Beznau nuclear power plant – reliable, environmentally compatible electricity production

Axpo – electricity for Switzerland

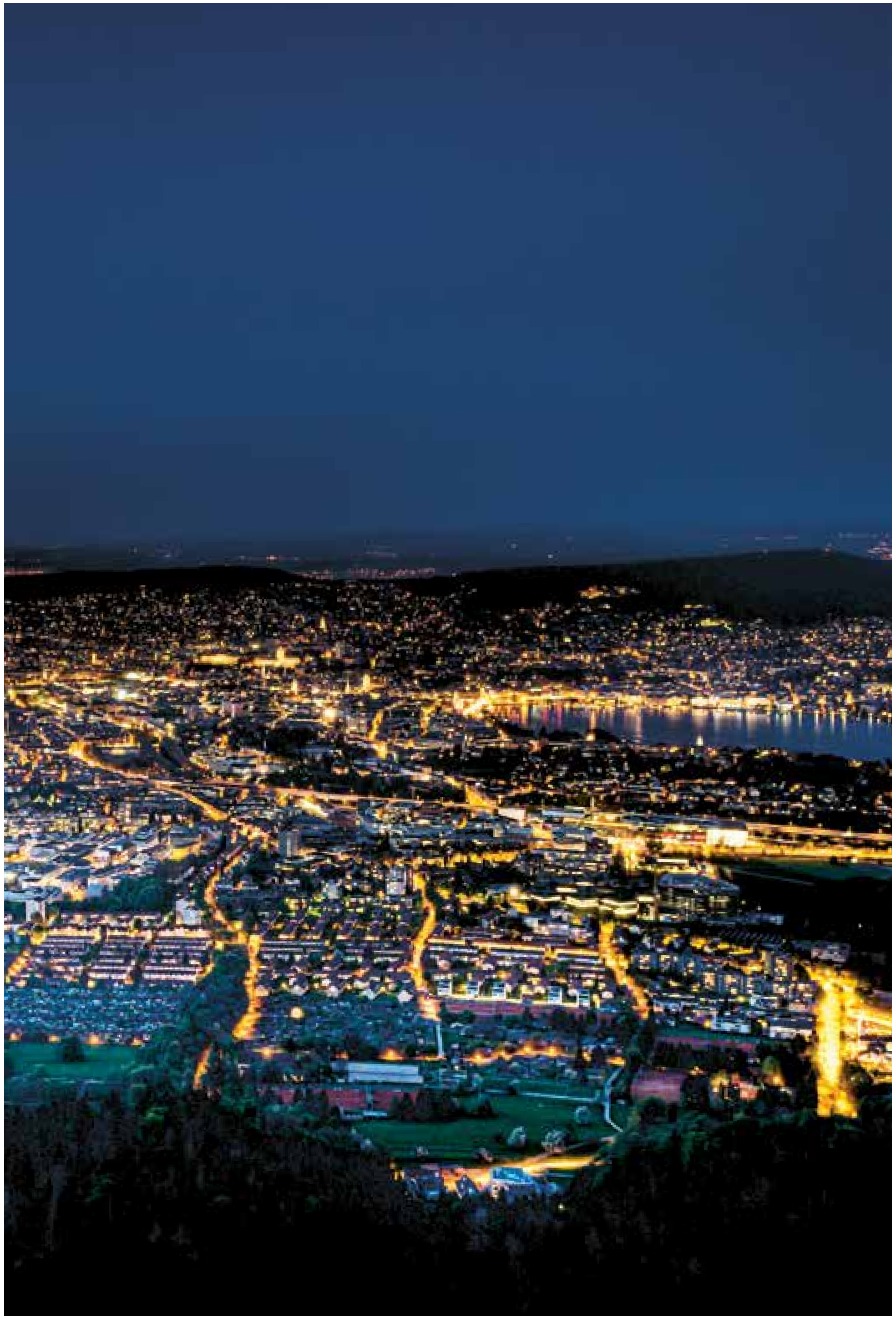
The Beznau nuclear power plant is part of Axpo's power plant park.

Nuclear power plants and run-of-river hydropower plants cover the base load electricity supply. Pumped storage power plants with their reservoirs are used to compensate fluctuations and peaks in demand.

Axpo Group produces, trades and distributes energy reliably to over 3 million people and several thousand companies in Switzerland. In addition, Axpo is present in over 30 countries in Europe. Axpo is 100 percent owned by the cantons of north-eastern Switzerland.

Some 4500 employees combine the expertise from 100 years of climate-friendly power production with innovative strength for a sustainable energy future. Axpo is an international leader in energy trading and in the development of tailored energy solutions for its customers.

In Switzerland, Axpo has an environmentally compatible power plant park with largely CO_2-free electricity production. The power plant park is optimally aligned with the requirements for reliable, environmentally friendly and cost-efficient electricity production.



Production around the clock

The Beznau nuclear power plant comprises two largely identical light water reactors (Unit 1 + 2), each with an electrical net output of 365 megawatts. They generate approximately 6000 gigawatt-hours of electricity per year. This corresponds to around twice the electricity consumption of the city of Zurich. In addition to power production, Beznau supplies hot water to REFUNA, the regional district heating network for the lower Aare Valley, and provides ancillary services for the reliable operation of the integrated grid.

Beznau NPP powerhouse

The commercial commissioning of Beznau Unit 1 took place in December 1969 after a construction period of about 48 months. Unit 2 followed in April 1972 after about four years of construction. Both units have an open-ended operating permit.

Since its commissioning the KKB has produced more than 250 000 gigawatt-hours of electricity. In comparison to the generation from a brown coal-fired power plant, about 300 million tonnes in CO_2 emissions were saved.

Important base load energy

With the exception of a few weeks each year during which refuelling or maintenance work is carried out, the power plant produces electricity around the clock. Together with the run-of-river hydroelectric plants, the nuclear power plant covers the base load electricity supply for Switzerland.

When the units are taken off line in the spring for refuelling and in summer for maintenance, electricity demand is met by domestic hydropower plants or imports.

