Olkiluoto 3 Basic Facts

Operating Principle, Operation, Safety

Front cover photo: AREVA

Contents

FOR THE READER

The purpose of this brochure, Olkiluoto 3 Basic Facts, is to provide everyone interested in the plant unit with some basic information on how the unit functions and is operated and to describe how TVO operates as a company. The brochure also includes information about nuclear safety and environmental issues. If you wish to learn more in-depth technical details about OL3, the Nuclear Power Plant Unit Olkiluoto 3 brochure can be ordered and downloaded free of charge – just like this brochure – at the TVO website at ***www.tvo.fi.***

The production of TVO's existing nuclear power plant units, Olkiluoto 1 and 2, covers about one sixth of all electricity consumed in Finland. Half of the electricity produced at Olkiluoto is consumed by Finnish industry and the other half by the rest of society, such as households and the public sector.

TVO – a World-Class Nuclear Power Company

Teollisuuden Voima Oyj (TVO) is a privately owned company, founded in 1969, which produces electricity for its owners at cost price. TVO is the owner and operator of the nuclear power plant units Olkiluoto 1 and 2. At the moment, the company is also building a third power plant unit, Olkiluoto 3 (OL3), and has submitted an application to the Government for a decision-in-principle for a fourth unit.

TVO employs about 800 people. Because of the low personnel turnover, many current employees have over 30 years of experience in operating and maintaining a nuclear power plant, which has benefited TVO in the construction of OL3 unit. Maintaining and further developing personnel's expertise are important things for TVO.

Continuous improvement and proactivity belong to TVO's values, as even good things can always be improved and prediction helps to prevent disturbances. Sound nuclear power expertise and the operation, development and modernisation of plant units have helped improve safety, production capacity and economic efficiency of the Olkiluoto plant.

The most important resource for TVO's success is the competence and experience of the company's 800 experts.

Top Results in International Comparison

Since the early 1990s, the capacity factors for Olkiluoto plant units have been between 93% and 98%. For a long time, they have dominated the top positions in international comparisons. High capacity factors are possible through careful, predictive planning for outages and modifications. They testify not only to TVO's high level of nuclear expertise, but also to the reliable operation of the plant units. Radiation doses to the personnel at the Olkiluoto plant are low in international comparison.

TVO's Corporate Way

TVO's vision is to be a world-class nuclear power company, highly valued by the Finnish society. The ways to achieve this are responsibility, proactivity, transparency, following the principle of continuous improvement and working in good co-operation with various interest groups.

The cornerstone of all actions is a high-standard quality and safety culture: safety, and anything affecting it, is always put before financial objectives when decisions are made.

TVO's mission is to produce electricity for its shareholders safely, reliably, economically, and in an environmentally sustainable way. These principles are also followed at OL3 already at the construction phase.

OL3 Responds to the Growing Electricity Demand

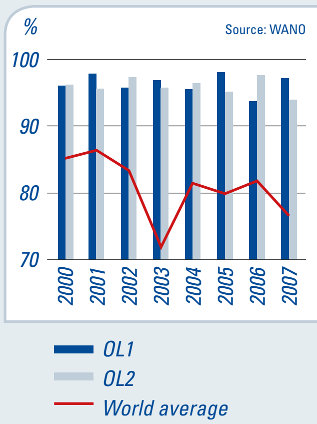
Nuclear energy is an emission-free, economical way to produce electricity. Partly due to increasing electricity consumption, in May 2002 the Finnish Parliament decided by votes 107 to 92 that it is in line with the overall good of the Finnish society to add nuclear power capacity.

Licence to construct the fifth Finnish plant unit was granted to TVO which, consequently, made the investment decision on OL3 in December 2003. Once OL3 is in operation, it will be one of the most efficient nuclear power plant units in the world.

Reasons for OL3

- *Helps to replace old, soon-to-be-decommissioned fossil-fuel-based electricity production capacity.*
- *Assists, together with renewable energy forms, Finland to reach its carbon dioxide emission targets.*
- *Ensures for its part a steady and predictable electricity price, which is an important competitive edge for Finnish industry and for every citizen.*
- *Contributes to reducing Finland's dependence on imported electricity.*

Capacity factors for boiling water reactors



The capacity factor is the share of electricity produced over a certain period of time as a percentage of the electricity that the unit would have produced over that same period of time if it had operated without disturbances at full capacity.

OL3 is equipped with a new generation pressurised water reactor. The unit's technology is based on good operating experiences and results from the latest reactors commissioned in Europe. N4 plants in France and Konvoi plants in Germany have served as models for OL3.

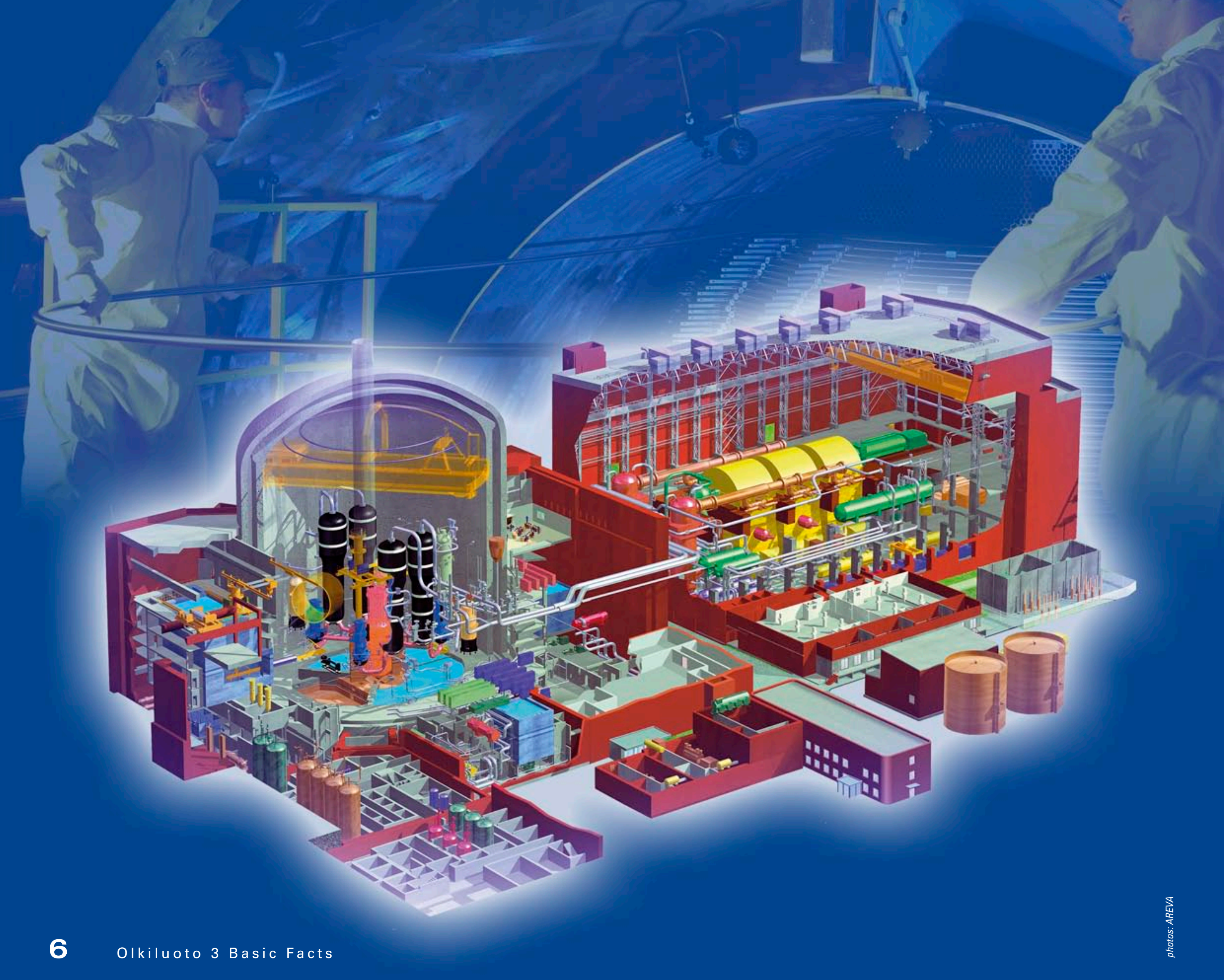
Germany (Konvoi)

Emsland	*1,290 MWe*	*1988*
Isar 2	*1,400 MWe*	*1988*
Neckarwestheim 2	*1,269 MWe*	*1989*

France (N4)

Chooz 1	*1,450 MWe*	*1996*
Chooz 2	*1,450 MWe*	*1997*
Civaux 1	*1,450 MWe*	*1997*
Civaux 2	*1,450 MWe*	*1999*

In the turnkey contract AREVA NP is in charge of constructing the nuclear island and Siemens of constructing the turbine island. Both are top experts with long experience in the industry. TVO is responsible for, among other things, the excavation work at the construction site.



photos: AREVA

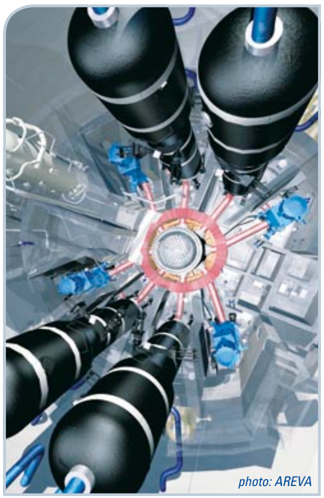
Progressive and Moderate Development at OL3

In December 2003, TVO made an investment decision to construct a new plant unit Olkiluoto 3 (OL3) in Olkiluoto. After competitive bidding, from among many plausible options, an EPR (European Pressurized water Reactor) was selected as the reactor type. OL3 will be a unit with an electrical power output of approximately 1,600 MW.

