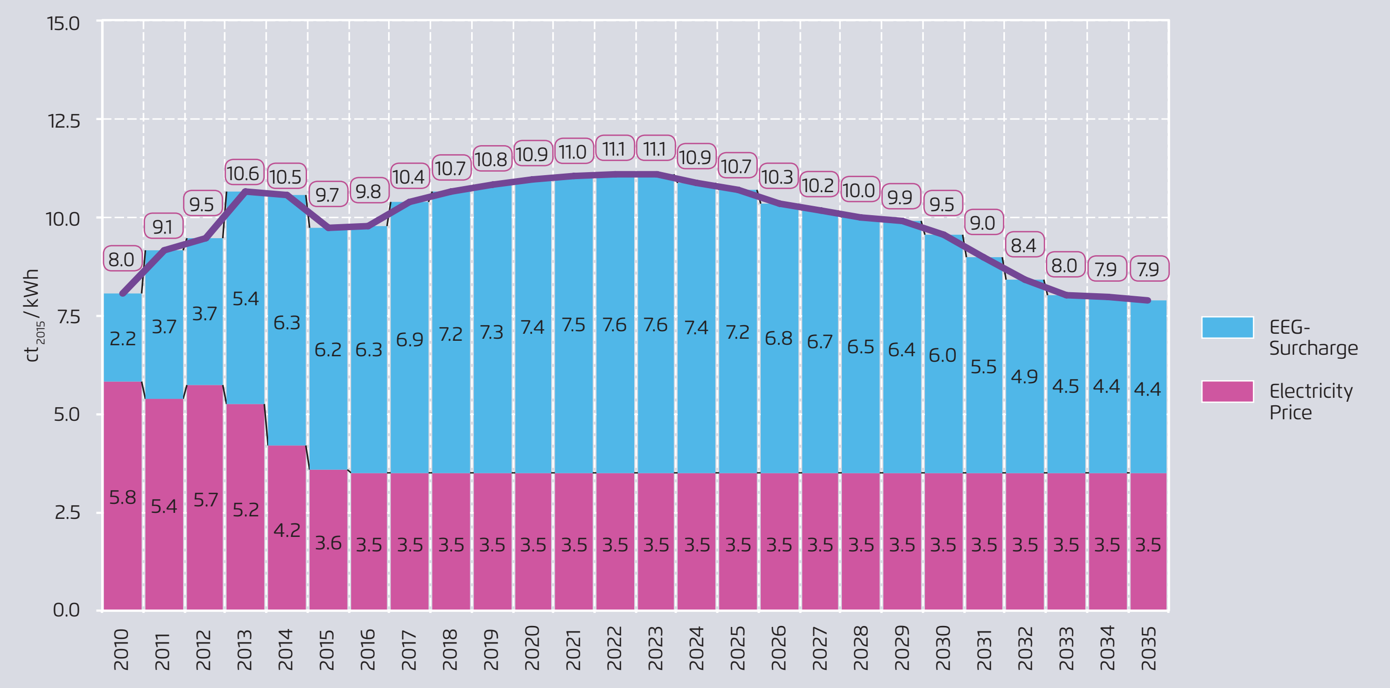
37 The level of the EEG surcharge also depends indirectly on the EU emissions trading scheme, since higher CO_2 prices would also result into higher wholesale market prices.

The past and future costs of supporting renewable energy development — Figure 13



Öko-Institut (2015) — The graph indicates the development of the yearly feed-in payment for old (hatched areas) and new (plain areas) renewable energy capacity (in billion euros) up to 2035

Sum of the electricity wholesale price (Phelix Base Year Future) and the EEG-levy in cts €/kWh from 2010 to 2035 Figure 14



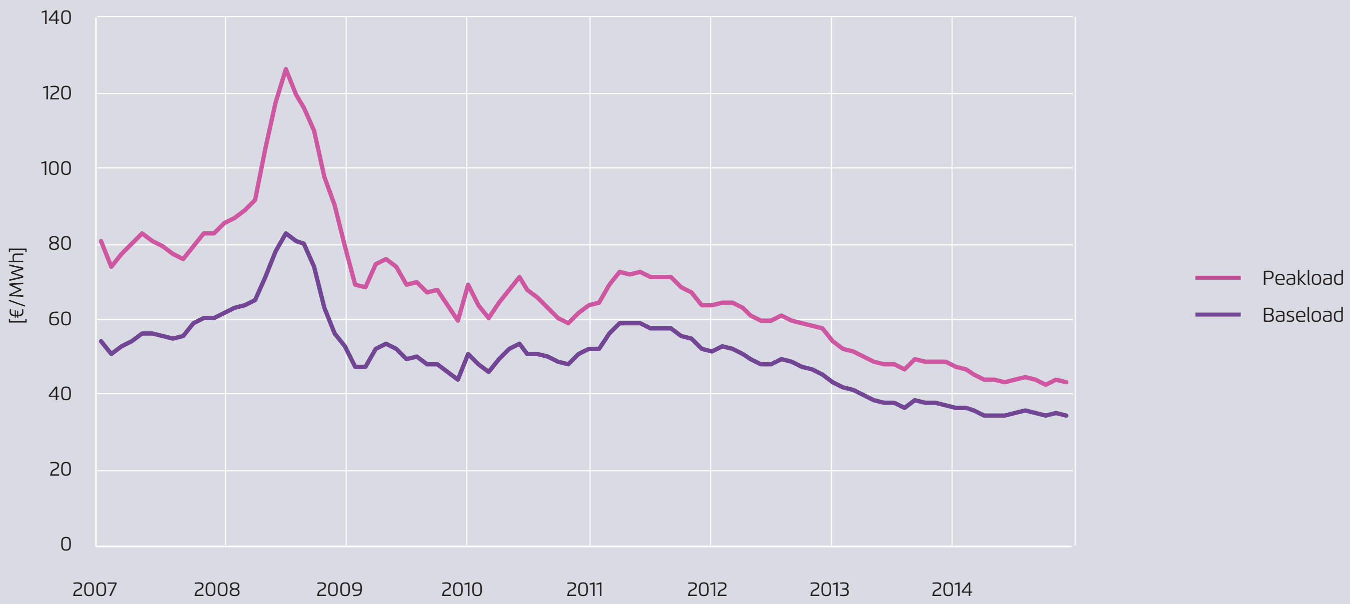
Öko-Institut (2015)

The decline in wholesale electricity prices (see Figure 15) benefits energy suppliers and consumers who can purchase electricity directly on the wholesale market. This decline is itself the result of a stagnation of electricity demand, along with an increase of thermal generation capacities, and the deployment of renewable energy, especially wind and solar PV. With their short-term marginal costs close to zero (i.e. they are automatically dispatched when the wind blows and the sun shines), new renewable capacity, together with inflexible baseload power plants, push more expensive marginal thermal power plants (like gas-fired power plants) out of the market. This “merit order effect” was responsible for a reduction of the wholesale market by about 10€/MWh (1 ct€/kWh) in 2012.[38] A more coherent picture of the cost of renewable energy must combine the EEG surcharge with the spot market prices. As can be seen in Figure 14, the overall cost increase only reaches 1.7 cts€/kWh between 2010 and 2015. Furthermore, one can see that the cost increase will be much more moderate in the years to come.

38 Cludius et al. 2014

Wholesale electricity prices (1-year future) in Germany, 2007 - 2014

Figure 15



EEX (2015)

4. Who pays for the *Energiewende* and how much?

The major findings at a glance:

- → Distributing the costs and benefits of the energy transition in a fair and transparent manner has become an important political focus of the energy policy debate in Germany.
- → Electricity prices for German households are among the highest in Europe (currently about 30 cts€/kWh). Due to the efficient use of electricity, however, the actual costs are comparable to countries with lower prices but higher consumption levels.
- → Energy-intensive industrial consumers benefit from exemptions on taxes and levies (including the EEG surcharge) to preserve their competitiveness in international markets. Low wholesale prices ensure energy-intensive industries in Germany enjoy one of the lowest electricity rates in Europe.
- → Non energy-intensive industries pay relatively high electricity prices compared to other European countries. For these companies, however, energy represents only a small portion of their total costs and has not affected their competitiveness thus far.

4.1 Distributing costs fairly, without affecting the competitiveness of German industries

Distributing the costs and benefits of the energy transition in a fair and transparent manner has become an important topic of the energy policy debate in Germany. It is essential to maintain the support of German society for the *Energiewende* project. Different consumer groups (households, commercial, small and large industries, energy-intensive industries) pay very different electricity prices, depending on their consumption level and localization. Generally speaking, the higher the consumption level, the lower the electricity price paid, as large consumers are frequently exempt from paying certain fees[39] and purchase their electricity directly on the wholesale market. In particular, specific privileges exist for energy-intensive industrial players in order to maintain their competitiveness in international markets. This industrial policy aims at maintaining the weight of the industrial sector in the country's GDP (22 percent in 2014), currently one of the highest in the EU (France: 11.4 percent, UK: 9.4 percent). It nevertheless shifts part of the costs of the energy transition to household consumers.

In 2013, private households contributed to more than a third (8.3 billion euros) of the total costs (23.6 billion euros) related to the support of renewable energy, even though their consumption reaches only a fourth of the total national consumption. The German business sector contributes about a half of the costs (11.8 billion euros), including 7.4 billion euros paid by industry (less than a third of the costs, for more than 40 percent of the national power consumption) and 4.5 billion euros paid by the tertiary sector.[40] The last amendment of the renewable energy act has kept the global cost repartition unchanged.

