LINGEN POWER PLANTS

Where the energy is
RWE Power is Germany’s biggest power producer and a leading player in the extraction of energy raw materials. Our core business consists of low-cost, environmentally sound, safe and reliable generation of electricity and heat as well as fossil fuel extraction.

In our business, we rely on a diversified primary energy mix of lignite and hard coal, nuclear power, gas and hydropower to produce electricity in the base, intermediate and peak load ranges.

RWE Power operates in a market characterized by fierce competition. Our aim is to remain a leading national power producer and expand our international position, making a crucial contribution toward shaping future energy supplies.

A strategy with this focus, underpinned by efficient cost management, is essential for our success. All the same, we never lose sight of one important aspect of our corporate philosophy: environmental protection. At RWE Power, the responsible use of nature and its resources is more than mere lip service.

Our healthy financial base, plus the competent and committed support of some 15,300 employees under the umbrella of RWE Power enable us to systematically exploit the opportunities offered by a liberalized energy market.

In this respect, our business activities are embedded in a corporate culture that is marked by team spirit and by internal and external transparency.

With an about 30 per cent share in electricity generation, we are no. 1 in Germany, and no. 3 in Europe, with a 9 per cent share. We wish to retain this position in future as well. That is what we are working for – with all our power.
Germany is a highly developed industrialized country and cannot cover its tremendous electricity needs from just one source. What is more, it depends heavily on energy imports.

Germany’s 2009 power generation was composed of an energy mix: 24.6 percent lignite, 22.6 percent nuclear energy, 18.3 percent hard coal, 12.9 percent natural gas, 10.4 percent wind power and hydropower and 11.2 percent other, like pumped-storage, oil and incineration. None of the above energy carriers is ideal, each has its merits and drawbacks, weak spots and sweet spots. What matters is that they have their place in a balanced mix that combines environmental protection, security of supply and economic efficiency.

Fossil fuels
The fossil sources lignite and hard coal, natural gas and crude oil currently – not only in Germany, but worldwide – provide the largest share by far of the energy required. Fossil fuels have emerged in millions of years from the residues of prehistoric plants that grew thanks to photosynthesis, i.e the utilization of sunlight; so they are stored solar energy, as it were.

There is no denying that the industrial revolution that culminated in our modern, industrialized society would never have happened without the discovery and systematic use of fossil energy.

The great advantages of fossil fuels are their high availability and universal, relatively simple usability. Even if lignite and hard coal in particular are still available for centuries to come, the reserves of all fossil energy sources are finite, since they are non-renewable. Moreover, when coal, oil and gas are combusted, carbon dioxide \((\text{CO}_2)\) is produced. Its increase in earth’s atmosphere is held responsible for climate change.

Nuclear energy
Nuclear-based power generation uses the energy that is produced by uranium fission. The great advantages of nuclear energy are its high energy density and electricity generation without any \(\text{CO}_2\) emissions. Uranium, too, is a non-renewable energy source, but it will be available for centuries to come and can be used safely and reliably by deploying modern technology.

Renewable energies
Wind power, solar energy, hydropower and biomass are playing a growing role in the energy mix, not only in Germany. Renewables are available in virtually unlimited amounts, at least in theory. Since in practice they do not release residues with an impact on the climate, they are being politically promoted in Germany and elsewhere. However, most renewables can only survive economically in the foreseeable future with direct or indirect subsidies. In addition, wind power and solar energy in particular are not always available, since generating power from such sources depends on fluctuating weather conditions that ignore the needs of modern society. For this reason, the search is on for ways to temporarily store electricity from wind or solar energy.
Power consumption is not always constant, but subject to daily, seasonal and business-cycle fluctuations. No matter what the demand for electric power looks like at any moment, utilities must satisfy it on target at all times. This is because electricity cannot be stored on a grand scale, but must be generated the second it is needed. Another aggravating factor: in Germany, electricity from renewables has absolute priority in the grid over conventionally produced power. If the wind is strong, the stations must be powered down or switched off. Wind power in particular is already making a significant contribution to the generation of electricity. By its nature, however, wind power is hard to count on. Unlike a gas-fired power plant, wind cannot be switched on or off at the push of a button.

