Federal Foreign Office

Energie wende
Switch to the Future

The German Energiewende

The German Energiewende

Transforming Germany's energy system

The Energiewende – transforming Germany’s energy system

Welcome!

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 CO_2 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.

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.

Energy efficiency

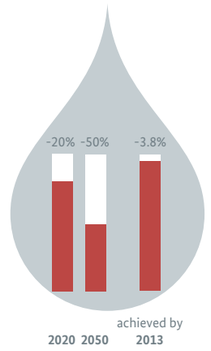
Using energy more efficiently

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 over 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.

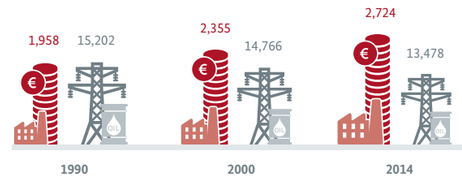
Germany's reduction targets

Reduction targets for primary energy consumption compared with 2008



The economy is growing, while energy consumption is falling

Development of gross domestic product and primary energy consumption



"The very best kilowatt hour is the one we don't use."

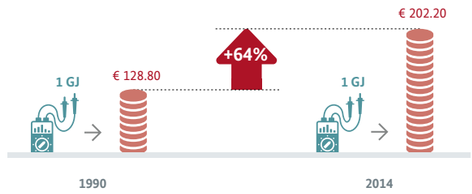
Angela Merkel, Federal Chancellor

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.

Large increase in energy productivity

Amount of output generated by one gigajoule (GJ):



1973

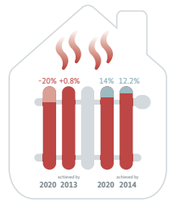
The Yom Kippur War (October 1973) sparks a global oil crisis. Germany introduces four car-free Sundays in order to save energy.

Heat

Pleasantly warm, renewable and efficient

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.

Reducing heating energy demand
Reduction targets for total heating energy demand

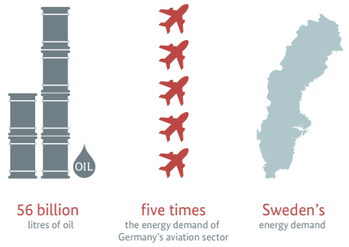


Heating demand
(compared with 2008)

Share of renewable energies
in heating demand

2,026 petajoules
were consumed by Germany's 40 million households for heating and hot water in 2013.

This is equivalent to



56 billion
litres of oil

five times
the energy demand of Germany's aviation sector

Sweden's
energy demand

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.

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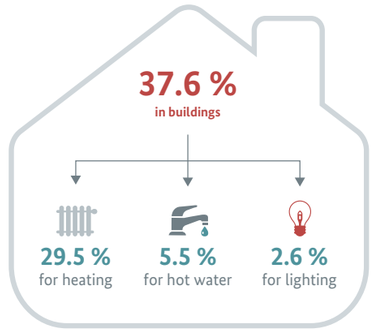
Germany was quick to realise how much energy can be saved in buildings. As far back as 1976, the German Government adopted the first Energy Conservation Act and the first Thermal Insulation Ordinance in response to the oil crisis. Their provisions have been constantly updated and adapted to technical 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.

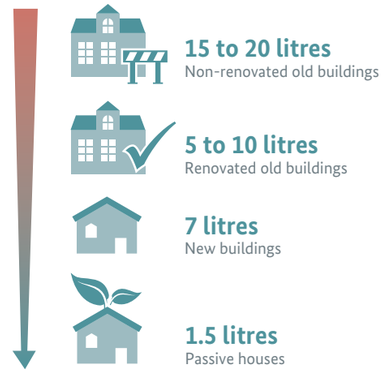
components, modern heating and cooling systems, and better control technology. In 2013 alone, around 55 billion euros were invested in energy-efficiency improvements. The German Government provides grants and low-interest loans as incentives.

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?
Share of total final energy consumption in Germany