OL3 is built on a turnkey basis by a consortium formed by AREVA NP and Siemens. Features considered in the selection criteria included safety, reliability, technical solutions and electricity production costs.

Thoroughly Assessed Development of Proven Technology

OL3 is an evolutionary plant unit employing the latest know-how in the field, while the basic technical design features of the unit are based on good operating experiences and results from the French and German nuclear power plants that have served as models for OL3.



OL3's technology has been developed with caution. Particular attention has been paid to factors that further increase the safety of the unit, as well as to the efficiency, including cost-efficiency, of production.

Particular attention has been paid to features that further increase the unit's safety as well as to the efficiency, including cost-efficiency, of production. The management of severe reactor accidents, for example, has been taken into account with many improved solutions; for more information on multiple safety systems, see page 20.

OL3 is more economical when compared with the most recently commissioned European plants. The reactor power of the unit is one per cent higher, and its output of electricity is ten per cent larger. Thus the costs of electricity production are smaller. Consequently, the fuel consumption is lower, and OL3 produces less long-lived radioactive waste for each megawatt hour.

Electricity for Several Decades

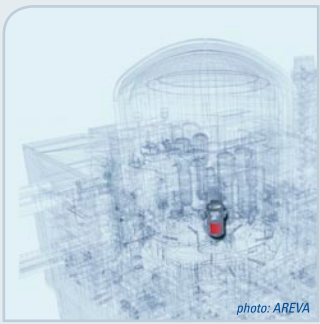
It is economically feasible for the OL3 unit to achieve a minimum of 60 years of operating life, since it is already the case with TVO's existing plant units, the guiding principle also at OL3 is to keep the plant unit as good as new at all times. This can be achieved by carefully conducted outages, thus proactively aiming for safe, reliable and cost-effective electricity production.

Important Dates for OL3

4/1998	*Beginning of feasibility studies*
8/1998	*Environmental impact assessment report*
11/2000	*TVO's application for a decision-in-principle*
1/2002	*Favourable decision by the Government*
5/2002	*The Parliament ratifies the decision-in-principle*
9/2002 to 10/2003	*Competitive bidding*
12/2003	*TVO's investment decision and signing the agreement*
2004	*TVO begins excavation work at the site*
2005	*Handing the site over to the plant supplier; construction begins.*

Olkiluoto 3

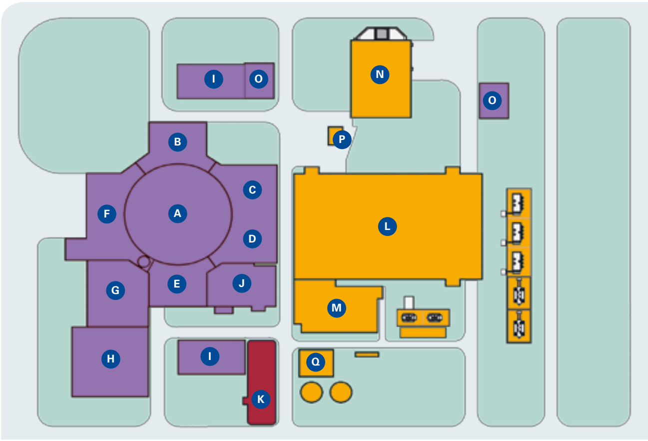
- *European Pressurised water Reactor (EPR)*
- *Energy output 1,600 MW*
- *Efficiency 37%*
- *1 high-pressure turbine and 3 low-pressure turbines*
- *The total building volume is about 1,000,000 cubic metres, equal to 10 Finnish Parliament buildings*
- *AREVA NP is in charge of constructing the nuclear island, Siemens of constructing the turbine island*
- *The investment decision for the project was made in 2003. To this day, OL3 is the largest single investment in the history of Finnish industry.*



There is about 130 tons of uranium fuel in the OL3 reactor.

OL3 buildings

- AREVA NP
- Siemens Power Generation
- TVO



- A Reactor building
- B Safeguard building division 1
- C Safeguard building division 2
- D Safeguard building division 3
- E Safeguard building division 4
- F Fuel building
- G Reactor plant auxiliary building
- H Radioactive waste processing building
- I Emergency power generating building
- J Access building
- K Office building
- L Turbine building
- M Switchgear building
- N Circulating water pump building
- O Essential service water pump building
- P Anti-icing pumps
- Q Auxiliary boiler building

OL3 will be one of the most efficient plant units in the world, and its construction site is one of the largest that Finland, or Europe for that matter, has ever seen. 52,000 tons of reinforcement steel bars and over 250,000 cubic metres of concrete will go into its structures. People representing more than 60 different nationalities and companies from 30 different countries have contributed to constructing of OL3.

photo: AREVA

OL3 Consists of Three Building Complexes

Olkiluoto 3 is located to the west of the existing plant units in Olkiluoto island. The unit buildings can be roughly divided into three entities: the nuclear island, the turbine island, and the auxiliary and support buildings.

Nuclear Island

The main buildings of the nuclear island are the 64-metres high reactor containment building, and the surrounding fuel building and four safeguard buildings. The safety solutions in all these buildings take into account various operational transients and their potential effects. They have, for example, been protected against the collision of a large aircraft.

The turbines in OL3 have the highest electric output in the world. The diameter of one low-pressure turbine is almost seven metres at its widest.

The reactor, producing the thermal energy for the unit, is situated in the containment building. In addition to storage pools for fresh and spent fuel, the fuel building houses some repair shop facilities. Before interim storage and final disposal, all spent fuel is kept for a few years in water pools in the fuel building. Here, the radiation level and the thermal energy of the fuel decrease considerably.

Low-level and intermediate-level operating waste is processed in the radioactive waste building. Thanks to years of experience and developing technology, there is less waste generated than before.

Turbine Island

The thermal energy generated at the nuclear island is conveyed to the turbine island, where it is first transformed into kinetic energy of the turbines and then, with a generator, into electricity. All components needed for this process are located in the turbine building. Other buildings belonging to the turbine island are the circulating water pump building, the switchgear building and the separate concreted facilities for transformers of the plant unit.

Sea water is pumped through the circulating water pump building to the condenser where the steam coming from the turbines is condensed back to water. Power for different functions of the unit is supplied from the switchgear building and the main transformer transforms the 27 kV voltage coming from the generator to 400 kV, suitable for the national grid.

As is typical for a pressurised water plant, the radiation level at the turbine island does not significantly differ from the background radiation levels elsewhere, as the radioactive water cycle in the nuclear island and the water-steam cycle at the turbine island are not in direct contact with each other.

Auxiliary and Support Buildings

Besides the two building complexes presented above, the OL3 area contains a number of various support buildings, an access building and an office building.

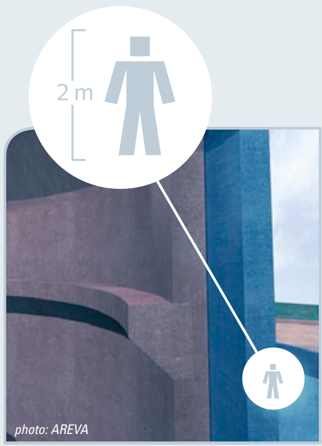
There are also two diesel buildings at the plant site. Both of these have two emergency diesel generators that ensure on their part the power supply to the plant unit during operational transients.

Multiple Safety Solutions

One of the features enhancing nuclear safety is the way the EPR is constructed: it has double shell that rests upon a thick basemat.

The wall structures for both shells are of thick reinforced concrete. In addition, the inner wall has been cladded with a steel liner. The steel liner guarantees the gastightness of the containment building, as it has been designed to keep the effects of a severe reactor accident – though unlikely – inside the building.