4.2 Electricity prices for German households are among the highest in Europe – but electricity bills are similar to those in other industrialized countries

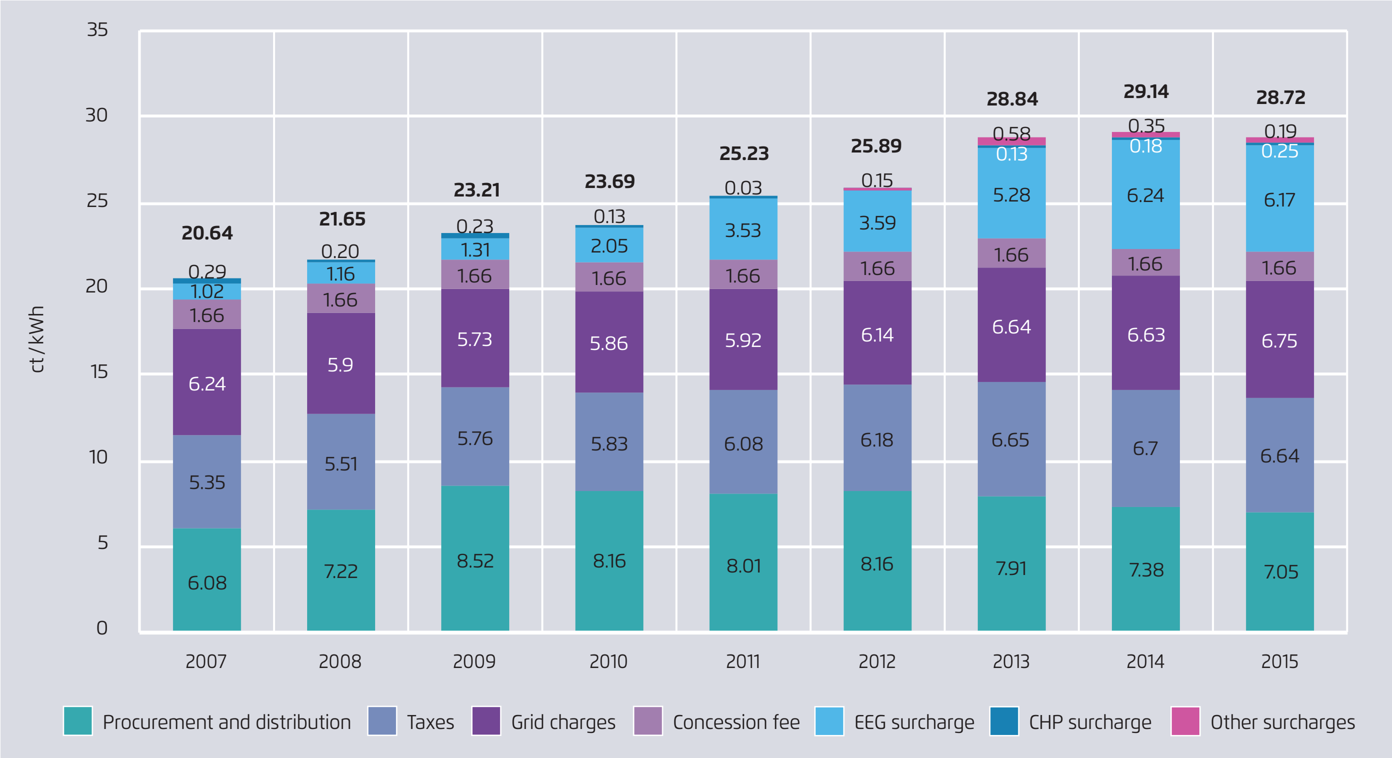
Electricity prices for German households, currently about 30 cts€/kWh, are the second highest in the EU, behind Den-

39 Besides typical costs of power systems (generation, distribution and supply of electricity), prices in Germany are also determined by various levies, surcharges, and taxes.

40 BMWi 2014a

Average household electricity prices. 2007 - 2015

Figure 16



BDEW (2015b)

mark. As seen in Figure 16, power prices have increased by about 50 percent since 2007 (in nominal terms), due to a continuous increase in almost all price components, including the EEG surcharge (see Figure 14), the grid tariffs, and several levies and taxes. The prices are nevertheless expected to increase only slightly for the years to come, as the major cost drivers belong to the past (as explained in section 3.3).

Despite high electricity prices, German households pay about the same electricity bills as consumers in other industrialized countries, e.g. the US or Spain, as they are comparably more efficient and consume less electricity, as can be seen in Table 2.

On average, German households spend around 2.5 percent of their income for electricity, a level which is comparable to the 1980s, and slightly higher than the spending in 1990s and 2000s (roughly 2 percent of household expenditure). However, low-income households are affected more strongly by electricity price increases; their electricity bill accounts for up to five percent of household expenditures.[41]

4.3 Industrial consumers benefit from exemptions and falling wholesale electricity prices

Electricity prices paid by German industrial consumers vary considerably, as they benefit from different exemptions on many price components (depending on consumption levels, the share of electricity costs in total added-value, and exposure to international competition). These different exemptions make it difficult to compare industrial electricity prices between German industries and those in other countries.[42] While small German industrial consumers (consumption below 20 MWh) pay one of the highest retail prices in Europe, German energy-intensive industries pay

41 Neuhoff et al. 2012

42 Agora Energiewende, 2014c.

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

	Annual household consumption kWh	Electricity price EURct/kWh	Annual electricity bill EUR
Denmark	3,820	29.4	1121
US	12,294	9.0	1110
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

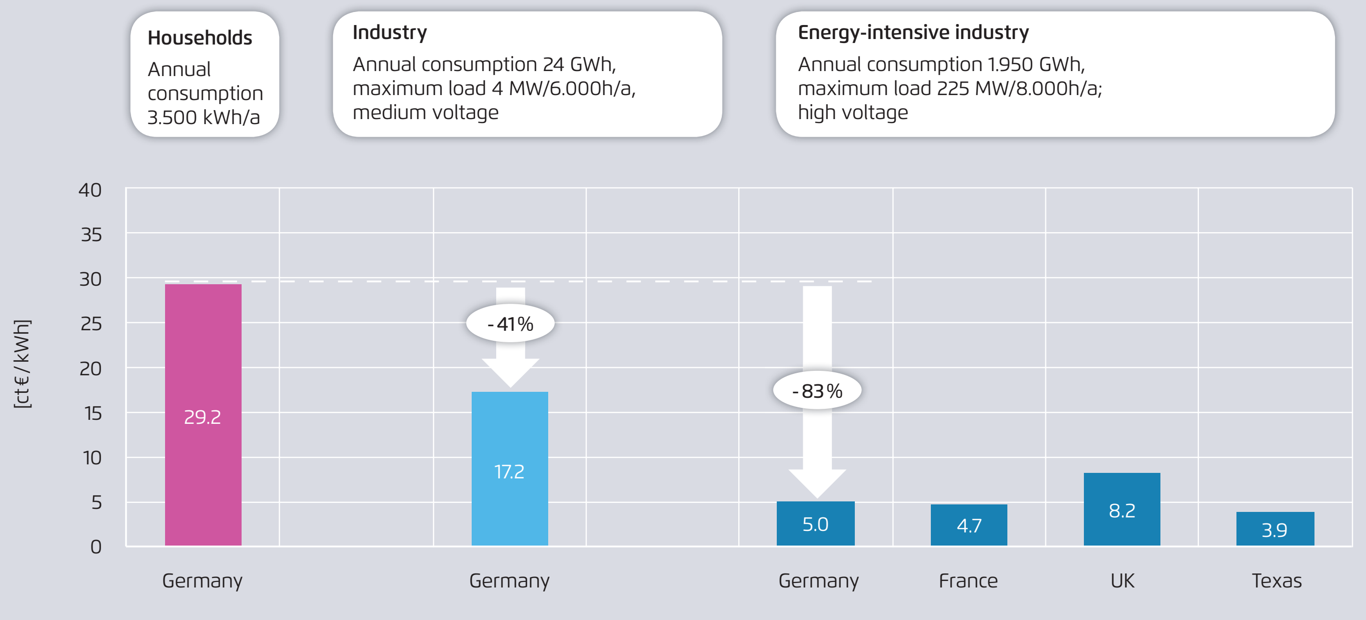
Source: Enerdata (2015), World Energy Council (2015), own calculations

* consumption data from 2013; electricity prices data from 2014

one of the lowest, as seen in Figure 17. In fact, the energy-intensive industries (steel, aluminum, cement) pay almost no taxes and levies (pro kWh consumed) in order to preserve their international competitiveness.[43] They also purchase

43 Qualified companies consume more than one gigawatt-hour per year and have a high share of energy costs relative to gross value-added (more than 16 percent).

Average electricity prices for households and industrial consumers, 2013 — Figure 17



BNetzA (2014b), Ecofys/ISI (2014)

their electricity directly on the wholesale market, benefiting from declining prices (see section 3.4). In 2014, about 2000 companies in Germany – representing 20 percent of the national consumption[44] – benefited from this situation.

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 as compared to their added-value. 98.5 percent of German industrial gross value-added is generated by industries with energy costs (electricity and heating), representing less than 6 percent of their total revenues.[45]

44 118 TWh for a national consumption of 579 TWh in 2014.

