Nuclear Power Plant Beznau

Reliable, environmentally compatible electricity production
Axpo – electricity for Switzerland

Axpo has an environmentally compatible pool of power plants with largely CO₂-free electricity production. Nuclear power plants, river-based hydroelectric plants and biomass power plants cover the base load of the electricity supply. High-pressure pumped storage power plants with their reservoirs are used to compensate fluctuations and peaks in demand. This pool of power plants is perfectly aligned with the requirements of safe and cost-efficient electricity production.
Electricity production around the clock

Nuclear Power Plant Beznau comprises two largely identical plants, Unit 1 and Unit 2, each with an output of 365 megawatts (MW). Both plants are designed for 8000 full-load hours or approximately 355 days a year. Together they generate approximately 6000 gigawatt-hours (GWh) a year. This corresponds to around twice the electricity consumption of the city of Zurich.

First nuclear power plant with environmental product declaration
Nuclear Power Plant Beznau is the first power plant in Switzerland for which an EPD®, Environmental Product Declaration, has been drawn up in accordance with ISO 14025. The key feature of the environmental product declaration is a life cycle assessment. It enables the quantification and estimation of emissions into the environment and also of the utilization of resources along the entire process chain of electricity production. As further environmental information, a survey was made of biodiversity in the area around the nuclear power plant, radiation exposure of the staff and the electromagnetic fields.

Together with the run-of-river hydroelectric plants, Nuclear Power Plant Beznau is thus one of Switzerland’s most environmentally compatible power plants.

Vital base load capacity
Apart from a few weeks each year during which refueling, maintenance and annual inspections take place, the nuclear power plant produces electricity around the clock. Nuclear power and river-based hydroelectric plants cover the base load of the electricity supply. When the system goes offline each summer for maintenance, the electricity demand can be met by the hydroelectric plants.

Over 500 people work at the nuclear power plants. The plants are monitored by a team of specialized operating staff working in a three-shift pattern. In the control room, the settings, values and changes relating to all components are indicated and displayed. The slightest deviations from the defined set points are announced immediately, both acoustically and visually, so that the correct precautions can be taken.

Containment building of Nuclear Power Plant Beznau.
Nuclear power plants are basically steam power plants. The heat necessary for evaporation of the water is not, however, the result of a combustion process but is obtained in a nuclear reactor. The steam is routed to a turbine that drives a generator. In the process, the rotor of the generator turns on the same shaft as the turbine, at 3000 revolutions per minute. At this high speed, its magnetic field generates an electrical voltage in the windings of the fixed stator. As a result, the kinetic energy is converted into electrical energy in exactly the same way as in a bicycle dynamo. The generator voltage is 15.5 kilovolts (kV). It is increased to 220 kV by a transformer and thus rendered transportable. The electricity is ultimately delivered to the high-voltage grid via a switching station.
Machine hall with turbines and generator.
The two round containment buildings dominate the image of Nuclear Power Plant Beznau. The primary systems, in which steam is generated from nuclear power, are situated in these double-walled buildings with a height of 67.5 m and a diameter of 38 m. They are surrounded by a gas-tight welded steel containment (3). It is 30 mm thick. The steel containment is completely enclosed by a concrete containment (1), which is 90 cm thick, with an intermediate space of 1.5 m. The concrete containment has on the inside a gas-tight steel liner (2), which is 6 mm thick. The air from the cavity is sucked into the interior of the steel liner where a vacuum is created. This prevents air – and radioactivity – from accidentally escaping to the outside. Accommodated in the machine hall are the secondary systems and the turbine generator assemblies, which first convert the heat generated into mechanical energy and then into electrical energy. The heat for the Refuna district heating supply is also taken off here.
The energy cycle