The first nuclear power plant with an environmental declaration

Beznau is the first Swiss power plant for which an environmental declaration (EPD®, Environmental Product Declaration) has been drawn up according to ISO 14025. The key element of an environmental declaration is an ecological assessment. This makes it possible to quantify and appraise emissions into the atmosphere as well as resource utilisation over the entire electricity production process chain. In addition, biological diversity at the plant, location radiation exposure to employees, and the electro-magnetic fields are identified.

Around 450 Axpo employees and another 100 from external companies work at the nuclear power plant. A team of specialists monitors the plant in three daily shifts. In the control room, all settings, values and changes relating to all the important plant components are displayed and recorded. Deviations from defined set points are reported immediately by means of acoustic and visual signals so that the necessary measures can be taken.

The generator voltage is 15.5 kilovolts. A transformer increases the voltage to 220 kilovolts and the electricity is fed into the Swiss high voltage grid via the Beznau substation.

Turbines and generator

Electricity from kinetic energy

Nuclear power plants are thermal power stations. The heat necessary for water evaporation is not created by means of a combustion process using fossil energy sources, but rather via a controlled chain reaction in a reactor. The steam that is produced in a steam generator is routed to a turbine that drives a generator.

The generator rotor turns at 3000 revolutions per minute. At this high speed, its magnetic field generates electrical voltage. In this process the kinetic energy is converted into electrical energy.

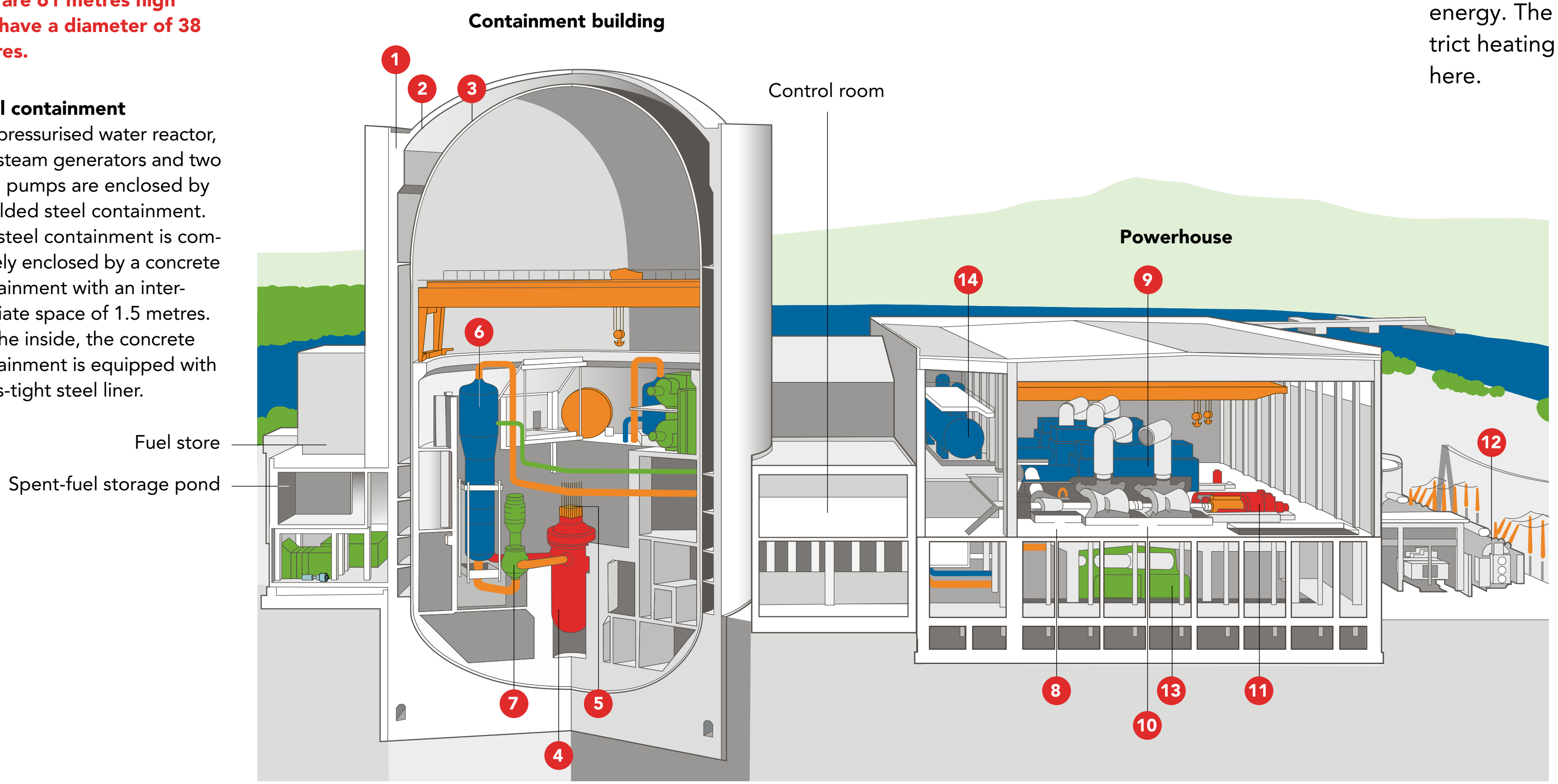
View inside the nuclear power plant

The two containment buildings are 61 metres high and have a diameter of 38 metres.

Steel containment
The pressurised water reactor, two steam generators and two main pumps are enclosed by a welded steel containment. The steel containment is completely enclosed by a concrete containment with an intermediate space of 1.5 metres. On the inside, the concrete containment is equipped with a gas-tight steel liner.