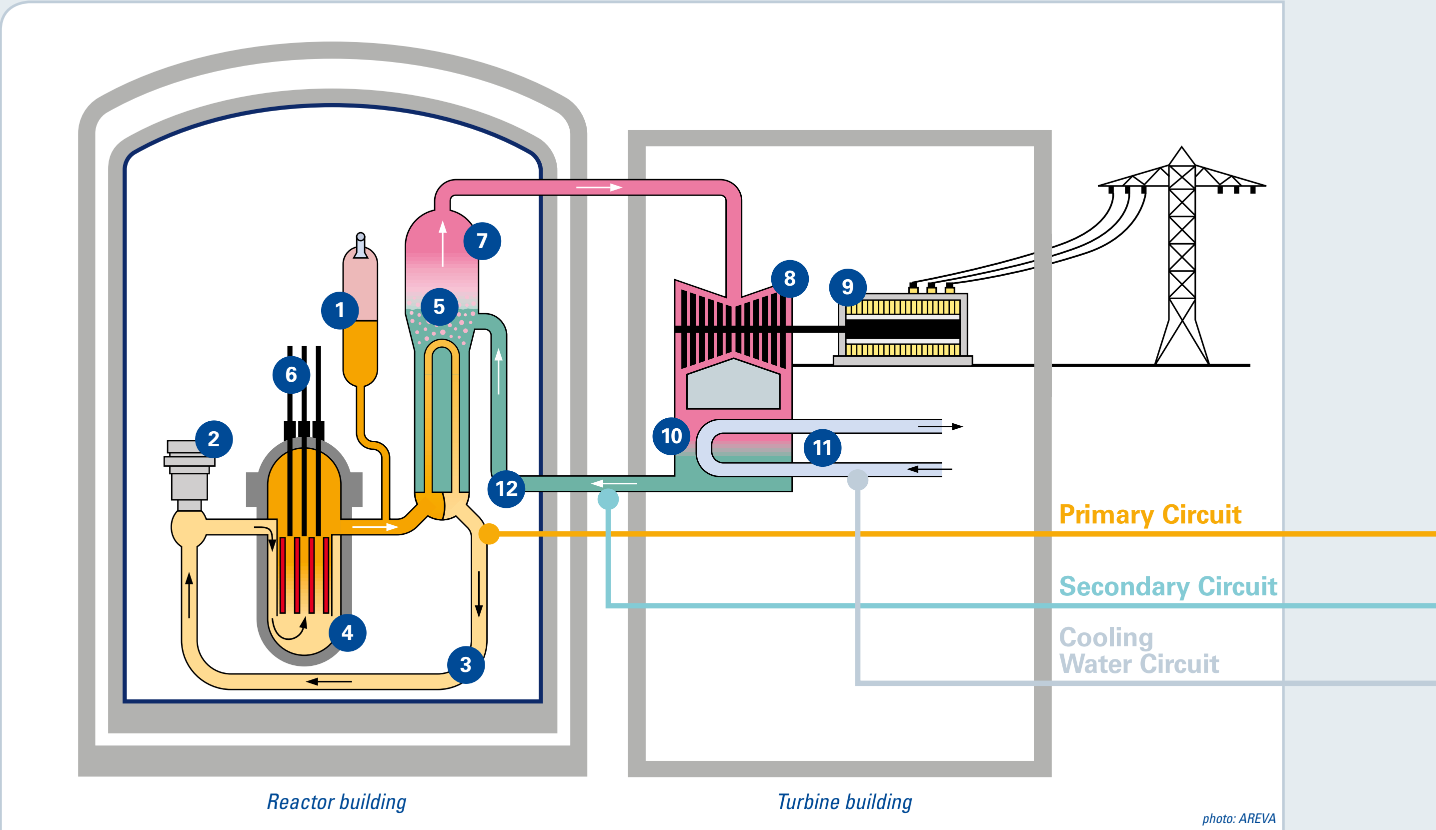
The controlled operation of the plant unit is also ensured by multiple safety systems that have been located physically separate, each in its own building. Since each of the four safety systems is capable of performing the required safety function independently, a failure of a single device cannot compromise the overall safety of the plant unit.



The containment building has been designed to withstand the impact of a collision of a large aircraft or a jet fighter.

Operating Principle

The reactor type in OL3 is called a pressurised water reactor, as the water never boils due to the high pressure inside the reactor pressure vessel. A unit with a pressurised water reactor has two separate circuits for transferring heat: the primary circuit at the nuclear island and the secondary circuit at the turbine island. Besides these two, there is also a cooling water circuit that condenses the hot steam in the secondary circuit back to water.

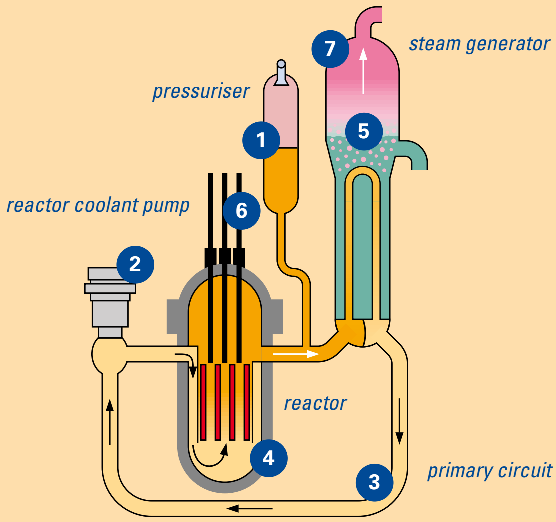


Simply said, producing electricity means transforming certain forms of energy into electricity. In a nuclear power plant, the reactor is first used to generate steam that contains thermal energy, and that steam is then used to rotate the turbines. This kinetic energy is then transformed into electricity with a generator that uses the same shaft as the turbines. The principle is similar in all other condensing power plants, except for the fact that in these, the fuel used to generate the thermal energy may be coal or biomass. In OL3, the fuel is uranium dioxide.

Primary Circuit

Unit's thermal energy is generated in the primary circuit

The coolant is kept at high pressure by the pressuriser 1 and can reach a temperature of almost 330 degrees (coolant is water with some boron added). Assisted by the reactor coolant pumps 2, the coolant proceeds in the primary circuit 3. It is pushed through the reactor 4, then it releases the thermal energy generated by the reactor to the secondary circuit 5 in four steam generators 7. The reactor power is adjusted with control assemblies 6.



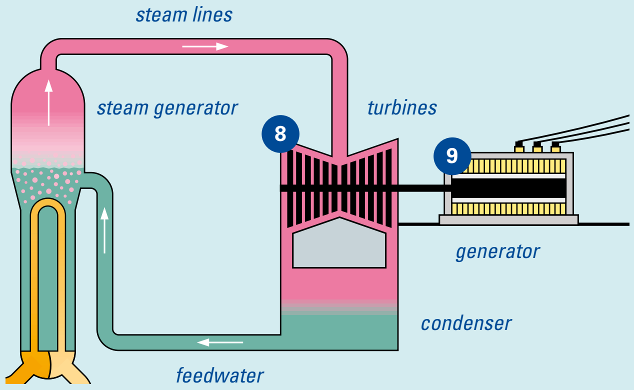
Main components

- *reactor*
- *pressuriser*
- *four steam generators*
- *four reactor coolant pumps*

Secondary Circuit

Thermal energy is first transferred into kinetic energy, then into electricity in the secondary circuit

The pressure in the secondary circuit is considerably lower than in the primary circuit, which causes the secondary circuit water to boil in steam generators. This hot but almost dry steam coming from the steam generators rotates the turbines 8 at a speed of 1,500 rpm. The generator 9, coaxially mounted with the turbines, transfers the kinetic energy of the turbines into electricity.



