



Nuclear power stations, safe and solid

In its power stations, Electrabel uses various technologies and sources of energy to produce electricity. This information folder tells you how a nuclear power station works, how priority is always given to safety, and what is done with the waste.

A quick look at a nuclear power station

The operating principle of a nuclear power station strongly resembles that of a conventional thermal power station fired by fossil fuels. The only thing that differs is the way heat is generated: nuclear power stations use fissile material, while conventional thermal power stations burn natural gas, coal or fuel oil.

In both cases, enough heat has to be generated to produce steam. In a nuclear power station, the heat comes from the fission process that occurs inside the reactor fuel rods. In a conventional thermal power station, a combustion process takes place inside a large steam boiler.

Electrabel's nuclear power stations are of the PWR (Pressurised Water Reactor) type. This Western design is the most common type, accounting for 65 % of all nuclear power stations around the world. In such a unit the heat from the **reactor core** is transferred to water that passes over the fuel rods in a closed circuit, known as the primary circuit. The water in the primary circuit reaches an average temperature of 300 °C. In a PWR, this water does not boil because it is kept under pressure, due to the functioning of the pressurizer.

The hot water in the primary circuit in turn gives up its heat to water in another closed circuit, the secondary circuit. Both circuits are kept separate from each other. The heat exchange occurs in a **steam generator**, a large, cylindrical heat exchanger made up of thousands of pipes. As a result of being heated the water in the secondary circuit is converted into steam.



Steam generator

The steam from the steam generators is used to drive one or more **turbines**, which convert the heat energy into mechanical energy. The turbine is in turn connected to a generator. The generator finally converts the mechanical energy into electricity, which is fed into the high-voltage grid.

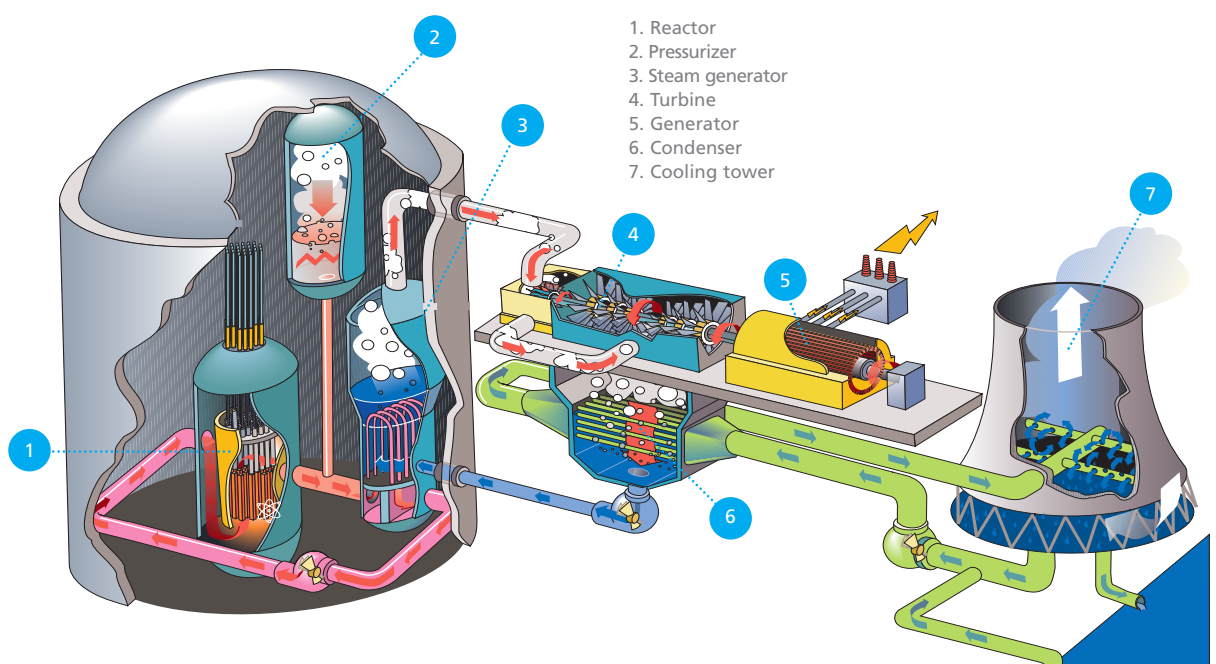
The exhaust steam from the turbines is cooled in a **condenser**,

where it is converted back into water by coming into contact with thousands of pipes in which cooling water flows from a third or tertiary circuit. The water returns to the steam generator, where it is once more heated and converted into steam.

As in large conventional thermal power stations, nuclear power stations have a **cooling tower** in which the heated cooling water is cooled by natural air circulation. In a nuclear power station the water in the tertiary circuit is used once more to cool the steam in the condenser. Only 1.5 % of this ordinary water escapes into the atmosphere, forming the characteristic vapour cloud that emerges from the cooling tower. The cooling towers in Electrabel's nuclear power stations are some 170 m in height, with a diameter of 145 m at the base and 78 m at the top.