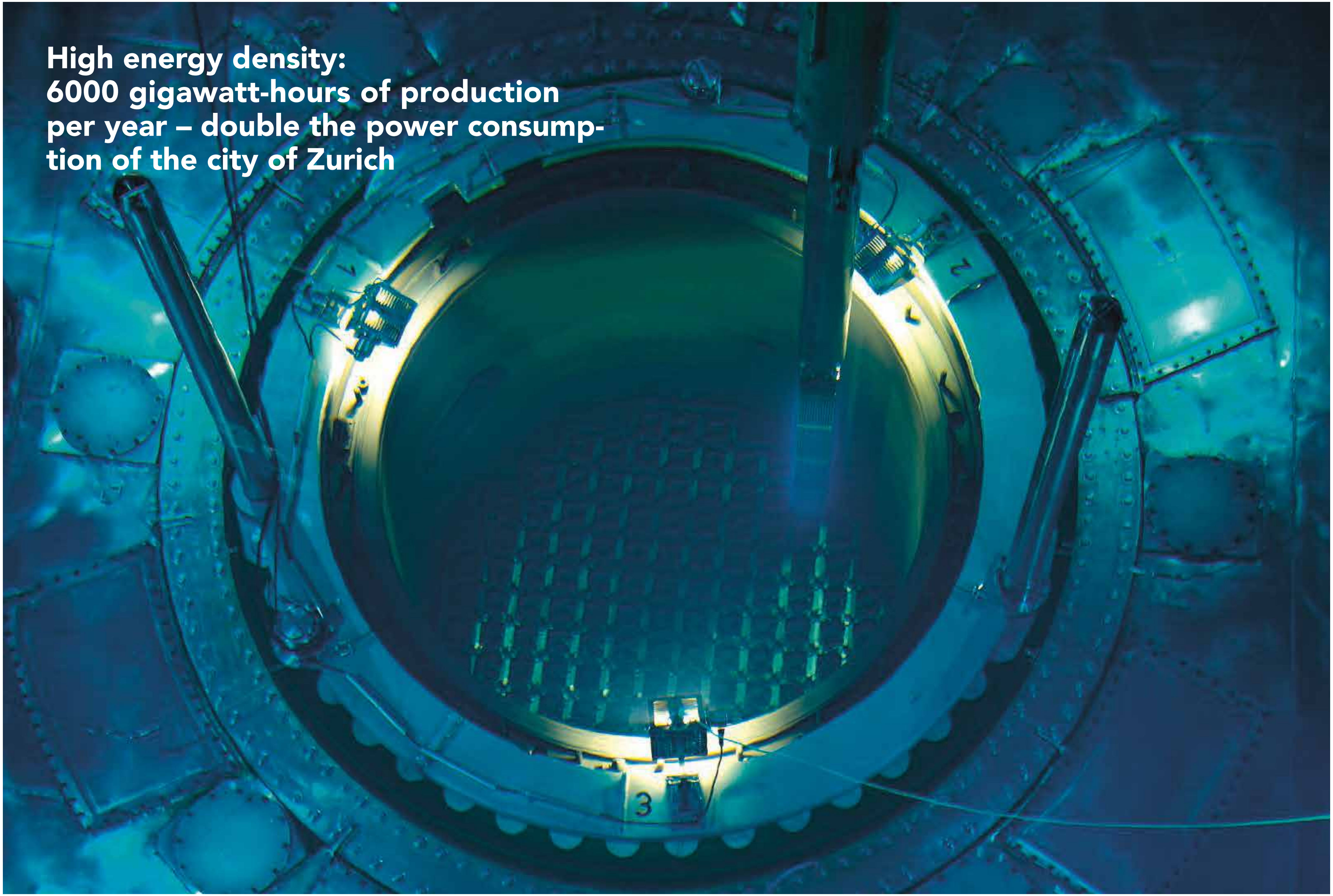
The two round containment buildings dominate the view of Beznau. The primary systems, in which steam is generated from nuclear power, are situated in these double-walled buildings.

The secondary systems and the turbine generator groups – two each per unit – are situated in the powerhouse. They first convert the generated heat into mechanical and then into electrical energy. The heat for the REFUNA district heating supply is also connected here.



1. Concrete containment
2. Steel liner
3. Steel containment shell
4. Reactor pressure vessel
5. Control rod drive
6. Steam generator
7. Reactor main coolant pump
8. High-pressure turbine
9. Moisture separator, reheater
10. Low-pressure turbines
11. Generator
12. Transformer
13. Condenser
14. Feedwater tank

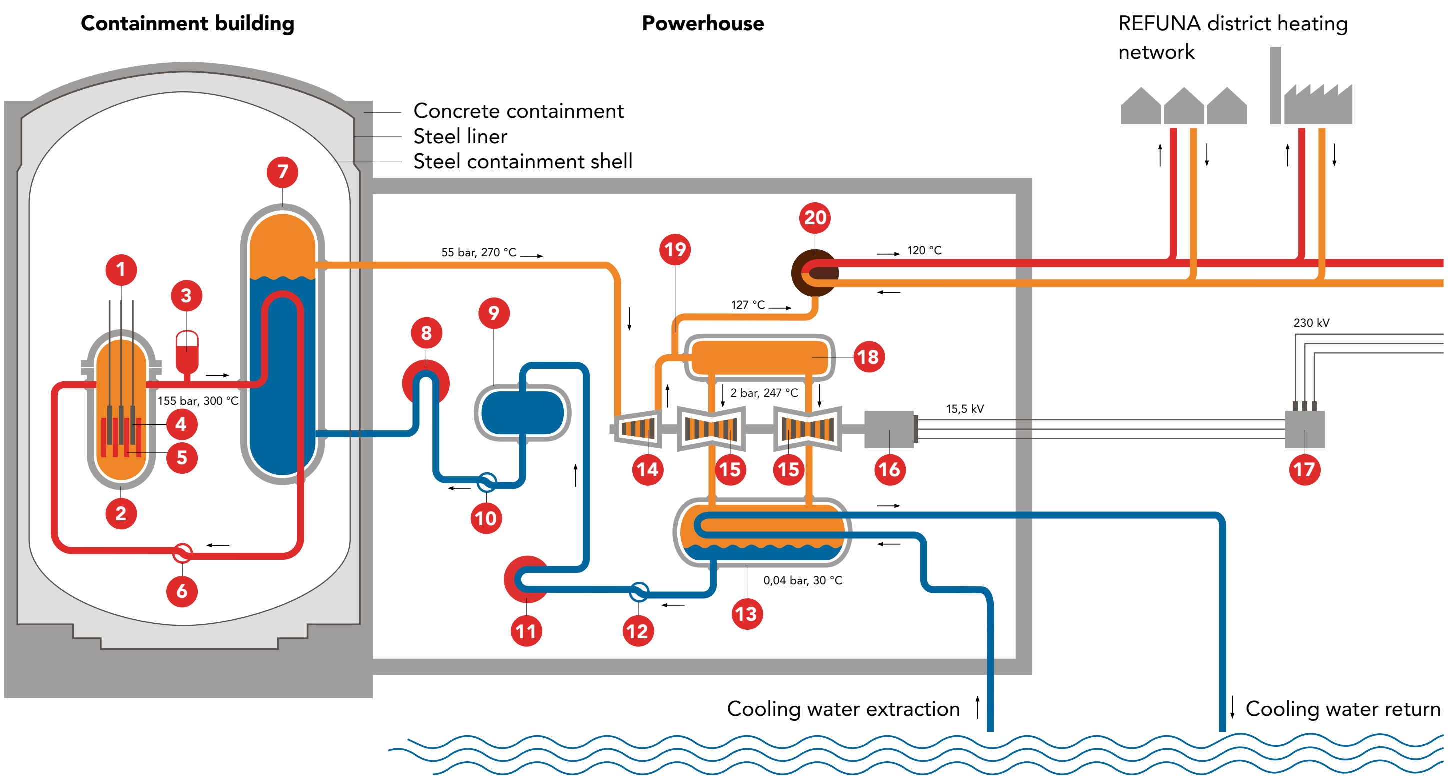
High energy density: 6000 gigawatt-hours of production per year – double the power consumption of the city of Zurich



