The German Energiewende
The German Energiewende
Transforming Germany’s energy system
We are very pleased that you are interested in learning about the Energiewende, one of Germany’s most important projects for the future.

We have decided to switch our country’s entire energy supply to renewables and to become increasingly energy efficient. In this way, Germany is playing a major role in climate protection.

The Energiewende is our answer to the question of how we can make the energy supply secure, affordable and sustainable. This unique opportunity for Germany as a location for business and investment will open up new business opportunities, foster innovation, create jobs, boost growth and make us less dependent on oil and gas imports.

Why are we holding this exhibition? The German Government is very often asked about the Energiewende. Indeed, the interest is so great worldwide that the term is already commonly used in many other languages. We are very happy about that.

At the same time, many people are surprised by the dimensions of the project and by how many aspects it involves. We want to present these wide-ranging tasks and challenges in this exhibition.

The exhibition also shows that Germany’s energy system will not be transformed overnight. We will switch to renewable energies by 2050, one step at a time, pursuing clear and ambitious targets and using a precise roadmap.

The Energiewende is firmly embedded in an international framework. We welcome in-depth dialogue with our European neighbours and international partners, and aim at cross-border cooperation and solutions. We need joint solutions in order to reduce global CO₂ emissions, limit global warming and create a secure, sustainable and affordable energy supply.

By transforming its energy system, Germany is taking its responsibility for the planet and its inhabitants seriously. We invite you to join us as we shift to green energy.

We hope you will enjoy the exhibition and that it will give you plenty to talk about.

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**The Energiewende – transforming Germany’s energy system**

**Welcome!**

1971

The German Government adopts its first environmental programme.

1972

One of Germany’s first solar-powered housing estates is built in the small town of Penzberg in southern Germany.
The efficient use of electricity, heat and fuel saves money, increases security of supply and protects the climate. Germany has to import a large proportion of its sources of energy. Imports have risen to about 70 percent of total energy demand, up from around 50 percent in the 1970s. This is why energy efficiency, along with the development of renewable energy, is a pillar of the Energiewende.

People in Germany have become more aware of the importance of energy efficiency over the course of several decades. The first global oil crisis in 1973 was a major incentive. It showed Germans how dependent they were on fossil fuels. The German Government responded by launching an information campaign on energy saving and setting a speed limit on the motorways. Since then, many further laws have been passed and energy-efficiency measures have been successfully implemented. These measures comprise three main elements: targeted funding, information and guidance, and binding targets for reducing energy consumption.

The strategy is working – Germany’s energy demand has fallen since 1990, although its gross domestic product has risen significantly. German industry now consumes over ten percent less energy than it did in the past, but has doubled its output. Technical advances allow households and companies to use energy more efficiently. Modern domestic appliances use up to 75 percent less electricity than comparable appliances of 15 years ago. Changes in daily habits also save energy. For this reason, tens of thousands of energy consultants conduct energy audits all over Germany; show tenants, home owners and companies ways of saving energy; and inform people about the state funding programmes.

All EU member states have agreed to reduce their primary energy consumption by 20 percent by 2020 and by at least 27 percent by 2030. Germany has also set itself the target of consuming 20 percent less primary energy by 2020. It stepped up its energy-saving activities via the National Energy Efficiency Action Plan of December 2014. Using targeted measures for households, industry, trade and transport, the aim is to reduce energy consumption by 1.5 percent each year by 2020.

1973
The Yom Kippur War (October 1973) sparks a global oil crisis. Germany introduces four car-free Sundays in order to save energy.
The success of the Energiewende also depends on reducing the energy needed for heating, cooling and hot water in buildings, as well as on the extent to which renewable energy covers the remaining demand. Heating accounts for over half of Germany’s energy consumption. Almost two-thirds of this is used for heating and hot water by the country’s 40 million households.

This is why the German Government wants to reduce primary energy demand for oil and gas in buildings by 80 percent by 2050. To achieve this target, buildings must become far more energy efficient, while renewable energies must play a greater role in providing heat and cooling. The aim is that renewables will cover 14 percent of heating and cooling demand by 2020. In this way, Germany is implementing European targets. The EU’s current directive on the energy performance of buildings stipulates that all new buildings in Europe must be “nearly zero-energy buildings” from 2021.

Germany was quick to realise how much energy can be saved in buildings. As far back as 1976, the German Government adopted the first Energy Conservation Act and the first Thermal Insulation Ordinance in response to the oil crisis. Their provisions have been constantly updated and adapted to technical advances. Under the Renewable Energies Heat Act, it has been compulsory for all new residential buildings to cover a minimum share of their energy demand through renewable energy since 2009. This can be achieved by using solar thermal energy to support a gas or oil-fired boiler or installing a renewable energy heating system, such as a heat pump or a pellet boiler.

However, 70 percent of all residential buildings in Germany are over 35 years old – in other words, they were built before the first Thermal Insulation Ordinance was adopted. This means that many buildings are not properly insulated and are often heated by old boilers and fossil fuels such as oil or gas. An average German household consumes around 145 kilowatt-hours per square metre of living space per year for heating, the equivalent of some 14.5 litres of crude oil. Highly efficient new buildings require only a tenth of this amount. Primary energy demand in old buildings can be reduced by up to 80 percent by making energy-efficiency improvements and switching to renewable sources. This requires better cladding insulation, new building components, modern heating and cooling systems, and better control technology. In 2015 alone, around 53 billion euros were invested in energy-efficient improvements. The German Government provides grants and low-interest loans as incentives.