45 In the manufacturing industry, energy related costs account on average for only 2.1 percent of gross production cost (Neuhoff et al. 2014).

5. Is Germany on track to meet its CO_2 reduction targets? Is coal making a comeback?

The major findings at a glance:

- → Germany has ambitious mid and long-term climate targets – namely, to achieve a 40 percent reduction in greenhouse gas emissions by 2020 (below 1990 levels), followed by an 80 to 95 percent reduction by 2050 (below 1990 levels).
- → In 2014, the emissions were 26 percent below 1990 levels; the German energy sector – still dominated by coal – was the largest emitter (449 $MtCO_2$ emitted in 2014).
- → Renewable energy sources contribute significantly to CO_2 reductions. Increasing renewables have more than compensated for the nuclear phase-out.
- → The high competitiveness of coal compared to gas – in the context of a weak European Emission Trading scheme (ETS) – has a negative impact on Germany's CO_2 emissions.
- → In order to meet its 2020 climate targets, the government decided in July 2015 to retire around 13 percent of Germany's oldest lignite power plants (2.7 GW) by 2020.
- → To reach the 2030 targets and beyond, a consensus on the gradual decrease of coal needs to be established.

5.1 Greenhouse gas emissions have declined since the 1990s; the power sector is still a large emitter

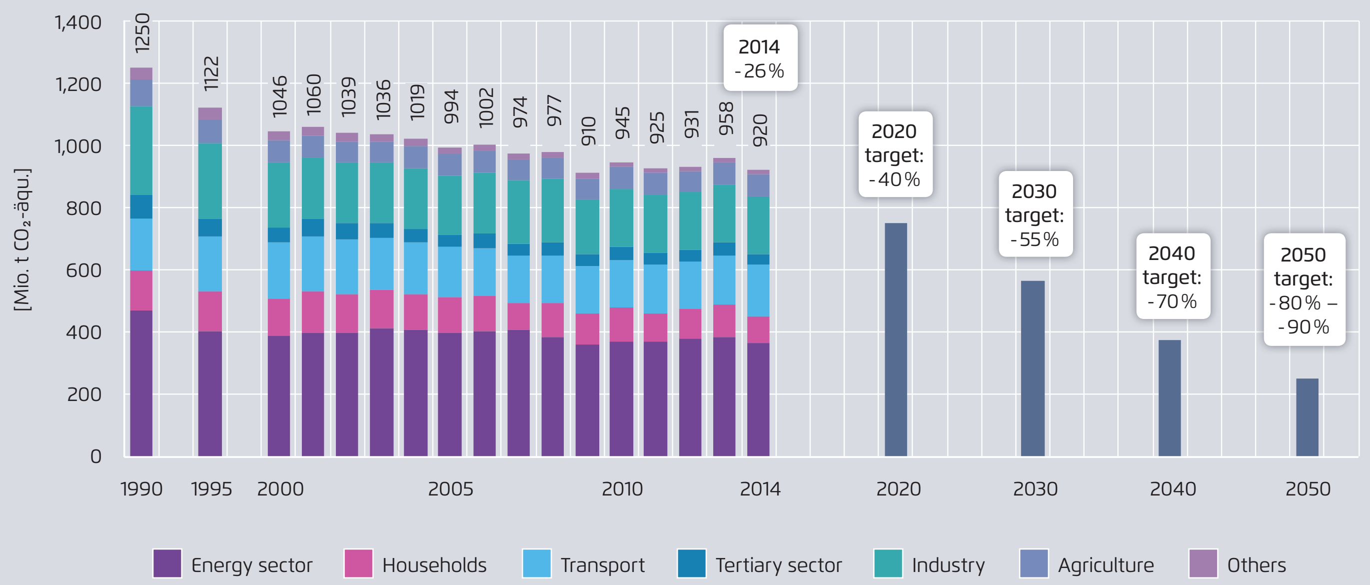
Germany has adopted ambitious national climate targets.[46] In 2014, the greenhouse gas emissions were 26 percent below 1990 levels, the German energy sector – still dominated by coal – being the largest emitter (449 $MtCO_2$ emitted in 2014). Nevertheless, after rising for two years, the CO_2 emissions of the power sector fell sharply in 2014 (5 percent reduction compared to 2013 level), due to favorable developments in renewable energy and energy efficiency, together with a mild winter and a decrease in power produced using hard coal (to its second lowest level since 1990). The emissions of the power sector are expected to decline further in a business-as-usual scenario by about 37 $MtCO_2$ 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 discussed in order to fill the gap, including the retirement of 2.7 GW of Germany's oldest lignite power plants (see section 5.3).

46 Reduction of CO_2 emissions by minus 40 percent in 2020, minus 55 percent by 2030, minus 70 percent by 2040 and minus 80-95 percent by 2050 (compared to 1990 levels). These targets are in line with the European energy and climate framework and the IPCC's recommendations in order to keep global temperature increases below the two degree threshold.

5.2 The high competitiveness of coal – in the context of a weak European Emission Trading Scheme (ETS) – has a negative impact on national CO_2 emissions

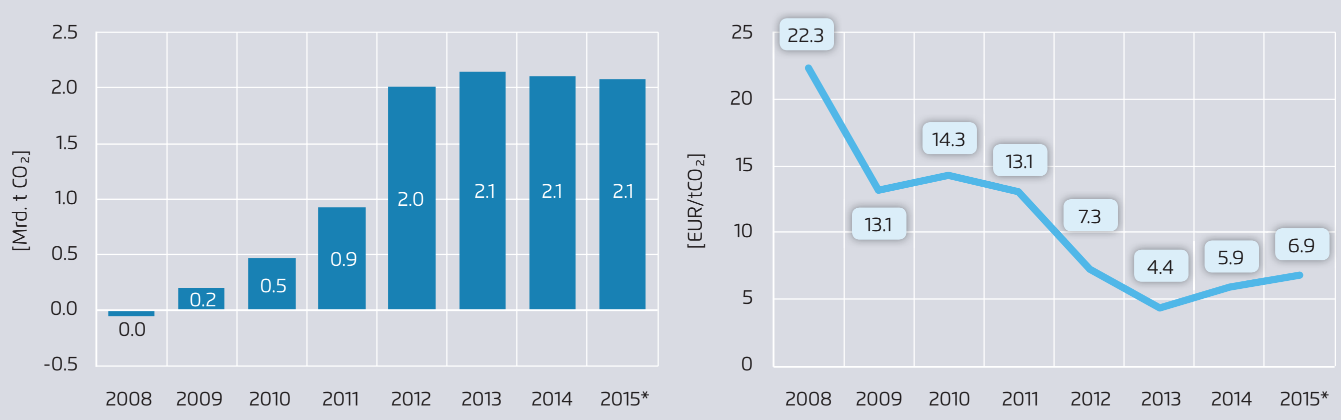
German coal power plants, especially lignite, are currently extremely competitive. This is the result of two factors. First, the European Emissions Trading System (ETS), the

Greenhouse gas emissions by sector, 1990 – 2014 and climate targets, 2020 - 2050 | Figure 18



AGEB(2015), UBA (2014), own calculations | *preliminary

Over-allocation (left) and price development of CO_2-certificates (right), 2008 – 2015* | Figure 19



Agora (2015c) | *preliminary

main European instrument for internalizing the costs of CO_2 emissions in the power sector, is weak (as a consequence of the vast over allocations of CO_2 certificates). This will lead – unless fixed – to persistent low CO_2 prices. Secondly, coal prices are currently very low on the world market (a side-effect of the US shale gas revolution). This leads to an increasingly wide spread between cheap coal and expensive gas. As a result, German coal power plants produce at very high levels, contributing to historically high export levels and a crowding-out of gas power-plants both in Germany and in neighbouring countries. This trend has led to an increase of CO_2 emissions between 2011 and 2013 in Germany, despite a rise in renewable energy during the same period (a counterintuitive development known as the "*Energiewende* paradox"). [47]

In 2014, this trend has started to reverse, as renewables and reduced demand are now also crowding-out hard coal power plants, leading to an overall decrease of domestic CO_2 emissions. Nevertheless, lignite power plants still generate at a high level and the export balance is still highly positive (up by 35.5 TWh in 2014, a new national record representing 6.1 percent of the national power consumption). Renewable energy sources have more than compensated for the nuclear phase-out (see Figure 20).