Open reactor pressure vessel

The energy cycle

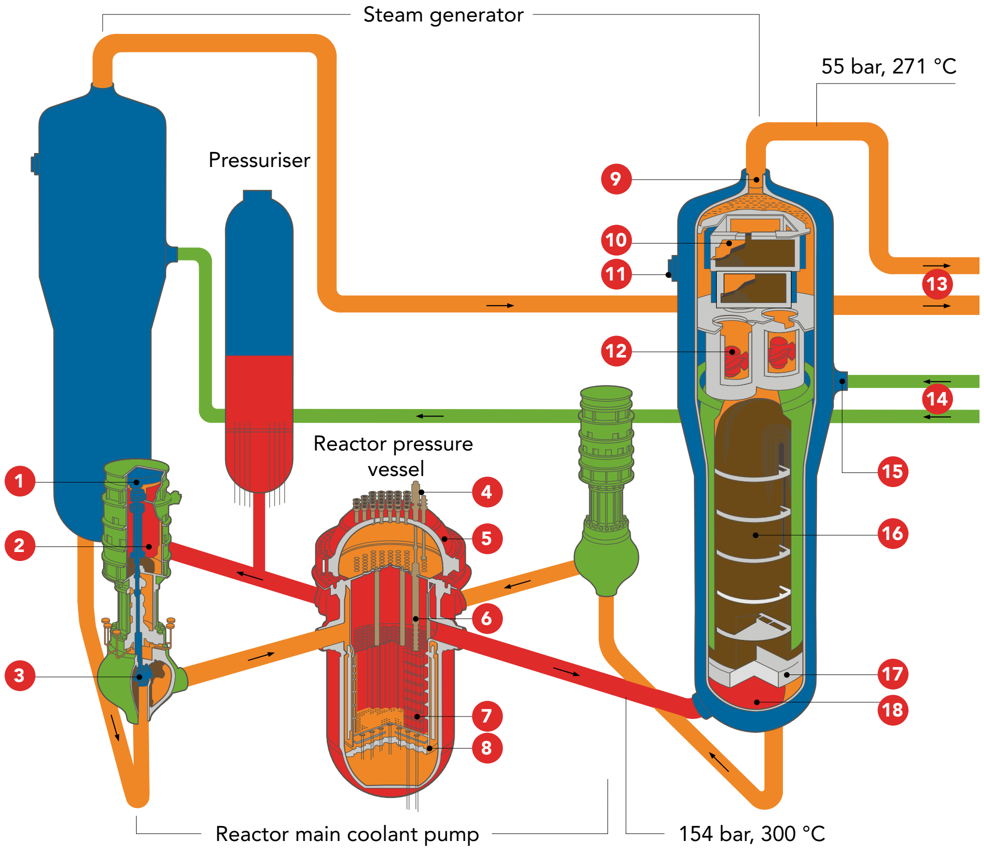
Beznau units 1 and 2 are pressurised water reactors with two separate water circulation systems. In the primary loop the water is heated under pressure by the heat of the fuel rods. Steam is generated in the secondary loop.



1. Control rod drive
2. Reactor pressure vessel
3. Pressuriser
4. Control rods
5. Fuel assemblies
6. Reactor main coolant pump
7. Steam generator
8. High-pressure feedwater heater
9. Feedwater tank
10. Feedwater pump
11. Low-pressure feedwater heater
12. Condensate pump
13. Condenser
14. High-pressure turbine
15. Low-pressure turbines
16. Generator
17. Transformer
18. Moisture separator reheater
19. REFUNA steam cogeneration
20. REFUNA heat exchanger

Steam generation

Steam is produced in the steam generators and then routed to the turbines. Pressure and temperature are lower than in the reactor.



The pressure in the primary loop is so high (154 bar) that water, which is heated by the fuel rods, cannot boil even at a core temperature of 300 °C.

Each reactor uses 121 fuel assemblies.

The secondary loop is used to generate steam. The steam under lower pressure (55 bar) drives the turbines with the connected generators.

The waste steam is converted back into water in the condenser (page 13, point 13) and is then ready for a new steam generation cycle.

1. Flywheel
2. Pump motor
3. Pump impeller
4. Control rod drive
5. Pressure vessel head
6. Control rod
7. Fuel assembly
8. Core support plate
9. Live steam outlet
10. Steam drier
11. Manhole cover
12. Water separator
13. Live steam to the turbines
14. Feedwater to steam generator
15. Feedwater inlet
16. U-tube bundle
17. Tube plate
18. Water chamber

Cooling with water from the Aare River

The two units need 40 cubic metres of cooling water per second.

