Flexibility and Efficiency

Hard coal and gas –
Newest technology for traditional fuels

RWE

Powering. Reliable. Future.

Contents

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Did you know ... Quick information Quick questions

RWE Generation – internationally strong, regionally rooted

Backbone of secure energy supply and partner in the energy revolution

RWE Generation SE is responsible in the RWE group for electric power generation by means of gas, hard coal, water power and biomass.

The company concentrates under its umbrella the expertise of some 2,800 employees in Germany, Great Britain, The Netherlands and Turkey.

Together they operate power stations with a total output of about 25 gigawatt. These systems, with their secure and flexible output, help ensure that, even with the ever growing contribution made by naturally variable renewable energies, the power supply along the European power network is available at all times.

A flexible application of man and system is called for.
Control centre of the Emsland power station

Hard coal and gas – backbone of energy supply

In spite of the growing proportion of renewable energies and regulations for reducing CO_2 emissions coal- and gas-fired power stations will also form the backbone of electric power supply in the coming decades.

Germany

In Germany, all signs point towards the turnaround in the energy policy, as decided by the government. Fossil-fuel-fired power stations are playing an important role here: they can offset fluctuations in the supply of electric power from renewable energies caused by the weather and so are guarantees of a secure power supply. RWE's plants are modern and highly efficient, so they also fulfill the goals laid down in the German government's climate protection scheme, which requires from the energy industry a volume reduction of 22 million tonnes of CO_2 from electric power generation. At present generating capacities in the conventional power station sector in Germany are being reduced. RWE is therefore shutting down gas- and coal-fired power stations or preserving them for the long term.

Pembroke gas- and steam-turbine power station, one of Europe's most efficient, can supply about 3.5 million households.

Great Britain

Great Britain has likewise committed itself by a political decision to reduce its greenhouse gas emissions by 80 per cent by 2050. As one of the country's major energy suppliers, RWE is faced with the task of guaranteeing a climate-friendly and at the same time affordable and secure supply. In Great Britain RWE has in recent years invested in, amongst other things, modern gas-fired power stations. With a net output of more than 2,000 megawatt Pembroke power station is Europe's largest gas-and-steam-turbine power station and at 59 per cent is also the most efficient.

Netherlands/Belgium

In The Netherlands and in Belgium RWE operates hard-coal- and gas-fired power stations with a total generative capacity of more than 6,000 megawatt. Two of the very latest environmentally friendly gas-fired power stations – blocks Claus C in Maasbracht and Moerdijk II – have been preserved for the time being since 2014. However, RWE anticipates that, as well as coal-fired power stations, highly efficient gas-fired power stations will play an important role in the future European energy mix. Because of Claus C's favourable location right on the Belgium border it may well have good prospects in the middle term.

We would be pleased to give you all the information you need!

Are you looking for more figures, data and facts with regard to power generation from hard coal and gas at RWE in Germany, Great Britain and The Netherlands? Would you like to know more about the company RWE Generation and its various locations? Are you interested in innovative technologies in conventional electric power generation? You can find answers to your questions in German, English and Dutch on our website.

Scan code and get more information.

Thanks to its efficiency and flexibility Eemshaven coal-fired power station is an ideal partner for wind-generated energy.

Reducing harmful substances effectively

RWE's philosophy also includes future-focused and responsible solutions for environmental protection. Its power stations are equipped with up-to-the-minute technology, so actual values are frequently achieved that are lower than the legally required ones.

In the case of coal-fired power stations the biggest problem is airborne dust, which is contained in flue gas, and hazardous chemical substances arising through combustion. For this reason, besides the removal of dust from flue gas, desulphurisation and denitrification are necessary to reduce sulphur dioxide and nitrogen emissions.

Dedusting of flue gas

When coal is burnt, ash is produced. To prevent the ash dust from getting into the atmosphere, almost all of it is removed from the flue gases in electric filter systems. For this the dust is negatively charged and magnetically attracted to positively charged electrodes. A beater mechanism then removes it from the electrodes. The dust collected is returned to the combustion chambers of the boiler and melted down with the slag. It is put to use later in the building industry.

Minimisation of immissions is a constant task for RWE in the interest of humankind and the environment.