The technical structure of power supply offsets all fluctuations. This is only possible, however, using different energy sources, flexible power stations and an efficient grid. The sprinters among power stations are gas and pumped-storage systems. They can be powered up practically from a standing start in less than a few minutes from zero to 100 percent. Due to their relatively high deployment costs, they are only on stream temporarily, i.e. during peak demand. Nuclear power stations are the marathon runners: thanks to their favourable generating costs, they mainly run at full capacity around the clock. It is in their nature, though, to change their operating mode very quickly. Lignite-based power plants, too, are long-distance runners. Thanks to their cost advantages, they likewise work at full capacity as a rule, although modern stations can be reduced by half in 15 minutes. Hard-coal power stations are deemed the middle-distance runners in power generation: with their relatively high fuel costs, they show their strength in hour- or day-based deployment. Newer systems can increase their capacity in under 20 minutes from 25 to 100 percent, and back again.
Nuclear power stations are thermal power plants in which the heat required to generate electricity comes not from the combustion of coal, gas or oil, but from the controlled fission of U235 atomic nuclei.

The process takes place in the reactor core which, at the Emsland nuclear power station, contains 193 fuel assemblies with 300 fuel rods each of enriched U235. Then there are rod-shaped control assemblies which regulate the neutron flow that is important for the chain reaction, and the reactor’s output. With the aid of electric motors, these assemblies are lifted or lowered between the fuel rods. Once a year, the nuclear power station is shut down for two to three weeks for overhaul of the systems and refuelling. About one quarter of the fuel assemblies are replaced.

Pressurized-water reactor
In the pressurized-water reactor, water is heated by the nuclear fission of U235. In the primary cycle, there is a pressure of 155 bar, so that the heated water remains liquid despite a temperature of 320°C. In this state, it reaches the steam generator – which forms the interface between the primary and secondary cycles – via pipes. Here, the heat of the water is transferred by the pipes’ heat conduction to the steam generator’s feedwater surrounding the pipes and, hence, to the secondary cycle. At some 62 bar, the pressure there is much lower, so that main steam can emerge to drive a steam turbine with connected generator. Separating the two water circuits means that the steam in the secondary circuit remains free of radioactive materials. Below the steam turbine is the condenser. There, the steam "worked off" in the turbine is cooled down using cooling water to become liquid again. The condensate is pumped back into the steam generator. The heat absorbed by the cooling water is released into the atmosphere in the power plant’s natural draught cooling tower. Evaporation losses occurring in the cooling tower are compensated by water from the river Ems.

Nuclear power stations use the energy that is released during the fission of the radioactive element U235. In nature, this heavy metal always occurs together with ores and is extracted by mining. At the present consumption rate and with the technology now available, the Earth’s uranium reserves known today will last some 200 years. Uranium’s great merit is its exceptionally high energy content. One kilogram of natural uranium contains as much energy as 12,600 litres of crude oil or 18,900 kg of hard coal.

The uranium, which must be extracted from ores, consists of roughly 0.7 percent fissile U235, the rest being non-fissile U238. If the uranium is to be used in a nuclear power station, the U235 share must be increased 3 to 5 percent by so-called enrichment. The enriched uranium is then pressed into tablet form, or pellets, and filled into tube-shaped fuel rods made of particularly resistant material. The fuel rods are then bundled into fuel assemblies and used in reactors.

1 kg natural uranium
is equivalent to 12,600 litres of crude oil
or 18,900 kg of hard coal
The more neutrons you have, the more fissions you get. This means that more energy is released.

Since in uranium fission, more neutrons emerge than are required to maintain a controlled chain reaction, some of the neutrons are deflected from their actual target. To produce this effect, use is made of so-called control rods in a nuclear power station’s reactor. They are largely made of a material able to absorb neutrons. To lower the reactor’s output, rods are inserted; to increase it, they are withdrawn again. Nuclear fission is interrupted when they are inserted. The reactor works at max. output when the rods are removed. During operations, the control rods are powered by electric drives. For fast shutdown, a system is available that works independently of the drives.

But there is another way to control and regulate the chain reactions: when a boron solution is injected into the reactor, the neutrons can be captured and the fission process interrupted. Finally, the moderation effect, too, adds to the stabilization of the chain reaction.

