# Application for a Decision-in-Principle concerning the Construction of a Nuclear Power Plant Unit – Olkiluoto 4

OL4

Teollisuuden Voima Oyj
2008

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This publication does not include the following documents enclosed with the actual decision-in-principle application:

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| - Extract from the Trade Register, Teollisuuden Voima Oyj | (Appendix 1) |
| - Copy of the company's Articles of Association and Register of Shareholders | (Appendix 2) |
| - Annual Report 2007, Teollisuuden Voima Oyj | (Appendix 5.1) |
| - Environmental Impact Assessment Report, Extension of the Olkiluoto Nuclear Power Plant by a fourth Unit | (Appendix 12.1) |

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## TO THE COUNCIL OF STATE

# APPLICATION FOR A DECISION-IN-PRINCIPLE CONCERNING THE CONSTRUCTION OF A NUCLEAR POWER PLANT UNIT

## APPLICANT

Teollisuuden Voima Oyj, hereinafter "TVO".

## APPLICATION

The applicant requests for the Council of State's decision-in-principle referred to in Section 11 of the Nuclear Energy Act confirming that the construction of the new nuclear power plant unit described in the 'Scope of the application' section is in line with the overall good of society.

## SCOPE OF THE APPLICATION

The application concerns a nuclear power plant unit with a light water reactor of max. 4,600 MW thermal power and an electric power on the order of 1,000–1,800 MW that is to be located at the Olkiluoto power plant site owned by TVO.

Furthermore, the scope of the application includes the nuclear facilities associated with the operation of the new nuclear power plant unit at the same site, required for the storage of fresh nuclear fuel, interim storage of spent nuclear fuel, as well as the processing, storage and disposal of low- and intermediate-level operating waste.

## JUSTIFICATION FOR THE APPLICATION

Following the justification presented below, the applicant sees that TVO's venture to build additional nuclear power as part of the required new base-load capacity is in line with the overall good of society, taking into account Finland's climate and environmental objectives, the security of electricity supply, dependency on imports and a competitive and stable price of nuclear electricity. The current nuclear power plant site at Olkiluoto is suitable for the new plant unit. The new unit's fuel and nuclear waste management can be organised similarly to the fuel and nuclear waste management of the currently operating units and by relying on their arrangements.

## Applicant

The applicant is TVO and its domicile is Helsinki. TVO is the owner and operator of the Olkiluoto nuclear power plant located in the municipality of Eurajoki. The combined production of the two plant units, Olkiluoto 1 and Olkiluoto 2, currently accounts for approximately one-sixth of all electric power required in Finland. In addition, at Olkiluoto there is the Olkiluoto 3 plant unit under construction.

TVO owns 60 per cent of Posiva Oy, whose task is to take care of the final disposal of spent nuclear fuel from the nuclear power plants of its shareholders in Finland. The remaining 40 per cent of Posiva Oy is held by Fortum Power and Heat Oy ("FPH"), which is the owner and operator of the Loviisa nuclear power plant.

More detailed information about the applicant can be found in the appendices to this application.

During the construction of the Olkiluoto 1 and Olkiluoto 2 plant units at Olkiluoto and nearly thirty years of operation and during the construction of Olkiluoto 3, TVO's personnel have gained significant expertise in the construction and operation of nuclear power.

The operating results of the current plant units at Olkiluoto have been at the top level in the world. Finland has been the leading country in the world for about 20 years with regard to the annual capacity factor of nuclear power plants. The reliable operation of nuclear power plants is a proof of the high level of expertise in this field in Finland. The high utilisation degree also proves that there has been demand for TVO's stable electricity production. Olkiluoto 3 has been one of the first nuclear power plant units under construction in the western countries for more than ten years. Its construction has significantly increased the company's expertise in the design and construction of the next generation's plant units.

## General significance and necessity of the venture

Electricity is a necessary basic commodity in society and its uninterrupted and secured supply constitutes a prerequisite for the operations of society, including the functions serving well-being and production in households and workplaces. Sufficient and reasonable priced electricity means improved quality of living and is in the general interest of all Finnish people, regardless of the social and regional location.

The production structure of electric power in Finland is one of the most diversified in the world. The versatility of production forms for its part secures the supply and stable price development of electricity. The maintenance of the security and the economy of electricity production and the mitigation of climate and environmental impacts require that the versatility of electricity production is maintained without excluding any forms of production.

Alongside Finnish production, imports have played an important role in Finnish electricity supply. In 2007, imports accounted for 14 per cent of all electricity consumption, corresponding to the annual production of one large nuclear power plant unit. Finland is a net importer of electricity on the open Nordic electricity market where the supply and prices of electricity depend largely on the impact of rainfall for the availability of hydropower.

The consumption of electricity has increased by an average of 2 per cent a year in Finland over the last ten years. The consumption is estimated to increase by an average of 1.2 per cent a year until 2020 and by an average of 0.7 per cent a year during the next ten years. In 2020, the need for new production capacity will be about 5,500 MW. The new production capacity will cover the deficit caused by the increasing demand for electricity, and by the reduction of old power plants and of imports.

TVO produces the base electric power, i.e. base-load, available at every moment of the day around the year. The need for base-load power is still increasing as the use of electricity in housing and services is becoming more versatile and as industrial production is increasing. Nuclear power is well-suited for base-load production because its production is practically independent of any external factors and the share of operating costs in the production cost of electricity is small.

In open competition on the electricity market, the investments of electricity producers to increase production are aimed at production forms which require, according to short-term market forces less capital but more expensive fuels. In the long term, this may increase the price of base-load power significantly. This may also be the result if there are not enough investments to increase production.

The share of fuel costs in the overall price of nuclear electricity and the share of natural uranium cost, in particular, is small, resulting in stable prices of nuclear electricity. A stable electricity price lays the ground for long-term investment decisions in Finland. Because of the small share of costs of nuclear fuel, the domestic content of nuclear electricity is higher than that of production of base load power using fossil fuels.

Nuclear power does not cause greenhouse gas emissions, the mitigation of which Finland is committed to. With regard to impacts and expenses, the construction of additional nuclear power is the most efficient way to limit carbon dioxide emissions caused by electricity production in Finland.

## Schedule of the venture

The applicant has estimated that construction work for the power plant unit could be started in 2012 after the invitation to tender and construction licence processes following the decision-in-principle. The construction period for the plant unit will be approximately 6–8 years. The unit's production could be started at the end of the decade. The scheduling of the final investment decision will take into account the outlook for the shareholder's electricity demand, the development on the electricity market and the reduction obligations of greenhouse gas emissions valid at the time.

## Profitability and financing of the venture

The planned nuclear power plant unit is financially the least expensive option in the production of base-load power. The utilisation of the infrastructure serving the existing plant units at the nuclear power plant site at Olkiluoto will have a significant effect on the venture's economic viability.

Renewable sources of energy have an increasing importance and foothold in Finland's electricity acquisitions. However, they are not financially or technically valid alternatives for the planned nuclear power plant unit to be implemented in the wide-scale production of base-load power.

The preliminary cost estimate for the power plant unit amounts to EUR 3–4 billion depending on the size of the plant unit. The share of Finnish work, materials and equipment is estimated to account for about 35–45 per cent of all investment costs.

According to calculations, the venture is financially profitable. Experience indicates that nuclear power is inexpensive, particularly in the long term, as capital costs decrease. TVO's financial key figures and the ability to handle interest on loans and repayments will remain at a level satisfactory to financiers throughout the construction period. According to analyses, the venture's funding can be organised. The venture will not require State subsidies.

## Plant type and time of operation

The nuclear power plant unit referred to in the application will be equipped with a light water reactor. The majority of the world's current power reactors are light water reactors. The new unit can be either a boiling water or pressurised water reactor plant. The Olkiluoto 1 and Olkiluoto 2 plant units are boiling water reactor plants and Olkiluoto 3 is a pressurised water reactor plant.

The thermal power of the plant unit's reactor will be a maximum of 4,600 MW which has been used as the plant unit's maximum thermal power in its environmental impact assessment. The electric power of the plant unit will be approximately 1,000–1,800 MW.

TVO has carried out preliminary surveys on the feasibility of several nuclear power plant alternatives in Finland. They represent the latest developments in light water reactor technology with regard to their safety and economy-related properties. According to the investigations, there are several nuclear power plant alternatives available on the market that are feasible, without any changes or with reasonable changes, to be built in Finland. In addition, plant alternatives other than those targeted by feasibility studies may be considered in the selection of the plant alternative to be implemented.

The planned technical operational lifetime of the new plant unit is approximately 60 years.

## Safety and environmental impacts

In accordance with the Nuclear Energy Act, the starting point for the design, construction and operation of a nuclear power plant is that the plant must be safe and it shall not cause injury to people or damage to the environment or to property.

Finnish nuclear power plants have had only a small number of incidents that have had safety implications or disturbed the use of plant units. None of these incidents has caused the allowed radiation doses for employees to be exceeded or any radiation hazard to the environment.

The new nuclear power plant unit will be designed to meet the internationally advanced safety requirements valid in Finland. In addition, the principles and instructions issued by the International Atomic Energy Agency (IAEA) and some other countries will be taken into account.

The direct and indirect impact of the planned nuclear power plant unit on people, nature, and the built environment has been assessed in accordance with the Act on Environmental Impact Assessment Procedure. The Environmental Impact Assessment Report was submitted to the contact authority in February 2008. Appropriate attention will be paid to the aspects presented in the statements on the assessment report when developing the venture further.

## Nuclear fuel and nuclear waste management

Fuel management of the new nuclear power plant unit can be implemented reliably in a diversified manner from several sources using similar arrangements as for the existing plant units. The main principle is to use long-term agreements and reserve stocks for fuel.

The intention is to use the same plans, methods and waste management facilities that are used for the existing nuclear power plant units. There are disposal facilities for low- and intermediate-level operating waste at Olkiluoto, and these can be expanded to accommodate the needs of the new unit as well.

Spent nuclear fuel is to be disposed of in the final disposal facility at Olkiluoto designed by Posiva Oy, which is owned by TVO and FPH. The spent fuel from the new nuclear power plant unit referred to in this application has been taken into account in Posiva's plans regarding the final disposal facility. Posiva is submitting a separate application for the Council of State's decision-in-principle concerning the construction of the final disposal facility for spent fuel expanded so that spent fuel from Olkiluoto 4 can be disposed of in the facility. The capacity of the expanded repository will be 9,000 tons of uranium.

Helsinki, 25 April 2008

TEOLLISUUDEN VOIMA OYJ

| | |
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| Pertti Simola | Rauno Mokka |
| President and CEO | Executive Vice President |

## APPENDICES

Descriptions called for in Section 24 of the Nuclear Energy Decree:

1. Extract of the Trade Register

2. Copy of the company's Articles of Association and register of shareholders

3. Description of the expertise available to the applicant

4. Description of the nuclear power plant venture's general significance and necessity considering domestic energy supply, in particular, and its significance considering the operation of other nuclear power plants in Finland and their waste management

5. Description of the applicant's financial prerequisites for operations and the nuclear power plant venture's economic viability

6. Overall financing plan for the nuclear power plant venture

7. Outline of the technical principles of the planned nuclear facility

8. Description of the safety principles followed

9. Outline description of the ownership and occupation of the site planned for the nuclear facility

10. Description of the settlement and other activities and the planning arrangements at the planned nuclear plant site and its immediate vicinity

11. Assessment of the suitability of the planned site for its purpose and of land use restrictions in the plant surroundings caused by siting of the nuclear facility

12. Assessment report drawn up in accordance with the Act on Environmental Impact Assessment Procedure and an account for the design criteria the applicant intends to apply in order to avoid environmental damage and limit environmental burdens

13. Outline plan on nuclear fuel management

14. Outline of the applicant's plans and available methods for arranging nuclear waste management


OLKILUOTO

# DESCRIPTION OF THE EXPERTISE AVAILABLE TO THE APPLICANT

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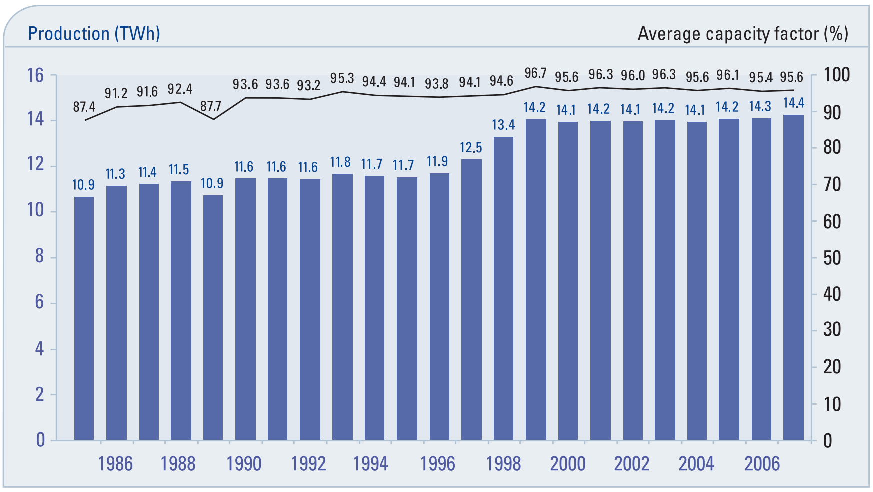
# 1. GENERAL

TVO's line of business is to construct and procure power plants and power transmission equipment and to produce, supply and transmit electricity primarily to its shareholders. The company has built and is operating two nuclear power plant units, OL1 and OL2, at Olkiluoto in the municipality of Eurajoki and is building the OL3 plant unit at Olkiluoto.

When the operation of the OL1 and OL2 plant units started, most of the technical personnel involved in the construction phase were transferred to tasks in support of the operation and maintenance of the plant units. Those who have been involved at Olkiluoto from the very beginning have accumulated nearly 30 years of experience in the operation and maintenance of the plant units, including the efficient implementation of annual outages. An indication of the company's competence is that the high capacity factors of the Olkiluoto plant units have held the top positions in international comparisons for a long time.

***Figure 3–1*** *Total production of Olkiluoto 1 and Olkiluoto 2 and average capacity factor in 1985–2007.*




In addition, the company's nuclear competence has been maintained and developed by the power upratings of the plant units and by their modernisation, by measures taken to prevent for severe accidents, the preparation of a probabilistic safety analysis (PSA), the use of a training simulator, the construction of interim storage facilities for low and intermediate-level waste, the construction of an interim storage facility for spent fuel, the construction of a repository for operating waste, the development of the final disposal solution for spent fuel and the construction of OL3.