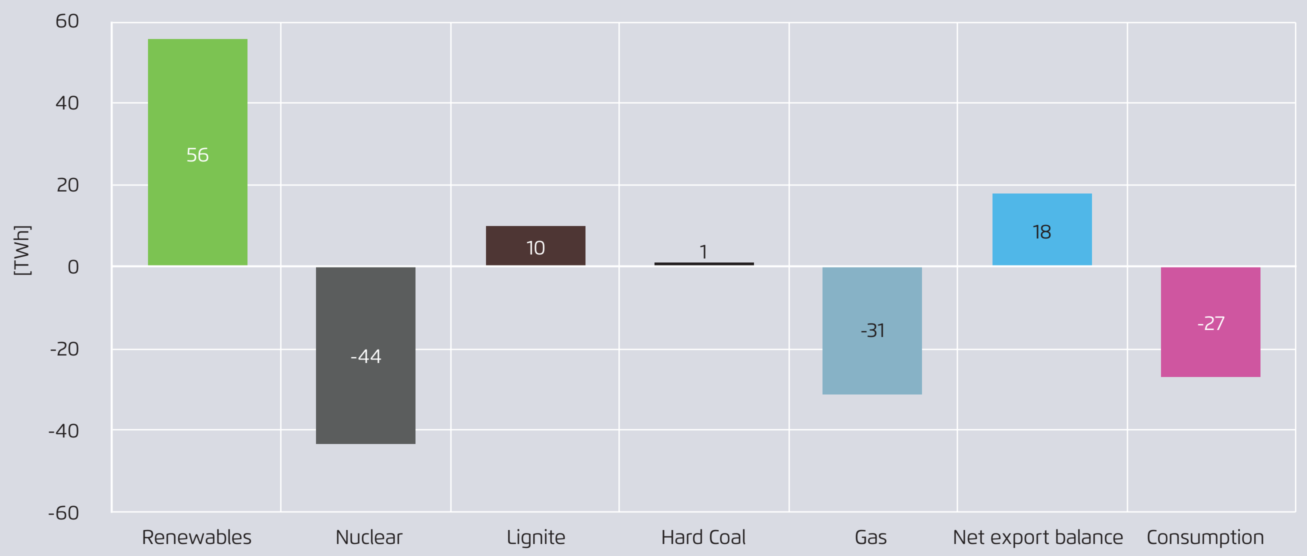
47 Agora 2014b.

5.3 The way ahead: The share of coal needs to be reduced gradually to reach the ambitious climate targets

Germany can only reach its 2020 emission reduction targets when it considerably reduces electricity generation from lignite and hard coal. An analysis from Agora *Energiewende* has shown that the share of lignite and coal need to go down from 45 percent in 2014 to at most 28 percent in 2030 to meet the 2030 climate target (see Figure 21).[48]

48 Agora 2014

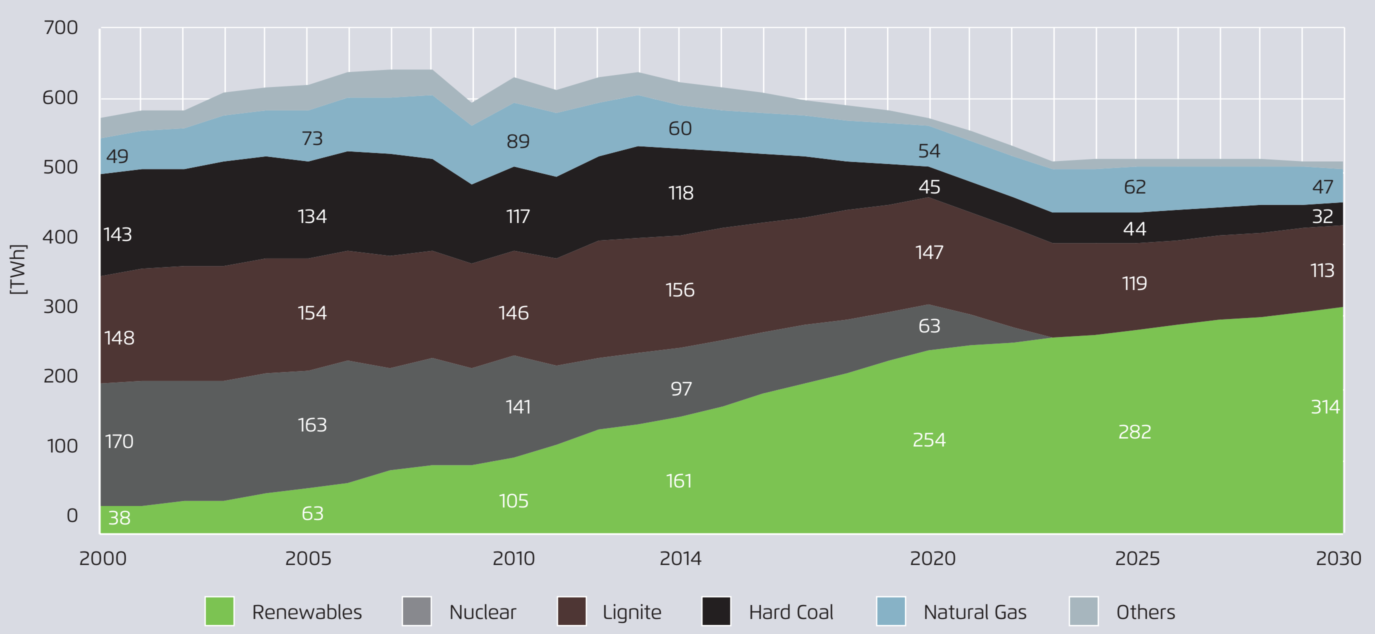
Change of electricity generation, consumption and net export balance, 2010 - 2014* Figure 20



AGEB (2015), own calculations *preliminary

Recent developments in gross electricity generation in Germany, 1990 - 2014 and scenario until 2030 to reach the government's targets

Figure 21



AGEB (2015)

Germany and the European Union as a whole need to fix their carbon policy, to reverse the coal resurrection witnessed recently all over Europe. The German government is pushing for structural reform of the EU emissions trading scheme, together with stronger energy efficiency measures. In parallel to its European engagement,[49] the German government in July 2015 adopted additional national policies and measures. In a new law that is expected to be decided by parliament in late 2015, 2.7 gigawatts of inefficient old lignite power plants are to be taken off the market by 2020. Once off the market, they would remain for four years in a so-called "climate reserve." Plants in this reserve would only be called upon to produce if there is the danger of a severe power outage. After four years, the plants will be shut down completely. In order to reach the 2030 targets and beyond, a consensus on the gradual reduction of coal in the German power mix needs to be established, together with power producers, unions, government, and environmental NGOs.

49 The modification of the EU emissions trading scheme is a complex process, as it involve all European Member states and institutions.

6. What are the forthcoming challenges and policy decisions?

The major findings at a glance:

- → A new design of the German electricity market is underway, enhancing flexibility and regional integration.
- → Financing low-carbon assets in the most cost-effective way, while promoting market integration, will be key.
- → The next amendment of the Renewable Energy Act will target stronger market integration and may generalize auctioning schemes for renewable energy projects.
- → Upgrading the grid from North to South is crucial for the German and European electricity market.
- → A coherent strategy and new business models have to be developed in order to leverage the potential of energy efficiency measures.
- → Distributed energy resources challenge the traditional business model of energy utilities but also bring new business opportunities.

The German energy transition is a long-term industrial and societal transformation. Given the transformational nature of the project, the stakeholders of this energy transition (policy makers, consumers, utilities, industries) will face many new challenges and opportunities in the coming years and decades.

Important policy decisions and regulatory changes will continue to reshape the power system to integrate higher share of variable renewables and enhance the overall flexibility of the system. The next steps have already been laid out by the government. This concerns primarily the re-design of the electricity market, additional measures for reducing CO_2 emissions, further cooperation with neighbouring countries and Europe as a whole, necessary grid expansion plans and a deeper reform of the renewable energy act.

6.1 A new design of the German electricity market is underway - some details have raised controversy

The transformation of Germany's power infrastructure (the "hardware" of the system, so to speak), which is driven by the development of wind and solar PV, requires refining the design of the power market (the "software," in a sense) to guarantee short and long-term system adequacy. Within the scope of a broad consultative process organized by the German Ministry of Economic Affairs (BMWi),[50] a set of "no-regret" measures have been discussed for enhancing system flexibility and reliability. These measures include adjustments to short-term markets (day-ahead, intraday, and balancing markets), the modification of grid usage fees,

50 The Ministry started its consultation process in November 2014. A green paper was published in October 2014 and a white paper in July 2015. Based on this consultation process, the Ministry is expected to adopt legislative proposals by fall 2015.

the expansion of electricity grids, and enhanced cooperation with neighbouring countries and with the European Union. The Ministry also envisages the temporary introduction of a capacity reserve to guarantee the security of the German power system during the transition phase toward new market arrangements.

A more controversial discussion has been raised regarding whether Germany should rely only on this improved market-design structure (which is referred to as "power market 2.0") or if it should also implement a second market structure (a so-called "capacity market") to assure long-term resource adequacy. The topic has been debated among stakeholders and experts.[51] The government published a white paper on the electricity market design in mid-2015, announcing it would stick to the power market 2.0 approach and not introduce a capacity market.

6.2 The next amendment of the Renewable Energy Act: Towards higher competition and market integration

The revised Renewable Energy Act (EEG 2.0) paves the way for larger reform to take place in 2017. In accordance with the European state aid guideline for environmental protection and energy from the European Union,[52] the next reform is likely to generalize competitive auctions for large-scale renewable energy projects. The goal is to implement a more competitive process for setting feed-in tariffs for renewables. Small-scale projects will still benefit from administratively set feed-in tariffs. A pilot auction for ground-mounted photovoltaics (for a total of 400 MW) has been already implemented in Germany in 2015 to test the scheme and gather experience.

51 Actors in favor of a capacity market argue that low or very volatile market prices alone will not trigger new investments and that additional revenue security is needed for long-term system adequacy. Actors arguing against capacity markets fear that this will be a subsidy for existing and new fossil-fuel based power plants and that alternative flexibility options – e.g. demand response – will not be taken into consideration.