Tihange nuclear power station



How energy is produced in the reactor

All matter is made up of atoms, in which negatively charged electrons orbit about a nucleus. The nucleus in turn is made up of positively charged protons, together with neutrons that do not carry any charge. In a nuclear reactor, energy is released by

splitting the nuclei of heavy atoms such as uranium, in a process known as fission.

Fission is provoked by bombarding the nucleus with neutrons. If a neutron hits the uranium nucleus with just the right speed, the

nucleus absorbs the neutron and then splits into two fragments. After fission has taken place, the combined mass of the particles obtained and the products of fission is slightly less than the original mass of the heavy atom and the neutron that hit it. The missing mass has been converted into energy.

Since the fission process also produces several neutrons, these in turn can provoke other fission reactions, thus producing a self-sustaining chain reaction. In a nuclear power station man regulates this chain reaction. It can be activated, stopped or directed using control rods in the reactor to slow down the chain reaction as required.



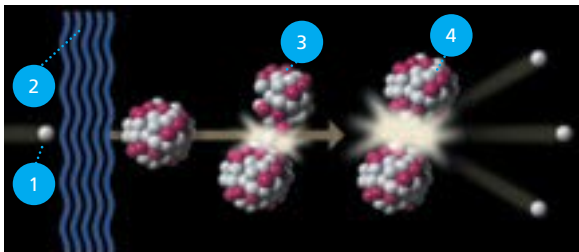
Reactor vessel reloading

Fissile material and neutrons collide, setting off a chain reaction

The fissile material forms the fuel for the nuclear power station. In most cases it consists of uranium from uranium mines. Before it can be used in a nuclear power station the uranium first has to

be enriched, i.e. concentrated. The enriched uranium is pressed into ceramic pellets that are then placed in long metal tubes, known as fuel rods. A number of fuel rods together form a fuel

assembly. It is these fuel assemblies that are placed in the core of the reactor where the fission reactions occur.



1. One neutron.
2. The water in the reactor vessel slows down or moderates the neutron, enabling it to hit the nucleus.
3. The neutron hits the nucleus of a uranium atom.
4. The resulting fission process releases energy in the form of heat and radiation. It also produces fission products and new neutrons that in turn hit other uranium nuclei. The process repeats itself over and over again, creating a chain reaction.

Safe operation, a constant priority

Safe operation guarantees protection of the operating personnel, society and the environment. It also ensures efficient operation in the long term.

Safety is the main concern right from the design stage and the construction of the installations. Electrabel's power stations are planned to be safe, specifically due to multiple safety precautions included. The vital structures are located inside a heavy concrete building, with a double containment wall. This is designed to resist various internal and external problems, including explosion, fire, flood, earthquake and certain types of aircraft crashing into it.

Day-to-day operation of the power station is in the hands of highly qualified personnel. The operators in the control room must have a special licence. This licence is awarded on the basis of intensive and specific education and training, including simulator exercises, culminating in an examination. By law it has to be renewed at regular intervals, on the basis of refresher courses, exercises and tests.



Measurement of radiation dose

Due to the complexity of the facilities, however, defects can never be excluded entirely. Any incident, no matter how small, is recorded and investigated. If necessary the nuclear power station can be shut down automatically within a second. All employees regularly practice internal and external emergency procedures.

In addition to constant internal inspections and regular overhauls, a major in-depth review of nuclear safety is required by law every ten years. Renewal of the operating permit depends on this

safety review. Checking for compliance with new regulations and international standards frequently leads to action plans to adapt the power stations and prevent obsolescence. Electrabel invests constantly and heavily to maintain the high level of safety.

Belgian nuclear power stations are also subject to inspections by outside bodies, such as the Federal Agency for Nuclear Control (FANC) and Association Vinçotte Nucléaire (AVN), the latter being a recognised, independent inspection agency. At international level the nuclear power industry is one of the most strictly regulated activities. The International Atomic Energy Agency (IAEA) and the European Atomic Energy Community (Euratom) keep watch over the safety of nuclear facilities, and make sure that the nuclear energy is used exclusively for peaceful purposes.



Control room



Reactor building

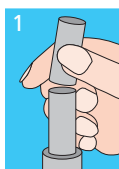
Five-fold containment for fissile material prevents the escape of radioactivity

A nuclear reaction produces not only heat but also radioactivity. Just as there exists natural radiation to which man is exposed daily, radioactive elements produce ionising radiation. Such radiation can damage living tissues, depending on its type and

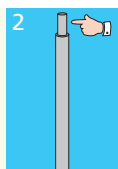
the amount of energy it contains. So all kinds of measures are taken to guard against higher levels of radiation.

A good example of this is the containment of the uranium and the fission products from the nuclear

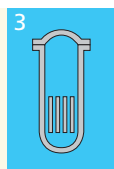
reactions. There are multiple layers of containment, to make absolutely sure that no radioactivity can escape.



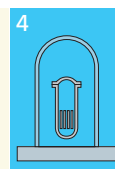
First of all, the uranium oxide is compressed into fuel pellets.