The focus is on replacing old heating systems and switching from fossil fuels to renewable energies. In 1975, oil was used to heat over half of the apartments in Germany, but this has now fallen to under a third. Most of the 650,000 new heating systems installed in 2013 were gas (77 percent) or renewable energy (18 percent) systems. Solar thermal energy plants, biomass heating systems and heat pumps that use ambient heat already meet around 12 percent of heating demand in Germany. The German Government has been providing incentives since 2000 to speed up the replacement of old heating systems.

How much energy is consumed in buildings?

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Heating</th>
<th>Hot Water</th>
<th>Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-renovated old buildings</td>
<td>29.5%</td>
<td>5.5%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Renovated old buildings</td>
<td>15 to 20 litres</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New buildings</td>
<td>7 litres</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passive houses</td>
<td>1.5 litres</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

New buildings consume only a tenth Annual heating consumption in litres of oil per square metre of living space for different types of buildings.
Electromobility

Driving with electricity

Cars are Germany’s most important export product. The automotive industry employs over 750,000 people, making it one of the biggest employers in the country. At the same time, the transport sector uses large amounts of energy, around a third of Germany’s final energy consumption. This is why the German Government is boosting its efforts to reduce consumption.

There have already been positive results. For example, the number of kilometres covered by freight and passenger travel per year roughly doubled between 1990 and 2013, but energy consumption only rose by nine percent during the same period.

In order to save even more energy, Germany is relying on efficient vehicle technologies and gradually switching to electric vehicles, with a focus on cars, light delivery vehicles, local public transport vehicles and motorcycles. The country aims to become a key international electromobility market by 2020. To this end, the German Government is promoting market and technology development via a large number of programmes.

Fuel cell vehicles are regarded as an important addition to battery electric vehicles. Hydrogen and fuel cell projects will receive 1.4 billion euros in state funding by 2016. Hydrogen hybrid buses are already being used in public transport in several German regions.

In addition to climate-friendly drive systems, new transport concepts such as car sharing are becoming increasingly popular. Car sharing reduces the amount of traffic on the roads and lowers emissions. 1.2 million users are currently registered among 150 car sharing providers in Germany.

Germany’s targets and progress in the transport sector

- Reducing final energy consumption
  - Achieved by 2011
  - 2020 (compared with 2005)
  - 10%
  - -10%

- Increasing energy efficiency
  - How much energy is needed to drive 100 kilometers?

<table>
<thead>
<tr>
<th>Year</th>
<th>100 km Energy Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>66.1 megajoules</td>
</tr>
<tr>
<td>2013</td>
<td>75.6 megajoules</td>
</tr>
</tbody>
</table>

- Electromobility
  - 2020 electromobility target
  - 1 million vehicles

1979 / 1980
The Iran-Iraq War sparks the second global oil crisis.

1984
Enercon develops the first modern wind turbine for production on a commercial scale in Germany.

1986
A major accident occurs in a reactor at the Chernobyl Nuclear Power Plant, Ukraine. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is set up in Germany.

1986
The first road-legal solar vehicle drives through Germany.
The development of renewable energy, along with energy efficiency, is a pillar of the Energiewende. Wind, the sun, hydropower, biomass and geothermal energy are climate-friendly and local sources of energy that make Germany less dependent on fossil fuels and play a key role in climate protection.

The use of renewable energies is most advanced in the electricity sector. Since 2014, they have been the most important source of energy in Germany’s electricity mix, supplying a third of the power consumed in the country. Ten years earlier, they met only nine percent of demand. Targeted funding is the reason for this success. It began in 1991 with the Electricity Grid Feed Act, which introduced fixed feed-in tariffs and compulsory purchasing with the aim of opening the market to new technologies. This was followed by the Renewable Energy Sources Act in 2000. It has three key components: guaranteed feed-in tariffs for various technologies; priority grid feed-in; and a surcharge system that shares the resulting additional costs among all electricity consumers.

Since the Renewable Energy Sources Act entered into force, annual investments have risen continually in new wind farms and PV plants in particular, but also in wood fired and biogas plants. The high demand has resulted in the creation of a new sector, with over 330,000 jobs in Germany alone. It has also boosted the efficient mass production of renewable energy technologies, thus leading to substantial price drops worldwide. For example, a solar module cost 75 percent less in 2014 than it did five years earlier. A kilowatt-hour of solar electricity received the equivalent of 50 eurocents in funding in Germany in 2000 – it now receives between seven and twelve eurocents. Despite the moderate amount of sunshine in central Europe, solar energy has become an important source of electricity in Germany. PV systems now provide over 20 percent of the electricity from renewable energies.

Wind power is currently the most important source of electricity from renewable energies. Electricity supplied by onshore wind turbines now costs only between 4.7 and 8.4 eurocents per kilowatt hour on average.