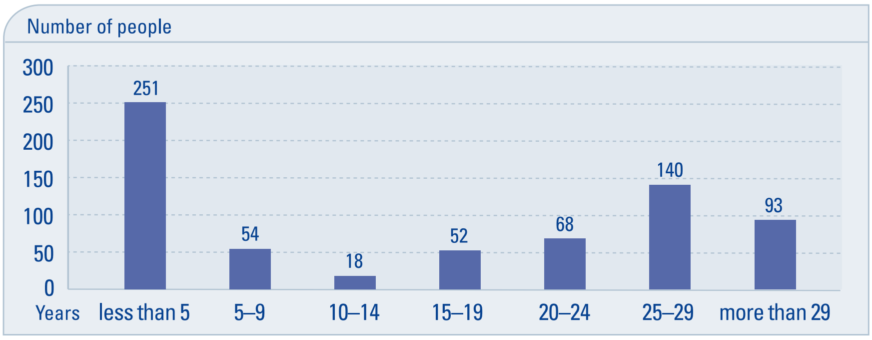
## 2. DEVELOPMENT OF COMPETENCE

Competence exists in people and in organizational routines.

Employee turnover has been at a low level in TVO and it has mainly taken place through retirement. TVO has prepared for maintaining competence in connection with retirements.

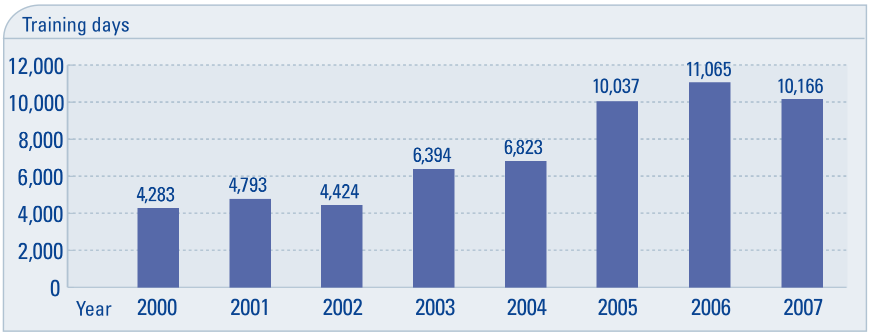
Nuclear power plant operations are typically well-documented. TVO has accumulated extensive material during its history concerning the plant's technical systems and the organisation's operations. TVO operational systems and information and their uses have been documented extensively and comprehensively. Numerous manuals, operating and maintenance manuals including operational and preventive maintenance instructions in particular, control the operations in great detail. TVO has a good safety culture which is a significant part of TVO's organizational memory.

***Figure 3–2*** *The duration of employment for TVO's personnel.*



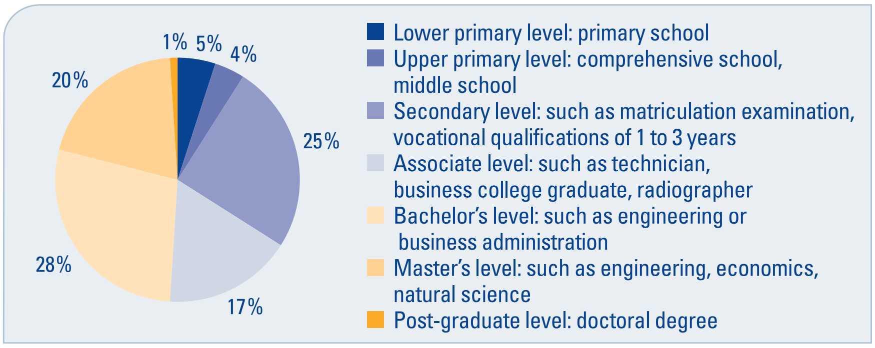

The development of personnel competence consists of continuous actions controlled by the key competence areas derived from the company's strategy and the competence requirements set for the personnel. The implementation of these requirements is monitored as part of supervisor operations in a coordinated manner at the company level. These operations are supported by the competence management data system. The regular number of personnel training days has annually been about 9–10 days/person and, in 2007, it was about 15 days/person. The increase resulted mainly from training related to the tasks of OL3.

***Figure 3–3*** *Training days for TVO's personnel.*




The company employs approximately 700 regular employees, 75 per cent of whom have technical or scientific educational backgrounds: there are 6 doctors, 4 licentiates, 111 Masters of Science in Engineering, 162 engineers, 73 technicians and 15 master mechanics. In addition to those with a technical or scientific degree, the company employs people with financial and legal expertise in the nuclear industry. The company supports its personnel's participation in different levels of post-graduate and continuing educational programmes.

***Figure 3–4*** *Education of TVO's personnel divided into educational levels.*




The company has realised at an early stage that a significant part of the current personnel has been in the company's service for a long period, that personnel turnover has been minor and that large share of the personnel is retiring around 2010. The company has, well in advance, initiated actions to ensure that the accumulated know-how and plant knowledge can be conveyed to new competent employees. Examples of competence transfer projects implemented in TVO include mentor projects where the retirement of key personnel has been/will be prepared for by recruiting followers as work partners 2–3 years before retirement, and the HILTI project aimed at planned operations supporting the transfer of tacit knowledge of technical experts. All of this is supported by good and comprehensive documentation concerning plant technology and procedures.

## 3. COMPETENCE IN OPERATIONS

TVO has thirty years of experience in the operations of a nuclear power plant in Finland. An important part of operations is the management of the operating staff's competence (control room personnel). TVO is continuously monitoring the recruitment need of personnel and trainee teams have been started in 2003, 2004, 2006 and 2007 (each including 4–8 people). The members of the trainee teams will be licensed operators after two years of training. TVO is constantly working on developing the selection procedures for operating personnel. TVO has highly developed practices for the training of operating staff. For example, the operating experience of its plant and other plants is continuously utilised as part of the operating personnel's basic and further training. The operating personnel have about 15 training days a year concerning plant technology and procedures.

Part of the training is carried out using the simulator, for which TVO has clear updating practices. TVO also has extensive experience in the utilisation of the simulator and wide competence in the didactic special features of simulator training. In addition to plant technology, the simulator is used to train procedures, such as control room communications. The operating personnel's competence management also includes the maintenance of licenses and different indications of work skills, for which TVO has standardised procedures. Operations constitute work in three shifts, including special requirements. Over the years, TVO has accumulated vast experience in manage the burden of shift work.

***Figure 3–5*** *Control room of the training simulator for OL1 and OL2 plant units.*

Simulator training comprised 630 training days in 2006 and a total of 930 training days in 2007 for the maintenance and development of the control room personnel's professional competence. The OL3 project has enabled wide-scale recruitment of new professionals. People who will develop in the operational tasks through tasks at the construction and implementation stages have been employed in the OL3 project. The future control room personnel of OL3 (about 35 people) were recruited in 2005 to be trained for the tasks. The OL3 project has increased the broad international cooperation of the company's experts.

## 4. OUTSIDE EXPERTISE

TVO also uses suppliers in its operations to the extent necessary. The principle has been to establish connections with institutions, companies and organisations representing the highest possible expertise in sectors related to the company's operations. The company has valid agreements on maintenance and expert services with several Finnish and foreign parties. TVO has long-term cooperation agreements with key plant, component and service suppliers. The expertise and competence of suppliers is inspected using regular assessments.

TVO has excellent long-term relationships with higher educational institutes and universities providing education in nuclear and energy technology. The company is taking active part in the institutes' research and development projects and supports students by offering training positions and possibilities to complete a thesis project in TVO.

TVO has participated and is participating in a number of national and international nuclear power development programmes. This will produce information about the latest development in the field and maintain functional connections to experts in the field. The company's representatives are actively involved in the operations of Finnish and international organisations in the field of energy and nuclear power.

Through broad operational experience and the OL3 project, TVO has extensive and fresh expertise and competence in the requirements of the design, construction and operations of nuclear power.

# DESCRIPTION OF THE NUCLEAR POWER PLANT VENTURE'S GENERAL SIGNIFICANCE AND NECESSITY CONSIDERING DOMESTIC ENERGY SUPPLY, IN PARTICULAR, AND ITS SIGNIFICANCE CONSIDERING THE OPERATION OF OTHER NUCLEAR POWER PLANTS IN FINLAND AND THEIR WASTE MANAGEMENT

CONTENTS

# 1. GENERAL SIGNIFICANCE OF THE VENTURE

A reliable and uninterrupted supply of electricity in all situations and self-sufficiency of its supply constitute starting points for social operations for each citizen, for industry, services and foreign trade. An uninterrupted supply of electricity at a reasonable price for private consumers and at a competitive price for business are prerequisites for the Finnish economy and well-being.

The venture referred to in the application primarily supports the reduction of carbon dioxide emissions in electricity production, the reduction of dependency on the import of electricity and fuels becoming more expensive and the replacement of old and removed production capacity using an emission-free option. In addition, provisions shall be made to cover the increases electricity need by using emission-free power plants.

The presented nuclear power plant unit as part of a diversified Finnish energy mix will increase the self-sufficiency and reliability in the electricity supply, will reduce emissions and produce electricity at a competitive price. The significance of reasonably-priced Finnish electricity will be emphasised in a situation where many European countries are more dependent on imported electricity and gas, resulting in tighter competition and more pressure to increase prices.

High-quality function of the energy system is particularly important in Finland. Despite the efficient use of energy, Finnish energy consumption per citizen is one of the greatest in Western countries. This is caused by the high standard of living, energy intensive industry structure, the cold climate and long distances.

In order to maintain and secure stable economic growth and positive employment development, it is important that Finland has favourable operational conditions for investments. Even though the electronics and IT industries have increased their share in our industrial production, the energy-intensive forest, chemical and metal industries play a central role in exports which forms the backbone of our welfare state. The share of the energy-consuming heavy industry of Finnish energy needs is nearly 40 TWh (27 TWh in forest industry, 6 TWh in basic chemical industry, 5 TWh in metal processing) constituting more than 40 per cent of the total electricity consumption in Finland. Reliable electricity supply at a reasonable price is a prerequisite for the existence of these branches.

The mitigation of climate change is one of the biggest challenges for mankind. Through the decision issued in 2007, the European Union is committed to reduce greenhouse gas emissions by 20 per cent by 2020, compared to the level in 1990. The emission reduction will be 30 per cent if countries outside Europe will be committed to similar reductions in emissions. Emission trading is a central control method selected within the EU to reduce emissions. The European Commission proposes separate country-specific binding objectives for sectors outside emission trading, such as traffic, services, households and farms. The objectives were issued on 23 January 2008. The proposed objective for Finland in the sector outside emission trading means that greenhouse gas emissions are reduced by 16 per cent compared to the level in 2005. Energy production causes about 80 per cent of Finland's greenhouse gas emissions. Annual carbon dioxide emissions in electricity production have been 10–25 million tons over the recent years. Therefore energy solutions have a central significance in climate change mitigation. The means for reducing emissions include the increase in energy efficiency and investments in low-emission and emission-free forms of energy, such as renewable energy sources and nuclear power.

Future energy solutions must be carried out so that the reliability and reasonable prices of energy supply can be secured, while taking care of the environment particularly in preventing climate change. This requires investments in improved energy efficiency and versatile energy production without excluding any forms of production from the energy mix.

### *Electricity demand and the future outlook in Finland*

Increased use of electricity has and will be connected to the increase in standard of living. Finland's gross national product has increased over the past decades, apart from the recession at the beginning of 1990s. The share of basic industry using plenty of electricity in the gross national product is high. The use of electricity has increased in all end user sectors – in industry, services and households.

The entire industrial sector used more than 50 per cent of all electricity in Finland. In 2007, the electricity consumption in industry was 47.8 TWh. The forest industry had a share of 58 per cent, the metal industry 17 per cent, the chemical industry 14 per cent and other industry and construction 11 per cent. Service production, including services produced by the private and public sector, consumed 16.2 TWh of electricity. Housing and farming consumed 13.9 TWh. The share of housing consists of household electricity, real estate electricity for multi-storey buildings and terraced houses and the electricity used by holiday homes. The energy need for electric heating amounted to 9.1 TWh.

Despite the continuous improvement in energy efficiency, electricity consumption will continue to increase in Finland. According to the WM (With Measures) scenario of the former Ministry of Trade and Industry, updated in 2005, the total consumption of electricity will amount to approximately 105 TWh in 2020 and 108 TWh in 2025. In the WAM (With Additional Measures) scenario for more efficient actions, the total consumption of electricity will amount to 102 TWh and 105 TWh.

The estimate of demand for electricity in 2020 and 2030 published by the Confederation of Finnish Industries (EK) and the Finnish Energy Industries in November 2007 had similar results for the future estimates of electricity use as the ministry. The estimate is based on a vision of a well-to-do and successful Finland. The estimate for demand is based on a favourable economical development and a steady growth that will lead to improved standard of living for citizens.

According to the estimate, the use of electricity will increase to 106.5 TWh by 2020 and to 115 TWh by 2030. The average annual increase will be about 1.2 per cent until 2020, and 0.7 per cent between 2020 and 2030.

Future industrial development will be a central factor in the assessment of the outlook for electricity needs. The need for industrial electricity is estimated to grow in all sectors. The increased demand for electricity in the forest industry is mainly based on renovation and new investments, through which the production capacity will also increase. In addition, the manufacture of paper grades with a higher processing degree will require more electricity business. The growth estimates of the need for electricity in the metal industry are based on expansion investments in production. According to the report, the need for electricity in the forest industry in 2020 is estimated to amount to 32.3 TWh (+4.6 TWh compared to 2007), 10.9 TWh in the metal industry (+2.9 TWh), 7.7 TWh in the chemical industry (+0.8 TWh) and 6.0 TWh in other industry and construction (+0.8 TWh). The total energy need in industry in 2020 is estimated to amount to 56.9 TWh (+9.1 TWh compared to 2007).

The electricity need in the service sector is estimated to increase by an average of 1.9 per cent a year from 2008 to 2030. The increased demand for services and the resulting need for more electricity in services results mainly from the increase in standard of living. The need for electricity in services and traffic (mainly rail traffic) is estimated to amount to 19.9 TWh in 2020 (+3.7 TWh).

The need for electricity in housing, farming and electric heating is estimated to amount to 26.2 TWh in 2020 (+4.2 TWh). The increase in electricity needs for housing comes mainly from a greater number of households and bigger apartments. The use of electricity is reduced by the estimated improvement in the energy efficiency of devices, even though the increase in the number of electric devices eats up a share of the savings arising from the improved efficiency.

### *Energy efficiency*

The significance of energy efficiency has increased in recent years. The main reasons include increased energy expenses and the prevention of climate change, the significance and impacts of which have got more attention. The future of Finland's energy efficiency is affected significantly by the energy efficiency decisions issued by the European Union, according to which energy efficiency should be improved by 20 per cent by 2020. In addition, the emissions trading sector, such as households, traffic, services and part of industry, is controlled by the Energy Services Directive which sets a binding 9 per cent energy saving target for these operators in 2008–2016.

In Finland energy efficiency is at a high level compared to the international situation. Finland is one of the world's leading countries in energy efficient combined heat and power production. Central element in improving the efficiency of energy use is energy efficiency agreements between the state and operators. The long-term agreement system were deepened and expanded through agreements signed at the end of 2007, involving the business community and municipalities. The traffic sector is also involved in the agreement entity. The agreement system covers 60 per cent of end use of energy in Finland.