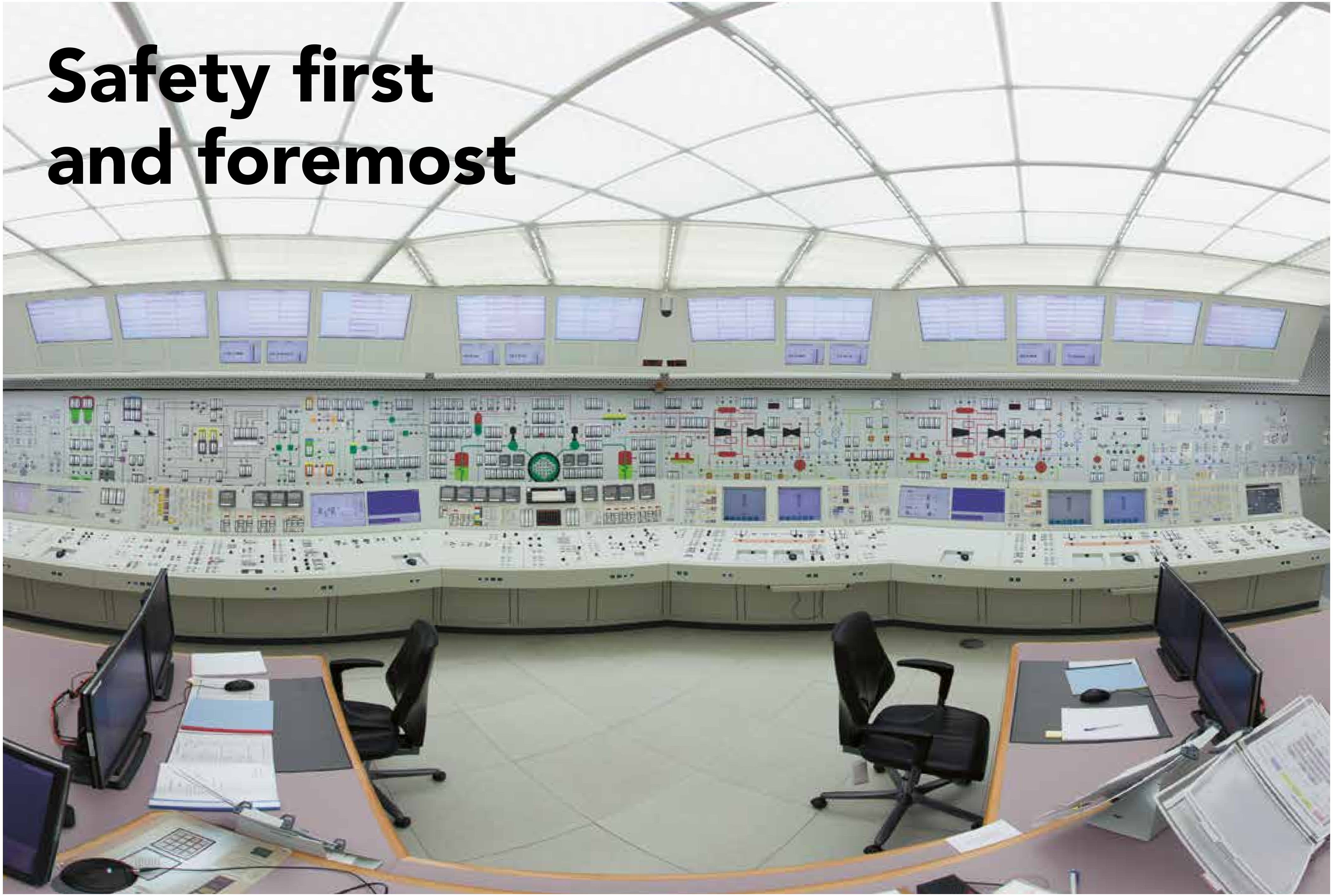
Optimal location thanks to the island situation.

The steam must be cooled down in the condensers to convert it back into water after passing through the turbines. In full-load operation, 40 cubic metres of cooling water per second are needed. This water is taken from the Aare River from the headrace channel of the Beznau hydroelectric plant.

As the drop between the headrace channel and the lower course of the Aare is 7 metres, the cooling water does not have to be transported through the condensers using pumps, as is usually the case in other nuclear power plants. In Beznau it runs naturally from the headrace channel of the hydroelectric plant to the lower Aare course. This was one of the reasons why the former NOK (Nordostschweizerische Kraftwerke, today Axpo) chose the site on Beznau Island in the 1960s.

1. Unit 1
2. Unit 2
3. Cooling water inlets in the headrace channel
4. Cooling water outlets in the natural Aare riverbed
5. Hydroelectric plant
6. Weir power plant
7. Beznau substation (connection to the electricity transmission grid)

Safety first and foremost



Operation is monitored in the control room.

Operational safety – redundancy and diversity

Operational safety is key at Beznau. This applies not only to normal operation, but also in the case of any extraordinary events. The Beznau nuclear power plant is well protected against weather impacts, earthquakes, floods and air plane crashes. Critical systems and components function independently of each other, have multiple redundancies and are spatially separated. If a system or component fails, additional systems or components are available to carry out the same function.