The challenge for Germany is to steer the expansion of wind and solar energy so that these sources remain affordable and increase security of supply. This is why the German Government has restructured funding for renewable energies in the electricity sector. This expansion focuses on the inexpensive technologies of wind and solar energy. Annual expansion corridors for the individual technologies make it easier to plan and steer the development of renewable energies. Operators of renewable energy plants have to sell increasing amounts of their electricity on the market, like other plant operators, thus taking on greater responsibility for the energy supply system. As of 2017, the amount of funding provided to all plants with an output of over 750 kilowatts has been calculated via calls for tenders for specific technologies. This affects around 80 percent of the annual expansion. There are also regional differences as regards expansion. Wherever there are shortfalls in the electricity grid, the amounts tendered are lower. These measures will enable the success story of renewable energies in the electricity sector to continue.
No, one goal of the Energiewende is to keep energy affordable in the future. Its two pillars, energy efficiency and the development of renewables, are aimed at reducing dependence on energy imports, increasing security of supply and facilitating profitable investments in Germany.

The price of crude oil rose sharply during the past decade. In 2014, heating oil cost almost twice as much in Germany as it did ten years ago. One effect is that consumers spent over eight percent of their total private consumption expenditure on energy in 2013, compared with less than six percent in the late 1990s. Heating, hot water, cooking and fuel for transport on the basis of imported fossil energy sources account for the largest share of German households’ energy bills. Although oil prices fell at the end of 2014, giving German consumers a welcome respite, no one can count on this in the long run, as the price and availability of fossil fuels depend on international politics.

**Costs**

“Won’t the Energiewende be too expensive for the German public?”

It is true that the Energiewende also has knock-on costs. Billions of euros have to be invested in order to set up a new energy infrastructure and carry out energy-efficiency measures. This means that the development of renewable energy was a factor in the increase in the average electricity prices paid by households in Germany in recent years. On average, consumers paid 21 eurocents per kilowatt-hour in 2007. Currently, they pay around 29 eurocents. With every kilowatt-hour of electricity, consumers are sharing the costs of the development of renewable sources via the Renewable Energy Sources Act surcharge. This surcharge currently stands at just under 6.9 eurocents. However, the amount actually paid by the public in the end depends on the interplay between various price factors. For example, the electricity exchange price has declined sharply due to the increasing amounts of power from renewable energies that is sold on the exchange. Taken together, both price elements – the Renewable Energy Sources Act surcharge and the electricity exchange price – have been decreasing for four years. As a result, the average electricity costs for households have remained stable during the same period.

It is also important to consumers that the German economy is not overburdened. High energy costs have a knock-on effect on product prices and companies’ competitiveness. This is why Germany has exempted some particularly energy-intensive companies from the Renewable Energy Sources Act surcharge. However, companies that have been granted an exemption also have to invest more in energy efficiency.

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**How much does a family spend on energy each month?**

Comparison of monthly expenditure in 2003 and 2013

<table>
<thead>
<tr>
<th>Item</th>
<th>2003</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating and hot water</td>
<td>66</td>
<td>96</td>
</tr>
<tr>
<td>Cooking</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>Lighting and electricity</td>
<td>22</td>
<td>41</td>
</tr>
<tr>
<td>Road fuel</td>
<td>78</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>2003</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating and hot water</td>
<td>176</td>
<td>260</td>
</tr>
<tr>
<td>Cooking</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Lighting and electricity</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Road fuel</td>
<td>78</td>
<td>78</td>
</tr>
</tbody>
</table>

**How much do German households spend on energy in total?**

Expenditure in 2013 in billions of euros

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road fuel</td>
<td>127.4</td>
</tr>
<tr>
<td>Heating and hot water</td>
<td>47</td>
</tr>
<tr>
<td>Cooking</td>
<td>11.4</td>
</tr>
<tr>
<td>Lighting and electricity</td>
<td>20.2</td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
</tr>
</tbody>
</table>
Climate protection and the Energiewende are mutually dependent. Both aim to keep the impact of climate change on people, nature and the economy at a sustainable level. According to calculations by the Intergovernmental Panel on Climate Change (IPCC), global warming must be kept to at most 2°C above pre-industrial age temperatures. This means that only a certain amount of greenhouse gases can continue to be emitted. As the atmosphere already contains 65 percent of this amount, major global and national endeavours to reduce greenhouse gas emissions are needed.

Carbon dioxide, which is mainly caused by the burning of fossil fuels, has the greatest impact on climate change. In Germany and globally, more than a third of all greenhouse gases are emitted by power plants. This is why the shift to climate-neutral resources, such as renewable energies, is a key part of climate protection.

In signing the Kyoto Protocol in 1997, Germany undertook to reduce its greenhouse gas emissions by 31 percent compared with 1990 levels by 2012. Significant progress has been made since then. By 2014, Germany had already achieved a reduction of 27.7 percent. An output of one billion euros by companies in Germany now produces only half the amount of greenhouse gases as it did in 1990.

Germany plans to significantly increase its efforts and to reduce its greenhouse gas emissions by at least 40 percent by 2020. Its aim is to reduce emissions by as much as 80 to 95 percent compared with 1990 levels by 2050. These national reduction targets are embedded in European and international climate protection policy. EU heads of state and government have resolved to reduce their countries’ greenhouse gas emissions by 20 percent by 2020 and by at least 40 percent by 2030. In December 2015, 195 countries signed the Paris Agreement. Using their own climate change targets, these countries want to limit global warming to well under 2°C over the course of this century.