The central parts of the agreements include the recognition of the potential to improve energy efficiency and the implementation of actions required for improved efficiency. In 1998–2006, the operators within the scope of the agreements had improved the efficiency of their electricity use so that 1.7 TWh of electricity is saved every year compared to a situation where actions had not been implemented. In addition, the contractual operators have the possibility to implement a similar amount of more efficient electricity use if the actions are financially profitable.

As the organisation responsible for the OL4 venture, TVO does not have access to any energy conservation means that would allow replacement of the quantity of electricity produced by the new nuclear power plant unit while continuing the operations of the shareholders and other electricity consumers as planned.

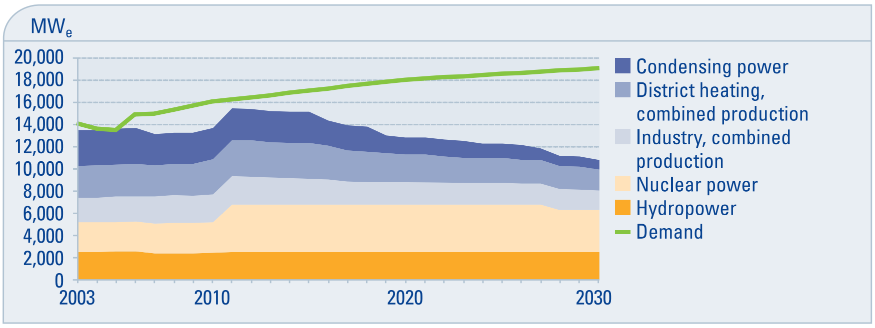
## 1.1. Current status of electricity supply and future outlook in Finland

Finland utilises different sources of energy in its electricity production in a versatile manner. The diversification supports maintenance of supply, competition on the open electricity market and, as a result, the availability of electricity as competitively as possible.

In 2007, 90.3 TWh of electricity was used in Finland. Combined production of electricity covered 29 per cent of this need. The share of nuclear power was 25 per cent and that of other condensing power 16 per cent. The import of electricity from Russia, Sweden, Norway and Estonia amounted to 14 per cent of the total electricity need in 2007. The share of wind power was 0.2 per cent.

On the basis of the Electricity Production Scenarios in 2030 issued by the Finnish Energy Industries, the need for maximum electric output and the available capacity in Finland will develop according to figure 4–1.

***Figure 4–1*** *Capacity available during maximum consumption: current plants and the plants for which an implementation decision exists at the beginning of 2008.*




According to the figure, the difference between the maximum need and the current capacity will increase to 2,800 MW before the new fifth nuclear power plant unit is completed and will decline to 1,200 MW after its completion. Then, the difference will increase to about 5,500 MW in 2020 and about 8,400 MW in 2030.

## 1.2. Alternatives for electricity supply

### *1.2.1. Renewable energy sources*

Renewable energy sources can be utilised in the production of electricity and heat and as a raw material for biofuels for traffic. Renewable energy sources in Finnish electricity production include hydropower, biomass (mainly wood but also field biomass), waste and wind power. Solar power cannot be utilised to a significant extent in Finland in the foreseeable future.

In March 2007, the European Union decided to increase the use of renewable energy sources in the EU area to constitute 20 per cent of the total energy consumption. This overall objective will be divided into member state-specific obligations. In its directive proposal issued on 23 January 2008, the European Commission proposed a binding objective of 38 per cent for renewable energy in the consumption of end energy in Finland in 2020. This means an increase of nine percentage points in renewable energy compared to the level in 2007. The directive proposal does not deal with the methods of how renewable energy should be used in electricity and heat production and traffic. This division will be carried out in each member state.

*Hydropower*

Hydropower is used to produce 12.8 TWh of electricity a year during average flow years, i.e. about 15 per cent of the total electricity consumption in Finland. The production varies according to the water situation. The difference between a dry and a wet year in Finnish hydropower production is about 5 TWh, i.e. 5 per cent of the total electricity need.

The production of hydropower can be increased in Finland. A large part of Finnish hydropower resources has already been utilised in electricity production. In addition, the Rapid conservation law limits the possibilities of using hydropower. The largest possibilities of increasing the use of hydropower are the Vuotos and Kollaja projects and the Ounasjoki River. Production can also be increased by developing regulation, reducing by-pass flow, building unprotected rapids (mostly in small and micro hydropower production) and renewing the existing hydropower plants. According to the estimates of the Finnish Energy Industries, the quantity of electricity produced through hydropower can be increased annually by 1.3 TWh by 2020.

Electricity consumption varies at different times of day, on different weekdays and during different seasons. Electricity production must correspond to electricity consumption at all times. As a result, balancing power is required, for which balanced hydropower is well-suited. In order to even out variation in electricity need depending on seasons, leachate is to be stored in water systems so that it can be used during consumption peaks. Short-term regulation adapts electricity production according to daily variation in consumption which is 25 per cent of the average at maximum. Balancing hydropower can also balance wind power production which is fully dependant on weather.

*Forest and field biomass and waste*

Wood, field biomass and waste produce nearly 10 TWh of electricity, i.e. about 11 per cent of the total electricity need in Finland. Wood-based fuels are mainly used in combined heat and power production (CHP) in forest industry in Finland. The most important wood-based fuels in industry include bioliquid created in pulp processes and industrial waste wood. In practice, Finnish energy production utilises all of the wood material not viable for further industrial processing. Nearly all of the wood-based electricity, including the production of district heating, is produced in combined CHP in Finland. According to the estimates of the national energy and climate strategy in 2006, the volume of CHP can be increased to more than 32 TWh by 2020 compared to the current level. The electricity is produced using peat, coal, natural gas and biomasses, of which wood is the most important.

Increased energy use of wood is strongly affected by the development of the amount of forest industry production and the production structure. The amount of wood energy in forest industry can vary a great deal from year to year depending on changes in utilisation rates, and the felled volume in forests may vary depending on production in the forest industry. The increase in the wood energy volume in the forest industry is mainly tied to the increase in production volumes.

For wood energy, significant growth potentials are related to forest energy, i.e. wood chips obtained through final and intermediate harvesting and from stumps. The economic viability of the use of forest chips is significantly affected by the transportation distance of the wood material. Emission trading makes wood even more competitive compared to fossil fuels and peat. Wood harvesting also has an effect on regional employment. The use of forest chips amounts to 3 million cubic metres a year at the current level. In 2010, it is estimated to amount to 5 million cubic metres. The production of field energy, i.e. reed canary grass, has increased significantly in recent years. In 2007, the cultivation area of field energy was nearly 20,000 hectares, whereas energy plants were cultivated in an area less than 2,000 hectares at the beginning of the millennium. According to the estimate of the Ministry of Agriculture and Forestry, the cultivation area of reed canary grass could be increased to about 100,000–150,000 hectares by 2020. Reed canary grass is mainly used in CHP.

Recycled fuel produced from waste is also noteworthy but marginal energy source which can be used to reduce the amount of waste transported to landfill sites and, as a result, the environmental and health hazards caused by landfill sites. Recycled fuel can also be used to reduce the use of fossil fuels. Several waste incineration plants are currently being planned in Finland.

*Wind power*

At the end of 2007, Finland had nearly a hundred wind power plants that produced a total of 0.2 TWh of electricity, constituting about 0.2 per cent of the total electricity need in Finland. The best regions for increasing wind power are the coastal areas. Sea areas constitute the best production areas for wind power. Even though the theoretical increase potential of wind power is significant, it cannot be used to solve the need for additional capacity of base load power.

In practice, the construction of wind power is limited by production costs and regulations related to regional land use. The investment costs for wind power built at sea are 50–80 per cent higher than those built on land. Wind power plants must also be regionally accepted.

The improvement of competitiveness is one of the central challenges for wind power. As a result, the state grants investment support for wind power, the amount of which has been 20–30 per cent of the building costs depending on the project. In addition, wind power receives production support amounting to EUR 6.90/MWh.

The production of wind power is fully dependent on the amount of wind. A wind power plant produces one-fourth of the amount of electricity that could be produced in a power plant of a different type and a similar size. In order to even out variations in wind power production, the other electricity production mechanism has to adapt to the changing production of wind power and produce the additional electricity required. Because of the varying production and high production costs wind power is not suitable for the production of base load power.

*Solar power*

Currently, solar power has such high production costs in Finnish conditions that it can only be used reasonably in certain special applications. It is typically used in summer cottages and in technical systems in distant locations or behind difficult transportation connections, such as IT link stations and beacons.

### *1.2.2. Nuclear power*

In Finland 22.5 TWh of electricity was produced in 2007 using nuclear energy, amounting to about 25 per cent of the total electricity consumption. The third nuclear power plant unit at Olkiluoto will increase the amount of nuclear power by 13 TWh a year.

The majority of the production costs of nuclear power are formed of fixed costs. Fuel amounts to about 15 per cent of the total expenses. As a result, nuclear power is well-suited for the production of base load power. In addition, the dependence of nuclear electricity's production costs on fluctuations in fuel price and exchange rates is low, because the share of the fuel in overall production costs is minor. Nuclear power plants do not produce carbon dioxide emissions and, as a result, the EU emission trading does not cause any additional costs.

### *1.2.3. Coal*

Power plants that use coal as fuel produced a total of 12.7 TWh of electricity in 2007, corresponding to about 15 per cent of the total electricity consumption in Finland. 8.5 TWh was produced in power plants that produce only electricity and the remaining volume was produced in CHP plants. Coal is a significant fuel in combined heat and power production in e.g. Helsinki, Turku and Vaasa.

As balancing power and backup power during dry years, condensing coal power has a central role on the Nordic electricity market. In addition to

Finland, Denmark has significant condensing power capacity based on coal. The EU emission trading has a significant effect on the price of electricity produced using condensing coal and other fossil fuels. If the price of an emission allowance is EUR 20/ton of $CO_2$, the calculated electricity production costs of condensing coal power plants are increased by about EUR 16 per megawatt hour if the plant has to acquire emission rights.

Carbon dioxide emissions of coal power plants can be reduced significantly through carbon dioxide capture and storage. This technology cannot yet be utilised commercially, but research and product development are carried out around the world. According to preliminary estimates, the capture and storage of carbon dioxide will increase the production costs of condensing coal plants by tens of euros per megawatt hour.

### *1.2.4. Natural gas*

In 2007, natural gas was used to produce 10.3 TWh of electricity in Finland, covering more than 11 per cent of Finland's electricity consumption. Most of it was produced in combined CHP plants. In Finland, natural gas is only used in southern Finland where the natural gas network extends to. The natural gas network is planned to expand to the Turku region. All of the natural gas used in Finland is imported from Russia.

Also the use of natural gas creates carbon dioxide emissions advancing greenhouse effects. Because of the properties of natural gas and its electricity production technology, the emissions are about one half compared to a similar coal power plant. If the price of an emission allowance is EUR 20/ton of $CO_2$, the costs of condensing electricity produced using natural gas will increase by EUR 10 per megawatt hour.

### *1.2.5. Peat*

In 2007, peat was used to produce 6.6 TWh of electricity in Finland, covering 7.3 per cent of the total consumption. Approximately one half of peat electricity was produced in CHP plants and the rest in condensing power plants. Power plants that use peat mainly use multi-fuel boilers where several fuels can be utilised at the same time. Peat is often used together with wood.

Even though peat is a slowly renewable biofuel according to many researchers, its emissions are calculated in international greenhouse gas inventories as if it was a fossil fuel. As a result, the EU emission trading causes additional costs to condensing peat electricity. If the price of an emission rights is EUR 20/ton of $CO_2$, the production costs of peat electricity will be increased by nearly EUR 20 per megawatt hour.

### *1.2.6. Import*

In 2007, the volume of imported electricity was 12.6 TWh covering 14 per cent of the electricity need. The volume of imported electricity depends on the Nordic hydrological balance. Approximately one half of the electricity consumption in the Nordic countries is covered by hydropower. The difference in hydropower production between a dry and wet year is annually about 70 TWh in the Nordic countries. In dry years, condensing power produced in Finland and Denmark is exported to Norway and Sweden, and correspondingly, in rainy years, electricity produced by hydropower is imported from Norway and Sweden to Finland and Denmark.

In 2007, 10,2 TWh of electricity was imported from Russia corresponding to more than 80 per cent of the total imported electricity volume. Imports from Russia are significantly affected by the sufficiency of the country's electricity production capacity in the regions surrounding Finland. According to estimates, the possibilities of importing electricity will be reduced as compared to previous years because of the increase in electricity consumption in the St Petersburg region in particular. Russia may even become a buyer of electricity on the Nordic market, which may have a remarkable impact on Finland's electricity balance.

### *1.2.7. A summary of the supply alternatives for the additional electricity required*

With regard to renewable energy sources, the production of hydropower can be increased by 1.6 TWh from the current situation at an annual level. The use of biomass will be mainly focused on combined heat and power production and its volume can be increased to about 32 TWh a year from the current level. Increase in wind power production must take into account its variability, the resulting need for balancing power and its high production costs.

The aforementioned forms of production are not solely sufficient to cover the deficit between electricity consumption and production capacity. The main option for covering the deficit is to increase the production of condensing power. Fuels to be used in condensing production include peat or fossil fuels, such as coal or natural gas. Condensing power can also be increased through nuclear power which is a very good option worth increasing compared to peat and fossil fuels when considering the security of supply, the competitive production costs of electricity and the restriction of emissions. The plant unit referred to in the application will account for a significant part of the deficit in capacity to be created in Finland and will reduce Finland's dependency on imported electricity.

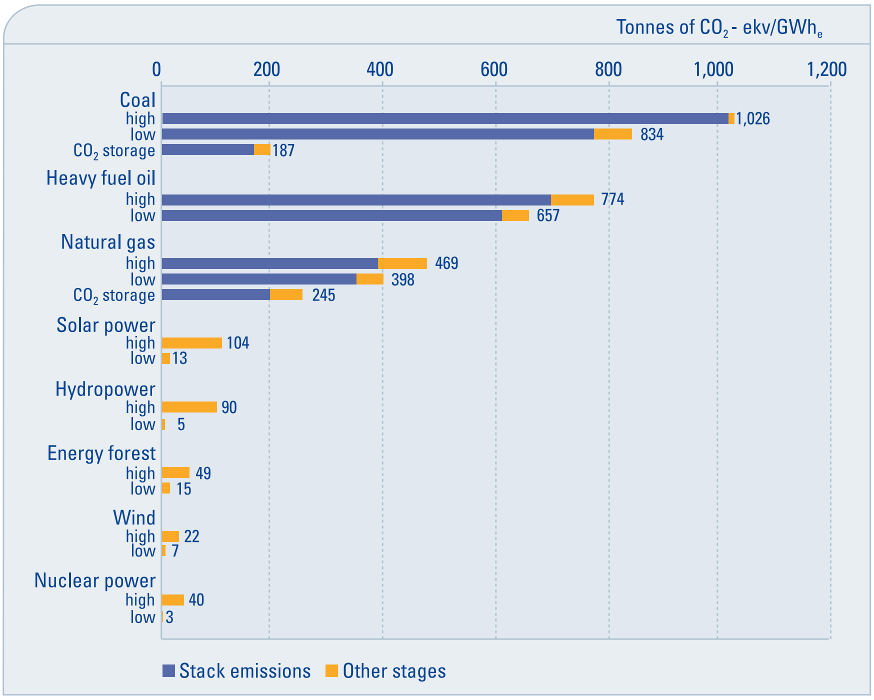
## 2. ENVIRONMENTAL IMPACT ASSESSMENT FOR ELECTRICITY PRODUCTION

Different energy sources have a different environmental impact with regard to their quantity and extent. Some of the impact is related to the production of fuel, some to the construction of power plants, some to energy production and some to the decommissioning of power plants.