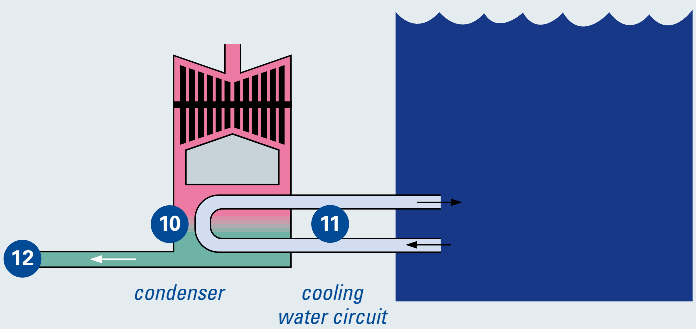
Main components

- *high-pressure turbine*
- *two moisture separator-reheaters*
- *three low-pressure turbines*
- *generator and exciter*
- *condenser*
- *cooling water pumps*
- *condensate extraction pumps*
- *preheaters*
- *feedwater tank*
- *feedwater pumps*

Cooling Water Circuit

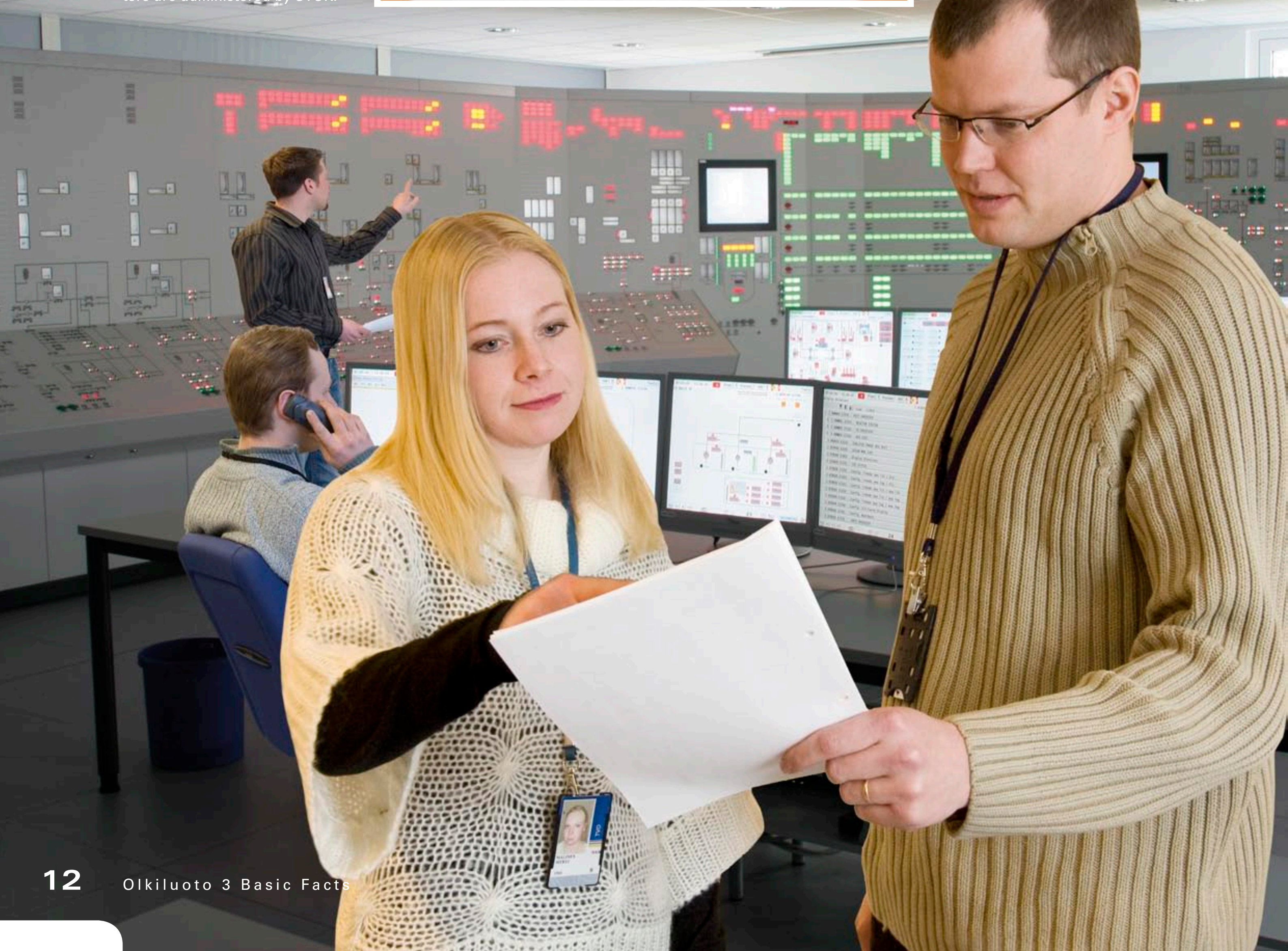
Steam is condensed into water in the cooling water circuit

Sea water 11 is used to condense the steam coming from the OL3 turbines back to water in the condenser 10. The condensate water is then fed back to steam generators with a feedwater pump 12. The temperature of the sea water used in the condensing process increases by approximately 11.5 degrees. Eventually, the sea water is released back into the sea on the other side of the island.



In a nuclear power plant, the operators are trained constantly. Using a training simulator that accurately simulates the plant operations is an essential part of the training and thus an important way of maintaining required know-how.

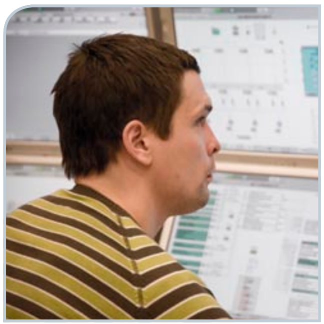
A licence to operate the plant is valid for three years at a time. The skills demonstration tests and written exams for the operators are administered by STUK.



background photo: AREVA

State-of-the-Art Technology Requires Competent Operating Personnel

No electricity will be generated without skilled personnel. Control room personnel, in particular, must have sound expertise, but running a plant unit demands high-standard professional skills and co-operation of all involved personnel.



Besides control room personnel, the operating personnel consists of professionals of various technology fields such as radiation protection, nuclear technology and chemistry. In addition, the company needs a variety of other skills from such fields as information technology, property management, finance and administrative services, personnel development and communications.

OL3 Needs around 200 Nuclear Power Experts

OL3 represents the state-of-the-art in current technology requiring well-trained operating personnel. Everyone employed by TVO knows the basics of radiation protection, environmental protection, fire safety, and occupational health and safety and is familiar with the company's operating culture. In addition, everyone must participate in vocational training depending on his or her task.

The most demanding training is for the control room personnel working in shifts: only the persons who have passed the skills demonstration tests and written exams administered by the Finnish Radiation and Nuclear Safety Authority (STUK) and been granted a licence are allowed to operate the nuclear power plant and work as operators. The licence is awarded as a proof of a high-standard command of the plant and the mastery of various systems.

A majority of OL3 personnel is employed by TVO for the first time, but some personnel members are experienced nuclear power experts who have already worked at the existing plant units at Olkiluoto or Loviisa.

The total number of personnel employed at OL3 will be around 200.

Maintaining Professional Competence on a Day-to-Day Basis

The competence of the personnel is maintained at TVO with versatile training and development options. For the operators, this means constant self-directed learning, a number of training days and an annual revision with the plant simulator – a full copy of the plant control room.

The simulator precisely imitates the plant functions and is used for practising for all possible events that may occur during the plant operation. Besides training for operational transients and incidents, the simulator is used to demonstrate that the operating procedures and guidelines for transients and emergencies are correct.

High Level of Expertise and Work Ethic

TVO personnel knows that working at a nuclear power plant requires high-standard professional skills and an uncompromising attitude. Continuous improvement and proactivity are among TVO's values and, true to them, TVO employees keep looking for targets for improvement and aim at always designing better and better practises.

TVO's operations and production are held in high regard by the global nuclear sector. OL3 will aim at the same excellent results and practises as the existing plant units, and the essential basis for this target is skilled personnel. The OL3 personnel has benefited on a major scale from participating already in the construction phase of the new plant unit.

Essential Criteria for the Nuclear Power Plant Control Room Personnel

The OL3 control room personnel will work in shifts. Six persons work on each shift: shift supervisor, reactor operator, turbine operator, auxiliary operator and two field operators. During the recruitment process, each of them has demonstrated

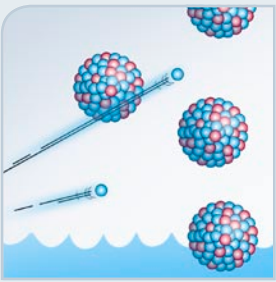
- *a strong sense of responsibility*
- *reflective decision-making abilities*
- *high tolerance for routine work*
- *suitability for shift work and*
- *a geniune interest in the operation of a nuclear power plant.*

In addition, anyone working at a nuclear power plant must be at least 18 years old, of good repute and substance-free.

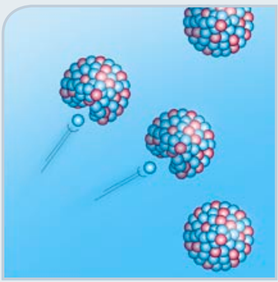
Nuclear power plant operators must have excellent knowlegde of different systems and processes.

Fission – Splitting of an Uranium Atom

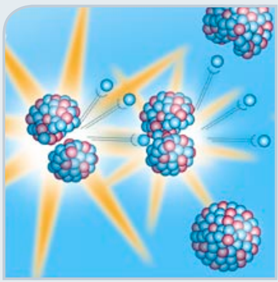
Fission means disintegration or splitting. It is a reaction in which a heavy atomic nucleus is split into two intermediate-mass nuclei, and energy is released in the process.