Emissions trading, which caps the total amount of pollutant emissions by all participants in the system, is a key European instrument for combating climate change. All large-scale greenhouse gas emitters must participate in the system, which covers a large part of the CO₂ emissions from industry and the energy sector. Companies must hold the right amount of emission allowances for every tonne of greenhouse gas they emit. If they do not have enough allowances, they can either buy more or invest in climate-protection technologies. This prevents CO₂ emissions where it is cheapest. The aim is to reduce greenhouse gas emissions by 43 percent by 2030 compared with 2005 levels in all of the sectors in the emissions trading system.

The German Government has adopted the Climate Action Programme 2020 and the Climate Action Plan 2050 to enable Germany to meet its national reduction targets. The Climate Action Programme includes various measures to improve energy efficiency and make transport, industry and agriculture more climate friendly. The Climate Action Plan contains long term CO₂ reduction targets for individual sectors such as the energy sector or industry.
The use of nuclear energy to generate electricity has sparked heated debate in Germany for decades. Many Germans find it difficult to assess the technological risk. They are concerned about the potential impact of a reactor accident on people, nature and the environment. These fears were confirmed by the accident in the Ukrainian city of Chernobyl in 1986 that also contaminated parts of Germany. In 2000, the German Government decided to completely phase out the use of nuclear energy to generate electricity and to switch to an energy supply based on renewable sources. The agreement reached with the nuclear plant operators set a time limit for the use of existing plants and banned the construction of new plants.

This plan was amended in 2010. Existing plants were to be used for a longer period of time in order to bridge the gap until nuclear power could be completely replaced by renewable energies. Following the reactor accident in Fukushima, Japan, in March 2011, the German Government overturned this decision.

The German Bundestag (Federal Parliament) voted by a large majority to end the use of nuclear energy to generate electricity as soon as possible. Several power plants had to stop producing power as soon as this law entered into force. Use of the remaining plants will be phased out by the end of 2022. Eight nuclear power plants currently still supply electricity in Germany.

The measures needed to dispose of radioactive waste also highlight the challenges involved in the use of nuclear energy. In order to protect people and the environment, this waste must be securely stored away from the biosphere for very long periods of time. Experts believe that the best way to do this is to store nuclear waste in deep geological formations.

Germany does not want to export its radioactive waste. However, the search for a suitable location for a final disposal site is proving to be difficult, with local people generally opposed to potential or explored sites so far.

This is why Germany is now taking a new approach. It is including all parts of society in a transparent and scientifically based search process. The aim is to find a location for a final disposal site for particularly high-level radioactive waste by 2031. This site should provide the best possible level of safety for a period of one million years.

Germany already has an approved final disposal site for low and medium-level radioactive waste, the Konrad repository, which is scheduled to open in 2022.
The Energiewende has various positive effects. It fosters innovation, lowers energy import costs, reduces pollution and greenhouse gas emissions, and increases added value in Germany. Most of the revenue from the development of renewable energies and energy-efficient building improvements stays in the local area, as the labour-intensive work involved, such as installation and maintenance, is provided by firms from the region.

The development of renewable energy and investments in energy efficiency create new professions and jobs in future growth sectors. The energy-efficiency measures carried out in trade, industry and buildings alone have generated over 400,000 jobs, while investments in renewable energy more than doubled the number of employees in the sector within a period of ten years.

Some of these new positions are replacing jobs in industries where fossil fuels play a major role, particularly in oil, gas and coal extraction, as well as in electricity generation. There have also been general structural changes. For example, the liberalisation of Europe’s energy markets has increased competition. This means that companies need to be more efficient. All of these factors are also bringing about changes in the workplace. The number of employees in the conventional energy sector has declined in recent years as a result.

“Won’t a lot of people lose their jobs because of the Energiewende?”

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“Won’t a lot of people lose their jobs because of the Energiewende?”
The Energiewende is not a luxury, but rather a project that fosters sustainable and profitable development by driving innovation, boosting growth and prosperity, and creating jobs in future growth sectors. The prices of innovative renewables technologies, such as wind and solar, have fallen sharply worldwide in recent years. Investments in research and development at an early stage, as well as funding to help renewable energy gain a foothold in the market in various industrialised countries, particularly in Germany, had a significant impact on the drop in prices.

Thanks to the decline in investment costs and to lower operating costs, renewable energies are now competitive without subsidies in some parts of the world. For example, in North and South America wind farms and large solar parks supply electricity more cheaply than new fossil fuel power plants do. Countries such as China, Brazil, South Africa and India are leaders in the development of renewable energies. However, this expansion is sometimes hindered by the fact that countries subsidise fossil fuels in order to keep consumer prices low. At around 325 billion dollars per year, these subsidies are more than twice as high as funding for renewable energies. If these subsidies were used instead for programmes to improve energy efficiency, three times as much funding would be available.

As local resources, renewables reduce dependence on energy imports and exposure to volatile market prices for fossil fuels. They can also play an important role in meeting the growing energy demand in newly industrialising and developing countries, without increasing greenhouse gas emissions or polluting the local environment. In regions with poorly developed infrastructure, where electricity has to be generated by expensive diesel generators, renewable sources are also the cheaper alternative. Solar plants and wind farms can be installed relatively quickly and need far shorter planning and construction periods than coal-fired or nuclear power plants do. In many cases, renewables give people access to electricity for the first time ever. This is another reason why many countries have set up funding programmes for renewable energy.