The environmental impact can be assessed in a number of ways. Life cycle analysis is a method used to assess the environmental impact caused by a product, process or action during its life cycle. This analysis also identifies the impact that is not caused at the energy production site or its immediate vicinity.

The most significant greenhouse gas emission in energy production is carbon dioxide. A number of reports have been prepared for the carbon dioxide emissions of different forms of electricity production. The World Energy Council (WEC) has prepared a summary including information from several different reports. The results are presented in figure 4–2.

***Figure 4–2*** *Greenhouse gas emissions of different forms of energy, in electricity production only, as equivalent carbon dioxide volumes per produced electric energy. The figure presents the maximum (top) and minimum (low) emissions obtained through different life cycle inspections. Source: World Energy Council.*




Carbon dioxide emissions are increased in energy production by the combustion of coal, oil, natural gas and peat. Biomass is considered to be a neutral fuel for climate change because the carbon dioxide released in its combustion is bound back to nature as plants grow. Hydropower, wind power, nuclear power and solar energy do not directly increase the carbon dioxide content in the atmosphere. However, these forms of energy production cause some quantities of greenhouse gas emissions that are caused by the procurement of materials and fuels, component manufacturing, transportation and the construction and decommissioning of plants.

In addition to carbon dioxide, environmental impacts are caused by sulphur dioxide, nitrogen oxide and particle emissions that also vary from one form of electricity production to another. Tables 4–1 and 4–2 present an estimate of the emissions created if the fourth production unit is not built at Olkiluoto. Because it is difficult to accurately estimate the production structure of electricity at the end of 2010s, the environmental impacts are assessed in a situation where the electricity capacity of the fourth Olkiluoto production unit would be replaced with production from the current average Nordic production capacity.

***Table 4–1*** *Estimated emissions of sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$) and carbon dioxide ($CO_2$) in a situation where the annual production of OL4 would be replaced in accordance with the average Nordic distribution of electricity production in 2005.*

| | Average emissions in electricity production | | | | | Avoided emissions tons/year | |
|---|---|---|---|---|---|---|---|
| | Finland kg/MWh | Sweden kg/MWh | Norway kg/MWh | Denmark kg/MWh | Electricity production's weighted value kg/MWh | **Production 8 TWh** | **Production 14 TWh** |
| $CO_2$ | 258.34 | 19.73 | 5.61 | 552.49 | 115.73 | **925,818** | **1,620,182** |
| $SO_2$ | 0.37 | 0.04 | 0.03 | 0.50 | 0.15 | **1,189** | **2,080** |
| $NO_x$ | 0.47 | 0.03 | 0.01 | 1.22 | 0.23 | **1,828** | **3,199** |

***Table 4–2*** *Estimated particle emissions in a situation where the annual production of OL4 would be replaced in accordance with the average Nordic electricity production in 2006.*

| | | | | | Avoided emissions tons/year | |
|---|---|---|---|---|---|---|
| | Production 2006, GWh | Electricity production, efficiency | Nominal emission factor, mg/MJpa | Share of total production 2006 | **Production 8 TWh** | **Production 14 TWh** |
| Coal | 42.9 | 45% | 17.5 | 11.2% | 125.1 | 219.0 |
| Oil | 3.1 | 45% | 15.0 | 0.8% | 7.8 | 13.6 |
| Peat | 6.3 | 42% | 17.5 | 1.6% | 19.7 | 34.5 |
| Natural gas | 19.6 | 57% | 1.5 | 5.1% | 3.9 | 6.8 |
| Biofuels | 19.5 | 42% | 17.5 | 5.1% | 60.9 | 106.7 |
| Waste | 4.2 | 42% | 3.7 | 1.1% | 1.1 | 4.9 |
| | | | | | 220 | 385 |

Currently and in the foreseeable future, condensing coal power is, for most of the year, the form of production that is the most expensive in the running order within the Nordic electricity market area. If the new nuclear power plant unit replaces condensing coal power production in full, the avoided emissions will be, according to the best technology available, 6–10 million tons for carbon dioxide and several thousands of tons for acidifying emissions, depending on the size of the plant (Table 4–3).

***Table 4–3*** *Avoided emissions (tons/year) in a situation where the new nuclear power plant would fully replace condensing power produced by coal.*

| | $CO_2$ | $SO_2$ | $NO_x$ | Small particle |
|---|---|---|---|---|
| 8 TWh | 5,924,127 | 3,288 | 3,288 | 219 |
| 14 TWh | 10,367,223 | 5,751 | 5,751 | 383 |

## 3. IMPACTS ON EMPLOYMENT AND THE REGIONAL STRUCTURE AND ECONOMY

The most substantial parts of the nuclear power plant investment constitute earth construction, the construction of power plant buildings and the procurement of equipment. The construction of the power plant unit is estimated to take about 6 to 8 years.

The employment effect of constructing a new nuclear power plant unit is substantial. The direct employment effect in Finland is expected to be 12,000 to 15,000 man-years. The indirect employment effect in Finland is expected to be 10,000 to 13,000 man-years. The domestic content of the nuclear power plant unit is estimated to be 35–45 per cent.

The venture's employment effects in foreign countries exceed those in Finland. However, significant part of foreign work will be carried out in Finland. The foreign plant supplier's operations on site will have economic effects through different factors, such as the demand for construction site services, short- and long-term accommodation for foreign employees and trade in consumer goods.

The fourth nuclear power plant unit will require approximately 200 people of operating personnel, and the increased need for outsourced services will correspond to the work input of approximately 100 people. Annual outages will require approximately 700 to 1,000 people of suppliers' labour force. The annual value of maintenance investments in the fourth plant unit will be EUR 20 million on average.

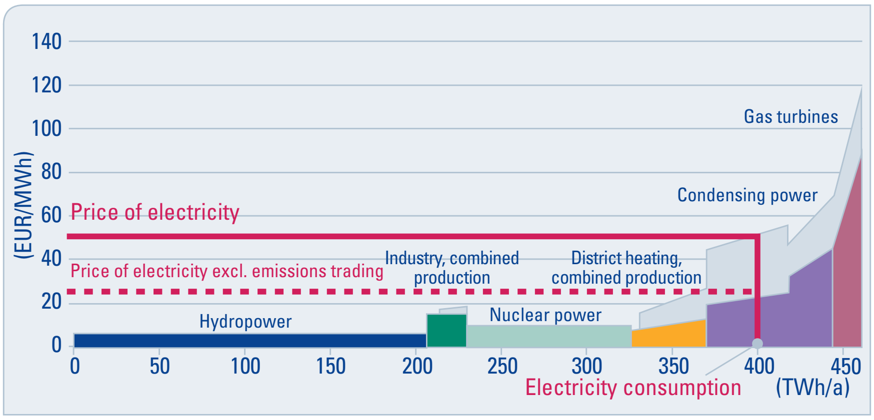
The construction of the new nuclear power plant unit will increase real estate tax income in the municipality of Eurajoki by a few million euros. The increase in real estate tax income will begin during the construction period and continue throughout the entire service life of the plant. Municipal tax on salaries will be increased by EUR 2 million a year in the region as the number of regular employees in the nuclear power plant at Olkiluoto will increase by approximately 300 people.

## 4. IMPACT ON THE NORDIC ELECTRICITY MARKET

Finland, Sweden, Norway and Denmark constitute a uniform Nordic electricity market area created during the last ten years as the countries have opened their electricity markets for competition. Electricity consumption within the Nordic electricity market area is about 400 TWh a year. The share of hydropower is one half, nuclear power constitutes one-fourth and conventional thermal power about one-fourth.

The price of electricity is determined on the Nordic electricity exchange on the basis of demand and supply and the Nordic marginal production cost as shown in figure 4–3.

***Figure 4–3*** *Variable production costs and the running order of power plants on the Nordic electricity market.*




As illustrated in the figure above, the variable production costs of hydropower are the lowest in comparison to other forms of production. Nuclear power comes next in the running order. It is followed by combined heat and power production in industry and communities, the volume of which depends directly on the heat need by industry and communities at each time. The production of pure condensing power is generally more expensive than combined heat and power production and, as a result, it comes next in the running order.

The new nuclear power plant unit will increase the share of nuclear power production by the marginal cost curve illustrated in the figure above. As a result, the need for using more expensive forms of production will be reduced. This will reduce the market price of electricity.

## 5. THE VENTURE'S SIGNIFICANCE FOR OTHER NUCLEAR POWER PLANTS AND NUCLEAR WASTE MANAGEMENT

The new nuclear power plant unit will be located at the power plant site at Olkiluoto where there are two operational nuclear power plant units and the third unit is under construction. The plant area contains infrastructure that serves the OL1, OL2 and OL3 units and that the new unit will utilise. For example, the distribution of general expenses related to administration, operations, maintenance and guarding over four units will significantly reduce the price of produced electricity. The use and maintenance of the new nuclear power plant unit will be supported on the nuclear power plant competence and services created by corresponding functions in the OL1, OL2 and OL3 units.

The Olkiluoto power plant site has an interim storage facility for spent nuclear fuel serving nuclear waste management of the existing plant units and has final disposal facilities for low- and intermediate-level nuclear waste. These facilities will be expanded for the requirements of OL3 in the near future. The nuclear waste management of the new unit will be supported by these existing facilities, the design of which takes into account the possibility of expanding the capacity.

The nuclear power plant's licence holder will be responsible for the implementation and costs of the plant's nuclear waste management. TVO's existing and planned nuclear waste management arrangements or similar arrangements are also appropriate for managing nuclear waste from the new power plant unit. The company's available and planned arrangements can be used for the management of all nuclear waste produced in the current and future plant units.

# DESCRIPTION OF THE APPLICANT'S FINANCIAL PREREQUISITES FOR OPERATIONS AND THE NUCLEAR POWER VENTURE'S ECONOMIC VIABILITY

CONTENTS

# 1. THE APPLICANT'S FINANCIAL PREREQUISITES FOR OPERATIONS

## 1.1. Shareholders and users of electricity

TVO's line of business is to construct power plants to produce, supply and transmit electricity primarily to its shareholders.

The company's shares are divided into series so that the rights and obligations of the OL1 and OL2 power plant units are directed at the A-series shares, the rights and obligations of the OL3 project are directed at the B-series shares and the rights and obligations of the Meri-Pori coal-fired power plant are directed at the C-series shares. The ownership shares of different sets are described below.

***Table 5–1** TVO's shareholders and shareholding of different series of shares in percentage, 1 January 2008.*

| | A-series | B-series | C-series | Total |
|---|---|---|---|---|
| Etelä-Pohjanmaan Voima Oy | 6.5 | 6.6 | 6.5 | 6.6 |
| Fortum Power and Heat Oy | 26.6 | 25.0 | 26.6 | 26.1 |
| Karhu Voima Oy | 0.1 | 0.1 | 0.1 | 0.1 |
| Kemira Oyj | 1.9 | 0.0 | 1.9 | 1.2 |
| Oy Mankala Ab | 8.1 | 8.1 | 8.1 | 8.1 |
| Pohjolan Voima Oy | 56.8 | 60.2 | 56.8 | 57.9 |

The largest shareholder in the company is Pohjolan Voima Oy (PVO), whose owners are Finnish forest industry companies, municipalities and towns as well as energy companies owned by them.

The shareholders of Etelä-Pohjanmaan Voima Oy are mostly distribution companies owned by the municipalities in the province of Etelä-Pohjanmaa.

Fortum Power and Heat Oy is part of Fortum Group, whose principal owner is the State of Finland. The company's business comprises the production, sales and transmission of electricity and heat. Its customers include distribution companies owned by towns and municipalities, industrial companies and other major consumers of electricity. Fortum Power and Heat Oy owns and operates the Loviisa nuclear power plant.

Kemira Group is a chemical industry company operating in four business areas: Kemira Pulp&Paper, Kemira Water, Kemira Speciality and Kemira Coatings. Kemira's largest owners are Oras Invest Oy (16.6 per cent) and the State of Finland (16.5 per cent).

Oy Mankala Ab is a company owned by the City of Helsinki which produces and procures electricity primarily for its shareholders.

Karhu Voima Oy is part of the German E.ON energy group.

Users of electricity produced by TVO include Finnish society and electricity consuming industry. Through the shareholding energy companies and other companies, TVO's electricity is distributed to about 60 Finnish industrial and electricity companies.

TVO's shareholders are responsible for the variable and fixed annual costs in accordance with the Articles of Association. Each of the company's shareholder is responsible for the company's fixed annual costs, including interest on loans and instalments according to the number of shares owned regardless of whether the shareholder in question has used its share in the electricity generated by the company. In addition, each shareholder is responsible for the variable annual costs in the proportion it has consumed the electricity generated or transmitted by the company.

The company sells the electricity it produces to its shareholders at cost price without aiming at profit. The shareholders and the Articles of Association maintain that TVO has sound financial prerequisites for its operations.

## 1.2. Financial position of the company

Information about the company's financial position can be found in the enclosed financial statements for 2007 included in the Annual report.

According to the financial statements, the company's balance sheet total on 31 December 2007 stood at EUR 2,951 million. Shareholders' equity and similar items amounted to EUR 826 million. The amount of debt was EUR 2,011 million, of which debt owed to the Finnish State Nuclear Waste Management Fund (VYR) and further lent to the company's shareholders amounted to EUR 648 million, and subordinated shareholder loans amounted to EUR 179 million. 15 per cent of the company's loans are allocated to the A-series, 80 per cent to the B-series and 5 per cent to the C-series.

Approximately EUR 800 million has been spent on annual maintenance investments, including investments in infrastructure, during the current service life of the OL1 and OL2 plant units. In addition, the low-pressure turbines and generators of both plant units will be renewed and, as a result, their nominal output capacity will increase to 885 MW from the current 860 MW. The investments will amount to about EUR 100 million and will be implemented during 2010 and 2011. Approximately EUR 1,285 million of the investment in the OL3 project were implemented by the end of 2007.