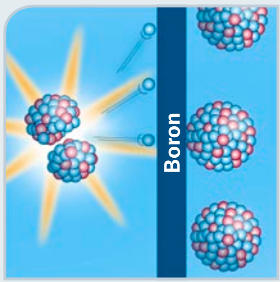
Neutrons move at a speed of about 20,000 km/s. Without a moderator, the speed of these so-called fast-moving neutrons is so high that uranium atoms cannot absorb them, which means that no remarkable extent of fission takes place.



The moderator at OL3 is water. Moderation reduces the speed of a neutron to 4.4 km/s, thus its potential to split uranium nuclei is increased.



In fission, two new atoms and two or three fast-moving neutrons are created. These are moderated by water and can, in turn, split more uranium atoms, maintaining the chain reaction.



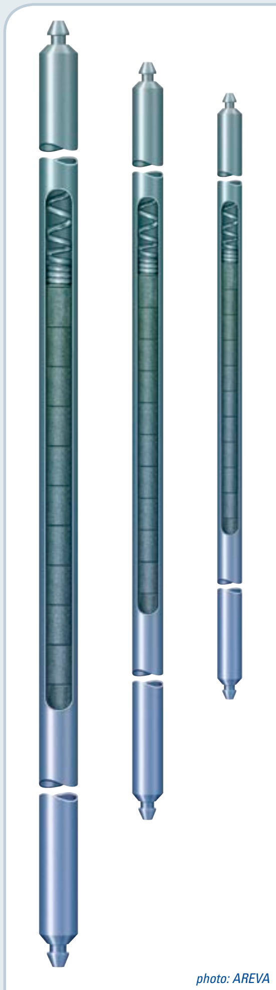
At OL3, the fission and the power of the reactor are controlled by adjusting the control assemblies and regulating the boron content in the coolant water.

Fission in a Nuclear Power Plant

Existing nuclear power plants are based on fission technology. Energy in these plants is released when the heavy nuclei of uranium fuel are split in a nuclear reactor into intermediate-mass nuclei, and energy and neutrons are released in the process. When neutrons are released, this creates a chain reaction that keeps the nuclear reaction going. Energy is released mostly as the kinetic energy of the fission products. The kinetic energy first transforms into thermal energy and, subsequently, is transformed into electricity.

Fuel Assemblies

<< OL3 contains a total of 241 fuel assemblies. One fuel assembly yields approximately 50 gigawatt hours of electricity each year. Therefore, five fuel assemblies would yield enough electricity to cover the entire electricity consumption in Åland for four years.



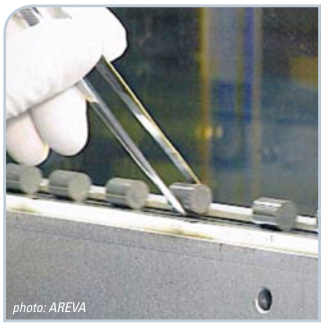
One fuel assembly contains 24 guide thimbles and 265 fuel rods (pictured). One fuel rod contains hundreds of fuel pellets. The metallic cladding of the fuel rod is the first barrier between the environment and the radioactive substances developing in the fuel. >>

Start of Electricity Production

A nuclear power plant is a practical application of nuclear physics in which the chain reaction caused by fission, or splitting of an atom, and the resulting thermal energy are exploited in controlled conditions.

To generate nuclear fission and to begin the production of electricity, the required elements are fuel (where the uranium nuclei split), neutrons (that cause the fission) and a moderator (that slows the neutrons down and increases the potential for fission).

All these are necessary in order to maintain the chain reaction. The fuel at OL3 is uranium dioxide compressed into small pellets with a height of around one centimetre.



One fuel rod contains hundreds of fuel pellets. Approximately eight fuel pellets is enough to produce electricity for one year for a family of four living in a detached house with direct electric heating.

The moderator is water, acting also as a coolant that transfers heat in the primary circuit.

The First Start-Up of a Plant Unit

Fresh fuel does not contain radioactive substances in amounts that would be harmful to people. It emits very little radiation and only produces a limited amount of fission-inducing neutrons. For this reason, the first start-up of electricity production can be considerably smoothened if separate neutron sources are used.

Neutron sources facilitate the fissions, and once the number of fissions is increased in a controlled manner the reactor power goes up.

After the amount of energy designed for an operating cycle has been produced, some of the fuel in the reactor core is replaced with new fuel during an outage. The fuel left in the reactor contains enough neutrons to restart the chain reaction, and a separate neutron source is no longer needed in later start-ups.

Producing Nuclear Electricity Is Subject to a Licence

The start-up of OL3 and the initiation of electricity production are only possible when the entire plant unit is ready for start-up and when the Government has granted an operating licence for the unit. Granting the operating licence is subject to the following requirements:

- All provisions of the construction permit have been followed while building the unit.
- STUK has confirmed that the plant fulfils prescribed safety requirements.
- Arrangements made for managing and financing the management of nuclear waste are adequate.
- Qualifications and training of the operating personnel of the plant are appropriate.

Application for the operating licence for OL3 will be applied for about one year before the unit's commerical use is set to begin.

TVO, Official Supervision and International Co-operation

STUK is the authority in Finland that supervises the different phases of the entire operating life of nuclear power plants. It drafts and maintains a collection of guidelines that defines the technical safety requirements for the construction and operation of a nuclear power plant.

STUK has participated in the OL3 project in many ways. As the supervisory authority, it has conducted preliminary inspections and supervised the manufacturing of components all over the world. STUK is also in charge of supervising the commissioning of the new plant unit.

TVO co-operates with various nuclear energy operators and international nuclear energy organisations, such as IAEA, Euratom and WANO. TVO's aim is to improve its own nuclear energy expertise as well as to create channels through which it can get information and support on developing the operation and safety of its plant units.

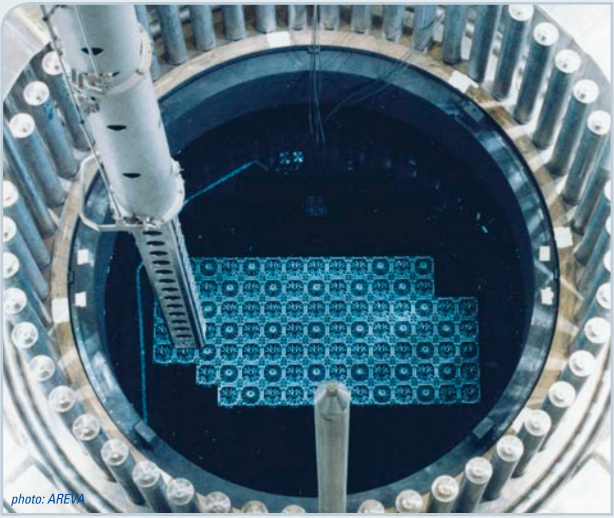
IAEA
International Atomic Energy Agency

EURATOM

W A N O
World Association of Nuclear Operators

Adjusting the Reactor Power

The reactor power is adjusted with finger control rods of the control assemblies. The control assemblies are moved vertically inside the fuel assemblies. If all 89 control assemblies in the reactor are driven to the bottom of the fuel assemblies, the reactor shuts down.



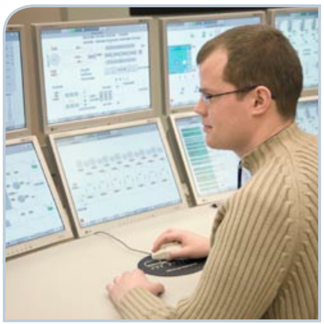
An essential matter in the reactor operation is the correct positioning of the fuel assemblies that vary in age and power. A uniform power distribution in the reactor guarantees a high safety level and a cost-effective fuel use.

TVO's chemistry laboratory serves the different organisational units by producing reliable and precise analyses and measurements. These results are utilised for example in monitoring and adjusting various processes.

Reliable Base-Load Power for the Entire Operating Cycle

TVO's objective is predictable, undisturbed electricity production, in other words, steady production of electricity for the entire operating cycle until the next outage. OL3 has been designed for operating cycles of 12 to 24 months.

As a rule, TVO aims at operating the units at full power for the entire operating cycle. In order to keep the production cost-efficient, periodic testing is the only designed reason for decreasing the plant capacity during an operating cycle.



Production Requires Constant Monitoring

During operation, changes in reactor power are relatively slow. All processes in the nuclear power plant and the functions of various components are constantly monitored by operating personnel, assisted by highly advanced automation.

A high-standard safety culture requires uncompromising adherence to rules as well as vigilance in everyone's separate tasks.

Periodic Testing Ensures the Functionality of Equipment and Systems

Functions of the equipment and systems of the plant unit are tested on a regular basis to ensure their safety and operability. Another reason for periodic testing is to detect any potential failures well before they could disturb the operation of the plant.

Periodic tests and controls are performed following pre-planned, approved programme and schedule. Depending on a particular equipment or system being tested, the time between tests may vary from one month to ten years, but the key safety operation and monitoring mechanisms are tested as often as once a month.