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



15 to 20 litres
Non-renovated old buildings

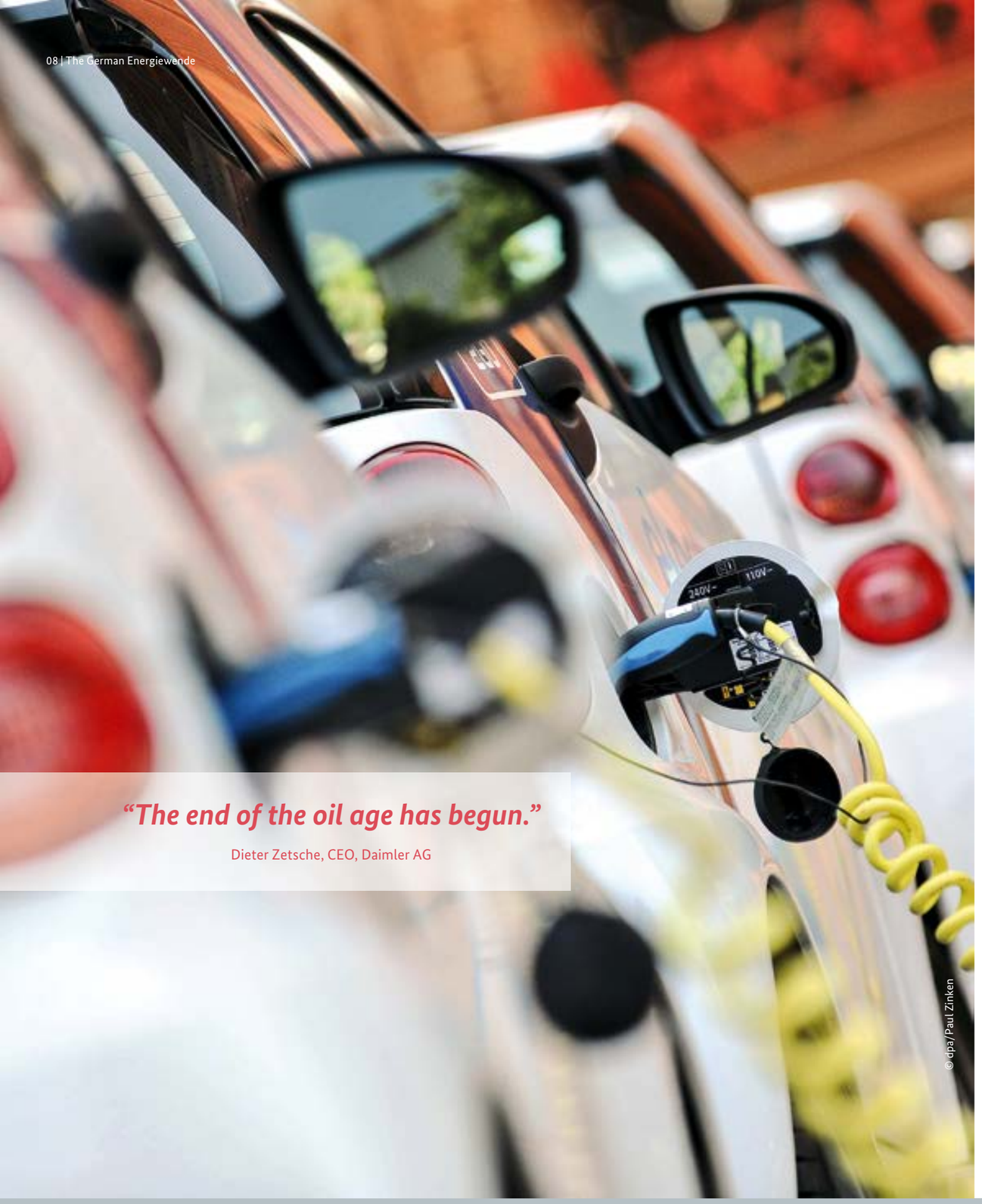
5 to 10 litres
Renovated old buildings

7 litres
New buildings

1.5 litres
Passive houses

1975
The Energy Security of Supply Act introduces higher energy reserve requirements and sets a speed limit on German roads. The German Government launches an information campaign on energy saving.

1977
The German Government sets the first energy-efficiency standards for buildings in its Thermal Insulation Ordinance.



“The end of the oil age has begun.”

Dieter Zetsche, CEO, Daimler AG

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Electromobility

Driving with electricity

Cars are Germany’s most important export product. The automotive industry employs over 700,000 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.

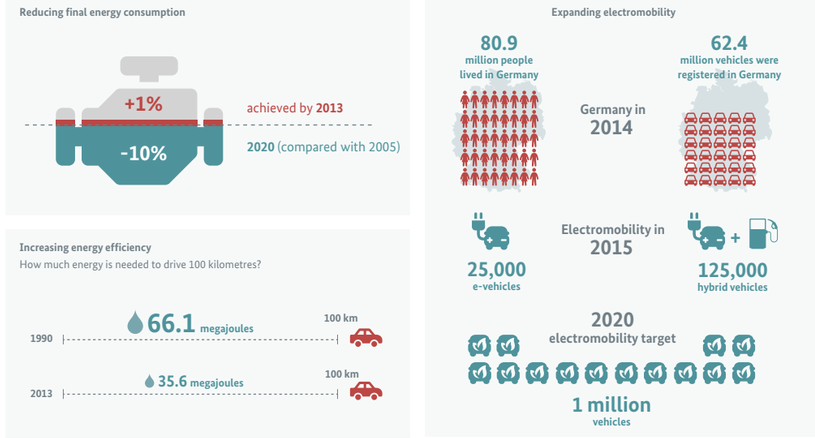
There have already been positive results. For example, the number of kilometres covered by freight and passenger travel per year roughly doubled between 1990 and 2013, but energy consumption only rose by nine percent during the same period.

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. Over one million users are currently registered among 150 car sharing providers in Germany.

Germany’s targets and progress in the transport sector



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.

Renewables

Electricity from the wind and sun

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 renewables is most advanced in the electricity sector. Since 2014, they have been the most important source of energy in Germany's electricity mix, supplying almost 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.