*Table 5–2 Development of Teollisuuden Voima Oyj's key figures. Financial statements according to the Financial Accounting Standards (FAS).*

| r | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|
| Electricity sales (GWh) | | | | |
| Olkiluoto 1 | 7,001 | 7,208 | 6,956 | 7,317 |
| Olkiluoto 2 | 7,072 | 6,984 | 7,278 | 7,032 |
| Meri-Pori | 1,797 | 250 | 1,509 | 1,374 |
| Total | 15,870 | 14,442 | 15,743 | 15,723 |
| | | | | |
| Assets in VYR (€ million) | 793 | 827 | 864 | 928 |
| Turnover (€ million) | 217 | 199 | 227 | 225 |
| Fuel costs | 69 | 44 | 65 | 66 |
| Nuclear waste management costs | 23 | 27 | 29 | 49 |
| Other income and expenses | 90 | 94 | 106 | 101 |
| Capital costs | 58 | 59 | 56 | 57 |
| EBITDA | -23 | -24 | -29 | -48 |
| Investments | 382 | 647 | 272 | 227 |
| Equity | 229 | 408 | 408 | 604 |
| Appropriations | 322 | 298 | 269 | 221 |
| Loans from financial institutes | 375 | 967 | 1,063 | 1,183 |
| Loans from shareholders | 179 | 179 | 179 | 179 |
| Loan from VYR | 573 | 595 | 620 | 648 |
| Balance sheet total | 1,745 | 2,519 | 2,639 | 2,951 |
| Debt/equity ratio (%) | 62.3 | 46.0 | 42.5 | 43.6 |

$$\text{Debt/equity ratio, \%} = 100 \times \frac{\text{equity + appropriations + loans from shareholders}}{\text{balance sheet total – loan from the Finnish State Nuclear Waste Management Fund (VYR)}}$$

## 1.3. Funds for nuclear waste management

TVO's liabilities for nuclear waste management (the estimated future expenditure for decommissioning plant units and the management of nuclear waste produced until now) stood at EUR 1,080 million at the end of 2007. EUR 928 million of this amount has been collected in the Finnish State Nuclear Waste Management Fund. The difference is covered through securities. The amount in accordance with the liabilities will be collected to the Finnish State Nuclear Waste Management Fund pursuant to the Government decision in 2008–2012.

The new OL3 plant unit under construction will join TVO's preparation system for nuclear waste management when the plant unit starts operating and the assets required will be collected as part of electricity price to the Finnish State Nuclear Waste Management Fund.

The same procedures will be applied to the new OL4 plant unit.

### 1.4. Risk management and insurance

TVO has a comprehensive risk management plan that is revised regularly. Risk management is monitored by the company's Board of Directors. Risks are to be minimised primarily through internal actions and to be covered through insurance.

The company has a valid nuclear unit material damage insurance for both Olkiluoto 1 and Olkiluoto 2. Property is insured for its full value and the insurance includes separate coverage for decontamination costs.

A separate nuclear liability insurance is valid for each nuclear power plant unit Olkiluoto 1 and Olkiluoto 2 up to the amount of liability required by law. The insurance will pay for damages that TVO as the operator of the nuclear facilities is liable to compensate for by virtue of the Nuclear Liability Act (484/72) and its amendments. The Finnish nuclear liability system is based on the Paris Convention and the Brussels Supplementary Convention.

The insurance amount for each nuclear unit in 2008 is 210 million Special Drawing Rights (SDR) referred to in the Nuclear Liability Act. At the current exchange rates, this corresponds to approximately EUR 230 million per plant unit.

For the OL3 project, the company has full value insurance during construction. In addition, the company has delay insurance, transportation insurance and liability insurance for the OL3 project.

As the Nuclear Liability Act changes, the plant holder must take up insurance or security by the amount of EUR 700 million with a 30-year limitation of actions in personal injuries covering all environmental damage.

## 2. ECONOMIC VIABILITY OF THE VENTURE

### 2.1. General

The venture will increase the production of foreseeable and stable base load power with low production costs. The long-term production costs of electricity will have a crucial impact on power plant investment decisions of the applicant and its shareholders.

The venture's economic viability will be examined below on the basis of electricity production costs. It is in the overall good of society that electricity is produced in as inexpensive manner as possible. For this purpose, the costs of electricity produced using alternative power plant types suitable for the production of base load power will be compared and certain central issues related to the production costs will be examined. Key factors related to the economic viability of the nuclear power plant investment will also be presented.

## 2.2. Cost structure of the options for electricity production

Several national and international estimates have been prepared for the costs arising from the alternative production options for base load electricity. Local conditions have a significant effect on the results.

The cost structures of base load electricity produced using different power plants and fuels differ from each other significantly. This is illustrated below in the figure in Section 2.3 by dividing the total production costs of each production alternative into capital, operational and fuel costs. In addition, any expenses arising from carbon dioxide emissions must be accounted for.

Power plants producing electricity in a stable and foreseeable manner where electricity can be produced in sufficiently large units are the most suitable for the production of base load power.

Nuclear power and wind power are the most capital intensive forms of production but nuclear power is the best-suited for base load power production because of its steady and high utilisation rate. Among the examined base load power alternatives, nuclear power is clearly the most capital-intensive, while natural gas was the least capital-intensive.

The share of investment costs in electricity production costs (without any emission trading costs) is about 60 per cent for nuclear power, 25 per cent for coal, more than 10 per cent for natural gas, about 30 per cent for peat and more than 30 per cent for wood. Thus the investment costs have a significant effect on the economy of nuclear power. On the other hand, the large share of investment costs makes the costs arising from electricity produced using nuclear power stable and predictable.

The share of fuel costs in the total electricity production costs varies greatly between the examined forms of production.

For nuclear power, the share of fuel costs in the calculations is only about 15 per cent of the total electricity production costs, whereas the share is far greater in other energy sources – generally more than one half of the production costs. The small share of fuel costs makes the nuclear power costs stable and predictable.

The fuel costs for nuclear power comprise the raw uranium, its conversion into material suitable for the enrichment process, uranium enrichment, and the manufacture of fuel elements. The share of the actual raw material, i.e. uranium, is approximately one half of the fuel costs, so the share of uranium in the production costs for nuclear electricity is about 7–8 per cent. The rest of the fuel costs comprise the other phases of fuel manufacturing, which constitute normal industrial production and whose costs can be reliably predicted.

The dependence of nuclear power production costs on fluctuations in fuel price and exchange rates is low because the share of the fuel in the total production costs is minor. The dependence of production costs on the market prices of coal, natural gas, peat and wood is significant for these corresponding forms of electricity production. This will significantly increase the insecurity of long-term estimates for these alternatives. Furthermore, the price of electricity produced by coal or natural gas is very sensitive to foreign exchange rate fluctuations.

The forms of production using fossil fuels (coal, gas and peat) include costs arising from carbon dioxide emissions, increasing their production costs substantially.

### 2.3. Reports and calculations prepared

TVO has prepared calculations for the power plant venture's economic viability and funding. The reports prepared indicate that nuclear energy has the lowest production costs.

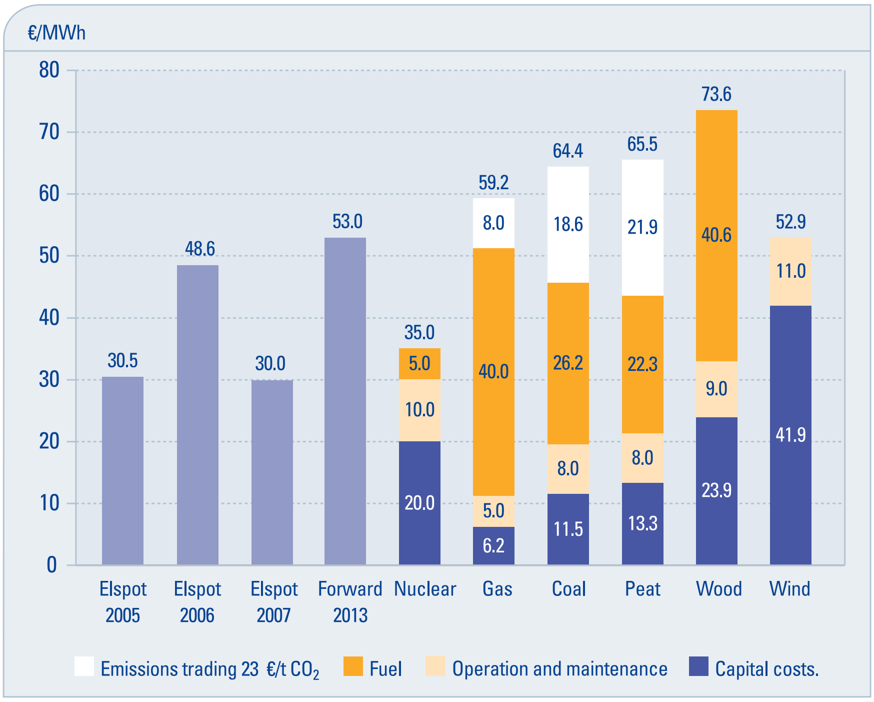
With regard to investment costs for nuclear power plants, the calculations are based on TVO's experiences and preliminary price information and implementation schedules received from some nuclear power plant suppliers. Correspondingly, fuel and operational costs are based on the realised and estimated costs for Olkiluoto.

On the basis of the reports prepared, the total investment costs for the new nuclear power plant, including interest during construction, will amount to EUR 3–4 billion depending on the size and plant type. The investment costs include costs for connections to the infrastructure and nuclear waste management as well as interest during construction calculated using 5 per cent interest rates over the estimated construction period.

The costs for the alternative forms of production for base load electricity have also been compared in the study conducted by the Lappeenranta University of Technology in 2008. The results are presented in figure 5–1.

The study compared the cost structures and production costs of nuclear power, coal, natural gas, peat, wood and wind power using different annual operating volumes. The study proved a 1,500 MW nuclear power plant to be the least expensive option when the plants were used for base load power production and the operating rate was 8,000 hours a year.

***Figure 5–1*** *Electricity production costs for the base load power options using an 8,000 hour operating rate (apart from wind power whose operating rate is 2,200 hours). Real rate of interest 5 per cent, price level January 2008, emission allowance price EUR 23/t $CO_2$, wood and wind without any support. Source: Lappeenranta University of Technology 2008, Professor Risto Tarjanne.*




In the estimate, the new production unit is located at a plant site where other units are already operating. As a result, the capital costs do not account for any infrastructure costs, such as network connections, road connections, port, fresh water management, wastewater treatment systems, environmental monitoring and standby arrangements.

## 2.4. Realised electricity production in the current Olkiluoto plant units

The electricity production of the current plant units at Olkiluoto has varied between 14.1 TWh and 14.3 TWh over the past five years. Production costs are estimated to increase slightly in the near future because of the increased cost estimates related to increased fuel costs and final disposal of nuclear waste.

The net electric power of the Olkiluoto 1 and Olkiluoto 2 plant units are 860 MW after the turbine modernisation implemented in 2005–2006. After the turbine and generator renewals to be implemented at the end of the decade, their net power will increase to 885 MW.

The annual production objective of the OL3 plant unit under construction is 12–13 TWh on the basis of the utilisation rate assessed for the first years.

The electric power of the new planned nuclear power plant unit will be 1,000–1,800 MW depending on the plant type selected. Based on the above and the utilisation rate assessed for the first years the planned annual production objective is 8–14 TWh.

### 2.5. Summary

According to the reports prepared, nuclear power is the most economical option among the compared alternatives. In addition, costs can be reduced further as the new power plant unit will be built in the existing plant at Olkiluoto, in which case the built infrastructure can be utilised.

A special benefit of nuclear power is the long-term predictability of production costs. Because nuclear power does not generate greenhouse gas emissions and does not cause any related additional costs, the competitiveness of nuclear energy is assumed to improve in the future.

The additional construction of nuclear power is a strategic investment for the energy policy of the entire nation and it will have a long-term stabilising effect on the price level of electricity within the entire market area.

If the new plant unit's electricity production is valued at the long-term market price, the venture will produce sufficient profit on the invested capital. Furthermore, the company's financial key figures and its ability to manage funding are at a level satisfactory to financiers.

## 3. APPENDICES

Teollisuuden Voima Oyj, Annual Report 2007


www.tvo.fi

# OVERALL FINANCING PLAN FOR THE NUCLEAR FACILITY VENTURE

CONTENTS

## 1. INVESTMENT

The preliminary cost estimate for the venture is on the order of EUR 3 to 4 billion depending on the size and type of plant. The cost estimate includes interest during the construction time.

With regard to the investment costs of the nuclear power plant unit, the calculations are based on TVO's own experience, as well as preliminary pricing information and implementation schedules received from nuclear power plant suppliers.

The amount of investment costs will be specified in more detail when binding offers are received from plant suppliers.

## 2. SCHEDULE

According to the preliminary venture implementation schedule, the financing of the basic investment will be distributed over approximately seven years. Actual construction work at the plant site will take some six to eight years.

## 3. SOURCES OF FINANCING

Financing will be arranged so that the shareholders commit themselves to increasing the company's share capital and/or providing loans to the company at terms and conditions that allow the use of diversified sources of debt financing. Most of the venture costs will be financed through loans from financial institutions and the capital markets. Furthermore, financing arranged by the plant supplier may possibly be utilised. The venture will not need financial support from society.

## 4. STAGES OF FINANCING

Financing shall separately consider the characteristics of the construction stage and the operating stage. The sources of financing and their interrelations may be different during the construction stage and the operating stage.

## 5. REPAYMENT OF LOANS

The venture is estimated to increase TVO's debt by some EUR 2.5 to 3.0 billion. At the end of 2007, the company had EUR 1.36 billion of loans. Once the Olkiluoto 3 project is completed in 2011, the total amount of loans is estimated to be approximately EUR 3.5 billion. The company's long-term target is to maintain an equity ratio of approximately 25 per cent.

The substantial proportion of debt financing is made possible by the excellent operating history and operational reliability of the existing power plant units, the predictability of the production costs of nuclear power, as well as the fact that the company's shareholders will commit to using the power produced for the entire service life of the plant. According to TVO's Articles of Association, the company's shareholders are responsible for annual costs specified in the Articles of Association, including interest and instalments of loans.

The intention is to repay the external debt required for the venture in approximately 30 years. The planned service life of the plant unit is approximately 60 years.

## 6. SUMMARY

Taking into account the above plans concerning equity and debt capital, financing for the venture can be arranged in a way that is satisfactory to the parties.


TVO

# OUTLINE OF THE TECHNICAL PRINCIPLES OF THE PLANNED NUCLEAR FACILITY

CONTENTS

# 1. POWER PLANT PROCESS

The planned new nuclear power plant unit will operate on the principle of a light water reactor plant. Heat generated by uranium fuel is used to produce high-pressure steam. The steam is conducted to a turbine that drives an electric generator. In its basic principle, a nuclear power plant is a steam power plant, just like a coal-fired power plant.

In the reactor, the fuel is in small pellets approximately one centimetre in diameter, encased in gas-tight fuel rods of approximately four metres in length. The fuel rods are assembled into fuel assemblies, and there are hundreds of these in the reactor. The typical amount of uranium fuel in the reactor is on the order of one hundred tonnes.