"Keeping water clean is one of our most important tasks with regard to comprehensive and effective environmental protection. Accordingly we regularly take samples of waste water and subject them to a rigorous examination."
Thomas Hilse, Plant Officer for Immission Control, Water Conservation, Waste and Hazardous Material at Westfalen power station

Desulphurisation of flue gas

Coal contains sulphur, which forms sulphur dioxide when the coal is burnt. Flue gas desulphurisation systems (FGD) scrub almost all of this out of the flue gases together with small amounts of fluorine and chlorine, using a spray of lime slurry. FGD systems operate with an efficiency of more than 90 per cent. The plaster produced here is likewise a valuable raw material for the building industry.

Denitrification of flue gas

When coal is burnt, nitrogen oxide is formed from nitrogen and oxygen. After dedusting and desulphurisation the flue gas passes through a denitrification system. There the nitrogen oxides contained in the flue gas are whirled around with a mixture of ammoniac and air and converted into the hazardous-substance-free constituents nitrogen and water vapour in a catalyser.

Like all power stations that operate on fossil fuels, gas-fired power stations also emit carbon dioxide – though only half as much as coal-fired power stations.

Noise prevention

All noise-generating parts of power stations are as far as possible designed to prevent noise emissions. Design measures include insulation, noise suppressors and protective hoods. Moreover, noise-intensive equipment is as far as possible set up inside buildings.

Did you know ...

that natural gas is especially environmentally friendly? Because it produces no ash when burnt, no systems are needed to dedust flue gas. If power stations are also run as combined-cycle gas-and-steam-turbine power stations (CCGT power stations), the primary energy source natural gas sets standards in matters of efficiency. This is made possible by a dual system of electric power generation: the natural gas fuel drives the turbines, the waste heat from which in turn sets the steam turbines turning. By means of this technology high efficiencies are achieved that contribute to the conservation of our resources. For, the higher the efficiency, the less primary energy is needed per kilowatt-hour generated.

Making the best use of valuable fuel

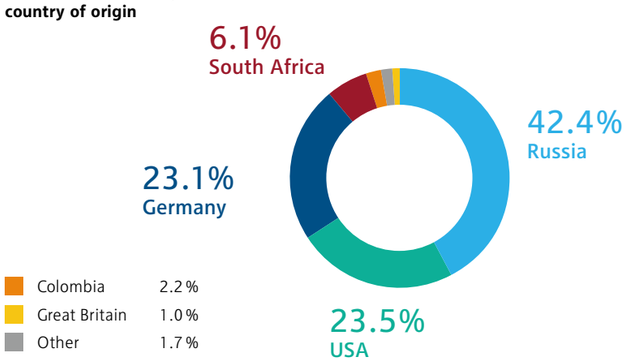
Hard coal and gas not only have an ancient tradition as energy sources, they also have a future. Because they are widely available, and that at calculable prices.

Their efficiency and their flexibility make modern hard-coal-fired power stations the ideal partner for renewable energies with their fluctuating infeed. Thus, the new systems achieve the highest efficiencies – that is, the best use of fuel – globally. That also means that they emit the least CO_2 per kilowatt-hour of electric power. And if for modern power stations old, less efficient systems are taken off the grid, they will actually make a real contribution to climate protection.

Even more efficient and environmentally friendlier than modern hard-coal-fired power stations are power stations that are driven with natural gas – particularly if they are operated as combined-cycle gas-and-steam-turbine power stations (CCGT's). This is made possible by a dual system of electric power production: the natural gas fuel drives the turbines, the waste heat from which in turn sets the steam turbines turning.

And flexible high-tech power stations have yet another advantage: they also operate on biogas. Still at the trial stage is a process by which excess electric power from renewable energies is first converted into hydrogen by electrolysis and then into methane by the addition of CO_2. Methane can be stored problemfreely and then, as required, be used in gas-fired power stations.

Hard coal purchase by country of origin



The two remaining German mines closed at the end of 2018; in Great Britain since closure of the last underground hard-coal mine at the end of 2015 hard coal has still been mined open-cast. Increasingly however there, too, power stations will be converted to what is known as "world-market coal" from various mining areas. In The Netherlands they stopped mining hard coal as early as 1974. With world-market coal the long-term organisation of the supply chain is an important concern. For this reason RWE is together with other European suppliers committed to the "Better-coal" industrial initiative. The aim is to ensure adherence to environmental and social standards in mining countries. The diagram shows the countries from which RWE obtains hard coal for its own power stations (as at 2018).