View into the open reactor pressure vessel.
The two units at Nuclear Power Plant Beznau are equipped with pressurized water reactors, i.e. they have two separate water circulation systems. The pressurizer system ensures such a high pressure in the primary loop that the water in the core cannot boil, despite a temperature of 312°C. In the steam generators, the water in the primary loop releases the absorbed heat to the secondary loop. The steam produced by the low pressure drives turbines connected to steam generators. In the condenser, the steam is converted back into water – ready for another cycle of steam generation.
The steam must be cooled down in the condensers to convert it back into water after passing through the turbines. In full-load operation this means taking 40 m³ of cooling water per second from the River Aare. As the drop between the headrace channel and the lower course of the Aare is 6 m, the cooling water does not need to be conveyed through the condensers using pumps, as is usual in other nuclear power plants. In Beznau it runs naturally from the headrace channel of the hydroelectric power plant to the Aare riverbed further down. This was one of the reasons why the site on Beznau Island was chosen at the time.
Following pages: In the control room, electricity production is monitored continuously.
Safety first and foremost

For Axpo, safety takes top priority. Nuclear Power Plant Beznau is protected against earthquakes, floods, and airplane crashes. Critical systems and sections of buildings function independently, have multiple redundancies built in and are spatially separated. In addition, Nuclear Power Plant Beznau invests in safety technology and replacement on an ongoing basis.

Six barriers
Radioactive products are created during nuclear fission. These highly radioactive materials may not escape into the environment. Several barriers ensure that this cannot happen:
- The fission products are virtually unable to leave the microstructure of the hard sintered fuel pellets.
- The gas-tight welded cladding tubes of the fuel assemblies prevent fission products from escaping into the cooling water.
- The fuel assemblies are enclosed in the reactor pressure vessel and water circulates around them. This remains in the enclosed primary loop.
- The entire primary loop is encased inside the steel containment made of 30 mm thick steel plates that are welded gas-tight.
- The vacuum in the space between the steel containment and the concrete containment prevents radioactive gases from escaping.
- A steel liner seals off the inside of the concrete containment.

Shielding of the radioactive radiation
The 3 m thick biological shield and the shielding concrete effectively prevent the escape of radioactive radiation. The concrete containment has a wall thickness of 90 cm.

Operational safety
Maximum attention is paid to operational safety – not just during normal operation but also in the event of any extraordinary events, such as unforeseeable defects in plant components. For this reason, the most important plant components, such as controllers and alarm releasers, are present in duplicate or in multiple form. If one fails, there is always a second or a third available that can perform the same function.
Double-walled containment building
67.5 m high, 38 m outer diameter

Steel containment (3 cm)
Intermediate space with vacuum
Steel liner (0.6 cm)
Concrete containment (90 cm)
Shielding concrete

Biological shield
Fuel pellets
Cladding tube
Reactor pressure vessel
Fuel assemblies
How long will uranium reserves last?
Uranium is the raw material that fuels today’s nuclear power plants. It is a metal found nearly everywhere in terrestrial volcanic rocks and in substantial quantities in the oceans. The globally known uranium reserves, which can be mined economically for a price of 130 US dollars per kilo, are sufficient for the next 100 years at current usage levels. Actual uranium reserves are substantially higher. A rise in market prices would make it worthwhile to develop new deposits or use new means of extraction. The available alternatives include extracting uranium from phosphates or seawater, two approaches that have already been proved. Under these conditions, reserves should last for many centuries or even millennia. Recycling of nuclear fuel by means of reprocessing and increasingly enhanced utilization of the fuel in reactor operation are reducing the consumption of fresh uranium and thus significantly extending the ranges referred to. Even a rise in price could be absorbed since uranium costs amount to only 5 to 10 percent of the cost of generating electricity in a nuclear power plant.

Higher energy content
One metric tonne of ore yields on average approximately 1 to 5 kilos of natural uranium. The uranium’s high energy content – one metric tonne of uranium can generate the same amount of energy as 10,000 metric tonnes of crude oil – even makes it profitable to develop deposits with a relatively low uranium content. Natural uranium consists mainly of a mixture of two atoms that differ merely in their physical properties. 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 nonfissile uranium 238. To be able to operate 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 (U₃O₈). This is also referred to as “yellow cake” because of its yellowish color. The next processing step is conversion of the uranium concentrate into gaseous uranium hexafluoride (UF₆).
Two fuel pellets of uranium dioxide (UO$_2$) will supply electricity for a four-person household for one year.