Renewables enhance energy generation and climate protection

Benchmarks for 2014

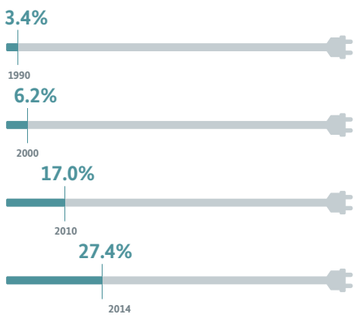
~ 1.5 million
electricity-generating facilities funded under the Renewable Energy Sources Act

161.4 terrawatt-hours
of electricity generated
equivalent to the entire amount of electricity generated in Poland in 2012

151 million tonnes
of CO_2-equivalent saved
equivalent to the combined greenhouse gas emissions of New Zealand and Portugal in 2012

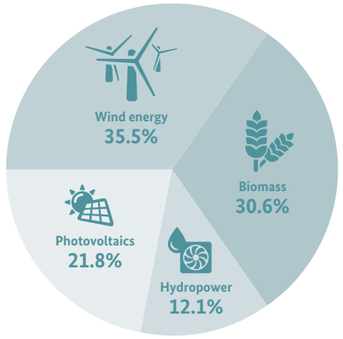
Renewables are the most important source of energy in the electricity mix

Share of renewables in gross electricity consumption



Wind supplies the most electricity from renewable sources

Share of total renewables generation in 2014



Since the Renewable Energy Sources Act entered into force, annual investments in new wind farms and PV plants in particular, but also in wood-fired and biogas plants, have risen continually. The high demand resulted in the creation of a new sector, with over 370,000 jobs in Germany alone. It 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. By mid-2015, this support had fallen to less than nine 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 renewable source of electricity. Electricity supplied by onshore wind turbines now costs only between 5.5 and 8.9 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 restructured renewable energy funding in the electricity sector in the summer of 2014. The amendment put an end to overfunding, thus resolving the issue of rising costs. Annual expansion corridors for the individual technologies make it easier to plan and steer the development of renewable sources. This expansion focuses on the inexpensive technologies of wind and solar energy. Operators of renewable energy plants have to sell an increasing proportion 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 will be calculated via calls for tenders for specific technologies.

1987
Westküste, Germany's first wind farm, is built. It has 30 turbines.

1990
The German Government launches a thousand-roof programme to fund photovoltaic (PV) plants. East and West Germany are reunited. The Intergovernmental Panel on Climate Change (IPCC) publishes its first assessment report on the global climate.

1991
The Electricity Grid Feed Act requires all German energy suppliers to purchase electricity generated from renewable sources and to feed it into the grid.

Costs

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

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.

How much does a family spend on energy each month?

Comparison of monthly expenditure in 2003 and 2013

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.

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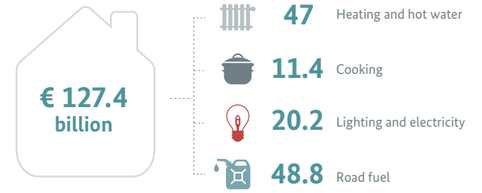
How much do German households spend on energy in total?

Expenditure in 2013 in billions of euros



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, which peaked at 6.24 eurocents per kilowatt-hour of electricity in 2014.

However, the rise in costs was halted in 2015, and the surcharge decreased for the first time. The rapidly falling prices for renewable technologies are now having a tangible impact, as is the targeted steering of expansion under the amended Renewable Energy Sources Act. This meant that households paid less for electricity in 2015 than they did during the two previous years.

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.

1992
The United Nations Conference on Environment and Development in Rio de Janeiro adopts the principle of sustainable development.

1994
Europe’s first mass-produced electric car is launched on the market.

1995
The first United Nations Climate Change Conference is held in Berlin, marking the start of talks to reduce greenhouse gas emissions worldwide.

Climate protection

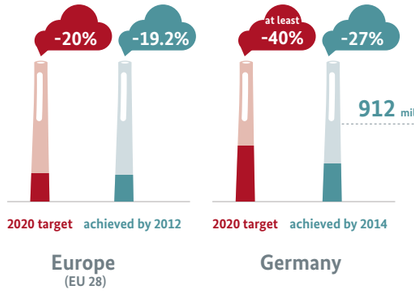
Reducing greenhouse gas emissions

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, 38 percent of all greenhouse gases are emitted by power plants. Worldwide, this figure is 35 percent. This is why the shift to climate-neutral resources, such as renewables, is a key part of climate protection.

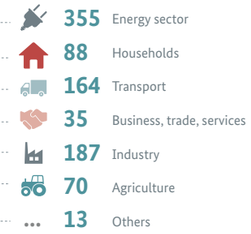
Climate targets and progress

Planned and achieved greenhouse gas reductions



Who emits greenhouse gases?