Several protective barriers

Radioactive products result from nuclear fission. These radioactive materials may not be released into the environment. Several barriers ensure this:

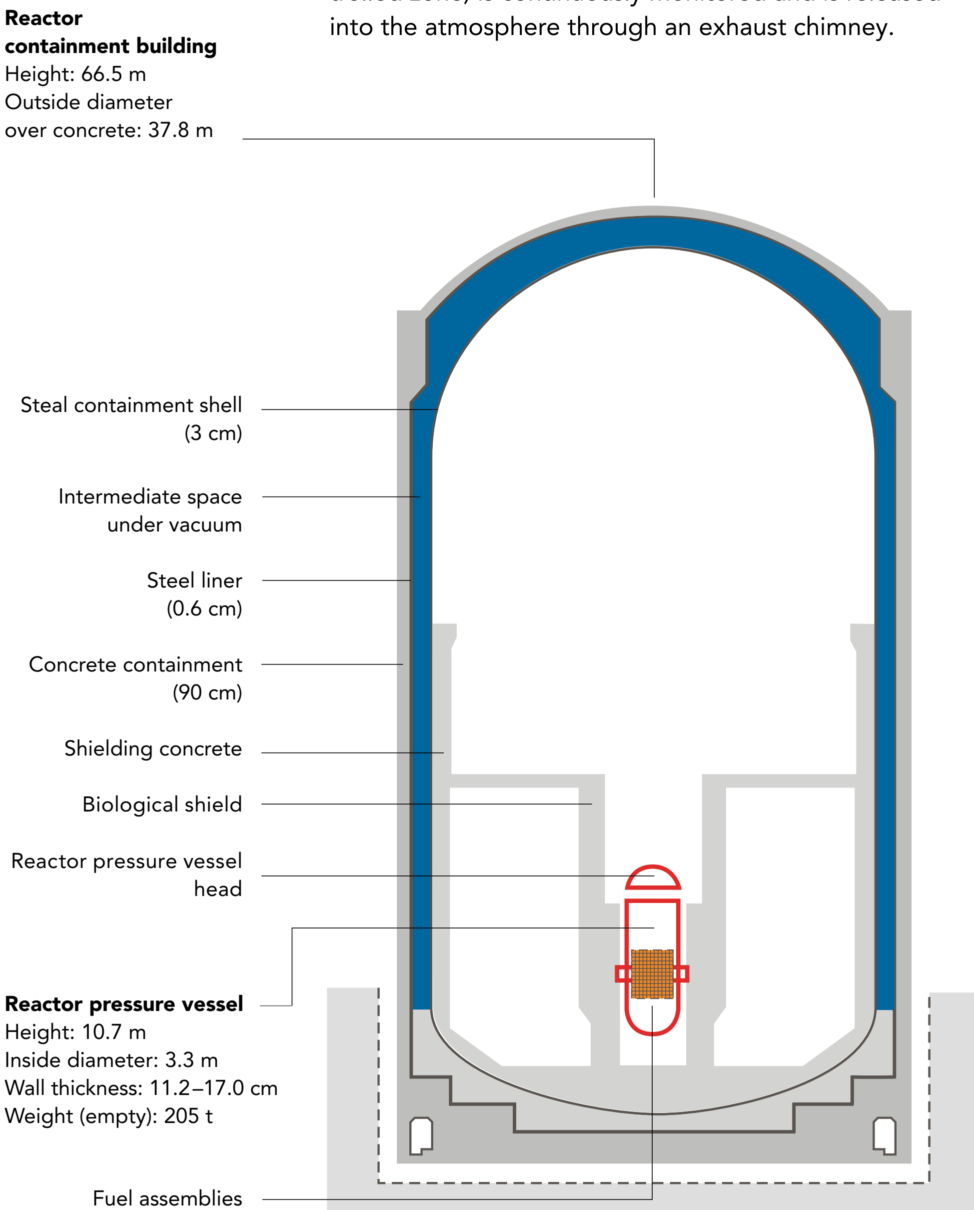
Cladding tubes	The gas-tight welded cladding tubes of the fuel assemblies prevent fission products from entering the cooling water.
Primary loop	The primary loop is enclosed in the steel containment made of 3-centimetre thick plates that have been welded gas-tight.
Containment	A steel liner seals off the inside of the concrete containment.

Radioactive radiation shielding

The 3-metre thick biological shield and the shielding concrete effectively prevent radioactive radiation from escaping.

Reactor containment building

Double-walled, steel pressure shell, exterior concrete containment with steel lining, intermediate space under vacuum. The exhaust from the interior (controlled zone) is continuously monitored and is released into the atmosphere through an exhaust chimney.



Investments in safety and reliability

The Beznau nuclear power plant fulfils all the regulatory, specified safety requirements. Through upgrades and replacements amounting to over CHF 2.5 billion since commissioning, Axpo has ensured that the plant complies with state-of-the-art technology and the required safety standards.

Axpo plans to operate the plant as long as it is safe and economical. With the operation of Beznau, Axpo makes a substantial contribution to electricity supply in Switzerland and the realisation of the Federal Energy Strategy.

1993/99

Replacement of steam generators in both units:
The preventative replacement of the steam generators reduces the risk of an unscheduled outage.

2015

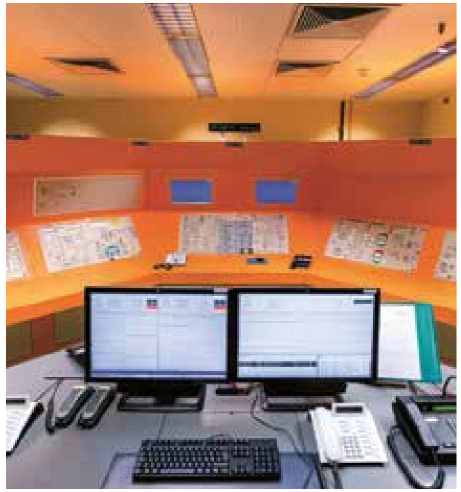
Preventive replacement of the reactor pressure vessel heads based on experience from abroad.

1993

Realisation of the NANO emergency system. NANO returns the plant to stable, safe operation after a malfunction of the control centre or the primary existing safety systems.

2015

Autarkic, bunkered, earth-quake- and flood-proof emergency power supply: 4 diesel engines with an out-put of 3750 kW each, which corresponds to 400 percent of the power needed in the event of a malfunction.



2015

Commissioning of a new plant information system: State-of-the-art hardware and software solutions process thousands of signals per unit in order to ensure seamless monitoring and recording of the operating history.

There's a great deal of energy in uranium

Uranium is the raw material used to operate nuclear power plants. It is a metal that can be found nearly everywhere on earth and in great quantities in the ocean.

How long will uranium reserves last?
The known, economically mineable uranium reserves are sufficient for the next 60 years at current usage levels in existing nuclear power plants. Actual uranium reserves are substantially higher if other mining forms are used. This includes the extraction of uranium from phosphates or seawater, two proven approaches. In these conditions, reserves would last for many centuries or even millennia. Other factors include technological development of the reactors to ensure better utilisation of the fuel as well as reprocessing.