Germany supports sustainable, innovative and affordable energy policy worldwide; shares its experiences with the Energiewende with other countries; and works closely with its European neighbours and international partners. Germany also plays an active role in multilateral bodies and organisations. In addition, it has many bilateral energy partnerships with countries such as India, China, South Africa, Nigeria and Algeria.
Modern and efficient infrastructure is needed to transform Germany’s energy system. This means that new electricity and gas power lines must be installed, while the system as a whole needs to become more flexible. When Germany’s nuclear power plants are shut down, renewable energy plants in northern and eastern Germany in particular will meet the shortfall. This energy is needed in southern Germany. Most of the country’s nuclear power plants are located in the south, which is also home to a large population and major industrial firms. New electricity highways with particularly efficient technology will transport the electricity generated by wind farms in northern and eastern Germany directly to the south.

The European internal energy market is the second driving force behind grid expansion in Germany. Better infrastructure is needed in the member states and across borders so that electricity can flow freely all over Europe and becomes cheaper for consumers. European transmission grid operators present a joint grid development plan every two years. All German projects are included in this plan.

Grid operators in Germany conduct their own assessments, looking 10 to 20 years ahead to calculate what power lines the country will need. Their proposals are examined by a state authority, the Federal Network Agency. The public is highly involved in this process. The organisation uses a dialogue-based approach to weigh up what solution best meets the needs of people, the environment and the economy.

The distribution grid also has to be upgraded for the shift to green energy. Originally designed only to transmit electricity to consumers, it functions like a one-way street. However, almost all solar plants and many wind turbines now feed electricity into the distribution grid. What is not needed locally flows in the opposite direction. Furthermore, the electricity generated by renewable energies fluctuates depending on the weather. Solar plants are very productive when the sun is shining, but their output drops rapidly when skies are overcast. Distribution grids must be upgraded. They need to become smart grids so that they remain stable even when electricity generation fluctuates. In a smart grid, there is communication between all those involved, that is, the people and firms that generate, transport, store, distribute or consume electricity. Generation and consumption can thus be coordinated more efficiently and adjusted at short notice.
Security of supply

“Can supply be secure with so much electricity provided by wind and solar energy?”

Germans can count on a continued reliable supply of electricity in the future. The country’s energy supply is one of the best in the world. Over the 8,760 hours in a year, its supply is down for an average of only 13 minutes. Indeed, power cuts have been reduced even further in recent years, despite the increasing amount of electricity generated by wind and solar energy.

Renewable energy already provides over 60 percent of Germany’s electricity supply at certain times, and this share will continue to increase in the coming years. The various renewable sources complement each other. Punching projects have shown that it is possible to combine power generation from the various types of plants, thus enabling them to provide a far more reliable supply of electricity. At times when there is no sunshine or wind, flexible conventional power plants bridge the gap. Gas power plants work particularly well in such cases, but pumped storage plants and bioenergy plants are also able to provide electricity quickly. However, the plan is that storage systems will bridge the gap during such periods in the future.

Electricity consumers also play an important role. They can be given incentives to use electricity when supply is high, such as times of high winds. Large-scale consumers – factories or cold storage warehouses, for example – can significantly reduce the burden on the overall system in this way.

The great challenge is to restructure the electricity market. Germany has started a reform process in this field and put the first measures into practice. Flexibility is important. All actors in the electricity market must react as well as possible to the fluctuations in the electricity generated by wind and solar energy. At the same time, there must be competition between the various balancing options in order to keep the overall costs low.

Transnational grid expansion and the integration of what were previously separate regional electricity markets in Europe are also bringing about greater stability and flexibility in Germany.

Power cuts are very rare in Germany

Average length of power cuts in minutes in 2013

<table>
<thead>
<tr>
<th>Country</th>
<th>Average Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxembourg</td>
<td>16.0</td>
</tr>
<tr>
<td>Denmark</td>
<td>13.3</td>
</tr>
<tr>
<td>Germany (2014)</td>
<td>12.3</td>
</tr>
<tr>
<td>Switzerland</td>
<td>11.6</td>
</tr>
<tr>
<td>Germany (2015)</td>
<td>12.7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>12.6</td>
</tr>
<tr>
<td>France</td>
<td>10.1</td>
</tr>
<tr>
<td>Sweden</td>
<td>7.0</td>
</tr>
<tr>
<td>Poland</td>
<td>5.46</td>
</tr>
<tr>
<td>Malta</td>
<td>0.66</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Power cuts are rarely caused by fluctuations in electricity generation. They mainly result from external factors or human error. This was also the case during the last major blackout in parts of Germany on 4 November 2006. This power cut, which lasted for around two hours, was caused by a planned routine disconnection of a power line. This overloaded other power lines and led to a chain reaction in the European grid. Since this incident, the security mechanisms in Germany and neighbouring European countries have been improved even further.

For example, Germany has set up a fixed reserve of additional power plants in order to prevent shortfalls. These plants are particularly important during the winter months when consumption is especially high and German wind turbines are at their most productive. If the power grids are overloaded because they are transporting large amounts of electricity from northern to southern Germany, these back-up plants cover demand in the south.

How does generation by renewable energies fluctuate?