All figures in millions of tonnes of CO_2 equivalents in 2014



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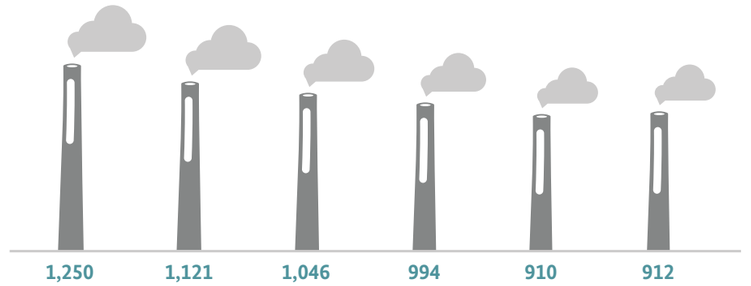
By how much has Germany reduced its greenhouse gas emissions?

All figures in millions of tonnes of CO_2 equivalents



In signing the Kyoto Protocol in 1997, Germany undertook to reduce its greenhouse gas emissions by 21 percent compared with 1990 levels by 2012. Significant progress has been made since then. By 2012, Germany had already achieved a reduction of 24.7 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. They have included these targets in the talks on a new global climate agreement.

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 CO_2 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 CO_2 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 to enable Germany to meet its national reduction targets. This programme includes various measures to improve energy efficiency, boost energy-efficient building improvements, and make transport, industry and agriculture more climate-friendly. The German Government will draw up a National Climate Protection Programme 2050 for reduction targets from 2020.

1996

Europe decides to liberalise its electricity and gas markets, which had previously been restricted to national territories. The European Commission publishes the first joint European strategy on the development of renewable energies.

1997

The Kyoto Protocol on the global reduction of greenhouse gases is adopted. Since then, 191 countries have ratified the agreement.

Nuclear power

Phasing out nuclear energy

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.

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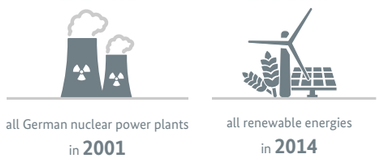
Where are Germany's nuclear power plants located?

Decommissioned and operational plants

Largest amount generated in a year

Largest amount of electricity generated in a year in terawatt-hours

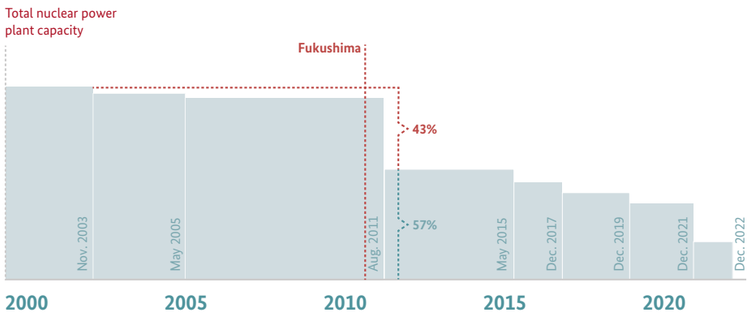


171 TWh
all German nuclear power plants
in **2001**

161 TWh
all renewable energies
in **2014**

When will Germany's nuclear power plants be switched off?

Planned reduction in the capacity of German nuclear power plants by the end of 2022



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.

1998
Germany adopts a law liberalising its electricity and gas markets.

2000
The European Commission publishes the first joint strategy for enewable energy, energy efficiency and climate protection in Europe. The Renewable Energy Sources Act enters into force in Germany. It will become the driving force behind the development of renewable energies in Germany.

2000
The German Government decides to phase out nuclear power. Nuclear power plants will be allowed to operate for a maximum of 32 years.

Employment and the economy

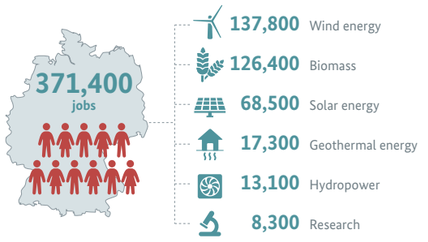
“Won’t a lot of people lose their jobs because of the Energiewende?”

High investments in all types of renewable energy plants

Annual investments in power-generating plants in Germany in billions of euros

Jobs provided by renewable energies

Jobs in Germany in 2013



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.

2002
The first Energy Saving Ordinance comes into force. It sets standards for the overall efficiency of new and existing buildings. The first Act on Energy Efficiency Labelling creates transparency on the amount of energy consumed by products such as vehicles and domestic appliances.

2003
Europe adopts a binding emissions trading system for greenhouse gases.

2004
The renewable energy sector employs 160,000 people in Germany.

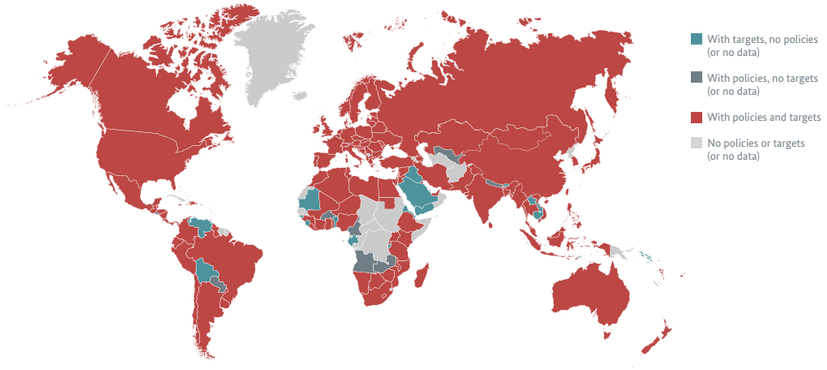
The global energy transition

“The Energiewende may work in Germany – but what about countries that don’t have such a strong economy?”