52 EU Commission, 2014

Deeper reflection is also likely to take place in the years to come on how to finance low-carbon assets in the most effective way while promoting market integration of these technologies. With share of renewables rising from 25 percent to 50 percent by the year 2030, periods where renewables will cover the whole electricity demand will increase substantially. With their marginal costs close to zero, PV and wind energy will therefore deeply influence price formation in an energy-only market, "eroding" their own market price as their contribution to demand rises. In this context, wind energy and PV may not be able to recover their costs in a marginal cost based market, even when their total costs are below those of coal and gas. Essentially, this requires designing new financing mechanisms able both to close the cost recovery gap and to minimize overall system costs. Some proposals, including one published by Agora *Energiewende*, suggest a move towards technology-specific capacity payments for renewable producers (to complement the revenues made by selling electricity on the market).[53]

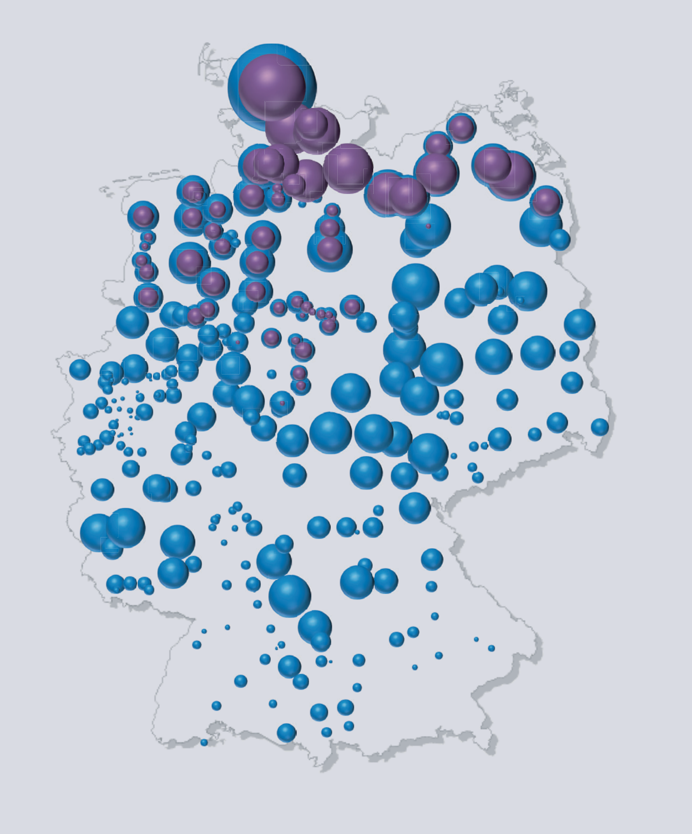
6.3 Upgrading the grid from North to South is crucial for the German and European electricity market

Grid expansion – both nationally and with neighbouring countries – constitutes an important flexibility option to balance volatile influx from wind and PV over long distances. In geographically larger areas, supply and demand can be balanced more easily, especially when complementary production and consumption profiles exist. In addition, a well-developed grid enables the utilization of other flexibility options across regions.

In Germany, the major challenge lies in accelerating the reinforcement of the grid on the South-North axis. This is also important for the European market integration, e.g. in order to avoid loop flows, especially in central-eastern Europe. The four German transmission system operators publish an annual national network development plan which contains the expansion and reinforcement measures required for the next ten years to ensure stable and reliable opera-

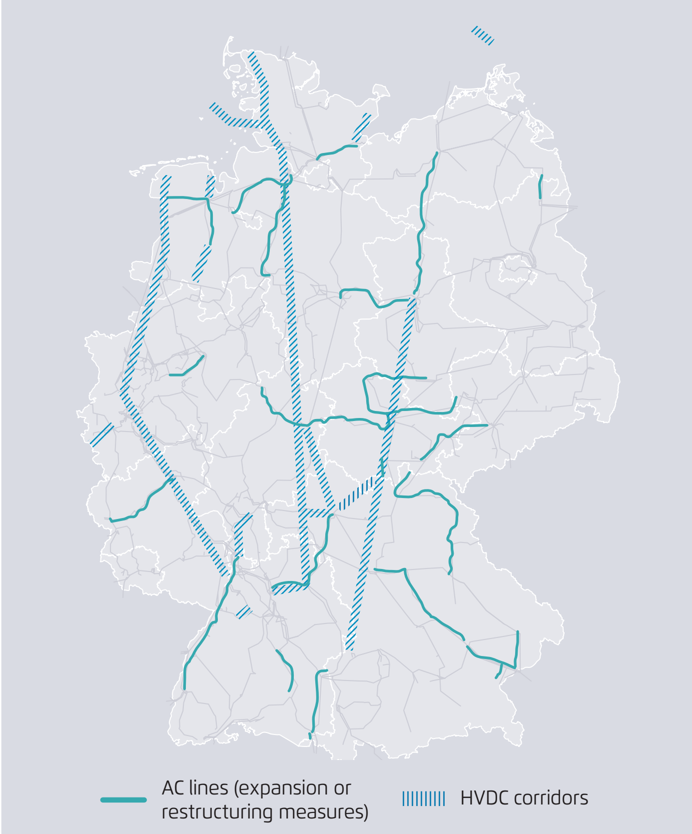
53 Agora 2014b

Scenario "Best sites" expansion of windmills up to 2033 — Figure 22a



Agora Energiewende (2013)

Necessary expansion and restructuring of the German electricity grid up to 2024, according to the German network development plan NEP 2024* — Figure 22b



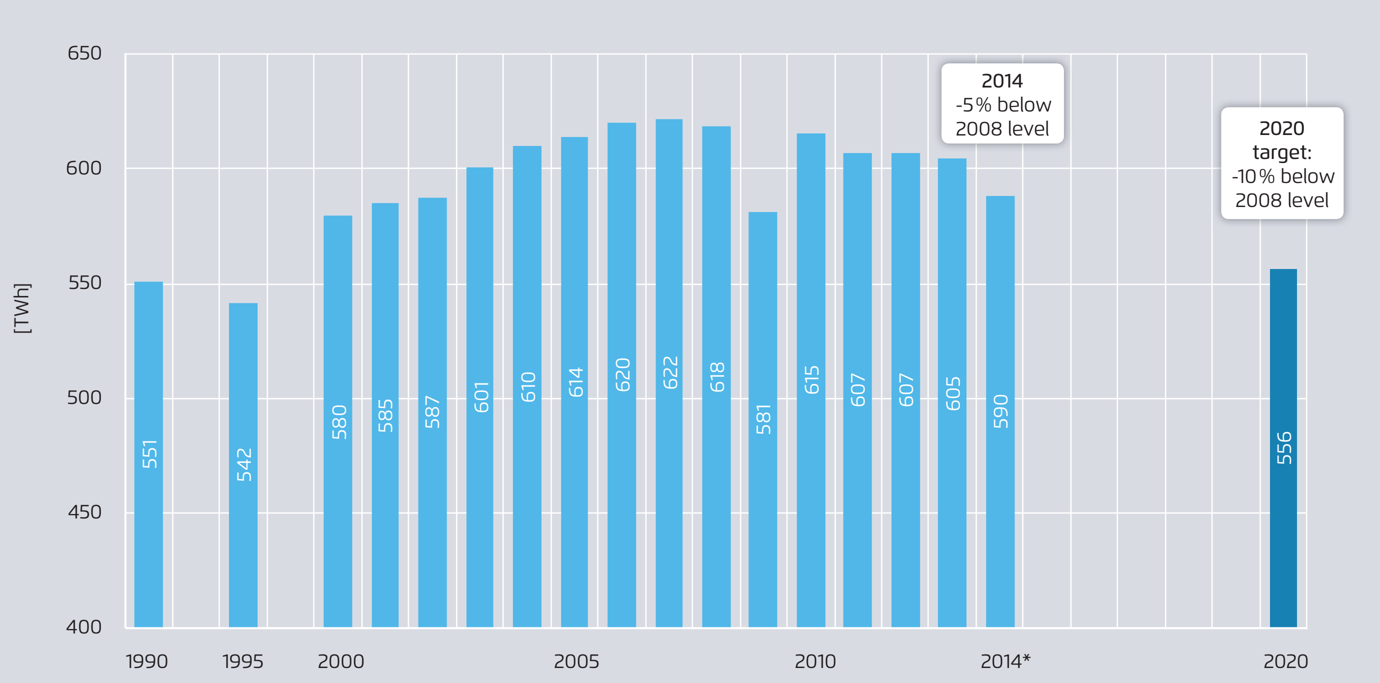
BNetzA (2014c) * approved by the federal network agency in 09.2015

tion of the grid. The grid development plan estimates a need for 3,500 kilometers of new transmission lines, of which 2,000 kilometers are allocated to the erection of four HVDC North-South corridors.[54] This expansion need arises predominantly from the fact that the additional wind power in Germany will be built in the north close to the coast, while major industrial power consumers are situated in Southern Germany. Surplus power produced in the North can lead to unplanned power flows through the grids of Germany's neighbours in order to reach the south of 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) which will be followed in the next year by the introduction of physical phase-shifters on the German–Polish and later on the German–Czech borders. Unsolved loop flow issues can slow down the integration process of power markets in Europe.

Furthermore, expansion and reinforcement measures of the distribution network are absolutely necessary, as a large bulk of wind energy onshore and PV are directly connected at this level. Grid developments often face acceptance problems from local populations, leading to delays in the deployment of this infrastructure. Building consensus at the local level through enhanced dialogue with a variety of stakeholders will be key for widening the necessary public acceptance for these projects.