"We monitor and guide our highly complex power station processes using up-to-the-minute technology: here at the control centre we have all the operations under our eye and can control the power station as required." **Dr. Julia Heslop** and **Malcolm Redford**, Chemist and Team Leader at the Pembroke power station in Great Britain

What is the difference between gas-fired power stations and other fossil-fuel power stations?
Their biggest advantage is their faster availability: whereas coal-fired power stations take several hours to get up to operating temperature from cold, the turbines of modern gas-fired power stations are ready to deliver electric power in a markedly shorter time.

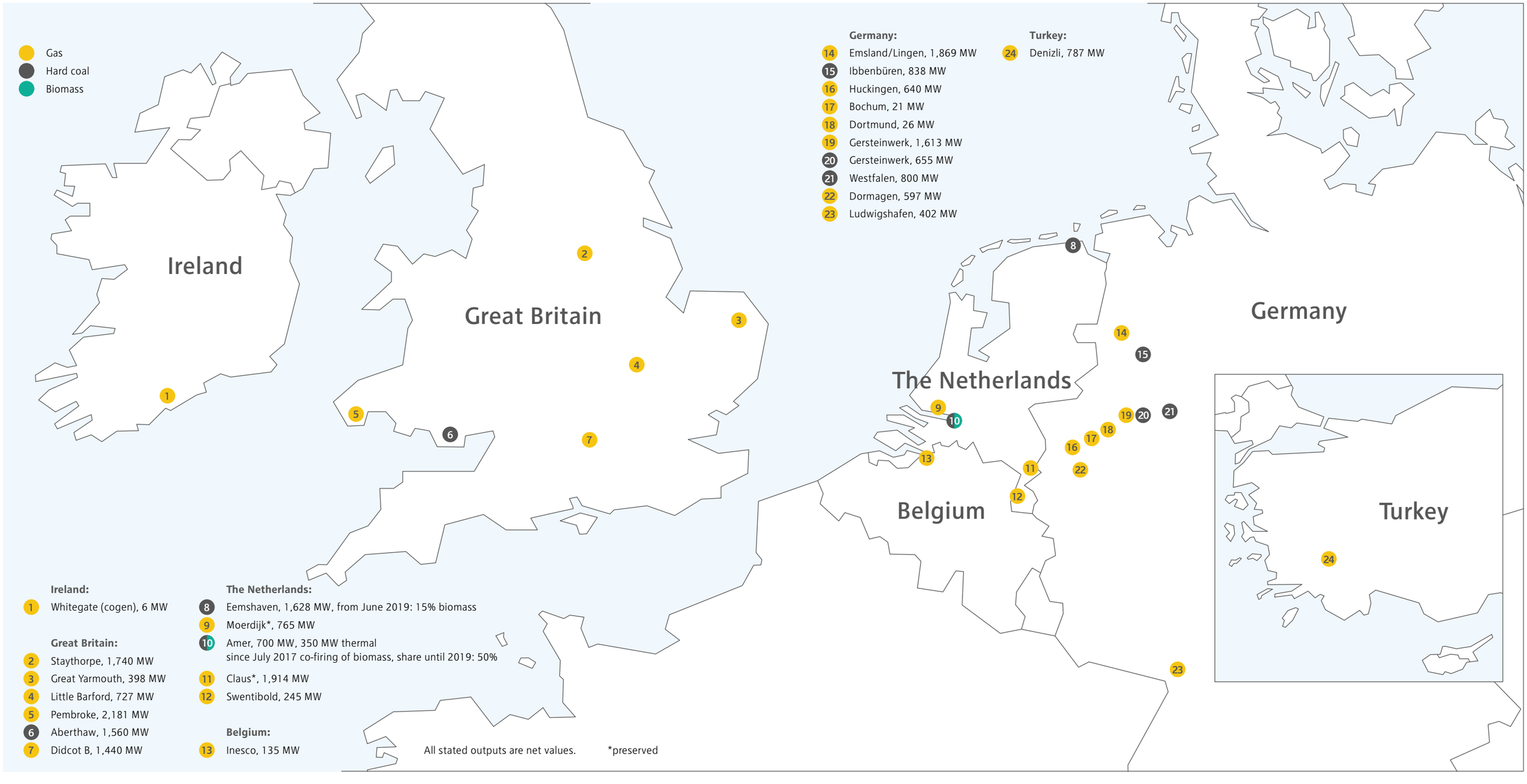
Are gas-fired power stations as efficient as other power stations?
Natural-gas-fired power stations have a markedly better energy yield than other power stations. That means that they need less energy to generate electric power. The latest generation achieves an efficiency of up to 60 per cent and in conjunction with the technology of cogeneration (power-heat coupling) up to as much as 85 per cent.