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.

More than 160 countries want to develop renewable energy

Countries with renewables policies and targets



Thanks to the decline in investment costs and to lower operating costs, renewable sources 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 energy. However, this expansion is sometimes hindered by the fact that countries subsidise fossil fuels in order to keep consumer prices low. At around 550 million dollars per year, these subsidies are four times higher than funding for renewables. If these subsidies were used instead for programmes to improve energy efficiency, five times as much funding would be available.

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Where are the most renewable energy plants worldwide?

Power-generating plant capacity as of December 2014

Biomass
1 | United States
2 | Germany
3 | China

Offshore wind
1 | UK
2 | Denmark
3 | Germany

Geothermal energy
1 | United States
2 | Philippines
3 | Indonesia

Onshore wind
1 | China
2 | United States
3 | Germany

Hydropower
1 | China
2 | Brazil
3 | United States

Photovoltaics
1 | Germany
2 | China
3 | Japan

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, Morocco, Nigeria and Algeria.

2005
Emissions trading starts in Europe. All EU member states participate in the scheme.

2007
The EU adopts a 2020 climate and energy package with binding targets for the development of renewable energies, climate protection and energy efficiency.Louis Palmer begins a journey around the world in the Solartaxi, a car powered entirely by solar energy. His trip takes 18 months.

2008
Germany introduces an energy passport for buildings, which provides information about buildings’ energy consumption and efficiency. The Renewable Energies Heat Act stipulates that a certain amount of heat generation must be provided by renewable sources in new buildings.

2009
The International Renewable Energy Agency (IRENA) is founded by 75 countries.

The power grid

A smart grid

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 German power grid is 1.8 million kilometres long

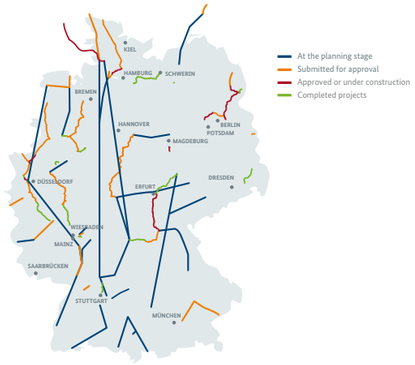
This equates to

45

times the circumference of the earth at the equator.

Where is the power grid being expanded?

Planned new power lines in Germany's maximum-voltage grid



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.

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"The Energiewende is the German equivalent of the project to get the first man on the moon."

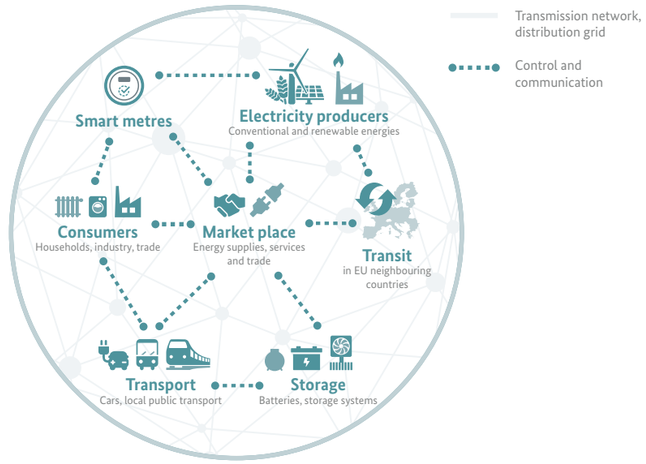
Frank-Walter Steinmeier, Federal Minister for Foreign Affairs

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.

How a smart grid works

Simplified diagram of actors, infrastructure and channels of communication



2009
The Power Grid Expansion Act speeds up the approval process for new high-voltage power lines.

2010
The German Government adopts an Energy Concept, a long-term strategy for Germany's energy supply until 2050. The EU adopts a directive on the energy performance of buildings. From 2021, all new buildings are to be "nearly zero-energy buildings".

2010
The German Energy Agency (dena) publishes a study on the grid expansion needed for renewable energy to provide around 40 percent of Germany's electricity.

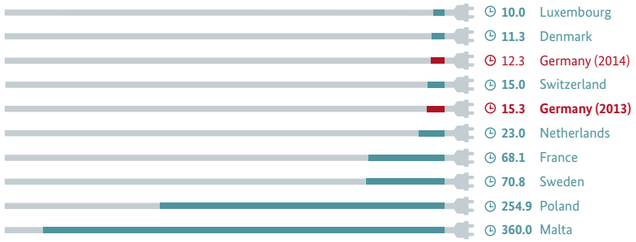
Security of supply

“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 12 minutes. Indeed, power cuts have been reduced even further in recent years, despite the increasing amount of electricity generated by wind and solar energy.