Uranium costs amount to only 5 to 10 percent of electricity generation costs.

Two fuel pellets can supply electricity for a four-person household for one year.

High energy content
One metric tonne of ore yields on average approximately 1 to 5 kilos of natural uranium. Uranium's energy content is high – one metric tonne can generate the same amount of energy as 16 000 tonnes of hard coal. This makes the development of deposits with a relatively low uranium content profitable.

Only uranium 235, which is present in natural uranium in a concentration of 0.7 percent, is fissile in light water reactors. The remainder consists of non-fissile uranium 238. For the operation of nuclear reactors, the proportion of fissile uranium 235 must be increased from 0.7 percent to 3 to 5 percent, i.e. it must be enriched. Once extracted the ore is crushed. The uranium is leached from the ore using acid and subsequently processed into uranium concentrate (U_3O_8). The next processing step is the conversion of the uranium concentrate into gaseous uranium hexafluoride (UF_6).

The uranium concentrate is also referred to as "yellowcake" owing to its yellowish colour.

From enrichment to fuel assembly
Gas centrifuges are primarily used for the next refining step. After enrichment, the uranium hexafluoride is converted into powdered uranium dioxide (UO_2), then pressed into pellets and sintered at approx. 1700 °C, i.e. transformed into ceramic material. The pellets are loaded into zirconium tubes to manufacture fuel rods.

The fuel rods are welded gas-tight, grouped into assemblies of different sizes depending on the type of power plant and, after extensive outgoing inspection by Axpo as the operator, delivered to the power plant. They can be used to produce energy without further processing.

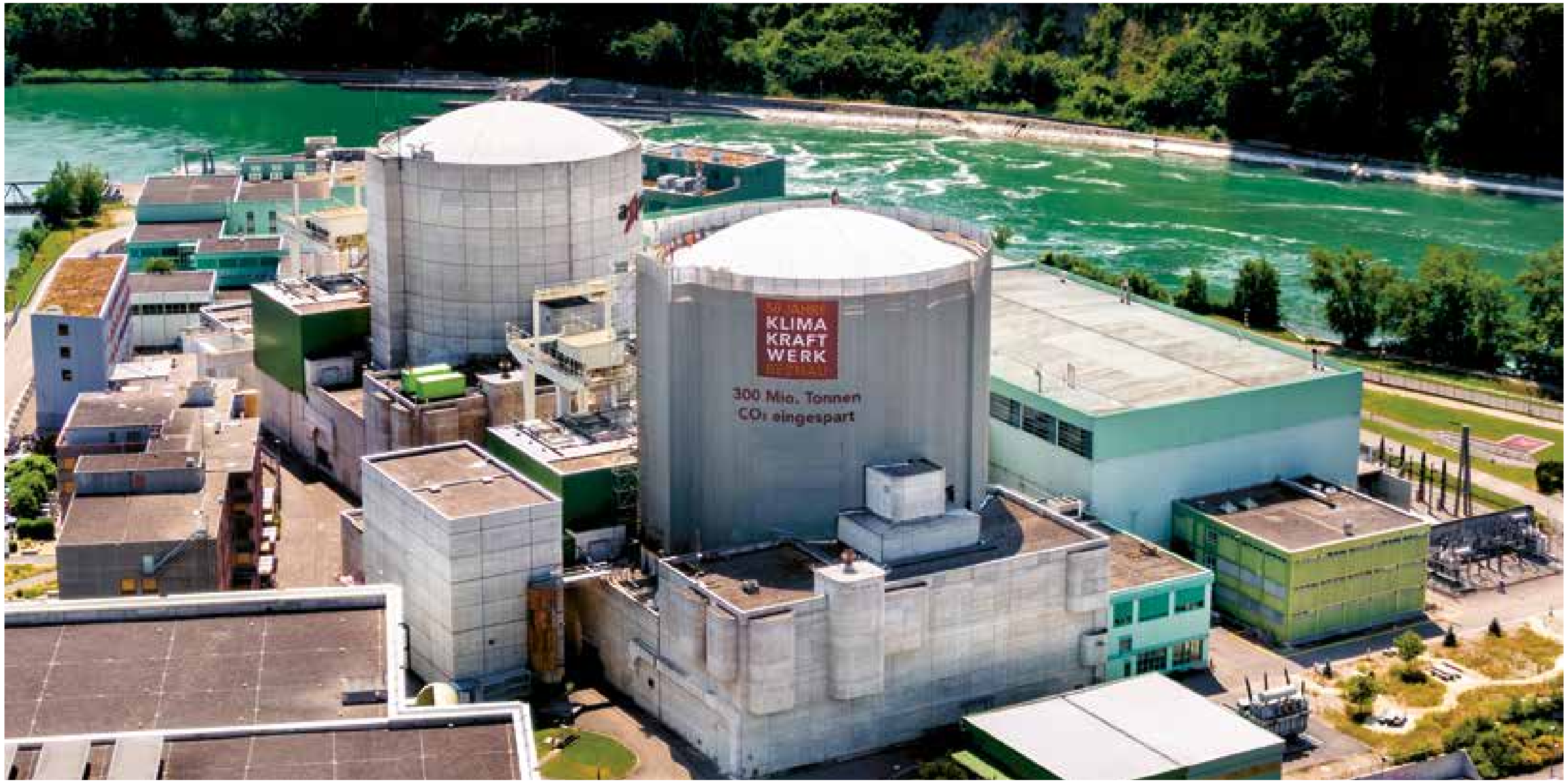
Careful waste handling

Waste with various levels of radioactivity is produced at the Beznau nuclear power plant. 99 percent of the radioactivity remains in the irradiated fuel assemblies, which are stored in the water-cooled spent-fuel storage pool for at least six months. They are then removed to storage containers and taken to the interim storage facility at the Beznau nuclear power plant.