54 TSOs 2014

Gross electricity consumption in Germany, 1990-2014 and 2020 target — Figure 23



AGEB (2015), BReg (2010), own calculations

6.4 A coherent strategy and new business models must be developed to leverage the potential of energy efficiency measures

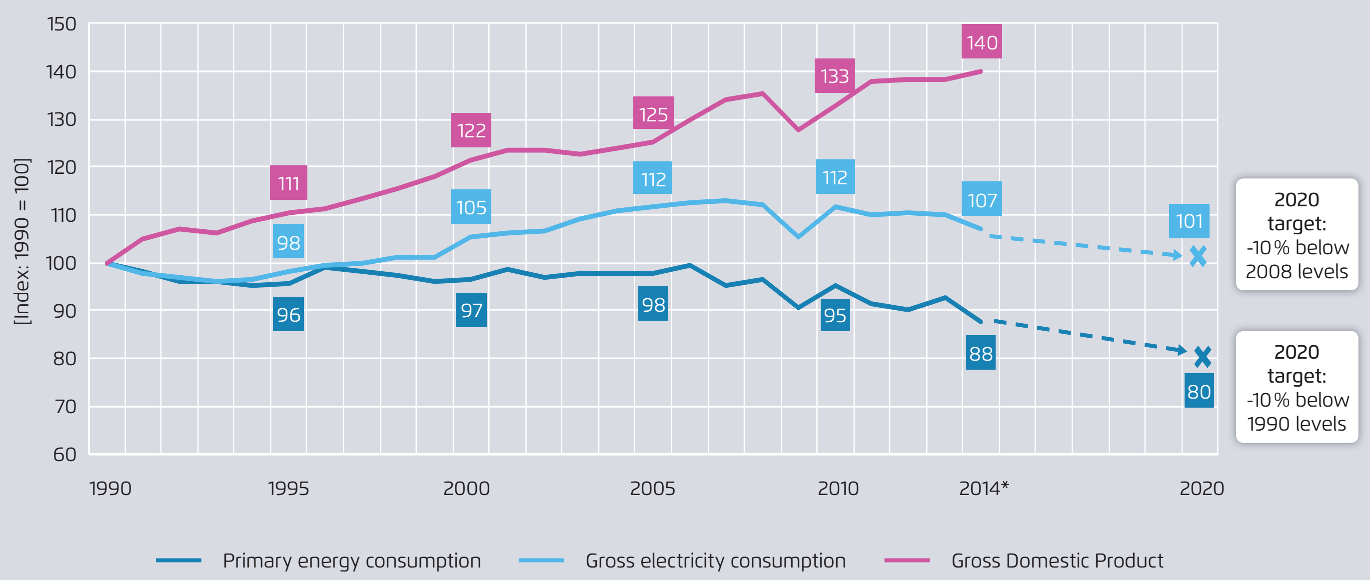
In addition to renewable energy targets, the *Energiewende* sets ambitious goals in terms of energy efficiency: Primary energy consumption is to be reduced by 20 percent by 2020 and 50 percent by 2050 (compared to 2008 levels). This requires an increase of energy productivity of 2.1 percent per annum.[55] In the electricity sector, consumption is to decrease by 10 percent until 2020 and 25 percent by 2050.

Although Germany has managed to decouple economic growth from energy consumption (see Figure 24) further policies and measures are needed to consolidate recent trends in electrical efficiency and to speed up the decline in primary energy consumption.

55 Federal Cabinet Energiekonzept (fn. 10); BMWi (2012). BMWi (2014a).

There is already a broad mix of energy efficiency instruments and programs in Germany, but more effort is needed. Market-based solutions for triggering investments in energy efficiency do not appear sufficient, as business models that focus on energy efficiency are usually associated with high initial costs and long payback periods. A coherent strategy and additional instruments need to be implemented in order to support investments. One possibility – as offered by the EU Energy Efficiency Directive – is to require energy suppliers and/or network operators to implement efficiency obligation schemes (to comply with binding targets). In Germany there is still no majority to implement such obligations. Therefore, in its National Action Plan on Energy Efficiency (NAPE), the German government aimed instead at alternative measures, including funding and support programs, regulatory instruments for setting standards, information and advice programs, and financial incentives. The NAPE adopted in December 2014, together with the Climate Action Program 2020 aims at setting forth an Energy Effi-

Energy consumption, electricity consumption and economic growth, 1990 - 2014 and 2020 targets — Figure 24



AGEB (2015), BMWi (2015), BReg (2010) — * preliminary

ciency Strategy for the current (18th) legislative term to meet the national and European energy efficiency targets.

6.5 Distributed energy resources challenge the traditional business model of utilities and bring new business opportunities

Technological innovation and new societal aspirations are driving the power sector transformation towards more decentralization. Thanks to the development of communication and control technologies, the power system is becoming multi-directional, with real-time flows of electricity and information between consumers and producers. The role of consumers is fundamentally evolving in this context, with a stronger environmental awareness and an increasing willingness of people to control their energy supply at a smaller scale (see also Figure 4). Consumers are becoming active players in the power system, while they were – in the past – confined to passive behavior (purchasing electricity delivered by monopoly utilities). They are increasingly generating locally part of the electricity consumed (prosumer), and can potentially modulate their energy demand, as a response to price or regulatory incentives. New electricity uses (e.g. electric vehicles) and storage development may also fundamentally alter their traditional role and consumption profile.

This trend is profoundly challenging the traditional business model of utility companies, historically designed around large centralized power plants and driven by growing electricity demand. This distributive transformation has threatened their business models (with erosive effects on profits), but it also offers new business opportunities.[56] The optimal system will require new flexible foundations and stronger need for coordination, relying on large amount of data-based solutions to match intermittent supply and demand efficiently. Many regulatory challenges remain to enable the emergence of these new integrated solutions and value creation.

56 See, for example, e-lab (2013) for an extensive description of the way the decentralized energy revolution is challenging business models of energy utilities.

7. Is Germany alone in its attempt to build a sustainable energy system?

The major findings at a glance:

→ The German energy transition is embedded in a wider European policy framework designed to bring greater sustainability, energy security, and competitiveness in Europe. According to the decision of the European council in October 2014, Europe will continue its ambitious energy and climate policies until 2030 – decreasing CO_2 emissions, developing renewables, and increasing energy efficiency.

→ Many other European member states have equally ambitious short and long-term targets. Thus, the challenges faced by Germany are a snapshot of what is likely to occur in several countries in the medium to long-term.

→ Germany and its neighbours are strongly interconnected. Whatever happens on the German power market affects its neighbours and vice versa.

→ Stronger European and regional cooperation, especially on power market design and support schemes for renewable energy, can bring overall benefits.

→ The transformation of electricity systems towards renewable energy is taking place not only in Europe but also on the global scale: For the third year running, worldwide investment in new renewable capacity exceeded investment in fossil-fuel power.

7.1 Europe aims to decarbonize its electricity system by 2050

In the last decade, the European Union has established a comprehensive and complex framework of policies and targets which should lead to the decarbonization of the entire European electricity sector by 2050. [57] These ambitions are embedded within the 2008 Energy and Climate package, which sets binding targets for the year 2020.[58] They have been reinforced by the European Council decision of October 2014, which set further targets for 2030, both for greenhouse gas emission reduction (40 percent reduction by 2030), the share of renewables in final energy consumption (binding share of 27 percent in 2030), and the improvement of energy efficiency (indicative target of at least 27 percent by 2030). The European commitment is part of the broader strategic framework of the Energy Union, designed to bring greater energy security (including less dependence on energy imports), sustainability, and competitiveness in Europe.