Power cuts are very rare in Germany

Average length of power cuts in minutes in 2013



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.

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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. Pilot 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.

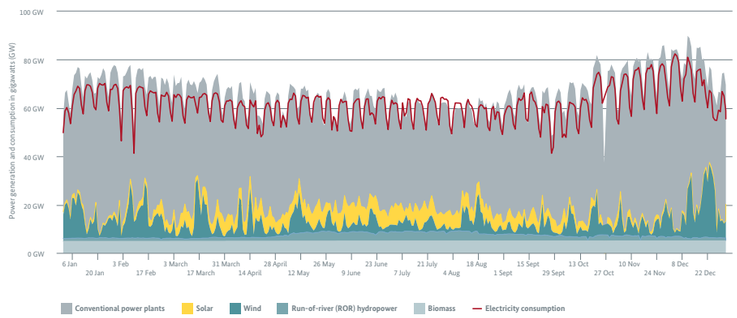
Electricity consumers also play an important role. They can be given incentives to use electricity when supply is high, such as times of high winds. Large-scale consumers – factories or cold storage warehouses, for example – can significantly reduce the burden on the overall system in this way.

The great challenge is to restructure the electricity market. 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.

How does generation by renewable energies fluctuate?

Power generation by all sources of energy and power consumption in Germany over the course of 2014



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.

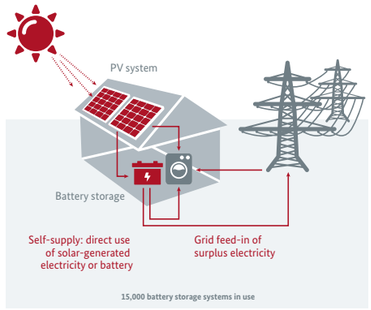
Storage

Energy on tap

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.

Home storage: batteries

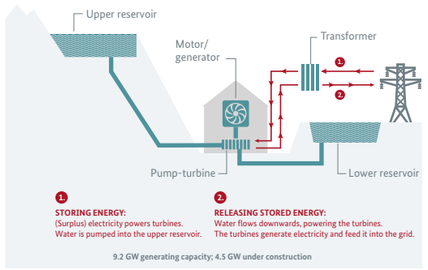
Combination of a PV system and a battery for self-supply and grid feed-in



15,000 battery storage systems in use

Pumped storage: using natural reservoirs

Diagram of a pumped storage system



9.2 GW generating capacity; 4.5 GW under construction

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.

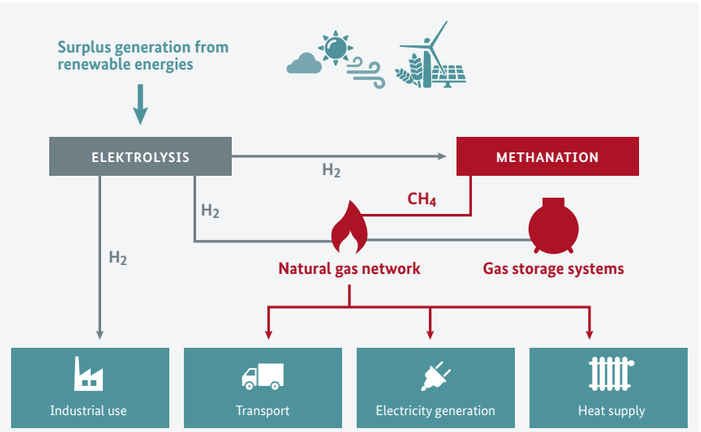
Power to gas is a new type of long-term storage. It uses electrolysis to convert electricity from renewable energies into hydrogen or synthetic natural gas. The advantage is that hydrogen and natural gas can be stored, used immediately or fed into the natural gas network. These gases are easy to transport 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.

Converting electricity into gas

Using electrolysis and methanation; potential applications



15 operational pilot projects; 6 projects under construction or at the planning stage

2013
Germany adopts the first Federal Requirements Plan Act on the necessary expansion of the electricity transmission network. The first completely newly developed electric drive car is mass-produced in Germany.

2013
The first industrial-scale power-to-gas plant goes online in Germany.

The people and the Energiewende

“And how will the public benefit from the Energiewende?”

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.

How many plants are owned by the public?