Natural uranium consists mainly of two isotopes: 99.3 per cent of the isotope U-238 and 0.7 per cent of the isotope U-235. Fuel for light water reactors is manufactured by enriching the uranium to contain slightly more than 3 per cent of the isotope U-235, with the rest being isotope U-238.

During operation, the U-235 in the fuel produces energy and is transformed into fission products. A fraction of the isotope U-238 is transformed into plutonium, which also produces energy. Depending on the degree of enrichment, spent fuel contains almost 96 per cent U-238 and approximately 3 per cent fission products, as well as a total of more than 1 per cent fissionable uranium and plutonium.

Light water reactor plants may be either boiling water reactor plants or pressurised water reactor plants. At Olkiluoto, the nuclear power plant units Olkiluoto 1 and 2 currently in operation are boiling water reactor plants, while the Olkiluoto 3 unit under construction is a pressurised water reactor plant. The Loviisa plant is a pressurised water reactor plant.

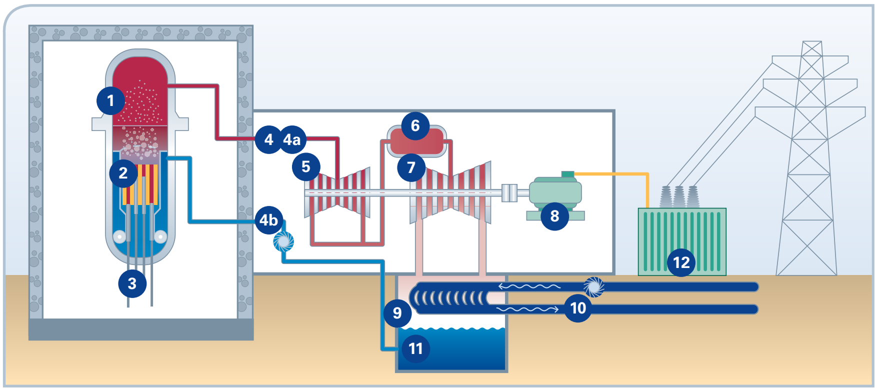
## 1.1. Boiling water reactor plant

Within the pressure vessel of a boiling water reactor (BWR), water is circulated through the fuel bundles in the reactor core by reactor coolant pumps or natural circulation. This heats the water to a typical temperature of approximately 290 °C, which makes it boil and generate steam at a pressure of approximately 70 to 75 bar.

The saturated steam is conducted through steam separators and a steam dryer located within the pressure vessel to a high-pressure turbine, an intermediate reheater and low-pressure turbines. The turbines are connected by a shaft to a generator that produces electricity.

The steam coming from the low-pressure turbines is conducted to a condenser, in which it is condensed into water using sea water cooling. There is underpressure in the condenser, meaning that in the case of a leak, sea water will leak into the process, not vice versa. From the condenser, the water is pumped through pre-heaters back to the reactor.

***Figure 7–1*** *The operating principle of a boiling water reactor plant.*



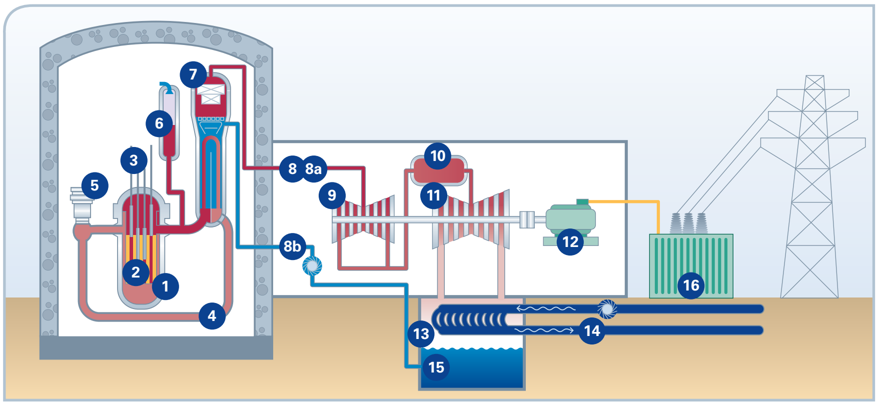

*1. Reactor*
*2. Core*
*3. Control rods*
*4. Primary circuit*
*4a. Steam to the turbine*
*4b. Feed water to the reactor*
*5. High-pressure turbine*
*6. Reheater*
*7. Low-pressure turbines*
*8. Generator*
*9. Condenser*
*10. Seawater circuit*
*11. Condensate*
*12. Transformer*

## 1.2. Pressurised water reactor plant

Also in a pressurised water reactor (PWR) plant, fuel heats water but the reactor circuit is maintained at such a high pressure that the water will not boil. The pressure in the reactor is typically approx. 150 bar and the temperature is approx. 320 °C.

The pressurised water generates steam in separate heat exchangers belonging to the primary circuit, also known as steam generators, from where the water is pumped back into the reactor. The steam circulates in the secondary circuit, driving the turbines and generator.

***Figure 7–2*** *The operating principle of a pressurised water reactor plant.*




*1. Reactor*
*2. Core*
*3. Control rods*
*4. Primary circuit (water circulation)*
*5. Reactor coolant pump*
*6. Pressuriser*
*7. Steam generator*
*8. Secondary circuit*
*8a. Steam to the turbine*
*8b. Feed water to the steam generators*
*9. High-pressure turbine*
*10. Reheater*
*11. Low-pressure turbines*
*12. Generator*
*13. Condenser*
*14. Seawater circuit*
*15. Condensate*
*16. Transformer*

## 2. TECHNICAL DATA

Table 7-1 below presents some technical data on the prospective power plant unit. The figures are preliminary.

*Table 7–1 Preliminary technical data on the plant unit.*

| Quantity | Value and unit |
|---|---|
| Electric power | approx. 1,000 to 1,800 $MW_e$ |
| Thermal power | 2,800 to 4,600 MW |
| Overall efficiency | approx. 35 to 40% |
| Fuel | Uranium dioxide $UO_2$ |
| Consumption of uranium fuel | approx. 20 to 40 tonnes/year |
| Average degree of enrichment | approx. 2 to 5% U-235 |
| Uranium content of reactor | approx. 100 to 150 tonnes |
| Annual electricity production | approx. 8 to 14 TWh |
| Need for cooling water | approx. 40 to 60 $m^3/s$ |

The planned technical service life of the plant unit is approximately 60 years.

## 3. PLANT ALTERNATIVES INVESTIGATED

Jointly with nuclear power plant suppliers, TVO has investigated the feasibility of certain plant alternatives for being built in Finland. The investigations have shown that there are several plant alternatives available that can be implemented in a way that complies with the Finnish safety requirements, that are advanced by international comparison.

Other types of light water reactors beside those included in the feasibility studies so far may also come into question when choosing the plant alternative to be implemented.

The plant alternatives included in the feasibility studies are presented in Table 7–2 below in an alphabetical order by reactor type.

*Table 7–2 Plant alternatives investigated.*

| Reactor type | Name | Manufacturer | Country of origin | Electrical power MW |
|---|---|---|---|---|
| BWR | ABWR | Toshiba-Westinghouse | Japan, Sweden | Approx. 1,650 |
| | ESBWR | GE Hitachi | United States | Approx. 1,650 |
| PWR | APR 1400 | Korea Hydro & Nuclear Power | South Korea | Approx. 1,450 |
| | APWR | Mitsubishi Heavy Industries | Japan | Approx. 1,650 |
| | EPR | AREVA | France, Germany | Approx. 1,650 |

The designs of the investigated plant alternatives are advanced in comparison with the plants that are currently in operation. A significant new feature in the investigated plant alternatives is that so-called severe accident management has been taken into account in their design from the very beginning. In these extremely unlikely accidents, the reactor core is assumed to suffer severe damage (meltdown). The design of all of the plant alternatives also includes provisions for a large airliner crash.

The plant alternatives include so-called evolutionary plant types based on existing plants, as well as new passive plant types, the safety features of which are more extensively based on solutions known as passive. The operation of passive equipment and systems is based on laws of nature, such as gravity, and various degrees of independence from external power.

In addition to safety, the design of the plant alternatives pays special attention to economy. Structural solutions have been simplified in order to reduce investment costs. A shortened construction schedule has also been one of the crucial objectives. In order to ensure problem-free operation, all of the plant alternatives share the aim of using equipment based on proven technology in systems essential to the production of electricity.

In the following, short descriptions of each plant alternative are provided in alphabetical order. The following basic information is presented for each plant alternative:

- reactor type, boiling or pressurised water reactor
- manufacturer and country of origin
- design approach, either evolutionary or passive
- approximate thermal power of the reactor
- approximate net electric output of the plant
- number of steam generator circuits for pressurised water reactors

Furthermore, the principles of implementation of the following safety functions are briefly described for each alternative:

- reactor shutdown
- decay heat removal from the reactor
- emergency core cooling
- decay heat removal from the containment building
- severe accident management

More detailed descriptions of the plant alternatives will be submitted to the Radiation and Nuclear Safety Authority (STUK) for safety assessment.

## 3.1. ABWR

### *3.1.1. Basic information*

The ABWR boiling water reactor plant by Toshiba of Japan represents the evolutionary approach but also includes some passive safety systems. The United States Nuclear Regulatory Commission granted type approval (design certification) for ABWR in 1997. There are three ABWR plant units in operation in Japan. The most recent of these, Hamaoka-5, is the reference for the version planned for Finland and has been developed further to account for Finnish safety requirements.

The thermal power of the reactor in the plant alternative is approximately 4,300 MW. The net electric output of the plant is approximately 1,650 MW.

### *3.1.2. Safety functions*

*Reactor shutdown*

One passive system is available for reactor shutdown, based on hydraulic insertion of the control rods into the reactor. Furthermore, there is one active system that inserts the control rods into the core using electric motors, and another active system that is based on pumping boron solution into the reactor. Each of these systems alone is able to safely shut down the reactor in connection with all anticipated operational transients, taking a single failure into account.

*Decay heat removal from the reactor under normal operating pressure*

An isolation condenser is available for decay heat removal from the reactor. It consists of four heat exchangers and makes it possible to remove decay heat without having to remove any coolant from the reactor. Furthermore, there is an active high-pressure makeup water system with three parallel independent subsystems each having 100 per cent capacity.

*Emergency core cooling*

An active low-pressure emergency cooling system is available for emergency core cooling. It consists of three parallel independent subsystems each with 100 per cent capacity. In some situations, the operation of the low-pressure emergency core cooling system will additionally require reduction of reactor pressure, and to implement this, eight of the reactor's eighteen relief and safety valves will contribute to the automatic depressurization function as necessary.

*Decay heat removal from the containment building*

There is an active system for the removal of decay heat from the containment building, comprising three redundant and independent subsystems each having 100 per cent capacity.

If steam is released into the containment building, for example in case of leaks in the reactor circuit, the rise of pressure and temperature in the containment can also be limited using a passive containment cooling system. It comprises four heat exchangers that are connected to the upper drywell section of the containment. The steam in the containment will find its way to the heat exchangers in which it is condensed, and the released heat is conducted to a water pool outside the containment. The condensate resulting from the steam is conducted back to the containment.

*Severe accident management*

Severe accident management is based on cooling the molten core material discharged from the reactor at the bottom of the containment. For this purpose, a so-called core catcher is designed for the containment that ensures the coolability of the molten core and prevents it from getting into direct contact with the pressure-bearing parts of the containment. In order to ensure cooling, the space below the reactor pressure vessel is automatically flooded by draining water from the condensation pool. Flooding will be triggered automatically by a signal indicating a rupture of the pressure vessel. A separate depressurization system exists for keeping the reactor pressure low in connection with a severe accident. Its valves are designed to stay reliably open also in conditions corresponding to a severe accident.

With regard to its volume and pressure resistance, the containment is designed so that the amount of hydrogen generated in complete oxidation of the zirconium inventory of the core can be retained within the containment building. In the long term, the pressure in the containment building can be reduced by releasing non-condensable gases into the environment through a filtered venting system. This can be done in a controlled manner at a suitable time because containment pressure can be managed using the passive containment cooling system referred to above.

## 3.2. ESBWR

### *3.2.1. Basic information*

ESBWR is a passive boiling water reactor plant by the American company General Electric Hitachi. The passivity is not limited to safety functions but also the circulation of coolant and the transfer of heat released in the fuel out of the reactor are based on natural circulation.

No plant units of this type are in operation or under construction at present but a combined construction and operating licence application for one ESBWR unit is currently pending approval by the US Nuclear Regulatory Commission. GE has also initiated actions to obtain type approval for the plant alternative from the US NRC.

The ESBWR reactor has a thermal power of approximately 4,500 MW and a net electric output of approximately 1,650 MW.

### *3.2.2. Safety functions*

*Reactor shutdown*

For the purpose of reactor shutdown, there is a passive system typical of boiling water reactor plants based on inserting the control rods into the core from below using pressurised nitrogen and water. The operation of hydraulic scram is supplemented in the normal manner through active electromechanical insertion of the control rods.

If, for any reason, the control rods could not be moved at all, rapid shutdown of the reactor is also possible using a passive boron system comprising two circuits. Both circuits have a tank containing boron solution, the contents of which can be injected into the reactor using pressurised nitrogen gas. Each of the subsystems alone is able to bring the reactor to hot shutdown state.

Each of the three above mentioned systems alone is able to safely shut down the reactor in all anticipated situations where scram is needed.

*Decay heat removal from the reactor under normal operating pressure*

Decay heat removal from the reactor under normal operating pressure primarily takes place using isolation condensers. The isolation condensers comprise four parallel independent heat exchanger circuits, at least three of which are required to operate in accordance with the design bases for the system. Furthermore, each of the separate circuits is separately tolerant against single failure with regard to active functions (the opening of valves).

The system capacity together with reactor properties (large amount of water, large steam volume) is sufficient to limit the increase in reactor pressure at the closure of the steam line isolation valves so that not a single relief or safety valve needs to open.

Decay heat removal from the reactor at high pressure is also possible using the shutdown reactor cooling system that is originally categorised as an operating system. This system is also used for bringing the reactor to cold shutdown state. The system has two parallel branches, one of which is sufficient to remove the decay heat generated by the reactor at normal operating pressure.

*Emergency core cooling*

The operation of the low-pressure emergency core cooling system, which is categorised as a safety system, is based on gravitational draining of water from pools in the containment into the reactor. The system comprises four parallel circuits, each of which is further divided into two trains. The design basis for the system is a situation in which one subsystem has a pipe rupture preventing operation, and one of the two trains of another subsystem has a valve fault preventing operation. The system is started by blasting open a closing valve of the rupture disk type located in the pipeline.

The operation of the low-pressure emergency core cooling system requires rapid reduction of reactor pressure. A total of 10 of the reactor's 18 normal relief and safety valves contribute automatically to this function. The steam released through these valves is conveyed to the condensation pool. Furthermore, there are eight depressurization valves that have no other tasks beside the automatic depressurization. The release from these valves is directed into the upper drywell section of the containment.