Are there any alternatives to gas-fired power stations?
Electric power from gas-fired power stations is relatively costly compared with that from other conventional power stations. For this reason, unlike coal-fired power stations, they are mostly used during periods of peak demand. With regard to fast availability the only alternative is pumped hydro storage: only waterpower can serve as a faster energy reserve in cases of need. However, there are hardly any locations for new pumped hydro storage systems left. Moreover, they only store energy but do not generate it.

Did you know ...

that hard coal was formed more than 300 million years ago? At that time the landscape was covered in swamps in which grew the most varied vegetation. When this vegetation died, it sank into the water and was turned into peat. Later on rivers and seas flooded the landscape and left behind large deposits of sand and rock. The weight of this sand and rock compressed the peat layer and sealed it airtight. In this way first lignite and then finally through more pressure and higher temperatures at a greater depth hard coal was formed.

Our power station locations throughout the world



Ireland:
1. Whitegate (cogen), 6 MW

Great Britain:
2. Staythorpe, 1,740 MW
3. Great Yarmouth, 398 MW
4. Little Barford, 727 MW
5. Pembroke, 2,181 MW
6. Aberthaw, 1,560 MW
7. Didcot B, 1,440 MW

The Netherlands:
8. Eemshaven, 1,628 MW, from June 2019: 15% biomass
9. Moerdijk*, 765 MW
10. Amer, 700 MW, 350 MW thermal
since July 2017 co-firing of biomass, share until 2019: 50%
11. Claus*, 1,914 MW
12. Swentibold, 245 MW

Belgium:
13. Inesco, 135 MW

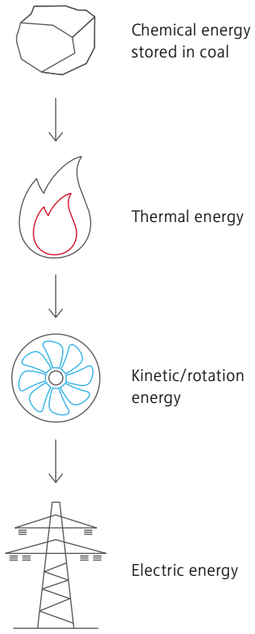
Germany:
14. Emsland/Lingen, 1,869 MW
15. Ibbenbüren, 838 MW
16. Huckingen, 640 MW
17. Bochum, 21 MW
18. Dortmund, 26 MW
19. Gersteinwerk, 1,613 MW
20. Gersteinwerk, 655 MW
21. Westfalen, 800 MW
22. Dormagen, 597 MW
23. Ludwigshafen, 402 MW

Turkey:
24. Denizli, 787 MW

All stated outputs are net values. *preserved

How electric power comes from coal

Hard coal is burnt in the power station; the energy released by this is used to generate electric power. RWE is continuing to further-develop this proven and reliable technology.



From coal to electric energy

Hard coal naturally contains up to ten per cent moisture. It is therefore dried before being burnt in the power station: the lumps of coal drop into coal mills, where hot air is blown over them and removes a large part of the water. Next what are known as beater-head mills reduce the coal to a fine dust. Hot air then blows this coal dust into the boiler's combustion chamber, where it is burnt up. This converts chemically bound energy into heat energy; the temperature rises to about 1,500 degrees.

The walls of the tall-building-high boiler consist of kilometre-long water pipes clustered tightly together. There are also pipe coils hanging in the firebox. Circulating through these is chemically purified, totally desalinated water. This water is the work medium, the most important energy transporter in the power station process: it takes up the heat energy from the fire and evaporates. In the upper firebox at high pressure and still at a temperature of more than 500 degrees the steam is converted to what is known as superheated steam.