From enrichment to fuel assembly
Gas centrifuges are used primarily for the next refining step – enrichment. After enrichment, the uranium hexafluoride is converted into powdered uranium dioxide (UO$_2$), pressed into pellets and sintered at 1700°C, i.e. transformed into ceramic material. To manufacture fuel rods, the pellets are loaded into zirconium tubes. The fuel rods are welded gas-tight, grouped into assemblies of different sizes depending on the type of power plant and, after a rigorous outgoing inspection by a plant representative, delivered to the power plant. There they can be used to produce energy without further processing.

Two fuel pellets of uranium dioxide (UO$_2$) will supply electricity for a four-person household for one year.
At Nuclear Power Plant Beznau waste is produced with varying levels of radioactivity. 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 of Nuclear Power Plant Beznau (Zwibez). Here low-level waste is stored before being carted away to a geological repository. Solid radioactive nuclear waste is transported to the central interim storage facility in Würenlingen (Zwilag) where it is incinerated or melted down. This process reduces the volume and improves final disposability through vitrification.
<table>
<thead>
<tr>
<th>Wastewater</th>
<th>Ion-exchange resins</th>
<th>Combustible material</th>
<th>Fusible objects</th>
<th>Spent-fuel assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td>From operation, laboratory, showers, laundry etc.</td>
<td>From chemical water purification</td>
<td>Preservatives, cleaning materials etc.</td>
<td>Pumps, valves, pipes, insulating materials etc.</td>
<td>At least six months’ storage in the water-filled spent-fuel storage pool</td>
</tr>
<tr>
<td>Cleaning with chemical precipitation, centrifuging, microfiltration</td>
<td>Solidified with synthetic polymer, placed into canisters</td>
<td>Incineration in the incineration and melting plant in Zwilag</td>
<td>Melting down in the incineration and melting plant in Zwilag</td>
<td>Transport to the Zwibez for interim storage</td>
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<td>Residue (sludge) solidified with concrete, placed into canisters</td>
<td>Ash solidified with glass in molds, placed into canisters</td>
<td>Melt solidified in molds, placed into canisters</td>
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Each year the operation of NPP Beznau produces approximately one hundred 200-liter canisters of solidified low-level residues amounting to a volume of around 20 m³. They are carted away to geological repositories in NPP Beznau or put into interim storage in Zwilag.

Highly radioactive residues are vitrified and placed in special flasks – around 1.5 m³ per year from NPP Beznau.
The Regionale Fernwärme Unteres Aaretal (Refuna) supplies 11 municipalities in the region and around 15,000 residents with heat from the Nuclear Power Plant Beznau. The connected load in 2010/11 was approximately 81 MW. This means that 12,000 tonnes of fuel oil can be saved annually. In winter 1983/84 the Paul Scherrer Institute (PSI) was connected to the environmentally compatible heating system. The first private customers followed a year later. Today, the length of the main network is 31 km and that of the local network 103 km.

Heat is extracted between the high- and low-pressure section of the turbine where steam with a temperature of 127°C is extracted and routed to a heat exchanger. There, the heat contained in the steam is transferred to the district heating network, whose water heats up in the process to 120°C. As each of the two power plants has such a heat extraction system, district heating is available at all times, including during the annual inspection. The power station’s electrical output decreases by up to 7.5 MW during heat extraction.
Visitor Center
Axpo | Axporama
Schlossweg 16 | CH-5315 Böttstein
T +41 56 250 00 31 | F +41 56 250 00 35
axporama@axpo.com
www.axpo.com/erleben

Axporama opening times
Monday to Friday 9 a.m. – 5 p.m.
Saturday, Sunday, holidays 11 a.m. – 5 p.m.

Unrestricted viewing for individuals and families. Free entry. Guided tours for booked groups are also possible outside the opening hours. Please contact the center in good time.

Plant tour of Nuclear Power Plant Beznau
Visitor groups may tour NPP Beznau with an experienced guide. Please contact the Axporama visitor center if you are interested. Your application should be made at least two weeks prior to the desired date.
The Axporama visitor center is situated close to NPP Beznau. The exhibition offers an exciting insight into the world of energy and provides extensive information about the energy mix of Axpo.