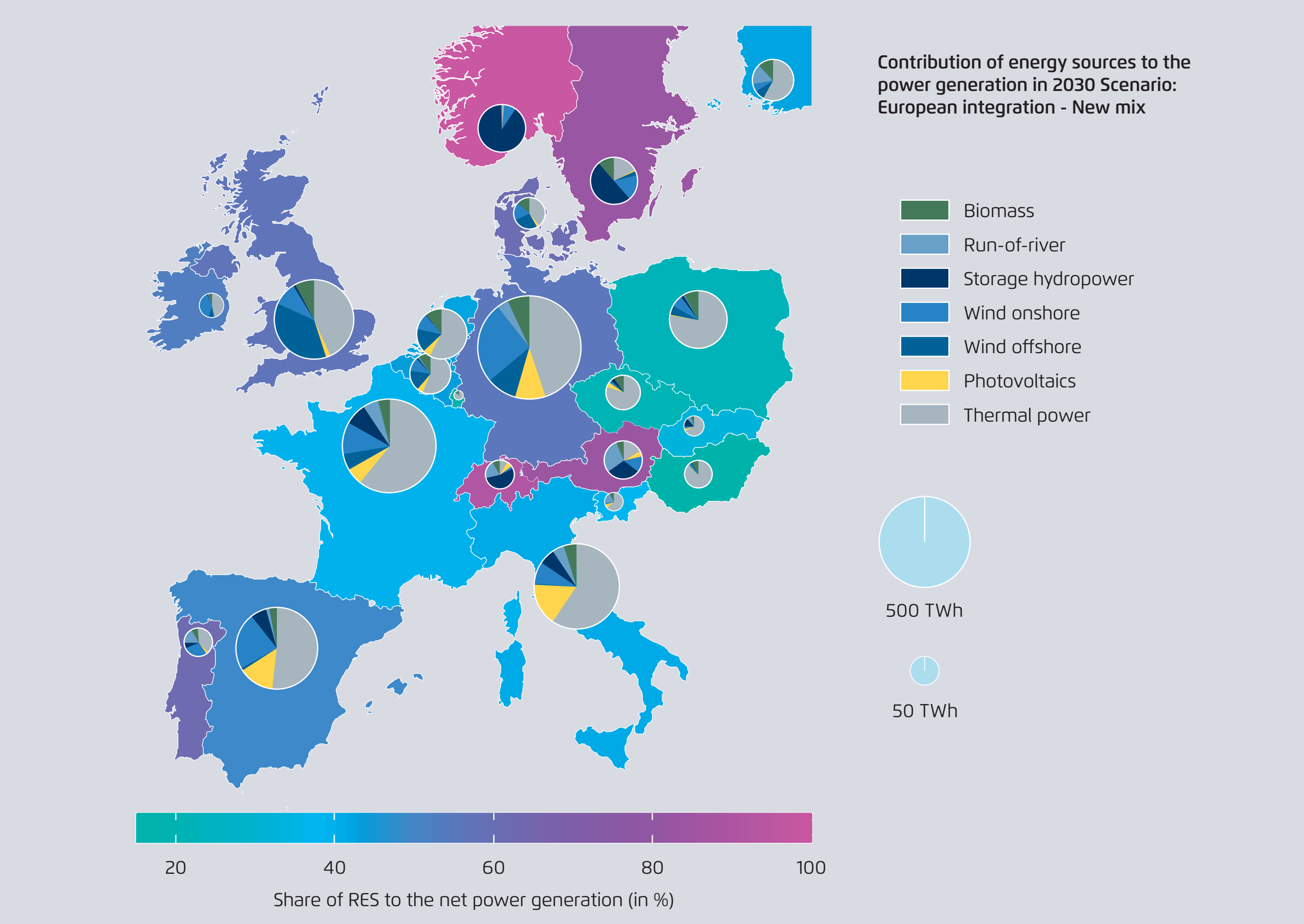
The German *Energiewende* contributes to this wider European effort and its long-term objectives are fully in line with the European energy and climate roadmap.[59] Other European countries – for example Denmark, Italy, Spain, France – are also implementing comparable energy transition policies that make use of renewable energy and energy efficiency, but to different degrees and at different speeds (see Figure 25). Although European countries pursue differ-

57 EU Commission, 2011b

58 The EU Climate and Energy package fixes 2020 targets for greenhouse gas reduction, renewable energy development, and energy efficiency improvement.

59 As part of the European "effort sharing" approach, high income countries which are also large emitters contribute more to reaching the long-term European targets that other countries.

Breakdown of the European power generation mix in 2030 — Figure 25



IWES (2015) — Based on national energy strategy documents and ENTSO-E (2014)

ent strategies to achieve these goals, they face similar challenges, especially concerning the need of enhanced flexibility of their power system.

Impact assessments conducted by the European Commission[60] confirm that high shares of renewable energy sources, energy efficiency measures, and smarter energy infrastructure are "no regret" options for transforming the EU's energy system – irrespective of the electricity mix. They also show that the costs of a low carbon transition do not differ substantially from a business-as-usual scenario, given the need of reinvestments due to aging energy infrastructure, rising fossil fuel prices, and adherence to existing climate and energy targets. In addition, positive employment effects can be generated.[61] In all scenarios analyzed by the European Commission, the share of renewable energy rises substantially, to at least 55 percent of gross final power consumption by 2050.[62] The German challenges – in terms of renewable energy development and flexibility needs – are therefore a snapshot of what is likely to happen in several European countries in the medium to long-term.

60 EU Commission 2013

61 Cambridge Econometrics, 2013

62 EU Commission 2011a; 2014. This includes a partial replacement of fossil fuels in transport and heating through further electrification.

7.2 Other EU countries have equally ambitious short and long-term targets for renewables

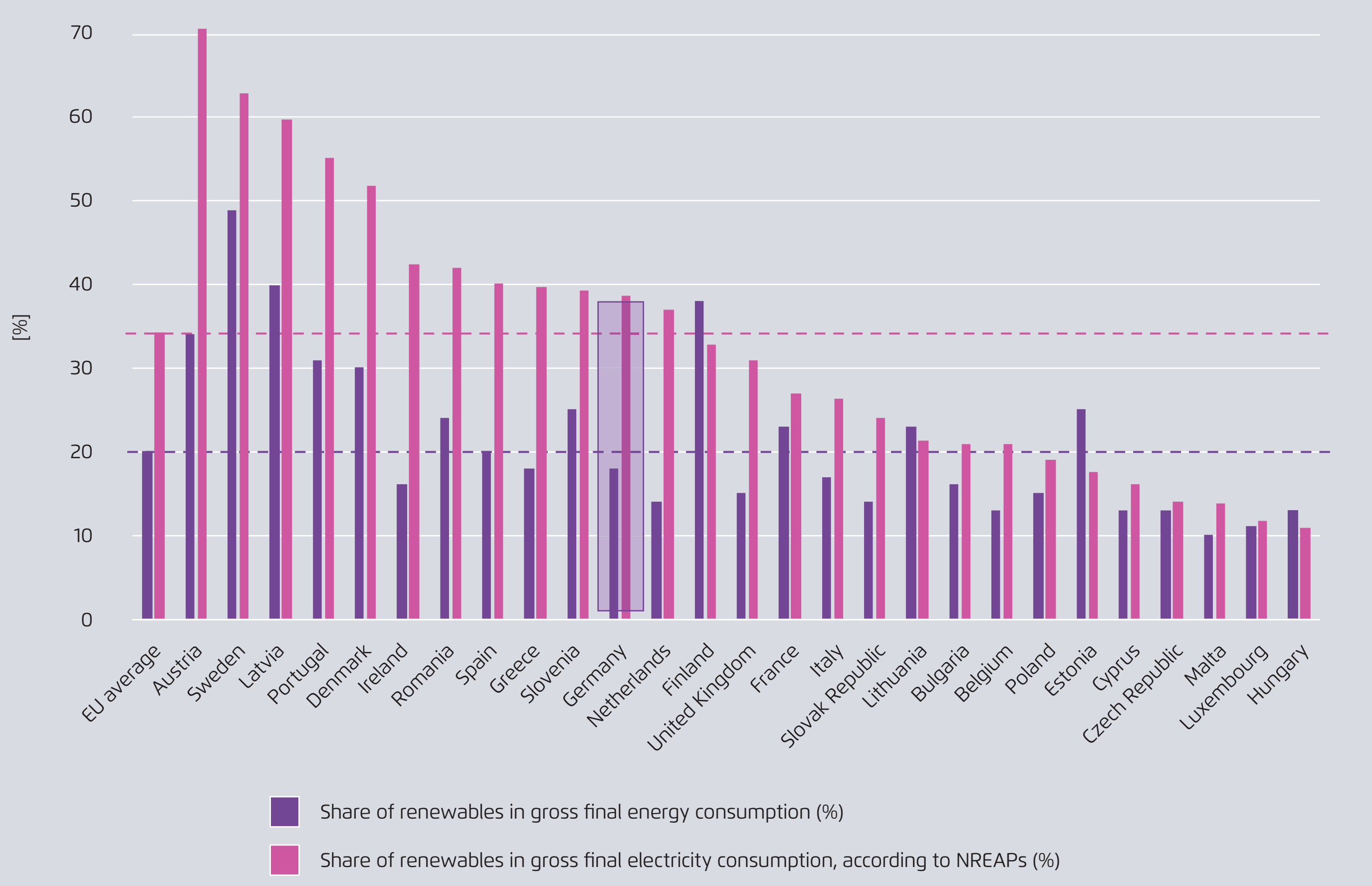
As seen in the previous section, the German *Energiewende* is not a unilateral energy and climate strategy. In fact, the German 2020 renewable energy targets are in the middle range of EU commitments,[63] as seen in Figure 26. Renewables have become mainstream in the European electricity system, representing more than 70 percent of newly installed capacity in 2013. This is a dramatic shift compared to the 1990s, when 80 percent of newly installed capacity were fossil-fuel power plants.[64]

In Scandinavia, Denmark has decided to establish an energy and transport system which relies 100 percent on renewable energy sources by 2050. As an intermediate step, there is the target of an electricity and heat sector based 100 percent on renewables by 2035, including a coal phase-out by 2030. Notably, wind energy accounted for 39 percent of Danish electricity consumption in 2014. Already now, during certain days the wind generation of the country is

63 This is explained among others by the low level of hydropower potential in Germany, way below the one of, say, Austria or Sweden.

64 REN21 2014

2020 targets for renewable energies in EU member states — Figure 26



EU (2009), EREC (2011)

higher than national demand. While the other Nordic countries rely significantly on hydropower, vast potentials of wind energy are also available in these countries.