The majority of periodic testing is performed while the plant unit is operating at full power. Only a handful of periodic tests require reduction in power, and they are visible in the production statistics as short-term losses of production.

Regular Reporting

During operation, STUK controls the operation, maintenance and monitoring activities at the plant on a regular basis. In addition, TVO reports regularly to STUK on matters concerning the operation of the plant. A daily report, for example, contains the details of the operational events at the plant during the previous 24-hour period. Production data, monitoring results of various systems and the radiation doses to the personnel, in turn, are reported once a month.

The Annual Electricity Consumption in Finland Is Almost 90 TWh

The current electricity production capacity in Finland is insufficient. To cover the total annual Finnish consumption of nearly 90 terawatt hours some of it has to be covered with imported electricity.

The major share of imports – two-thirds – comes from Russia. One-third comes from Sweden.

Increasing the degree of self-sufficiency in energy issues has been politically confirmed to be in line with the overall good of the Finnish society as a whole. In April 2008 TVO submitted to the Government an application for a decision-in-principle for building a fourth nuclear power plant unit at Olkiluoto. The OL3 project has provided TVO with good assets to launch the OL4 project promptly, and the company is well prepared to supply the Finnish society with reliable nuclear electricity at a fair price, helping fight climate change in the process.

It is estimated that the consumption of electricity will increase in the future – also as an energy source for cars.

Handling the Nuclear Fuel at OL3

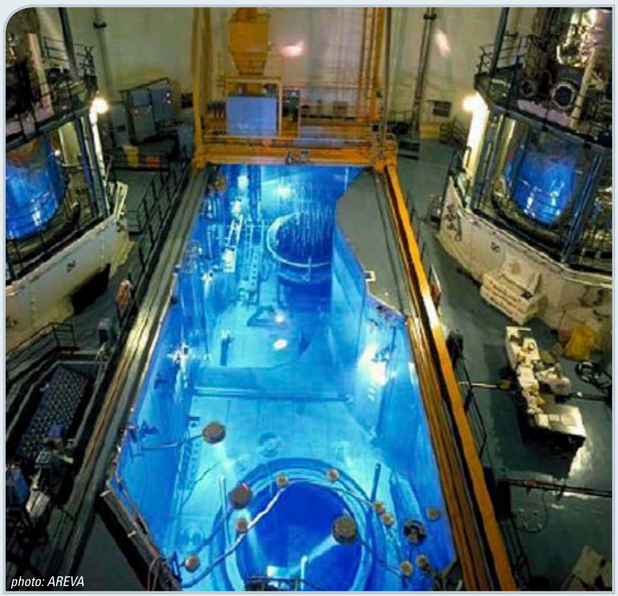
Fresh fuel does not emit radiation in amounts that would be harmful to people. It can be stored in the fuel building either in the dry storage for fresh fuel or under water in the spent fuel pool storage racks, where the spent fuel assemblies are also kept. Spent fuel assemblies are always handled underwater. Water both cools down the assemblies and provides an effective radiation shield.

During a refuelling outage, some of the assemblies in the reactor that have provided their energy are replaced with fresh ones. If the reactor is operated for one year at a time, one-fourth of the fuel is replaced.

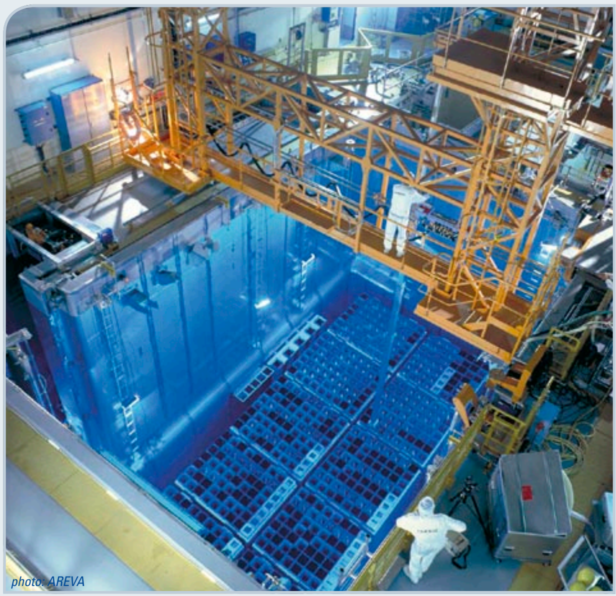
Fuel removed from the reactor is first stored in the fuel building for a few years, then transferred to the interim storage facility for spent fuel, called the KPA store, shared by OL3 with OL1 and OL2. Fuel assemblies are stored in KPA store water pools for several decades. During this time, their radioactivity level and heat producing capacity are decreased to one-thousandth of the original level, facilitating the further processing of the assemblies.

The final disposal of TVO's spent fuel will take place in Olkiluoto.

Functionality of system as well as safety and usability factors are tested in outages.



During refuelling outages some of the spent fuel is replaced with fresh ones.



Both fresh and spent fuel removed from the reactor are stored in the OL3 fuel building. Within one year the radioactivity level of the spent fuel is decreased to one-hundredth of the original level.

Spent fuel is stored in the interim storage called KPA store for several decades before final disposal.

Well-Planned Maintenance and Nuclear Waste Management

TVO aims to operate and maintain the OL3 nuclear power plant unit according to the same operation and maintenance principles that have enabled the successful production of electricity in Olkiluoto already for over thirty years.

It is economically feasible for the OL3 unit to achieve at least 60 years of operating life. The key enablers of this objective are outages, which are planned years before implementation.

Implementation of outages require seamless co-operation of various teams of experts.

The operation cycle of OL3 is designed to be held as an interval, ranging from 12 to 24 months. During these outages, OL3 employs approximately one thousand extra workers.

Unit Shutdown

The reactor power of a plant unit is decreased by driving the control assemblies inside the fuel assemblies following a plan made in advance. When the reactor power has decreased enough, the plant unit is disconnected from the national grid, the reactor is shut down and the actions planned for the outage may begin.

Typical tasks during an outage include replacing part of the fuel in the reactor core, maintaining equipment and testing the safety and usability features at the unit. Outages also provide an opportunity to test the operation of such systems that cannot be tested when the unit is in operation.

Special Attention to Easy Maintenance

Many features of OL3 are aimed to facilitate both the operation of the unit and the maintenance work. It has also been possible to cut down the length of outages and, simultaneously, the maintenance costs.

One important development is the increase in the number of such technical solutions that reduce the radiation doses to the maintenance personnel.

Nuclear Waste Management

Radioactive waste is separated according to their radioactivity and their physical and chemical characteristics. According to the primary separation criteria, three different types of nuclear waste are generated at a nuclear power plant:

- highly radioactive spent fuel
- intermediate-level operational waste and
- low-level operational waste.

Low-level waste is contaminated miscellaneous waste. It includes fabrics, plastics, protective clothing and tools. Intermediate-level waste consists of the ion-exchange resins used to purify the process water. Both are packed in barrels, which will then be taken in concrete boxes into their separate silos in the final repository for power plant waste, known as the VLJ repository, also located in Olkiluoto.

The spent fuel from OL3 will first be kept for a few years in a water pool in the unit's fuel building and then transferred to the interim storage facility for spent fuel, called the KPA store. Spent fuel will be disposed of in Olkiluoto in the bedrock at a depth of hundreds of metres. Posiva Oy, owned by TVO and Fortum Power and Heat Oy, is responsible for the final disposal of spent nuclear fuel coming from its shareholders' nuclear power plants at Olkiluoto and Loviisa. It is estimated that the final repository should be in use in 2020.

Less Waste, More Electricity

The amount of radioactive waste is on the decrease at TVO. One important factor contributing to this trend has been the development of the technology as such; another is the streamlining of practises at the nuclear power plant.

One example is the removal of protective plastic wraps and packing materials of tools, components and other such accessories before these objects are taken to the plant thus decreasing the amount of low-level waste.

Thanks to the advanced technology at OL3, the fuel is utilised effectively. Compared with existing plants elsewhere in Europe, less radioactive waste is generated for every megawatt hour.

Solid power plant waste is packed into 200-litre barrels and concrete boxes.

The design basis for the safety systems is the quick shutdown of the reactor, i.e. the reactor scram, if anything extraordinary happens. Thanks to quick shutdown, the reactor power decreases rapidly. The OL3 reactor can be shut down with control assemblies in 3.5 seconds.