At low reactor pressure, emergency core cooling can also be achieved using a system consisting of two parallel circuits with 2 x 100 per cent capacity that is originally categorised as an operating system. However, start-up of the system requires manual action by the operators. The system gets water from the condensation pool in the containment.

If the leak in the reactor circuit is minor, the required additional makeup water can also be obtained from the control rod drive hydraulic system categorised as an operating system. The system is able to pump water into the reactor at full operating pressure but its capacity is only sufficient to compensate for relatively small leaks. The system gets water from the feedwater storage tank.

*Decay heat removal from the containment building*

Decay heat removal from the containment building can take place in a completely passive manner in situations where the decay heat generated by the reactor can be transferred to the gas plenum of the containment building as steam. The steam can be condensed in six heat exchangers, which can be put into use in a completely passive manner without the operation of any active device. From the heat exchangers, the heat is transferred to water pools outside the containment, and ultimately as steam to the environment. The volume of water in the pools is sufficient for decay heat removal for 72 hours without replenishment.

Heat can also be removed from the condensation pool using an active system comprising two subsystems that is categorised as an operating system and also caters to the task of cooling the fuel pools. The system can also be used for emergency cooling of the core at low reactor pressure as described above in the section concerning emergency core cooling. Cooling the containment to a temperature less than 100 °C requires the operation of an active system.

*Severe accident management*

Severe accident management is based on cooling the molten core material in the containment. For this purpose, the space below the reactor is equipped with a core catcher. Flooding of the core catcher will be triggered automatically by a signal indicating a rupture of the pressure vessel. The water used for flooding comes from the same tanks used for low-pressure emergency core cooling. The pipelines used for flooding are also partially shared with the passive low-pressure emergency cooling system.

The passive containment cooling system referred to above is also able to operate in the conditions of severe accidents and prevent the containment pressure from exceeding the design limit of the building due to decay power.

Melt-through of the reactor pressure vessel at high pressure can be prevented using the eight depressurization valves mentioned above in the section describing emergency core cooling. The valves are actually a type of blind flange that is opened by blasting. Such valves will thereafter remain open in all conditions.

## 3.3. APR 1400

### *3.3.1. Basic information*

APR 1400 is a pressurised water reactor plant of the evolutionary type jointly designed by the Korean companies KHNP/KOPEC/DOOSAN. It is based on the System 80+ concept developed by the American company Combustion Engineering. The first four plants of this type are under construction in South Korea, with scheduled commissioning between 2013 and 2016.

APR 1400 has two steam generator circuits. Both steam generator circuits have two parallel cold legs and two reactor coolant pumps. The thermal power of the reactor is 4,000 MW, and the net electric output of the plant is approximately 1,450 MW.

### *3.3.2. Safety functions*

*Reactor shutdown*

There is a reactor shutdown system, based on dropping the control rods into the core, which is typical in pressurised water reactors. Reactor shutdown can also be ensured by pumping borated water into the reactor using the high-pressure emergency cooling system. Furthermore, according to the original design, the boron concentration in the reactor water can be increased by using the normal system for chemical and volume control of the primary circuit.

*Decay heat removal from the reactor under normal operating pressure*

An emergency feedwater system having 4 x 100 per cent capacity is available for decay heat removal from the steam generators. Two subsystems have electrical pumps, while two have pumps operated by steam turbines.

*Emergency core cooling*

There are four parallel trains for emergency cooling of the reactor, each of them containing a high-pressure emergency cooling system and a pressure accumulator. The water from the pressure accumulators will be released into the reactor in a completely passive manner once pressure has dropped sufficiently due to a leak in the primary circuit, for example. The pressure accumulators are equipped with flow limiters that release the water contained in the accumulators in a controlled manner and make it last longer. This has allowed the exclusion of a separate low-pressure emergency cooling system from the plant concept. Naturally, the high-pressure emergency cooling system is also able to operate at low reactor pressure.

An advanced feature of the emergency core cooling system is that all emergency cooling water is injected directly into the reactor pressure vessel through four nozzles. This improves the efficiency of emergency core cooling particularly in connection with accidents involving leaks from the cold legs.

There are four parallel relief lines available for reducing primary circuit pressure. The released steam is conducted to the emergency cooling water storage pool in the containment, in which it will be condensed.

The combined capacity of the parallel trains of the emergency cooling system described above will be sufficient to ensure the cooling of the core also in case of a major pipe rupture in the primary circuit even if one subsystem has a single failure preventing operation and another is simultaneously inoperable due to maintenance or repair.

An active decay heat removal system consisting of two parallel circuits is available at low pressures and temperatures.

It can be used to transfer heat from the primary coolant to the ultimate heat sink. At low reactor pressures, the system can be connected to the containment spray system by operator action, which allows the pumping of water from the emergency cooling water storage pool into the reactor to supplement the emergency core cooling function.

*Decay heat removal from the containment building*

A containment spray system is available for decay heat removal from the containment. The system has two separate circuits with two parallel pumps in each. If desired, the system can be connected to directly cool the primary circuit and, correspondingly, the pumps within the decay heat removal system can be connected to spray the containment as necessary.

*Severe accident management*

Severe reactor accidents have been taken into account in the containment building design. The space below the reactor pressure vessel is designed to ensure the best possible spreading of molten core material discharged from the pressure vessel into a layer that can be cooled down. The floor area of the space below the pressure vessel is 0.02 $m^2$ per thermal megawatt of rated reactor power. The space below the pressure vessel will be flooded as necessary by draining water to the space from the emergency cooling water storage pool. There are two parallel lines for draining. In the space below the reactor pressure vessel, the steel liner ensuring the tightness of the containment is covered with a protective layer of concrete of at least 90 cm thickness in order to prevent the molten core material discharged from the pressure vessel from damaging the steel liner.

A primary circuit depressurization system is available for reducing reactor pressure and maintaining it at a low level in connection with severe accidents.

The containment spray system mentioned above is available for decay heat removal from the containment after a severe accident.

The containment building is dimensioned so that the amount of hydrogen released in complete oxidation of the zirconium inventory of the core can be retained within the containment building. The hydrogen concentration and the pressure of non-condensable gases are regulated by controlled combustion of hydrogen using catalytic recombiners as well as igniters.

## 3.4. APWR

### *3.4.1. Basic information*

APWR is a pressurised water reactor plant of the evolution type designed by Mitsubishi Heavy Industries Limited (MHI) of Japan. It is based on four-circuit PWR plants previously delivered by MHI. The APWR plant type is not yet in operation or under construction but the licensing process for two plant units is underway in Japan.

APWR has four steam generator circuits. The thermal power of the reactor is 4,450 MW, and the net electric output of the plant is approximately 1,650 MW.

### *3.4.2. Safety functions*

*Reactor shutdown*

There is a reactor shutdown system, based on dropping the control rods into the core, which is typical in pressurised water reactors. The reactor can be shut down independent of the control rods by increasing the boron concentration in the reactor water by using the normal system for controlling the primary circuit chemistry and water volume.

Furthermore, the primary circuit pressure can be rapidly reduced using a separate depressurization system. In this case, the emergency core cooling system will automatically start to pump heavily borated emergency cooling water into the reactor, which will shut it down.

*Decay heat removal from the reactor under normal operating pressure*

There is an active emergency feedwater system for the removal of decay heat from the primary circuit through the steam generators, comprising four parallel independent subsystems each having 50 per cent capacity. Two of these are equipped with electric pumps and two with pumps operated by steam turbines.

*Emergency core cooling*

There are four parallel trains for emergency core cooling, each of them containing a high-pressure emergency cooling system and a pressure accumulator. The water from the pressure accumulators, which fulfil the single failure criterion, will be released into the reactor in a completely passive manner once pressure has dropped to the release limit due to a leak in the primary circuit, for example. The pressure accumulators are equipped with flow limiters that release the water contained in the accumulators in a controlled manner and make it last longer. This has allowed the exclusion of a separate low-pressure emergency cooling system from the plant concept. The high-pressure emergency core cooling system is also able to operate at low reactor pressure.

An advanced feature of the emergency cooling system is that the high-pressure emergency cooling system pumps its water directly into the reactor pressure vessel through four nozzles. The water contained in the pressure accumulators is released into the cold legs of the primary circuits.

There are two parallel relief lines categorised as safety systems for reducing the pressure in the primary circuit, each having 100 per cent capacity with regard to successful emergency core cooling.

The combined capacity of the parallel trains of the emergency core cooling system described above will be sufficient to ensure the cooling of the core also in case of a major pipe rupture in the primary circuit even if one subsystem has a single failure preventing operation and another is simultaneously inoperable due to maintenance or repair.

An active decay heat removal system, which constitutes a combined decay heat removal and containment spray system, is available at low pressures and temperatures. It can be used to transfer heat from the primary circuit coolant to the ultimate heat sink. This system comprises four parallel and independent subsystems, each with 50 per cent capacity. Depending on the situation, the system can be used to cool either the primary circuit or the emergency core cooling water pool located in the containment. At low reactor pressure, the system can also be connected to pump water from the emergency cooling water pool into the reactor by operator action, which will supplement the reactor emergency cooling function.

*Decay heat removal from the containment building*

The combined decay heat removal and containment spray system mentioned above is available for decay heat removal from the containment building. The system comprises four parallel and independent subsystems, each with 50 per cent capacity. The system can be used to cool the emergency core cooling water pool located in the containment by circulating water in the pool through heat exchangers. The containment atmosphere can also be cooled by spraying water into it through fine spray nozzles. The sprayed water flowing back will transfer heat from the atmosphere to the emergency core cooling water storage pool.

*Severe accident management*

Severe reactor accidents have been taken into account in the containment design. The space below the reactor pressure vessel is designed to ensure the best possible spreading of molten core material discharged from the pressure vessel into a layer that can be cooled down. The spreading area will be flooded with water as necessary using the extinquishing water system. In the space below the reactor pressure vessel, the steel liner ensuring the tightness of the containment is covered with a protective layer of concrete in order to prevent the molten core material discharged from the pressure vessel from damaging the steel liner.

A completely dedicated primary circuit depressurization line is available for reducing reactor pressure and maintaining it at a low level in connection with severe accidents.

For decay heat removal from the containment after a severe accident, there is an active system separate from the containment spray system referred to above. It condenses steam from the containment atmosphere using intermediate circuit water circulating in special cooling spirals. From the intermediate circuit, the heat is removed to the atmosphere through another set of cooling spirals using the natural circulation of air.

The containment building is dimensioned so that the amount of hydrogen released in complete oxidation of the zirconium inventory of the core can be retained within the containment building. The hydrogen concentration and the pressure of non-condensable gases are regulated by active controlled combustion of hydrogen using igniters.

## 3.5. EPR

### *3.5.1. Basic information*

EPR is an evolution type plant originally designed by Nuclear Power International, which was originally a joint venture of the French company Framatome and the German company Siemens KWU. It is based on the most recently commissioned pressurised water plants in both countries. These are called type N4 in France and type Konvoi in Germany.

EPR has four steam generator circuits. The thermal power of the reactor is 4,590 MW, and the net electric output of the plant unit is approximately 1,650 MW.

The nuclear power operations of Framatome and Siemens, including NPI, currently belong to the AREVA Group.

### *3.5.2. Safety functions*

*Reactor shutdown*

There is a reactor shutdown system, based on dropping the control rods into the core, which is typical in pressurised water reactors. Another rapid shutdown system independent of the control rods is an active emergency boration system with two redundant and independent subsystems, each having 50 per cent capacity. This system is also capable of safely shutting down the reactor in all anticipated operational transients.

*Decay heat removal from the reactor under normal operating pressure*

There is an active emergency feedwater system for the removal of decay heat from the primary circuit through the steam generators, comprising four parallel independent subsystems each having 50 per cent capacity.

*Emergency core cooling*

There are four parallel trains for emergency core cooling of the reactor, each comprising a so-called intermediate-pressure emergency cooling system (operating range below 80 bar), a pressure accumulator and a low-pressure emergency cooling system. There are three parallel relief lines for reducing the pressure in the primary circuit, each having 100 per cent capacity with regard to successful emergency cooling.

The combined capacity of the parallel trains of the emergency core cooling system described above will be sufficient to ensure the cooling of the core also in case of a major pipe rupture in the primary circuit even if one subsystem has a single failure preventing operation and another is simultaneously inoperable due to maintenance or repair.

At low pressures and temperatures, an active decay heat removal system is available for transferring heat from the primary circuit coolant to the ultimate heat sink. This system comprises four parallel and independent subsystems, each with 50 per cent capacity.

*Decay heat removal from the containment building*

There is an active system for the removal of decay heat from the containment building comprising four parallel and independent subsystems, each having 50 per cent capacity.

***Severe accident management***

Severe reactor accidents have been taken into account in the containment design. The space below the reactor pressure vessel is designed to ensure the best possible spreading of molten core material discharged from the pressure vessel into a layer that can be cooled down. The spreading area will be flooded with water by a passively initiated function. A completely separate 1 x 100 per cent primary circuit depressurization line is available for reducing reactor pressure and maintaining it at a low level in connection with severe accidents. It is redundant in terms of active components (valves).

There is an independent active system for removing decay heat from the containment building after a severe reactor accident, comprising two independent subsystems with 100 per cent capacity in each.

The system can also be used for cooling down the structures below the reactor pressure vessel, thus facilitating the cooling of the molten core material.

The containment building is dimensioned so that the amount of hydrogen released in complete oxidation of the zirconium inventory of the core can be retained within the containment building. The hydrogen concentration and the pressure of non-condensable gases are regulated by means of passive, catalytic recombination of hydrogen and oxygen.

# DESCRIPTION OF THE SAFETY PRINCIPLES OBSERVED

CONTENTS

## 1. GENERAL PRINCIPLES

In accordance with the Nuclear Energy Act, the starting point for the design, construction and operation of a nuclear power plant is that the plant must be safe and it shall not cause injury to people or damage to the environment or property. This is complied with through precautionary measures in design and construction, functions protecting the plant in cases of disturbance and damage, as well as functions limiting the consequences of accidents.

The new nuclear power plant unit must fulfil the currently valid safety requirements in Finland, the general principles of which are included in existing Council of State's Decisions and Decrees currently in preparation. Detailed safety requirements are presented in the YVL guides published by the Radiation and Nuclear Safety Authority. This appendix describes how the appropriate safety principles are going to be applied in the venture.

## 2. DECISIONS/DECREES OF COUNCIL OF STATE

The design, construction and operation of the nuclear power plant shall be implemented in accordance with the Decision of Council of State on the general regulations for the safety of nuclear power plants (VNP 395/91). The contents of and compliance with the safety principles specified in the Council of State's Decision are discussed in more detail in Section 4 below.

The arrangements to prevent unlawful actions against the nuclear power plant shall be implemented in accordance with the Council of State's Decision on the general regulations for physical protection of nuclear power plants (VNP 396/91). This will be realised by extending the security arrangements of the existing plant units to cover the new plant unit. The security arrangements will be discussed in more detail when applying for the construction and operating licences.