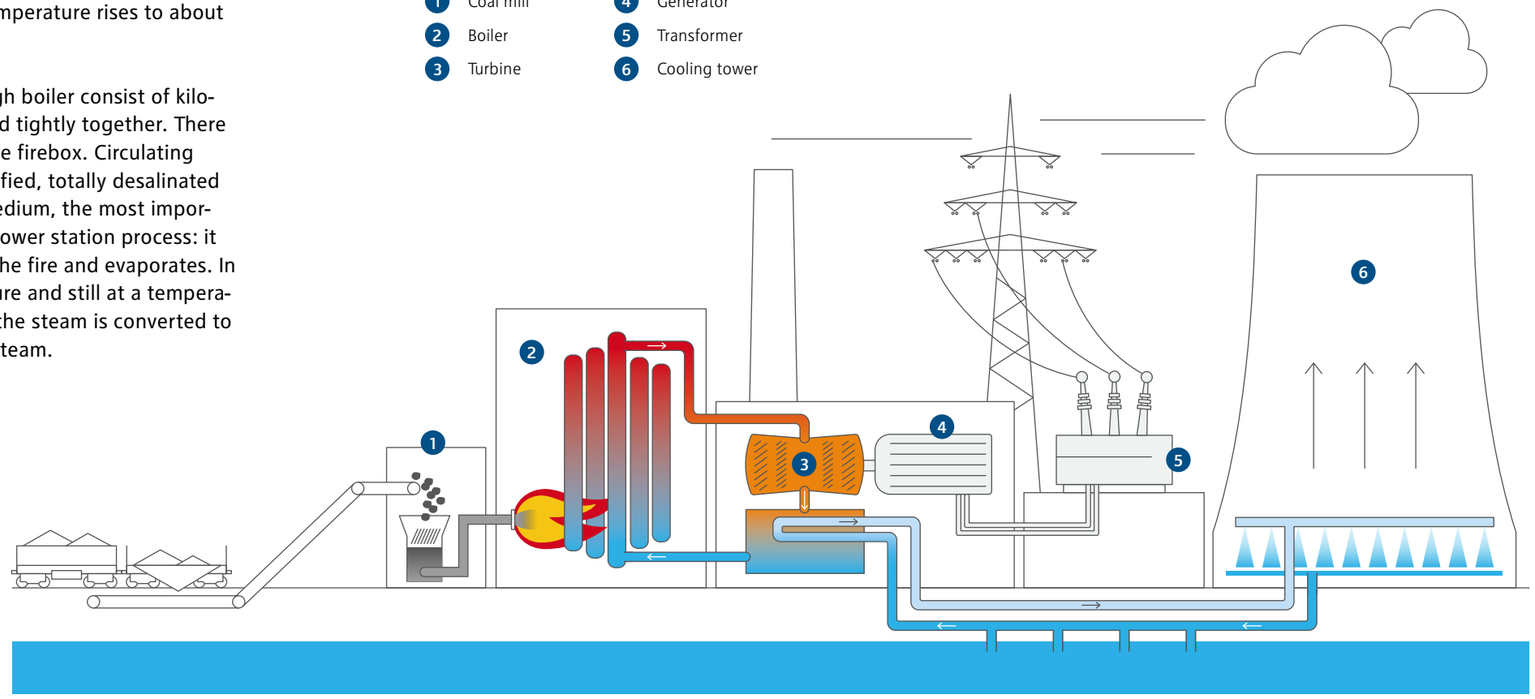
This steam then drives the blades of a turbine, just as wind sets a windmill turning. Heat energy is thus converted to kinetic energy. The turbine is coupled to the actual electric power generator. The rotary movement of the turbine is transferred to the generator rotor, which turns at a speed of 3,000 revolutions a minute. As in a dynamo, the kinetic energy is now converted to electric energy. The voltage of the electric power so generated is then increased in transformers before it is finally fed into the supply grid and to the consumer.

And the steam? At the end of the turbine its temperature has fallen to about 25 degrees. In the condenser behind the turbine it turns back to water. For this, water is used that absorbs the residual heat of the steam in cooling coils. The cycle of preheating, evaporation, superheating and turbine work then begins all over again.

The cooling water itself must also be cooled down again. This is done in cooling towers. In them the natural chimney effect sets up a powerful updraught. The warm cooling water there falls in fine drops from a few metres height. Part of it evaporates and is drawn upwards with the updraught. Depending on the weather, this is what causes the typical steam clouds.

How a hard-coal-fired power station works

1. Coal mill
2. Boiler
3. Turbine
4. Generator
5. Transformer
6. Cooling tower



How electric power comes from natural gas

Gas-fired power stations do not differ very much from coal-fired power stations in the way they operate. However, they need no additional infrastructure for the delivery of fuel: they merely need to be connected up to the existing gas grid.

In a gas-fired power station outside air is drawn in, conducted to the turbine and compressed. Then natural gas is fed into it, forming a combustible gas-and-air mixture. When it is burnt, flue gas is evolved, which is used to drive a turbine. The turbine drives a generator. This converts kinetic energy into electric energy and so generates electric power. Via the transformer that converts the voltage the electric power is fed into the grid.