Power generation by all sources of energy and power consumption in Germany over the course of 2016

2011

A major accident occurs in a nuclear power plant in Fukushima, Japan. Germany decides to phase out the use of nuclear power for electricity generation by 2022, earlier than originally planned. Eight old plants are immediately switched off. The European Commission publishes the Energy Roadmap 2050, a long-term strategy for climate protection and energy supply in Europe.

2012

The Kyoto Protocol is extended until 2020 at the United Nations Climate Conference in Doha.
By 2050, Germany wants to source 80 percent of its electricity from renewables, mainly from wind turbines and PV systems. When clouds suddenly appear or the wind drops without warning, the country needs an electricity system that can adapt quickly and flexibly to the situation. Energy storage systems provide a solution. When there is plenty of wind and sunshine, they can store electricity, which they then release as needed during times of low production, darkness or overcast weather.

There are many types of storage solutions. Short-term storage options, such as batteries, capacitors and flywheel systems, can take in and release electrical energy several times over the course of a day. However, their capacity is limited.

Germany mainly uses pumped storage plants to store electricity for a longer period of time. These plants, some of which are in Luxembourg and Austria, currently have a capacity of around nine gigawatts connected to the German grid. Although this gives Germany the largest pumped storage capacity in the EU, there is only limited scope for expansion. Germany is therefore working closely with countries that have large storage capacities. Austria, Switzerland and Norway are the most important countries.

Compressed air storage is another alternative for storing energy for a longer time. It uses surplus energy to compress air into underground space such as caverns in salt domes. When needed, the compressed air powers a generator, thus producing electricity.

Power to gas is a new type of long-term storage. It uses electrolysis to convert electricity from renewable energies into hydrogen or synthetic natural gas. The advantage is that hydrogen and natural gas can be stored, used immediately or fed into the natural gas network. These gases are easy to transport and can be used flexibly. Power plants can convert them back into electricity and heat as needed, while consumers can use them to cook, for heating or to power their car.

However, most energy storage systems are still very expensive, so the German Government is promoting research and development on this topic. In 2011, it launched the storage funding initiative. Since 2013, it has also been funding small, decentralised storage systems linked to PV systems. Rapidly balancing out minor imbalances in the power grid is a new way of using batteries. The market launch of these battery systems will foster research and innovation and reduce costs.

However, experts say that the demand for new storage systems will initially be limited. Low system costs for all storage technologies will only be possible in the long term, when renewables make up a very large part of the electricity mix. In the short to medium term, other options are less expensive. These include grid expansion or managing generation and consumption for efficient energy use.
The Energiewende can only be successful if it has public support – and this largely depends on energy remaining affordable for consumers. But the public will also benefit directly from the restructuring of the energy supply. Many people seek advice on how they can save the most energy at home.

People who replace an old heating system or make energy efficiency improvements benefit from low-interest loans and state funding. Those looking to rent a new apartment automatically receive information about how much energy it consumes and what this costs. And if they want to buy a new washing machine, computer or lamp, a label shows them the product’s energy efficiency rating.

And how will the public benefit from the Energiewende?

The public is also involved in the traditional energy sector. Electricity and heat are not only generated by small and large energy suppliers, but also by members of the public who have their own solar panels, invest in wind farms or operate biogas plants. Many of the over 1.5 million PV systems in Germany are installed on the roofs of detached houses. Members of the public have invested in around half of the wind turbines in Germany, while almost half of all bioenergy investments are made by farmers.

Those who do not have the option of installing or financing their own renewable energy technology can join forces with other people. Just under 900 energy cooperatives with a total of over 160,000 members are investing in Energiewende projects. Investments start at just 100 euros.

Moreover, when it comes to concrete aspects of the Energiewende, members of the public can have their say. For example, they can express their concerns and wishes when a new wind farm is planned in their region. The public plays an active role in the discussion on the planned transmission lines that will transport large amounts of electricity throughout Germany. Members of the public are welcome to join this discussion from the start, when the grid expansion requirements are calculated, and to share their views. They also participate in all other planning stages, including the decision on the exact route of the transmission line. In addition, they receive detailed information on the transmission line projects from the Federal Network Agency and the grid operators prior to the start of the formal procedures.

These activities are supplemented by the Power Grid Public Dialogue initiative, which has local offices and holds events for the public in the regions where expansion projects are planned. It also serves as a point of contact for all grid expansion matters. By fostering discussion at an early stage, it is easier to carry out energy projects and to increase their acceptance among the public.

How can people benefit at home from the Energiewende?

Energy efficiency options and use of renewable energy in a detached house built in the 1970s

-80% energy LEED lighting instead of high bulbs
-13% energy roof insulation
-10% energy triple glazing
-22% energy internal wall insulation
-5% energy basement ceiling insulation
-15% energy modernisation of the heating system
100% of heat for own use heat pump for heating and hot water
-70-80% of electricity for own use PV system with battery storage
-10% energy

With a share of 27.4 percent in the electricity mix, renewable energy becomes the most important source of energy in Germany for the first time.

The European Commission presents a framework strategy for an energy union. This focuses on five areas: supply security, a fully integrated internal energy market, energy efficiency, decarbonising the economy and energy research. The UN Climate Change Conference meets in Paris, where 195 countries agree to limit global warming to a maximum of 2°C.