The fuel pellets in turn are kept inside fuel rods, which are hermetically welded.



The rods are bundled together to form fuel assemblies, which are housed inside the reactor vessel with its steel walls 25 cm thick.



A primary containment wall designed to resist strong inside pressure prevents any radioactivity escaping from the reactor building.



A second containment wall made of reinforced concrete protects the facilities against outside influences. A partial vacuum between the two walls prevents any radioactivity from being discharged to the outside world.

Waste management and disposal

All human activities produce waste. Whether used for industrial, scientific or medical purposes, nuclear activity also produce waste, some of which is radioactive. This contains materials that create ionising radiation in the form of alpha radiation (helium nuclei), beta radiation (electrons) or gamma radiation (electromagnetic waves). Radioactive waste accounts for about 1 % of the total amount of dangerous industrial waste produced in Belgium.

Nuclear power stations produce a fairly small amount of radioactive waste: all facilities in Belgium together produce some 500 grams per inhabitant per year. Of this amount, 15 grams is high-level waste, about the weight of one ballpoint pen per family of four per year. Thanks to continuous efforts, the quantity of radioactive waste per kWh of electricity produced has been reduced by a factor of three in the past ten years. More than 95 % of the waste is low-level waste.

There are various kinds of radioactive waste, depending on the type of radioactive material that they contain and the length of time it presents a risk. There is low-level, medium-level and high-level waste, each of which has to be

dealt with in a particular kind of way. On the other hand, radioactive waste is one of the few types of waste that eventually loses its toxicity.

In Belgium, the body responsible for central management of radioactive waste is ONDRAF/NIRAS, the National Agency for Radioactive Waste and Enriched Fissile Materials. The waste producers entrust their waste to this public institution, but remain responsible for financing the management, including current and future costs. The producers also set aside reserves for final decommissioning of the nuclear power stations.

Various ways of disposing of the radioactive waste from nuclear power stations and the use of radioactive materials in industry and medicine in Belgium are being considered. For the moment, all types of waste are stored in specially designed structures such as containers and buildings, pending a final decision. Although there are no ecological, technical or economic arguments in favour of fast, final disposal, temporary storage cannot be a permanent solution. A number of countries already have final disposal for their low-level waste. When it comes to high-level waste, no quick decision is required because,



Nuclear waste treatment



Water and waste treatment building

before final disposal, the waste will first cool down and decrease in radioactivity for about 50 years. In Belgium, the government has decided to concentrate research on two possibilities: shallow and deep burial for low-level waste, and deep burial in stable geological strata for the other types.

Did you know?

TECHNOLOGY



Doel nuclear power station

Daniel Philippe

Scaldis training centre

Raf Beckers

- Electrabel operates two nuclear power stations in Belgium: Doel with four reactors and Tihange with three. In France the company has nuclear capacity in Chooz and Tricastin. Together, these facilities represent 6 270 MW capacity, or more than a fifth of Electrabel's total generating capacity.
- The nuclear power units generate about one third of the total electricity produced by Electrabel.
- The nuclear units in Belgium came into operation between 1975 and 1985. In early 2003 a law was introduced for nuclear power in Belgium to be phased out from 2015 onwards. Under this law, the reactors must be closed down 40 years at the latest after they were first commissioned.
- Doel and Tihange have special training centres for operators, with full scope simulators that enable operators to practice not only normal operation of the power stations but also emergency situations.
- Electrabel is pressing ahead with R&D work aimed at eventually having nuclear generating capacity of the European Pressurised Water Reactor (EPR) type. The EPR is a further development of the PWR, with improvements about energy efficiency and operational flexibility. EPR units are currently being built in Finland and France.
- Electrabel achieves excellent operating results with its nuclear units year after year, demonstrating their high level of reliability. Their availability factor is 88 %, compared with a worldwide average of 83 %.

ENVIRONMENT



- When it comes to protection of the environment, Electrabel's nuclear power stations have both ISO 14001 certification and EMAS (Environmental Management and Audit Scheme) registration.
- Nuclear power does not create greenhouse gases or other emissions such as sulphur and particulates. Partly because of its use of nuclear power, Electrabel's generating facilities have one of the lowest levels in Europe of CO₂ emissions per kilowatt-hour generated. The Doel and Tihange nuclear power stations avoid 35 million tonnes of CO₂ emissions per year in Belgium.

SOCIETY



Peregrine falcon

J. Breuer

Doel Eco-bike route

Raf Beckers

- Peregrine falcons breed on top of the cooling towers of Doel and Tihange nuclear power stations. The birds use them as an alternative to building nests on high cliffs, their natural habitat.
- The warm cooling water from Tihange is used to breed indigenous and exotic fish, in particular for scientific research.
- Doel nuclear power station forms the start of a wonderful Eco-bike route through the surrounding polder landscape.

This information folder forms part of the brochure 'Electrabel – A European electricity producer', which can be ordered from www.electrabel.com

C'est avec plaisir que nous vous enverrons cette plaquette d'information en français.
Graag bezorgen wij u deze informatiefolder in het Nederlands.

You've got the energy.