The safety system consists of four independent, mutually redundant subsystems, 1 2 3 and 4, replacing each other if a problem occurs

photo: AREVA

Nuclear Safety

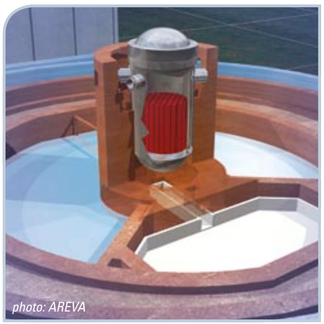
One of the fundamental cornerstones at TVO is guaranteeing nuclear safety. Issues affecting nuclear safety always get their deserved attention, and they come before financial objectives when decisions are made.

A common objective at both OL3 and TVO in general is to ensure the safety of the nuclear power plant in such a manner that the plant operation does not harm the people or the environment. Nuclear safety consists of a high-standard safety culture, good practises and appropriate technical safety solutions.

Multiple, Parallel Safety Systems

For extraordinary situations, OL3 is equipped with four parallel safety systems that are able to replace each other. This means that multiple systems and equipment are in charge of a same safety function.

As a special precautionary measure, the safety systems have been located in four separate buildings to prevent their simultaneous failure. As each of the four safety systems is capable of performing the required safety function independently, a failure of a single device would not compromise the safety of the plant unit.



Even the possibility of a very unlikely severe reactor accident has been taken into account in OL3 design.If each of the four, mutually independent safety systems failed simultaneously and the reactor core melted, a special area would collect and cool all core melt debris discharged from the reactor vessel. The reactor containment building retains all radioactive substances released in an accident, reducing the effects of the accident outside the plant area to a minimum, both temporally and spatially.

More Safety Features Than Ever Before

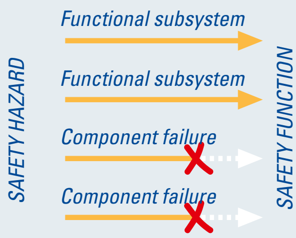
Many effective, proven safety features can be found at OL3. The primary emphasis in development has been on the safety systems as such, minimising the effects of operational transients, and preventing a severe reactor accident.

The design features maintaining nuclear safety take into account for many internal and external disturbances. An example of this design is the reactor building foundation: a three-metre thick reinforced concrete base that protects the tightness of the reactor building even in the case the earth would move.

Other features increasing the plant safety are the thick external reinforced concrete structures covering the reactor building, the fuel building and the two safeguard buildings designed to withstand, among other impacts, the collision of a large aircraft.

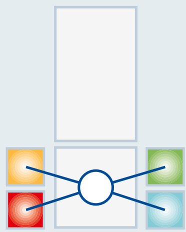
EXAMPLES OF OTHER IMPORTANT SAFETY PRINCIPLES

Redundancy Principle



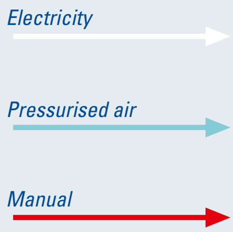
Safety systems consist of several parallel and mutually redundant subsystems.

Separation Principle



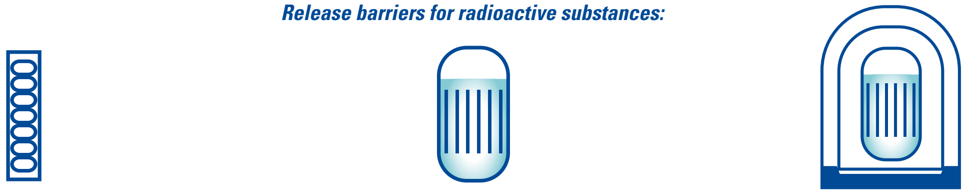
The parallel subsystems of various safety systems are located in such a manner that any simultaneous failure of them by fire or for other reasons is unlikely.

Diversity Principle



The same function is carried out with systems that are based on different functional principles.

Release barriers for radioactive substances:



1st barrier	2nd barrier	3rd barrier
Ceramic uranium fuel enclosed in a gas-tight fuel rod cladding	Reactor pressure vessel and primary circuit	A leak-tight reactor containment building with double concrete walls

Three Protective Barriers to Guarantee Safety

The concept of three protective barriers refers to leak-tight physical barriers between radioactive substances and the environment. The barriers prevent releases of radioactivities in all circumstances.

First barrier: *The uranium fuel in which radioactivities are formed is enclosed in a metal fuel rod cladding.*

Second barrier: *The primary circuit is a closed circuit made of thick steel. The reactor pressure vessel forms part of this circuit. The uranium fuel encased in metal cladding fuel rods is within this vessel in the reactor core.*

Third barrier: *The primary circuit is completely enclosed by the leak-tight containment with massive concrete walls. The double concrete walls of the OL3 containment are built on a thick base slab, and the inner containment is covered with a leak-tight metal liner.*

Any one of these barriers is tight enough to prevent any radioactive materials to be released into the environment.

Managing Exceptional Situations

OL3 has been designed so that operational transients and accidents can be identified and, consequently, the situation can be prevented from deteriorating. This task is performed by multiple safety systems that make sure that in every postulated accident

- the reactor can be shut down
- residual heat in the fuel can be transferred from the reactor and
- radioactive substances are effectively limited from entering the environment.

The means increasing the reliability of the safety systems include

- multiplying the systems with safety functions
- separating the parallel systems so that they are independent from each other
- ensuring the electricity supply of parallel systems with mutually independent sources and
- taking advantage of passive safety features.

There are four independent safety systems in OL3. They are physically separated and located in separate rooms and buildings around the reactor containment building.

Electricity Is Also Needed for Safe Electricity Production

A nuclear power plant not only produces electricity, but also consumes it. OL3 is equipped with several different, parallel and mutually independent electricity systems that ensure the uninterrupted power supply in the unit.

Safety-critical systems are equipped with several back-up power supply sources guaranteeing the power supply for these systems even if something extraordinary happened. This ensures that functions such as safe shutdown of the reactor and safe removal of residual heat are also operable in exceptional situations.

If necessary, the power supply to the unit is backed up with the 400 kV grid, the unit's separate generator, the 110 kV grid and the emergency diesels generators. There is also a gas turbine plant in Olkiluoto capable of supplying electricity to the plant unit.

400 kV main grid

photo: AREVA

Emergency diesel generator

Nuclear Non-Proliferation Control Is Part of Nuclear Safety

TVO's nuclear power plant operation is continuously supervised in accordance with the Nuclear Energy Act and the Nuclear Energy Decree. Authorities supervise the operation of plant units in accordance with strict guidelines.

In Finland, all operations associated with the production of nuclear energy are subject to licence. The licence for the possession and use of nuclear material is granted by the Ministry of Employment and the Economy. TVO regularly reports on its activities to STUK, which supervises the use of nuclear energy and its safety in Finland.

The use of nuclear fuel only for peaceful purposes is also controlled by the International Atomic Energy Agency (IAEA) and the European Atomic Energy Community (Euratom). Both national and international systems for recording and supervising nuclear material as well as various safety arrangements guarantee that the nuclear energy users follow the valid regulations and guidelines concerning nuclear energy and that the nuclear material is only used for the purpose for which the licence is granted.

The loading of the core has to correspond to records, and this is supervised by authorities like Euratom.

High-Standard Safety Culture Warrants Good Results

The primary objective of all personnel at TVO's nuclear power plant is to ensure the safe, reliable operation of the plant units in all circumstances. The personnel must commit themselves to safety without compromises. Therefore, the personnel aims to eliminate any disturbances in advance and are assisted in this task by multiple technical systems designed to this effect.

Designing a nuclear power plant is based on the assumption that equipment failure is possible and operators may make human errors. The various possibilities for failures have been analysed carefully already at the design phase, and the plant units have been equipped with multiple safety systems that use proven and reliable basic technology. This ensures that the potential mistakes made by an operator will not deteriorate into accidents and cause emissions to the environment.

Quality and Safety Culture at TVO

TVO is committed to a high-standard safety and quality culture. It is the prerequisite for everything and is also applied in all phases of the OL3 Project. Both the construction of the unit and the finished plant unit will fulfil all requirements set by the Finnish law, decrees and authorities.

OL3 also fulfils the criteria of the International Atomic Energy Agency's (IAEA) safety and quality recommendations that TVO has set as its objective. Moreover, everyone participating in the OL3 project is committed to prevention of risks and to a continuous improvement of operations.

TVO personnel knows that working in a nuclear power plant requires high-standard professional skills and an uncompromising attitude.

Everyone at OL3 is committed to a high-standard safety culture.

Nuclear power does not promote the greenhouse effect or produce carbon dioxide emissions. If the annual electricity output of OL3 was produced with coal, 10–11 million tonnes of carbon dioxide emissions would be generated – an amount produced by Finnish traffic in a year.

The most extensive environmental impact from a nuclear power plant is an increase in local sea water temperature by a few degrees.

TVO's Commitment to Its Corporate Social Responsibility

Corporate social responsibility is an integral part of TVO's business culture. TVO communicates openly to its various stakeholders, using different means of communication. Financial, social and environmental obligations – all part of the corporate social responsibility – apply also to the OL3 project.