The Paris Climate Agreement enters into force on 4 November after being approved by the first 55 countries’ national parliaments. Germany restructures funding for renewable energies. As of 2017, calls for tenders have been issued for all types of technologies.
Fuel cells are miniature power plants which use the chemical energy of the materials in the cell to produce electricity. If they are connected to a power circuit, they can provide electricity as long as the fuel lasts. Batteries, on the other hand, store energy in chemical form and release it when needed. The energy source for a battery is the chemical reaction between the materials inside the cell.

The German Energiewende

Fuel cells

If they need a car, they can hire one. Carsharing differs from traditional car hire services in that it is possible to book a vehicle at very short notice and for as little as 30 minutes. Many communities have created special parking spaces exclusively for carsharing services. They may also allow carsharing vehicles to use bus lanes.

Rational use of energy resources

Feed in tariff

The Renewable Energy Sources Act guarantees operators of wind and solar power stations a minimum tariff for the electricity they generate for a specified period. The relevant date for determining the tariff is the year in which the power station begins to operate. The tariff falls from year to year, as technological progress and the broader application of the technologies continuously help reduce investment costs. In Germany the auction procedure (see Auction) will replace the current fixed feed in tariffs over the coming years.

Energy efficiency

Energy efficiency describes the level of performance compared to the energy input, or how much energy someone has to invest to achieve a certain level of performance. The higher the energy efficiency, the less energy is needed to achieve the result. For example, a building with high energy efficiency will require less energy for heating or cooling than a similar sized building with low energy efficiency. Industrial production and transport are other areas in which energy efficiency is particularly important. Energy efficiency measures become interesting for enterprises when they save the firm more money than it cost to implement them. Private consumers can also help save energy and energy costs and thereby offset the higher market forces, for example in the form of a purchasing cooperative. In Germany, this particular form of enterprise is regulated in a separate law.

Energy cooperatives

The cooperative model has been given a new lease of life as a result of the Energiewende. Most of those involved are private individuals who finance the construction of solar or wind power plants, for example. They are not only motivated by the desire to save the firm more money than it cost to improve energy efficiency, the less energy is needed to generate electricity or to provide heat. Dark phases can be defined as periods when the power supply is not sufficient due to a lack of sunshine or wind. These periods are known as dark phases. The worst case scenario is an overnight night with a new moon and no wind. During these phases other energy sources, or previously stored power must be used to meet the demand for electricity.

Renewable Energy Sources Act surcharge on electricity

In Germany, this particular form of enterprise is regulated in a separate law. Cooperatives in the area of energy supply have existed for some time. At the start of electrification in Germany, rural areas in particular could not keep pace with the big cities and therefore formed energy cooperatives to generate their own electricity supply. Some of these cooperatives still exist today. The cooperative model has been given a new lease of life as a result of the Energiewende. Energy efficiency

Energy efficiency measures undertaken on buildings involve removing weak spots where more energy is lost than is necessary in view of the current state of technology. Potential improvement measures include insulating walls and roofs and installing, thermally insulated windows. Another option is to modernise the heating system.

Energy cooperation

Energy cooperatives as we know them in Germany are a now well established concept dating from the founding of the Raiffeisen movement. Friedrich Wilhelm Raiffeisen and Hermann Schulze Deltitzsche each had the simultaneous idea of establishing the first German cooperatives. The idea is that several individuals with similar business interests join together in a business cooperative. In Germany, this particular form of enterprise is regulated in a separate law. Cooperatives in the area of energy supply have existed for some time. At the start of electrification in Germany, rural areas in particular could not keep pace with the big cities and therefore formed energy cooperatives to generate their own electricity supply. Some of these cooperatives still exist today. The cooperative model has been given a new lease of life as a result of the Energiewende. The cooperative model has been given a new lease of life as a result of the Energiewende. Most of those involved are private individuals who finance the construction of solar or wind power plants, for example. Energy productivity

Energy productivity indicates the economic value (proportion of Gross Domestic Product) gained per energy unit used. In the case of an economy, primary energy is used as the basis for the calculation. Power to gas

The regional grid helps to make the development of renewable energy sources more predictable, improve integration into the power grid and keep additional costs to consumers manageable. The Renewable Energy Sources Act defines a separate target corridor for each type of renewable energy technology. If newly installed capacity exceeds the upper value in any one year, lower subsidies will apply in the following year. If less expansion takes place than the corridor envisages, the support tariffs are reduced by a lesser amount or not at all.

Auction

From 2017, auctions will be held to determine the support tariffs for large wind park projects or large photovoltaic facilities. Several projects will be put up for auction at the same time, and potential interested parties will then submit a bid for the respective project that defines the level of the initial tariff. A fair market price for electricity from renewable energy sources can thus be determined instead of a statutory tariff. In 2015, three auctions for major photovoltaic projects were held to test and optimise the process.

Battery

Batteries are electric storage devices. If they are connected to a power circuit, they can store electrical energy. Rechargeable batteries are used in devices such as mobile phones and electric vehicles. Rechargeable batteries are also used in connection with renewable energy sources, for example in photovoltaic facilities. Here they are referred to as battery storage systems. Batteries can only store a limited amount of electrical charge, depending on their capacity (measured in ampere hours – Ah).