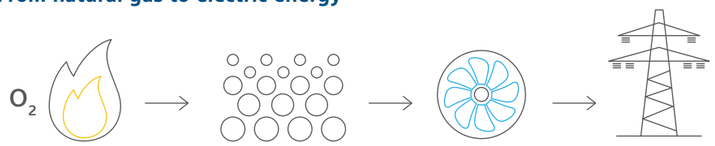
The waste gas from the steam turbine passes at high temperature into the steam generator. There combustion gases heat up feedwater, generating water vapour. The hot steam in turn drives a turbine. This likewise drives a generator, which converts kinetic energy into electric energy and generates electric power.

The flue gas evolved during combustion contains hazardous substances. It is therefore, just as in a coal-fired power station, thoroughly cleaned.

The heated water is finally sprayed into the cooling tower. The heated air rises upward with the steam and draws fresh cold air after it. The cooled water falls into the collecting basin of the cooling tower and is returned to the water circulation system. Part of it evaporates and emerges from the cooling tower as a steam cloud.

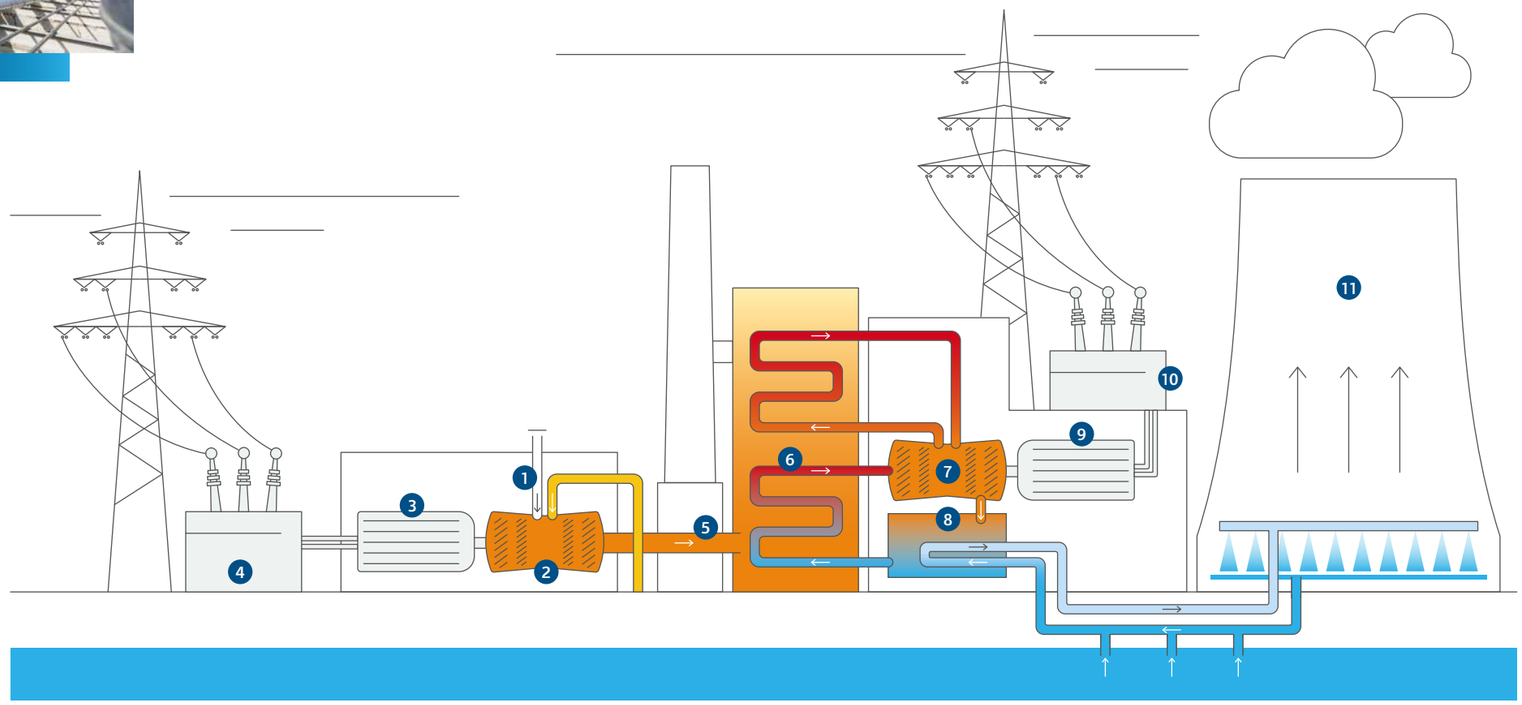
Pembroke natural-gas-fired power station is a gas-and-steam combination power station. A gas turbine serves as a heat source for a downstream waste-heat boiler, which in turn acts as a steam generator for the steam turbine.