Maintaining a high-standard safety culture and following ethical principles in the process are the most important corporate social responsibility issues for TVO. A sound foundation to this responsibility is TVO's history of over 30 years of safe, environmentally sustainable electricity production for the needs of the Finnish society.

The potential effects to the environment caused by the nuclear power plant operation are continuously monitored and studied at Olkiluoto island and the surrounding areas. One of the study methods is to take samples.

Uniform and Reliable Production of Electricity

TVO's objective as a company is not to yield profit, but to produce electricity to the owners at cost price.

With this cost price, the plant units can be kept up-to-date and in perfect condition. As has been stated in TVO's mission, the personnel is committed to ensuring that operating cycles are safe, predictable and undisturbed.

Personnel Is the Most Important Resource

Maintaining and developing the competence of personnel is important for TVO, as it is known that the prerequisite for operating a nuclear power plant is motivated, professional and competent personnel. TVO's aim is to ensure the personnel's well-being and safety at work by creating opportunities for the personnel to take good care of their working abilities and well-being at work.

As for health and safety at work, efforts are made to reach the target of zero accidents.

TVO also shares its responsibility for the rest of the society and communicates openly on matters concerning its activities. Every year, around 20,000 visitors learn about TVO's operations.

Environmental Sustainability

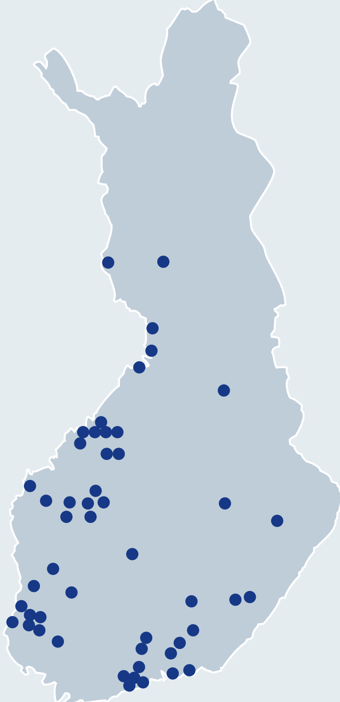
The operation of a nuclear power plant must not cause harm to people or to the environment. This is one of the cornerstones of the operation and requires that the environmental policies, environmental permits and environmental management systems are adhered to in all activities. TVO's target is to continuously improve and develop its environmental activities and to raise the standard of environmental protection from its already high level.

The most remarkable environmental effect of a plant unit is the heat conducted to the sea, which causes the sea to remain ice-free even in winter for an area of a few square kilometres. The radiation effect for the environment caused by the plant units is insignificant.

OL3 Produces Electricity for the Whole Finland

This is a national project. In addition to the Finnish industry, more than 60 power companies in all corners of the country from Helsinki to Lapland are looking forward to tapping into the electricity from OL3. With the electric power produced in the unit:

- *1.6 million washing machines could be running at the same time, if each one uses the electric power of one kilowatt,*
- *the annual electricity demand of four cities about the size of Frankfurt am Mein (Germany), could be covered, or*
- *depending on their power, 160,000 to 266,000 electric saunas could be on simultaneously.*



Technical Details

GENERAL

Reactor thermal power	4,300 MWth
Electrical power, gross	1,720 MWe
Electrical power, net	1,600 MWe
Efficiency	ca. 37%
The annual electricity output	ca. 13 TWh
Total capacity of buildings	ca. 1,000,000 m^3
Operating life	ca. 60 years
Sea water flow	57 m^3/s

NUCLEAR ISLAND

Primary coolant flow	23,135 kg/s
Reactor pressure	155 bar
Average temperature of coolant in the reactor pressure vessel	312°C
Design pressure for containment building	5.3 bar
Amount of uranium in the reactor	ca. 128 tU
Reactor containment building	
– height	ca. 65 m
– outer diameter	ca. 57 m
– distance from vent stack to the ground	ca. 100 m

Fuel assemblies

– mount	241
– ength	4.8 m
– weight	735 kg
Fuel uranium dioxide	UO_2
Annual fuel consumption	ca. 32 tU
Annual fuel consumption as assemblies	ca. 60 assemblies

Reactor pressure vessel

Inner diameter	4.9 m
Inner height	12.3 m
Weight with cover	526 t
Wall thickness	50 mm
Design pressure	176 bar
Design temperature	351°C

TURBINE ISLAND

Turbine generator unit	
– one high-pressure turbine (produces 40% of the gross electric capacity of the unit)	
– three low-pressure turbines (produce 60% of the gross electric capacity of the unit)	
– generator	
Gross electrical output	1,720 MW
Rated speed	1,500 rpm
Steam temperature	290°C
Steam flow	2,443 kg/s
Last stage of the low-pressure turbine	
– blade length	1,830 mm
– overall diameter	ca. 7 m
Length of the turbine generator shaft	68 m

Turbine building

– length	ca. 100 m
– width	ca. 60 m
– height	ca. 46 m
– volume	ca. 250,000 m^3

Glossary

Background radiation
Radiation from natural radiation sources. These sources can be radioactive substances of the earth, such as radon, radiation from space, or radioactive substances contained in the human body.

Capacity factor
A number describing the output of a power plant during one year, or other suitable period. Capacity factor is the share of energy produced by a power plant in a year as a percentage of the energy that the plant would have produced if it had operated without interruption at full capacity for the entire year.

Consortium
A temporary union of companies, formed for a certain busines venture.

EPR, European Pressurized water Reactor
A pressurised water reactor developed from the latest commissioned French and German pressurised water reactors with four steam generators and four parallel, mutually independent safety systems.

Euratom
European Commission's agency responsible for the monitoring of nuclear material.

Fission
The splitting of one heavy atomic nucleus into two or more intermediate-mass nuclei, releasing neutrons and a considerable amount of energy in the process.

Fission products
Habitually radioactive intermediate-mass atomic nuclei created in fission.

Gigawatt hour, GWh
A unit of energy. One gigawatt hour equals one million kilowatt hours.

IAEA
The International Atomic Energy Agency.

KPA store
Intermediate storage for spent fuel.

Megawatt, MW
Unit of power. One megawatt equals 1,000 kilowatts or 1,000,000 watts.

Nuclear material
Nuclear material (special fissionable materials and source materials suitable for the production of nuclear energy, such as uranium, plutonium and thorium) as well as other substances, devices, equipment, data materials and agreements that are relevant for the diffusion of nuclear weapons or that are subject to obligations by the international nuclear energy sector agreements signed by Finland.

PWR, Pressurized Water Reactor
A light-water reactor in which the pressure inside the reactor is so high that the coolant water will not boil. Hot water is led from the reactor to the steam generator. Here, the water inside the secondary circuit kept at a lower pressure becomes steam, which is then conveyed to rotate a turbine.

Radiation
Electromagnetic waves or particle radiation consisting of the smallest particles of matter.

STUK (The Finnish Radiation and Nuclear Safety Authority)
The authority that supervises the operation of nuclear power plants in Finland.

Terawatt hour, TWh
A unit of energy. One terawatt hour equals one billion kilowatt hours.

Uranium
An element (U). An average of 0.0004% of all materials in the earth's crust (four grams in a tonne) is uranium. All uranium isotopes are radioactive. Natural uranium is mostly in the form of isotope U-238, with a half-life of 4.5 billion years. Only 0.72% of natural uranium is in the form of isotope U-235, which can be used as a nuclear fuel.

VLJ repository
A final store for operational power plant waste. All low and intermediate-level power plant waste generated during the plant operation is deposited in the VLJ repository.

WANO (World Association of Nuclear Operators)
An international organisation of nuclear power plant companies. Within the framework of WANO, nuclear power companies can exchange operating experiences and thus increase the safety of their plants.

Multiple units

The values of naturally occurring quantities vary from very small values to considerable ones. In this case, multiple units are useful. Multiple units are generated from the measurement system units by multiplying the unit by a power of ten.

Relation to the basic unit is apparent in the multiple units. An example of a multiple unit is one kilometre that equals one thousand metres, or 1 km = 1,000 m. The tables on the right present some of the most commonly used multiple unit prefixes.

Name	Symbol	Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}

Name	Symbol	Value
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Teollisuuden Voima Oyj
Olkiluoto
FI-27160 EURAJOKI, FINLAND
Tel. +358 2 83 811
Fax +358 2 8381 2109
www.tvo.fi

Teollisuuden Voima Oyj
Töölönkatu 4
FI-00100 HELSINKI, FINLAND
Tel. +358 9 61 801
Fax +358 9 6180 2570

Teollisuuden Voima Oyj
4 rue de la Presse
BE-1000 BRUSSELS, BELGIUM
Tel. +32 2 227 1122
Fax +32 2 218 3141

Eura Print 05/2009 1,000