Fuel cell

Fuel cells are miniature power plants which convert chemical energy into electrical energy, thereby generating electricity. They are used to power electric, hybrid or in regions not connected to the power grid, for example. Often the only raw materials required are hydrogen and oxygen. This form of power generation does not produce any greenhouse gases, just steam. The hydrogen needed for power generation can be produced with electricity from renewable energy sources (see power to gas). However, fuel cells that use different source materials, such as methanol, also exist.

CO2-equivalent

The CO2-equivalent is a comparative value for the impact of a chemical compound on the greenhouse effect, usually over a period of 100 years, whereby carbon dioxide (CO2) has the value of one. If a substance has a CO2-equivalent of 20, the emission of one kilogram of this material is 20 times more harmful than the emission of one kilogram of CO2. NB: The CO2-equivalent tells us nothing about the actual contribution of a compound to climate change.

Compressed air storage

Compressed air storage uses electrical energy to store air under pressure in an underground cavern system. The compressed air can be released as necessary via a turbine, thereby generating power. This technology has been little used to date. It is, however, regarded as a viable way of storing surplus power generated by renewable energy sources. Hollowed out, bright salt caverns are considered secure formations for storage. The installation poses several technological challenges which need to be overcome. If the system should subsequently prove to be unstable, there is no way of stabilising it. Moreover, it is important that the tension in the surrounding rock is not affected. Dark phases

Phases in which wind power and photovoltaic facilities are unable to generate electricity are known as dark phases. The worst case scenario is an overnight night with a new moon and no wind. During these phases other energy sources, or previously stored power must be used to meet the demand for electricity.

Energy efficiency

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Capacitors

Capacitors can store electricity in the short term. A capacitor consists of two components, such as metal balls or plates. One of the components has a positive, the other a negative charge. If the two are connected, electricity flows until the charges balance out.

Kyoto Protocol

In Kyoto, Japan, in 1997, the Member States of the United Nations Framework Convention on Climate Change (UNFCCC) agreed on goals for reducing greenhouse gas emissions by 2012. The point of reference is the level in 1990.

Kyoto Protocol

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into a gas which can then be stored in gas stores and distributed via the gas grid. The first step involves using the electricity to split water into oxygen and hydrogen by means of electrolysis. The hydrogen produced can either be fed into the gas grid directly in controlled amounts or be converted into gas in a second step (methanisation). Methanisation involves adding carbon dioxide to hydrogen to produce methane. Methane is the main component of natural gas and can be fed into the gas grid without difficulty.

**Primary energy/primary energy consumption**

Primary energy is the sum of energy available from energy sources such as coal, oil, sun or wind. Conversion to final energy (see Final energy) incurs losses, the size of which depends on the original source of energy, for example, during power generation and transport. Primary energy consumption is therefore always higher than final energy consumption.

**Pumped storage**
Pumped storage is used to store energy. The storage works by pumping water into a reservoir using electricity. The water is then released back into the grid to drive an electric turbine which generates electricity.

**Flywheel accumulator**
Flywheel accumulators can store surplus electricity from the grid in the short term. The electrical energy is converted mechanically. An electric motor drives a flywheel. The electrical energy is converted into rotational energy. To retrieve it, the wheel drives an electric motor when it is needed. Like batteries, flywheels are suitable for modular construction. The basic technical principle has been known since the Middle Ages, even though it was not combined with electrical energy in those days. Flywheels are chiefly designed for short term peak production of electrical energy, which can then be quickly fed back into the grid.

**Smart grid**
A smart grid is a network in which all components communicate with one another, from the producer, through pipelines and storages, to the consumers. This takes place via automated digital data transmission. The rapid communication helps avoid bottlenecks and overproduction of electricity and adapt energy supply to the needs of all stakeholders. The irregular feed in of electricity from renewable energy sources in particular requires this kind of solution. At the same time smart grids make it possible to control demand by means of flexible electricity pricing models.

**Power grid – maximum voltage grid – distribution grid**
The power grid is the means of transporting electricity. In Germany and in other countries the power grid consists of four levels which work with different voltages: maximum voltage (220 or 380 kV), high voltage (60 kV to 220 kV), medium voltage (6 to 60 kV) and low voltage (330 to 400 V). The low voltage grid serves recipients such as private households. Maximum voltage networks work with a voltage around 1000 times greater and transport large amounts of electricity over long distances. High voltage networks distribute the power further to the medium or low voltage networks. Medium voltage networks carry the power further but also serve major consumers such as industry and hospitals. Private homes receive their power from the low-voltage grid.

**Greenhouse gases**
Greenhouse gases change the atmosphere in such a way that sunlight reflected from the earth’s surface does not radiate back into space but is reflected by the atmosphere back to earth, thereby contributing significantly to global warming. This effect is similar to the principle of a greenhouse, and the earth heats up. The best-known greenhouse gas is carbon dioxide, which is produced mainly by burning fossil fuels such as oil, gas and coal. Other greenhouse gases include methane and chlorofluorocarbons (CFCs).

**Heat pump**
Heat pumps absorb thermal energy from the surrounding area, for instance from deeper underground layers. This heat is used to generate warm water or heat buildings. The electricity they need can be generated from renewable energy sources. Fridges work on the same principle – they cool on the inside but give off heat externally.

**List of sources**