From natural gas to electric energy



How a gas-fired power station works

1. Outside air is drawn in
2. Gas turbine
3. Generator
4. Transformer
5. Combustion gas from the gas turbine
6. Feed water is heated up
7. Steam turbine
8. Condensator
9. Generator
10. Transformer
11. Cooling tower



More flexibility, higher efficiency

More flexibility combined with falling emissions and lower resource consumption: that is what the experts at RWE are continuously working at to further increase the efficiency of power stations. Many optimisations are already proving themselves in practice.

Against the background of the expansion of regenerative energy forms it is of especial importance to develop new solutions to finding a more flexible method of operating fossil-fuel power stations – because only in this way can these power stations optimally support renewable forms of energy.

Heavy-duty materials

RWE is working in a number of research projects with partners in Germany and other countries to develop and test new components and materials, for example, heavy-duty steels. Originally the aim was to use innovative materials to help increase the efficiencies of future generations of power stations ("700 °C power station"). Now the focus is on re-equipping the existing systems – for example, by using thin-walled components in the water-and-steam circulation system.

Reduction of mercury emissions

The reduction of mercury emissions is the subject of a collaborative project between RWE, the Mannheim large power station, EnBW and the University of Stuttgart. The aim is to securely adhere to future emission limit values in power station systems permanently and in all operating conditions. For this solutions are being trialled under system-specific and fuel-specific conditions, first to laboratory standard and then in a pilot system. Later the results of the project can be applied to RWE systems in accordance with requirements.

How innovations increase efficiency

Using the latest technologies, RWE achieves an efficiency of 46 per cent in hard-coal-fired power stations – which is considerably better than the European average of 36 per cent. Even more efficient are gas-and-steam-turbine power stations (G&S power stations): with downstream cogeneration or a combined heat and power method they achieve energy-use levels of up to 80 per cent; for pure electric power generation net efficiency can be as high as 59 per cent.

46 % efficiency in the latest hard-coal-fired power stations

up to **80 %** efficiency in CCGT power stations

"To reduce mercury emissions in the best possible way, we rely on a large number of individually adapted solutions along the whole flue-gas process. One very promising method is the introduction of active charcoal into the flue gas canal with jets like the one I have here in my hand."
Ferdinand Steffen, Research and Development – Manager CoC Flue Gas Cleaning

Did you know ...

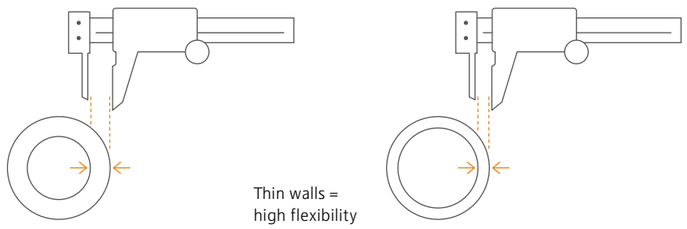
that not only flexibility but also speed is decisive when conventional power stations have to make up for the fluctuating supply of electric power from renewable forms of energy. One example is the Lingen power station in Germany: in this gas-and-steam system the gas turbines upstream of the steam turbines can be brought up to full power from cold in only 45 minutes. That means that 540 megawatt – about two thirds of the entire block output – are made available to the electric power market in a very short time. Internationally therefore the power station occupies a top position. The improvements were made possible by optimising the control technology and modifying the gas turbines, which can now actually be operated without the downstream steam circulation system. Before this the entire 900 megawatt system took about three-and-a-half hours to start up.

Process optimisation with big data

In power stations permanently large amounts of process data are recorded that provide information about the state of the systems. These data can be used to optimise the process as a whole and even individual components, using modern, computer-assisted methods. The aim is always to increase efficiencies, enable a more flexible method of operation and better predict operation. RWE develops and realises such applications in many different ways, using big data methods as a basis. Thus, for example, by the evaluation of process data the energy requirement of components can be reduced to a minimum or the starting-up of power station blocks be made more efficient thus allowing to save resources. In this way power stations will be able to even better fulfil their role as partners to fluctuating renewable energy forms.