Installed energy generating capacity by owner group in percent

46%
Members of the public
(individual owners 25.2%;
energy cooperatives 9.2%;
investments by members of the public 11.6%)

12.5%
Energy suppliers

41.5%
Investors
(institutional and strategic investors)

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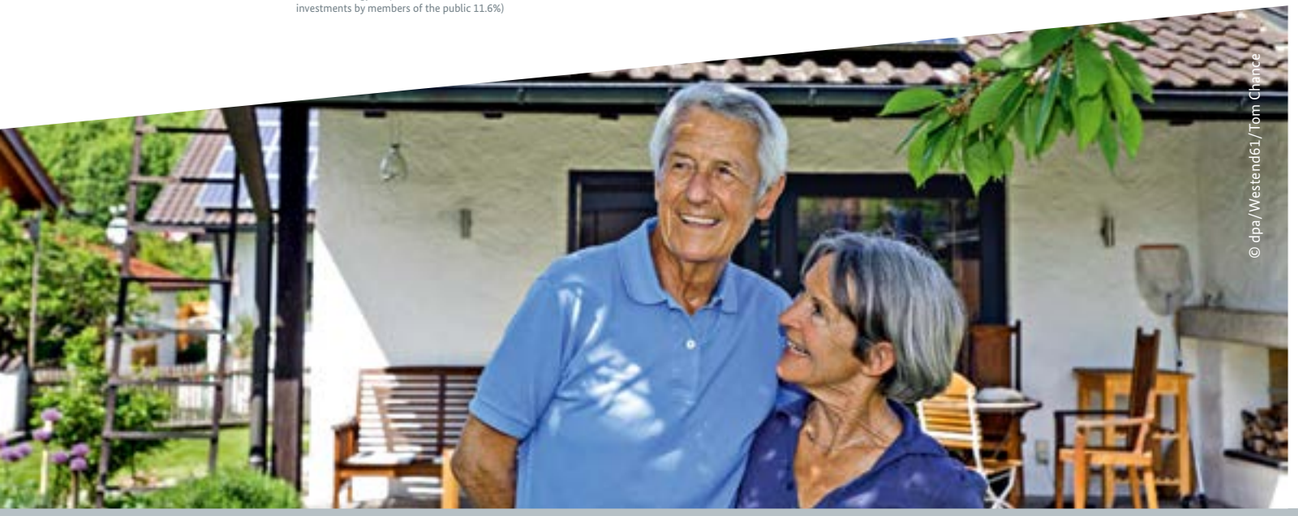

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The public is also involved in the traditional energy sector. Electricity and heat are not only generated by small and large energy suppliers, but also by members of the public who have their own solar panels, invest in wind farms or operate biogas plants. Many of the over 1.4 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.

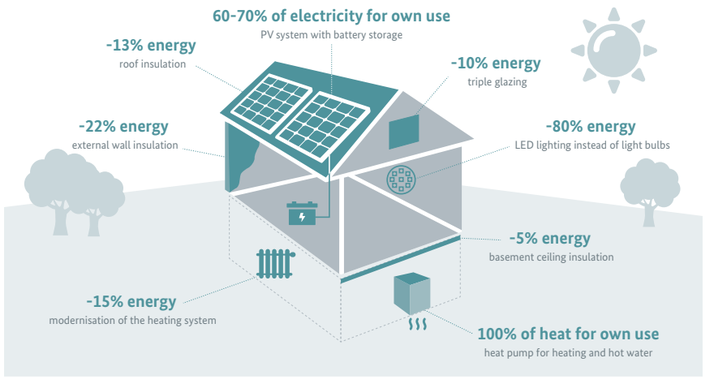
Those who do not have the option of installing or financing their own renewable energy technology can join forces with other people. Just under 1,000 energy cooperatives with a total of over 130,000 members are investing in Energiewende projects. Investments start at just 100 euros.

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



2014
Germany reforms the Renewable Energy Sources Act. The Act now includes annual development targets and imposes market integration.The EU agrees on energy and climate targets for 2030: to cut greenhouse gas emissions by 40 percent, to increase the share of renewables to at least 27 percent and to reduce energy consumption by at least 27 percent. Germany adopts the National Energy Efficiency Action Plan and launches the Climate Action Programme 2020.

2014
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.

2015
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.Solar Impulse, an aircraft powered entirely by solar energy, starts a journey around the world. The United Nations Climate Change Conference meets in Paris and negotiates a follow-on agreement to the Kyoto Protocol.

Glossary – travelling exhibition

Expansion corridor
Expansion corridors help 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 new 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 to determine 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 electro chemical storage devices. If they are connected to a power circuit, they release their charge and electricity flows. 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 vehicles 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.

Gross electricity consumption
To calculate a country's gross electricity consumption, the electricity generated in a country and the electricity imports from abroad are added. The amount of electricity exported is then deducted from this amount.

	Electricity generated in the country
+	electricity imports
-	electricity exports

=	gross electricity consumption

Carsharing
Carsharing is when several users share one vehicle. To this end they generally become customers of the company owning the vehicles. 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.

CO_2-equivalent
The CO_2-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 (CO_2) has the value of one. If a substance has a CO_2-equivalent of 25, the emission of one kilogram of this material is 25 times more harmful than the emission of one kilogram of CO_2. NB: The CO_2 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, airtight salt caverns are considered secure formations for storage. The installation poses several geological challenges which need to be overcome. For 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 overcast 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/ surcharge system
All electricity consumers in Germany finance the additional costs for power from renewable energy sources through a surcharge on the price of electricity, in accordance with the Renewable Energy Sources Act. The level of the surcharge results from the difference between the tariffs paid to the operators and the income from the sale of the electricity on the power exchange. Enterprises with very large electricity requirements do not have to pay the full surcharge.

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.