The hotter the moderator or the cooling agent becomes, the more vapour bubbles emerge, so that the braking effect is lost and more and more neutrons miss their targets.

Behind this principle lies an essential, inherent safety element in a pressurized-water reactor.
Ensuring a high safety standard is the central obligation of nuclear power station operators.

The basis of the high safety level is a high-quality technical design that reliably prevents disruptions. In addition, downtimes of systems and components are “thought of in advance”, and it is ensured that these have no implications for the environs. Comprehensive inspection and maintenance regimes help keep the system in an optimal state and enable any irregularities in components to be spotted and remedied early on. Besides ensuring an excellent technical state, the operator’s efforts focus on organizational issues and on the high safety awareness of the power-plant crew.

Operation of the nuclear power stations is also strictly monitored by the authorities and experts in charge.

The design principles

By way of precaution, the design of nuclear power stations always assumes a concurrence of unfavourable circumstances and damaging events. This being so, the planning and construction of a system implement the design principles of ‘redundancy’, ‘diversity’, ‘physical separation’ and the so-called fail-safe principle.

Redundancy: Several systems of the same kind perform the same function. One stands in for the other in an emergency. For instance, Lingen has four independent emergency cooling systems, two of which suffice for cooling purposes.

Diversity: Different systems have the job of performing the same function. If, eg, the lowering of the control rods fails, gravity takes over. In the long run, the reactor can also be safely shut down by injecting a boron solution.

Fail safe: In any disruption, all safety systems work toward safety. If the power supply fails, say, valves and dampers automatically switch to the safety-relevant position.

Thanks to the physical separation of the redundant and diverse systems, several systems cannot fail simultaneously due to one single cause.
THE GEESTE RESERVOIR

Like any other thermal power plant, the Emsland nuclear power station, too, needs water for cooling. It must replace the amount of water that evaporates via the cooling tower. For this, water from the river Ems is used. Since the river’s water level can fluctuate due to the seasons or the weather, an artificial reservoir was created for the nuclear power station, the Geeste reservoir.

The reservoir, which holds about 23 million cubic metres of water, is located some 12 km from the nuclear power station and is filled with water from the Ems via the Dortmund-Ems canal. Surrounding the reservoir is a large forested area and a wetland biotope, a feature that benefits both sustainable environmental protection and the leisure value of the region.

THE ENVIRONS – UNDER CONTROL AT ALL

The entire environs around the Emsland nuclear power station are continuously controlled by expert operatives and by independent institutions.

The remote-monitoring system of the environment office of the State of Lower Saxony, which is completely independent of the plant’s internal control systems, is used to monitor the stack air and effluent produced by the power plant. At the same time, measurements from the power station’s environs are read at regular intervals and transmitted to the competent authority for analysis. The analyses are freely accessible to the public at any time.

Measuring samples from the soil, air and water around the Emsland nuclear power station prove that the statutory thresholds are not only met, but are always well undercut.
When power is produced from nuclear energy, radioactive waste emerges that must be placed temporarily in safe intermediate storage facilities on site.

The storage building
The building is 110 m long, 27 m wide and approx. 20 m high, and was erected on site some 100 m away from the nuclear power station’s reactor building. Thanks to its 1.20-m thick outer walls and a 1.30-m strong roof, the building, which resembles a factory hall, is extraordinarily robust and can house about 130 Castor casks. This provides more than ample space, both for past spent fuel assemblies and for those that will come up during the power plant’s remaining operations.

The safety concept
The most important module in the safe storage and transport of spent fuel assemblies in the storage building is the cask of the Castor V/19 type, which can accommodate 19 fuel assemblies. Among other features, the Castor, with its 40-cm wall, is built so soundly that it can withstand a 9 m fall onto solid ground without damage and cope with external temperatures of at least 800°C. It shields off the radiation of the spent fuel assemblies so effectively that you can stand in the immediate vicinity of the cask without any risk of exposure. The storage building, too, with its massive walls, serves to shield off radiation and also provides effective protection against external impact, such as earthquakes, explosion-pressure waves and aircraft crashes.