Heavy-duty materials

The use of thin-walled components in the water-steam circulation system increases system flexibility.



Visitor information

Come and see for yourself!

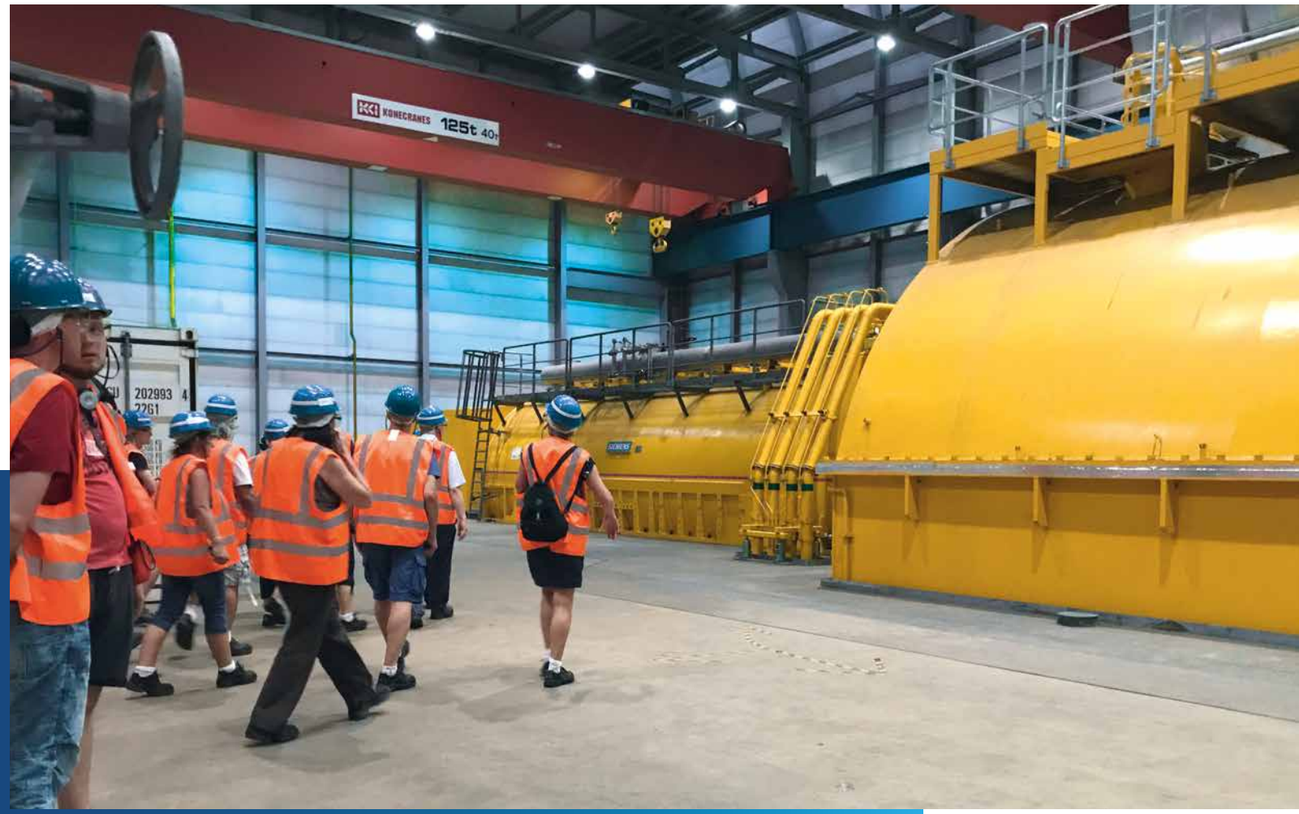
RWE informs people on site about electric power generation and its future challenges. Various locations provide exciting facts, guided tours afford a glimpse of what goes on behind the scenes.

Locations in Germany:
RWE visitor service offers neighbours, schoolchildren, university students and professional visitors free group guided tours of the power stations by prior arrangement all the year round.

RWE
Visitor service
Huyssenallee 2, 45128 Essen, Germany
Phone 0800 8833830 (toll-free)
Email besucher@rwe.com

Locations in The Netherlands:
RWE offers group guided tours of the Amer (Geertruidenberg) and Eemshaven power stations. Guided tours are possible only on working days and last for 2.5 hours. Group sizes and the age of participants are restricted.

To arrange a date for a visit, please visit our websites at www.eemshavencentrale.nl or www.amercentrale.nl.



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