Renewable energies
Renewable energies include wind power, solar power (photovoltaics, solarthermics), geothermics, biomass, hydropower and marine energy. In the case of hydropower a distinction is made: small scale hydropower is counted as a renewable energy source in many statistics, whereas large hydroelectric power stations with an installed capacity of 50 megawatts and more are often not included. Unlike conventional energy sources such as coal, oil, gas and nuclear power, renewable energy sources do not use up any finite natural resources to generate electricity. One exception to this is biomass, which is only considered climate neutral if it does not process any more raw materials than will grow back within the same period. Geothermics frequently come under criticism. The geological interventions can trigger earthquakes or lift the ground to such an extent that buildings above them are rendered uninhabitable.

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 becoming increasingly 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 by using especially energy efficient devices. In many countries, fridges, televisions, washing machines, etc. have an energy consumption label enabling consumers to see at a glance how energy efficient the appliance is.

Emissions trading
In Europe, CO_2 emissions have a market value. The energy sector and large sections of industry have to produce certificates for every ton of greenhouse gases they emit. If they do not have enough, they have to purchase them on specialised markets. If they reduce their emissions, they can sell any surplus certificates. As the total number of certificates available falls each year, companies have an incentive to invest in energy saving measures or to use other energy sources that are less damaging to the environment.

Final energy consumption
Final energy is the energy that actually reaches the consumer. Factors such as transmission line losses and efficiency related losses in power plants are deducted from this figure. However, losses arising at the consumers' end, for example due to heat generation in a power supply unit, are included in final energy consumption.

Single European market
The European Union Member States comprise a single market. This single market guarantees the free movement of goods, services, capital and, to a certain extent, persons across national borders. No customs duties or other taxes are levied on goods and services being transferred across borders, for example. Electricity, gas and oil also flow from one country to another. However, the existing electricity and gas pipeline infrastructure is not yet sufficient to ensure a functioning single European energy market. Standardised, cross border regulation is also still needed. Both of these concerns are due to be resolved in the next few years to ensure balanced electricity prices in the EU and increase security of supply.

Energy cooperatives
Cooperatives as we know them in Germany are a now well established concept dating from the 19th century. Friedrich Wilhelm Raiffeisen and Hermann Schulze Delitzsch each had the simultaneous idea of establishing the first German cooperatives. The idea is that several individuals with similar business interests join forces and thereby acquire a greater market force, for example in the form of a purchasing 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 energy cooperatives still exist today. 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) gleaned per energy unit used. In the case of an economy, primary energy is used as the basis for the calculation.

Building improvements
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 new, thermally insulated windows. Another option is to modernise the heating system.

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. More than 190 states have ratified the treaty. A second commitment period until 2020 was agreed at the UN Climate Change Conference in Doha. The Kyoto Protocol is a predecessor to the Paris Climate Agreement of December 2015, in which the now 196 UNFCCC states agreed on an upper limit for global warming of less than two degrees Celsius.

Nearly zero energy building
Nearly zero energy buildings is the term for buildings with particularly low energy consumption. From 2021, all new constructions in the European Union will have to comply with a corresponding standard. The regulation applies to public buildings from 2019. In Germany the primary energy requirement for such buildings must not exceed 40 kWh per square meter per year.

Pellet heating systems
Pellets are little balls or sticks made of compressed wood chips or sawdust. They are burned in special heating systems. The compression gives them a high energy density, yet they take up less storage room than wood, for example. Pellet heating systems are climate neutral, as they release only as much carbon dioxide when they are burned as the plant absorbed during its lifetime.

Power to gas (electrolysis, methanation)
Power to gas is a technology enabling the long term storage of surplus electrical energy. In a two stage process the electricity is converted

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 (methanation). Methanation involves adding carbon dioxide to hydrogen to produce methane and water. 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 or pumped storage plants are a tried and tested means of storing energy. Surplus energy from the grid is used to pump water into an elevated reservoir. If additional power is needed, the water is released to drive a turbine which generates electricity.

Radioactive waste
Radioactive waste is produced when nuclear energy is used to generate power. Radioactive materials are split into other substances in fuel rods. After a certain point, these substances can no longer be used, but they are still radioactive. To begin with they consist of isotopes of the elements uranium, plutonium, neptunium, iodine, caesium, strontium, americium, cobalt and others. In time other radioactive substances are produced as the decay rate proceeds. This waste has to be stored securely for a long period to avoid damage to humans and the environment. Highly radioactive materials have to be stored securely for at least one million years. Moderately radioactive waste requires fewer protective measures, slightly radioactive waste almost no protective measures. But this, too, has to be stored securely over a long period.

Back up power plant
Back up power plants are used if sudden bottlenecks occur in power supply. As they have to be fired up and shut down quickly, gas power plants are most suitable for this purpose.

Flywheel accumulator
Flywheel accumulators can store surplus electricity from the grid in the short term. The electrical energy is stored 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 storage of energy, which can then be quickly fed back into the grid.

Smart grid
A smart grid is a supply network in which all components communicate with one another, from the producer, through pipelines and storage systems, to the consumer. 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 many 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 (230 or 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.

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