The route of spent fuel assemblies
Spent fuel assemblies are removed from the reactor and taken first to a water-filled cooling pond inside the reactor building where they are stored for at least five years. In the process, their thermal rating declines considerably. Next, the Castor casks are loaded and transported by the power plant’s own railway to the on-site intermediate storage facility. The casks’ tightness is monitored not only during transport, but continuously for the whole storage period.

The residual heat emanating from the casks is removed by natural draught or with the aid of vents. Although the radiation emitted by the casks is extremely low, it is likewise continuously monitored.
NATURAL GAS FOR POWER AND HEAT – EMSLAND GAS-FIRED POWER STATION

Top technology in the peak load: RWE Power investing € 700 million in new-build and modernization.

Natural gas is one of the cleanest energies around. Gas-based power plants achieve high efficiencies and are virtually emission-free. When natural gas is burnt, no ash emerges. Another merit: the start-up time of a gas-fired power station from standstill to full load is very short. Which is why this plant type is used above all to cover peak loads or when there are power-plant downtimes in the grid.

The Emsland natural-gas power station consists of the two units B and C, which went on stream in 1974/75, and – since 2010 – unit D. At present, its operator, RWE Power, is replacing the gas turbines of the older units with new models, spending € 200 million.

In principle, the Lingen gas power plants are thermal power stations like any other: instead of coal or nuclear fission, they use natural gas to evaporate water, driving a turbine with connected generator. Units B and C, on the one hand, and unit D, on the other, differ in one crucial detail, however: B and C produce steam using a gas-firing system, unit D using only the hot waste gas from the gas turbines.
Unit D, the combined-cycle gas turbine plant (CCGT) at Lingen, sets standards worldwide when it comes to efficiency and environmental friendliness.

In unit D, the hot turbine waste gases are conducted to steam generators without firing systems, so-called heat-recovery steam generators (HRSGs). There, they convert water into vapour which then drives steam turbine and generator. The plant has a net efficiency of 59.2 percent.

Unit D consists of two gas turbines with 280 MW each, two HRSGs and a joint steam turbine with a capacity of 326 MW. It is designed for a main-steam temperature of 585°C and a pressure of 159.2 bar. Like its adjacent units B and C, unit D, too, is designed for co-generation. It can decouple 100 tons of process steam an hour.

This means: some of the steam is diverted away from the steam turbine and can be made available for industrial purposes (steam customers). This steam is highly charged energetically and is not at all to be confused with the only lukewarm cooling water or even the plumes coming from the power plants’ cooling towers.

Such an efficient input of fuel and heat also lowers CO₂ emissions perceptibly – benefiting the environment and the climate. Today already, some of the steam is extracted and delivered to Dralon GmbH (fibre factory) at Lingen’s South industrial estate. Customers use it to cover their heat needs in production, so that they can dispense with their own heat or power plants.

At the heart of both units are the two steam generators: the 16 gas burners per boiler reach flame temperatures of 1,350°C. They heat water which then – as steam that is 535°C hot – drives a steam turbine at a pressure of up to 185 bar. The steam flows across the turbine blades and sets the drive shaft in rotation. As in all turbines, this rotary movement drives a generator which produces the electricity, in this case with a net capacity of 355 MW.

Upstream of each steam generator there is currently one gas turbine with 55 MW. It drives a separate generator using the emerging mixture of combustion gases and air. Next, the 430°C hot and oxygen-rich combustion waste gases in the steam generator are used as combustion air to heat the water for the steam turbines. Since the gas turbines supplement the core process in this way, they are also referred to in this case as topping gas turbines. Due to the effective and environmentally-friendly combination of two different turbines, this plant type is called a combined-cycle plant.

At present, RWE Power is replacing the two gas turbines of units B and C with two new models. While the old units have an efficiency of 26 percent, the new Rolls Royce turbines reach 40 percent. The €200-million investment boosts the overall efficiency of the combined-cycle units by up to 12 percent and lowers CO₂ emissions – with unchanged power generation – by over 45,000 tons a year.
In its shape and structural principle, a power plant’s gas turbine resembles an aircraft’s jet engine: air enters at the front; in the centre it is swirled around and combusted together with fuel gas; and, at the back end, the thrust emerges that the aircraft needs.