Zwilag		Zwibez	
Combustible material Preservatives, cleaning products, etc.	**Fusible objects** Pumps, valves, pipes, insulation material, etc.	**Waste water** From operation, laboratory, showers, laundry, etc.	**Ion-exchange resins** From chemical water purification
Incineration in the incineration and melting plant at Zwilag	Melting down in the incineration and melting plant at Zwilag	Cleaning with chemical precipitation, centrifuging, micro-filtration	Solidified with synthetic polymer, placed in canisters
Ash solidified with glass in moulds, placed in canisters	Melt solidified in moulds, placed in canisters	Residues (sludge) solidified with concrete, placed in canisters	
Each year the operation of the Beznau nuclear power plant produces approximately one hundred 200-litre canisters of solidified low-level residues amounting to a volume of around 20 cubic metres			
They are placed in interim storage in the geological repositories at Zwilag until they are transported away		They are placed in interim storage in the geological repositories at Zwibez until they are transported away	

Two types of storage
In the Beznau nuclear power plant interim storage facility low-level waste is stored before it is transported to the geological repository. Solid radioactive nuclear waste is taken to the central interim storage facility in Würenlingen (Zwilag), where it is incinerated in the high-performance plasma burner at high temperatures or melted down. This process significantly reduces the volume and improves final disposability through vitrification.

Zwilag		Zwibez
Intermediate-level waste from reprocessing in FR and GB	**High-level waste from reprocessing in FR and GB**	**Spent-fuel assemblies**
Intermediate-level residues are vitrified and placed in special containers (180-litre moulds)	Highly radioactive residues are vitrified and placed in special containers	At least six months' storage in water-filled spent-fuel storage pond, then reloaded into special containers
The return of material to Zwilag for interim storage was completed in 2016		Transport to Zwibez for interim storage
Up until the ban on reprocessing 206 moulds were produced	Up until the ban on reprocessing 8 special containers were produced	Each year isolated special containers are produced from the operation of the Beznau nuclear power plant
They are placed in interim storage in the geological repositories at Zwilag until they are transported away		They are placed in interim storage in the geological repositories at Zwibez until they are transported away



A technical solution for the decommissioning of nuclear facilities has been found. Worldwide, over 110 commercially operated plants have been decommissioned.

Costs
Financing decommissioning and disposal is comprehensively regulated and ensured in Switzerland. Nuclear plant operators bear all the costs involved in decommissioning and waste disposal.

Decommissioning, dismantling and disposal

Axpo plans to continue operating the two Beznau units as long it is safe and economical to do so. The continued operation of the plant depends on technical as well as regulatory and political framework conditions and the market environment. Axpo is preparing for the future decommissioning process early on and pro-actively. An appropriate project was launched in the summer of 2016.

Decommissioning begins after the definite suspension of power operation followed by nuclear dismantling after the fuel assemblies have been removed from the plant. The plant will be decommissioned in steps until all the radioactive material has been removed from the units and the Swiss Federal Nuclear Safety Inspectorate (ENSI) has confirmed that the plant is no longer a radiological source. The power plant site will be used for other purposes following decommissioning. The entire decommissioning and dismantling process will take about 15 years.

District heating for the region

REFUNA (Regionale Fernwärme Unteres Aaretal) supplies industry, trade and residents of 11 municipalities in the region with heat from the Beznau nuclear power plant.

Thanks to district heating, some 12 000 tonnes of fuel oil and approx. 45 000 tonnes of CO_2 can be saved annually.

The nuclear power plant has been supplying REFUNA with inexpensive energy for over 30 years. In turn, REFUNA delivers an average of about 170 gigawatt-hours of thermal energy per year to over 2600 customers.

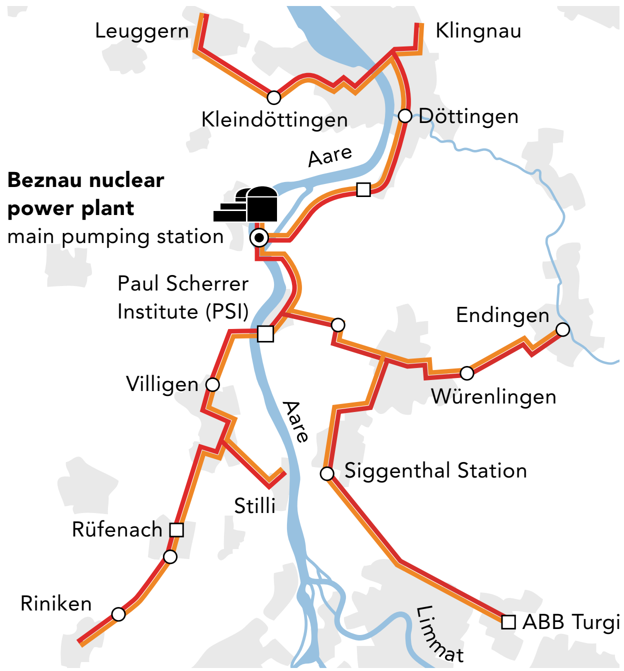
REFUNA pipe bridge over the Aare canal

In winter 1983/84 the Paul Scherrer Institute (PSI) was connected to the environmentally compatible heating system. The first private customer followed a year later. Today, the length of the main network is 31 km and that of the local network 103 km.

During heat extraction the power station's electrical output decreases by up to 7.5 MW.

Heat extraction takes place between the high- and low-pressure sections of the turbine where steam at a temperature of 127 °C is extracted and routed to the heat exchanger. There, the heat contained in the steam is transferred to the district heating network, where the water is heated up to 120 °C in the process. Since each of the two power plants has a heat extraction system of this kind, district heating is available at all times, even during scheduled outages.

The main lines are 31 km long, and the local lines are 103 km long.



Experience the nuclear power plant

Standing in the middle of the powerhouse or watching the monitors in the control room: Experience how CO_2-friendly electricity is generated from nuclear power.

Beznau nuclear power plant tours
Visitor groups can tour Beznau NPP with an experienced guide.
Please contact Axpo Power Visitor Services.

Group tours
Monday to Friday, 9:45 – 11:45 a.m. / 1:45 – 3:45 p.m.
Groups of 6 or more, minimum age 12 years. Tours are free.

Public tours
Public tours on certain dates with prior notification.

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Registration
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