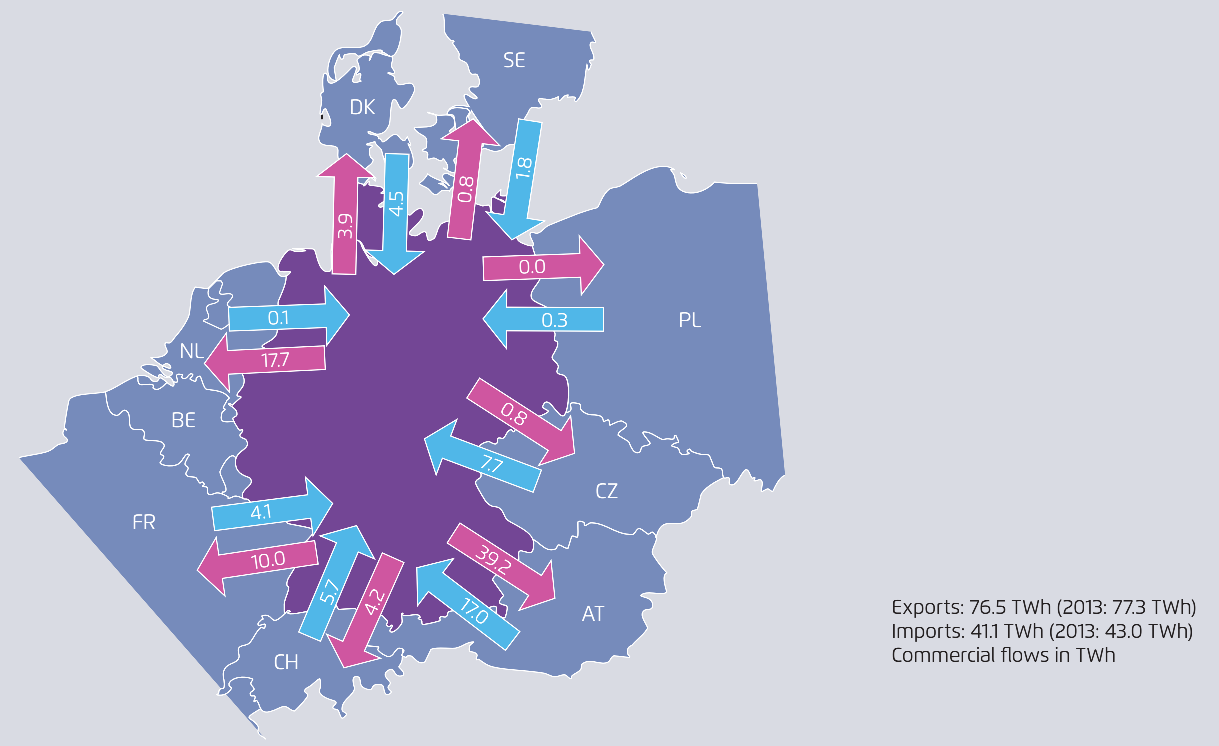
The Iberian Peninsula has already integrated large shares of variable renewable energy sources. In 2013, 21 percent of total power demand in Spain was covered by wind energy – the single largest source of electricity, prior to coal and nuclear. All renewables accounted for more than 40 percent of the Spanish power mix. Portugal produces about 50 percent of its electricity from renewable energy sources and is on track in reaching its 60 percent target by 2020.

Elsewhere in Western Europe, Ireland has set the ambitious target of providing 40 percent of its electricity from renewable energy sources by 2020 – including a 36 percent share from wind energy. Scotland is producing about 40 percent of its electricity from renewable energy sources and wants to reach 100 percent by 2020. France also adopted a new strategy for diversifying its power mix, with an objective of 40 percent renewable energy in electricity consumption by 2030.

7.3 Germany and its neighbours are strongly interconnected – European and regional cooperation can bring overall benefits

Germany has the largest power market in Europe (both in term of annual electricity demand and generation fleet). It is interconnected with ten countries, with a total transfer capacity of more than 20 GW. German and European energy systems are therefore heavily intertwined: whatever happens in Germany affects its neighbours and vice versa. Since the energy transition is happening on the European scale, it is widely accepted that enhancing cooperation among European partners would create positive social welfare for all. Of course, the integration process can bring specific redistributive effects, which may affect or ben-

Commercial electricity exchange between Germany and its neighbours, 2014 | Figure 27



ENTSO-E (2014)

efit different stakeholders (both producers and consumers) in different countries. This redistribution needs to be accounted for by policy-makers, e.g. by means of the cross-border allocation of network investment.

Sharing resources and developing joint regulatory frameworks could help achieve system reliability at lower costs and balance variable power generation across Europe (see also section 2.4). National energy policy instruments are, however, still very fragmented (for example, on renewable energy support schemes and adequacy measures, including capacity mechanisms), which can lead to inefficiencies and distortive effects. Regional cooperation is an important intermediate step towards achieving a pan-European solution. In this context, Germany is working closely with its neighbours, both bilaterally and within regional initiative (like the Pentalateral Energy Forum[65] or within the group of "12 electrical neighbours").[66]

While the German *Energiewende* is not a unique trend, its speed and scope is exceptional in Europe. This pace can lead to spillover effects in neighbouring countries, which need to be solved on the bilateral or regional level. The introduction of a phase-shifter on the German-Polish border is an example of such a cooperation for limiting loop flows (see section 6.3).

65 The Pentalateral Energy Forum (PLEF) comprises seven countries (Austria, Belgium, France, Germany, Luxembourg, the Netherlands and, as an observer, Switzerland).

66 The "12 electrical neighbours" Belgium, the Netherlands, Luxembourg, France, Germany, Austria, Switzerland, Norway, Sweden, Denmark, Poland, and the Czech Republic signed in June 2015 a declaration aimed at strengthening regional cooperation and ensuring the secure supply of electricity.

7.4 Investment in renewable energy technologies is now the global mainstream

Efforts to adopt renewables and increase efficiency are happening not just in Europe, but worldwide. As of 2013, 144 countries had established targets for renewable energy sources and 138 countries implemented support policies – including 95 developing countries.[67] Worldwide investment in renewables have increased five-fold within only one decade,[68] and they have exceeded investment in fossil-fuel power for the third year running.[69] In all major markets – the US, Europe, China – renewables accounted in 2013 for more newly added capacity than all other power sources (nuclear, coal, gas) counted together. Investment into renewable energy technologies have shifted from Europe to Asia; China and Japan being the key markets. In China, investment in renewable power capacity has surpassed new fossil and nuclear capacity for the first time.[70] The BRICS countries (Brazil, Russia, India, China, and South Africa) accounted for approximately 38 percent of newly installed renewable capacity worldwide. Since 2013, solar PV – with its strong price decrease of 70 percent since 2006 – has become the first renewable technology in terms of newly installed capacity, ahead of wind power.

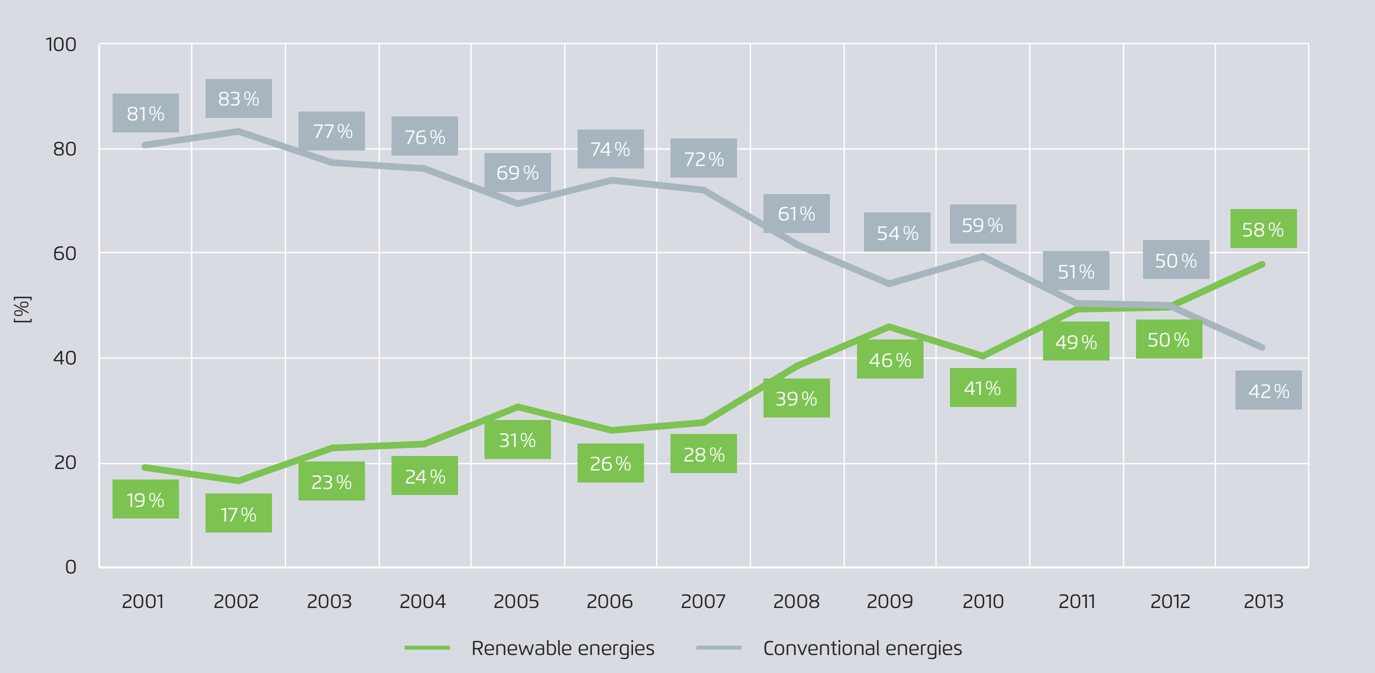
67 REN21 2014

68 Frankfurt School and BNEF 2014

69 IRENA 2014

70 REN21 2014

Renewables as a share of global capacity additions worldwide (2001-2013) Figure 28



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