With their high power density and ability to start up fast, gas turbines are the power packs in electricity generation: one single plant, roughly the size of an articulated lorry, can supply a city of 300,000 people with electricity, and that in the space of minutes.

The term “gas turbine” usually refers to the entire unit, which consists mainly of compressor, combustion chamber(s) and the turbine proper.

In the CCGT plant, RWE Power is deploying two turbines of the innovative type Alstom GT 26. In the front section, the compressor, outside air is sucked in and compressed by 22 blades. Owing to the rise in pressure, the air becomes hot. In the first combustion chamber, natural gas, preheated to 150°C, is admixed and fired under a pressure of 50 bar. Here, the air is conducted in such a way that the flame, at a temperature of about 1,200°C, does not come into contact with the metallic wall of the combustion chamber.

The hot, low-oxygen waste gas drives a high-pressure turbine and is swirled around with a gas-air mixture which self-ignites in the following, second combustion chamber. The 630°C-hot waste gases flow into the turbine’s low-pressure section where they drive a series of blades, thus creating the rotary movement to drive the generator. Next, they reach the HRSG’s heat exchanger where they are re-used to generate steam.

The novel feature of the Alstom GT26 is the serial or double combustion in two chambers. This increases the efficiency of gas-turbine technology without significantly raising the material-critical combustion temperatures. This ensures low emissions, both in full-load and in partial-load operations.

The Emsland natural-gas power plant benefits from its optimal link-up to the long-distance gas grid: RWE Power obtains the fuel from five different supply grids. To improve the power plant’s gas supply even further, RWE Power has additionally built a so-called gas pipe array. This subterranean line, some 15 km long and about 1.50 m thick, has been built approx. 3 km distant from the power station. It is used to stockpile fuel and can provide up to 900,000 cubic metres of natural gas.

The gas, compressed by a compressor station on the power-plant site to 100 bar, is equivalent to the amount that the power station needs for six hours of full-load operations. This enables us to offset short-term fluctuations in the electricity grid. Fuel procurement, too, on the international gas market becomes more flexible thanks to stockpiling, since price fluctuations are unable to have an unchecked effect. The gas pipe array acts as a buffer, both in terms of logistics and finances.
Our power plants at Lingen make a major contribution to the Emsland region’s economy.

They provide jobs for approx. 500 of our own employees plus numerous more among suppliers and service providers. On top of this comes versatile vocational training for young people who are being trained at the location in various commercial-technical activities.

The Lingen power plants also create important advantages for local industry. For decades now, the existing gas-fired power plants have been supplying industrial customers not only with electricity, but also and reliably with process steam. The new CCGT plant, too, has already been technically designed with this service in mind.

RWE Power has been operating a visitor centre at Lingen since 1984 and has already welcomed more than 300,000 guests.

Using modern interactive media, a permanent exhibition gives visitors comprehensive information about the power plants at the site and about energy topics.

A virtual tour of the power plant, for instance, offers insights into the way a nuclear power station works. Issues of nuclear power plant safety and the storage of used fuel assemblies are also discussed in depth.

One large exhibit in the centre of the permanent exhibition deals with Europe’s power supply now and in the future. It introduces all three energy sources (fossil fuels, nuclear energy, renewable energies) in connection with the three central aspects of energy supply: economic efficiency, security of supply and environmental protection.

Groups of visitors should book an appointment in good time using the telephone number stated, especially if they also plan to visit one of the power plants. Individual visitors are welcome at any time and need no advance booking.

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Opening hours
Mondays to Thursdays from 08.00 am - 05.00 pm
Fridays from 08.00 am - 04.00 pm
### TECHNICAL DATA:
**EMSLAND NUCLEAR POWER STATION**

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<tbody>
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<td>Gross output</td>
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<td>Net output</td>
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<tr>
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<td>Steam flow rate</td>
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<td>Condenser cooling-water flow</td>
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### Geeste reservoir

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<td>Base</td>
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<td>Maximum water level</td>
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### TECHNICAL DATA:
**EMSLAND NATURAL-GAS POWER PLANT**

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<th>Parameter</th>
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