The arrangements to limit nuclear damage within the nuclear power plant and its area shall be implemented in accordance with the Council of State's Decision on the general regulations for emergency response arrangements at nuclear power plants (VNP 397/91). This will be complied with by extending the emergency response arrangements of the existing plant units to cover the new plant unit. The emergency response arrangements will be discussed in more detail when applying for the construction and operating licences.

The Council of State's Decisions referred to above are being revised, and the designation will change to Council of State Decree. Once the Council of State's Decrees have entered into force, they will be complied with correspondingly to the present compliance with Council of State's Decisions.

# 3. YVL GUIDES

The YVL guides published by the Radiation and Nuclear Safety Authority form a comprehensive set of regulations that provides detailed specifications of the level of safety required of nuclear power plants in Finland.

The nuclear power plant's compliance with the requirements set forth in the YVL guides is proven by means of safety analyses that examine the behaviour of the plant in connection with disturbances and accidents. The safety analyses are presented to the authorities in connection with the plant's preliminary safety analysis report when applying for a construction licence. The final safety analysis report supplements the safety analyses with the effects of details associated with the construction of the plant. The final safety analysis report will be presented to the authorities when applying for an operating licence.

# 4. COMPLIANCE WITH SAFETY PRINCIPLES

## 4.1. GENERAL PRINCIPLES

### *4.1.1. General objective*

The general objective is to ensure nuclear power plant safety so that nuclear power plant operation does not cause radiation hazards that could endanger the safety of workers or the population in the vicinity or could otherwise harm the environment or property.

This Appendix discusses how safety is ensured. The radiation exposure of employees during operation will be discussed in more detail when applying for the construction and operating licences. The environmental impact is discussed in Appendix 12.

### *4.1.2. Safety culture*

A good safety culture shall be maintained when designing, constructing and operating a nuclear power plant. The management of the organisation in question shall, by virtue of its decisions and actions, demonstrate its commitment to safety-promoting procedures and solutions. The personnel shall be motivated for responsible work, and an open atmosphere encouraging the identification, reporting and elimination of safety-endangering factors shall be promoted in the working community. The personnel shall have an opportunity to contribute to the continuous improvement of safety.

The maintenance and development of a good safety culture is affected by the attitudes and operating practices of all the parties involved in the nuclear power plant venture, including suppliers at various levels, the power company and the regulatory authority. A good safety culture requires that factors affecting safety must be identified and that safety must be given priority in all situations where decisions must be made between safety and other factors, such as those related to finances, scheduling and production.

TVO observes the characteristics defined by the International Atomic Energy Agency (IAEA) as the criteria for assessing good safety culture. TVO has procedures in place for investigating and developing the state of the safety culture. Examples of this include the extensive self-assessments of safety culture carried out in 2004 and 2007. TVO monitors the atmosphere of the organisation through regular job satisfaction surveys and also carries out other surveys to support the development of the organisation.

All parties involved in the nuclear power plant venture are required to have clear targets and principles defined and confirmed by the highest levels of management; when operating in accordance with these, all factors affecting safety will receive the attention called for by their significance to safety. TVO aims at avoiding deviations in all sectors. This objective of zero tolerance shall be put into practice across all functions and organisations in the most comprehensive manner. The parties are required to have a quality/operations management system that supports and promotes the realisation of the characteristics of a good safety culture in practical operations.

TVO has a system for reporting deviations and near miss incidents. An incident report, special report or root cause investigation is prepared for the most significant incidents in terms of the development of safety or operations. TVO uses a variety of indicators to monitor the state of occupational safety; for example, the OL3 construction site uses the TR index indicating the level of occupational safety. All TVO employees and subcontractors are required to have a valid occupational safety card and regularly repeated introductory training. Furthermore, training related to safety and the safety culture is arranged regularly, and attendance is supervised.

### *4.1.3. Quality management*

A quality management system is prepared for the construction and operating stages of the nuclear power plant venture, and one of the subareas is quality assurance. The quality management system for the construction stage, which also covers the design stage, will be presented to the authorities for approval when applying for a construction licence for the plant. The quality management system for the operating stage shall be presented when applying for an operating licence. Quality management programmes shall be prepared in accordance with the requirements of YVL Guide 1.4.

In addition to the applicant's comprehensive quality management system covering the entire design and construction stage of the nuclear power plant venture, the main supplier of the plant unit and the fuel supplier will prepare separate quality management systems covering their operations. In addition to these, all organisations involved in the design, manufacture, installation and commissioning of objects affecting the plant's safety are required to have their own quality management systems covering their operations associated with the nuclear power plant venture.

At the operating stage, the quality management and assurance procedures will be arranged by observing the same principles applicable to the operation of the existing nuclear power plant units. The new plant unit will become part of TVO's activity based management system that covers all the nuclear facilities and functions located at the plant site.

All of the basic requirements for quality assurance stated in the YVL guides will be observed when preparing the quality management systems. The requirements set in the quality management system shall be categorised in accordance with their safety significance so that the strictest requirements will apply to the products or functions most important to nuclear and radiation safety. Furthermore, requirements set forth in generally used quality management standards will be taken into account in the preparation of the quality management system.

#### *4.1.4. Demonstration of compliance with safety regulations*

Accident analyses and probabilistic safety analyses shall be carried out for the purpose of justifying the safety of the nuclear power plant and the technical solutions employed in its safety systems.

Analyses are used to prove the plant's ability to overcome various disturbances and accidents with sufficient safety. The analyses deal with events that provide the best possible coverage of different types of disturbances and accidents in terms of their nature and severity. The course of disturbances and accidents is estimated starting from the initiating event that triggers the situation and ending in a safe and stable state.

The preliminary safety analysis report submitted to the authorities in connection with the potential application for construction licence includes analyses of anticipated operational transients, postulated accidents used as design bases for the safety systems and so-called severe accidents. Different acceptance criteria have been defined for different classes of events in relation to the loads on the fuel cladding, pressure-bearing primary circuit and reactor containment building, as well as in relation to the environmental impact of the event. These requirements are described in Sections 4.2.1 to 4.2.5 of this Appendix. The safety analyses prove the fulfilment of these criteria.

The analyses are carried out using calculation programmes whose applicability to modelling the phenomena in question has been proven, for example, by comparing the calculated results with measurement data obtained from model or plant tests.

Probabilistic safety analyses are also used to support the design of the plant unit and its safety systems. They will comprehensively account for operating experience from our own plants and other plants. The probabilistic models start with a wide range of identified disturbances (so-called initiating events) and examine the operation of the plant unit's safety systems in the event of those disturbances. The probabilistic models account for the frequency of the initiating events, single failures of systems and equipment, common-cause failures, as well as actions by plant personnel, including any human error. Probabilistic safety analysis is used to calculate the combined risk effect of all identified initiating events, rank the factors affecting nuclear safety in an order of importance and ensure balanced design of the plant unit in terms of safety. A preliminary probabilistic safety analysis will also be submitted for inspection and approval by the authority as an attachment to the potential application for construction licence.

## 4.2. Design requirements for ensuring nuclear safety

### *4.2.1. Levels of protection*

*Prevention of disturbances*

The so-called defence in depth principle is observed in the design of a nuclear power plant unit to ensure its safety. According to the principle, the aim is to block the progress of a disturbance at several successive levels. For both the safety and operating availability of the plant unit, it is the most preferable if the disturbance can be completely prevented. Thus the application of high quality requirements in the design, construction and operation of the plant unit is essential in order to prevent operating disturbances and accidents.

The principle of defence in depth also requires that the plant unit be designed and constructed so that its physical and technical properties counteract the development of disturbances. One of the most important design requirements for the reactor is that it must inherently resist all changes in reactor power. This has been achieved by designing the reactor so that the expansion of vapour volume in the coolant or an increase in the coolant temperature increases the leakage of neutrons out of the core, which lowers reactivity and mitigates the increase of power. Increases in the temperature of the uranium fuel itself also lower the reactivity. A correctly designed and dimensioned reactor is inherently stable with regard to minor power disturbances.

Inherent stability alone is not enough for satisfactory resistance against disturbances with regard to operation of the plant unit. Therefore the plant alternatives are equipped with control systems, the most important of these being the systems for regulating the water level in the reactor (BWR) or steam generator (PWR), as well as the reactor pressure and power. The task of the control systems is to eliminate small disturbances in the operating conditions of the plant so that their impact on plant unit operation and production is minimised.

*Reactor protection system and anticipated operational transients*

If a disturbance in the operating conditions of the plant unit is major enough, the inherent properties of the reactor and the control systems are not enough to eliminate its impact on plant unit operation. In this case, the reactor protection system must shut down the reactor in order to prevent the disturbance from developing into an accident. Most disturbances involving rapid reactor shutdown belong to the class of so-called anticipated operational transients. Anticipated operational transients are defined as events with a probability of one or more occurrences in a period of 100 operating years.

The aim is to design the reactor protection system so that in most disturbances, rapid shutdown, also known as scram, is triggered on at least two conditions which are independent of each other. This way, failure in a single scram condition does not prevent the protection system from working appropriately.

*Safety systems at the plant unit and postulated accidents*

In some cases the disturbance as such may be so major that reactor shutdown alone is not enough to stop its development. In the case of such a postulated accident, it is the task of the plant unit's safety systems to ensure fuel coolability and primary circuit integrity. Ensuring fuel coolability means that the fuel must not melt or be dislocated. The tasks of the safety systems include, among others, reactor overpressurization protection, emergency cooling and removal of decay heat.

The safety assessments of the plant alternatives include an analysis of the following postulated accidents: breaks of the major pipelines in the primary circuit and a reactivity accident (control rod dropping or ejection). The overpressurization protection analyses can also be equated with the design basis accident analyses. Furthermore, in its most recent guidelines, the Radiation and Nuclear Safety Authority has required that anticipated operational transients where reactor scram does not work must be equated with accidents. Postulated accidents also include the so-called design basis accidents on which the dimensioning of safety systems is based. Compare Section 4.2.3.

*Severe reactor accidents*

If an improbable multiple fault prevents the appropriate operation of the protection or safety systems during a disturbance, this may cause severe damage to the core. In this case, the defence in depth principle involves the pressure-bearing boundary of the containment building, the tightness of which will be ensured.

The measures for controlling severe accidents ensure the integrity of the containment building discussed in more detail in Section 4.2.2, slow down the increase of pressure within the containment building and, finally, if necessary, allow a controlled release through a filtered venting system. Severe accident management is discussed in more detail below in Section "Ensuring containment building integrity".

### *4.2.2. Technical barriers for preventing the dispersion of radioactive materials*

Dispersion of radioactive materials from the fuel of the nuclear reactor to the environment is prevented by means of successive barriers, which are the fuel and its cladding, the cooling circuit (primary circuit) of the nuclear reactor and the containment building.

Uranium fuel in the core is in the form of ceramic pellets that retain most of the radioactive materials formed in the uranium. These pellets of approximately 1 cm diameter are enclosed in gas-tight fuel rods. The fuel rods are further bundled into fuel assemblies, and there are hundreds of these in the reactor. The typical amount of uranium fuel in the reactor is on the order of one hundred tonnes.

The reactor core is located inside a pressure vessel that also contains the water cooling the core. Within the pressure vessel of a boiling water reactor, reactor coolant pumps circulate water through the fuel assemblies. This heats the water to a temperature of approximately 290 °C, which makes it boil and generate steam at a pressure of approximately 70 to 75 bar. In a pressurised water reactor, fuel also heats water but the reactor pressure vessel is maintained at such a high pressure that the water will not boil. The pressure in the reactor is typically approx. 150 bar and the water temperature at the core outlet is approx. 320 °C.

The reactor containment building forms a tight barrier preventing the dispersion of radioactive materials to the environment in accident situations.

The potential alternatives for pressurised water reactor plants have a full-pressure containment building operating on the so-called dry principle; the reactor and its main cooling system are located inside the building. In most PWR alternatives, the containment building comprises two protective shells, one inside the other. The inner protective shell is made of steel or pre-stressed concrete with a steel lining. The outer protective shell is made of reinforced concrete. Constant underpressure is maintained in the space between the outer and inner protective shells, preventing even the smallest leak from the containment building from entering the outside atmosphere. In the original design of some pressurised water reactors, the containment building is single-walled, made of pre-stressed concrete and sealed with a steel lining.

The containment building in the boiling water reactor alternatives operates on the pressure suppression principle. There is a water pool inside the containment building that serves as a heat sink and a source for emergency core cooling water and containment spray system water in certain accident situations. The containment building is made of reinforced concrete. Tightness is ensured using a lining plate of steel. The containment building is surrounded by the reactor building, which is ventilated in an accident situation through a filtered emergency ventilation system.

### *4.2.3. Ensuring fuel integrity*

No melting may occur in the fuel pellets during normal reactor operation, and the temperature of the fuel rod cladding may not significantly exceed the coolant temperature. In practice this means that the power of a fuel rod per unit of length and the power of a fuel assembly in relation to the coolant flow in the bundle shall be kept within the allowed limits. The compliance with the restrictions is ensured by means of the core supervision system using reactor-physical calculations and measurement results from the reactor instrumentation.

The power of the fuel rods is limited so that their internal pressure does not exceed the normal operating pressure of the coolant.

In order to prevent damage caused by mechanical interaction of the fuel pellet and cladding, limits for power changes and rates of power change during operation are specified for each type of fuel. Among other things, these limits take into account the stress corrosion of the cladding.

The fuel is dimensioned so that after being used in the reactor, it is suitable for long-term storage and the processing steps associated with disposal.

With regard to anticipated operational transients, the requirement is that the probability of fuel damage must be very small. This requirement may also limit the maximum fuel assembly power allowed during normal operation. The endurance of the fuel in such conditions is proven sufficient by so-called transient analyses that constitute a crucial part of the nuclear power plant unit’s safety analysis report. Typical transients include the tripping of one or more reactor coolant pumps or disturbances in primary circuit pressure.

Postulated accidents are divided into two categories based on their probability: the probability of level 1 postulated accidents is in the range of 0.01 to 0.001 per year, and the probability of level 2 accidents is lower than this. The latter category includes the actual design basis accidents.

In connection with level 1 accident, the number of fuel rods suffering heat transfer crisis may not exceed one per cent of the total number of fuel rods in the reactor. The fuel cladding temperature may not exceed the limit of 650 °C.

Fuel coolability may not be endangered in postulated accidents of level 2. This means that the fuel assemblies may not melt or otherwise suffer damage severe enough to prevent the insertion of control rods into the reactor or the entry of cooling water into the assemblies. The fuel cladding temperature may not increase to levels high enough to cause metal/water reactions between the hot metal and steam to any significant extent. Fuel damage in postulated accidents must be minimised. In practice, this requirement is interpreted so that cladding damage may not occur in more than 10 per cent of the fuel rods.

The behaviour of the reactor during postulated accidents is proven to be acceptable by means of accident analyses. These analyses contribute to the foundations for dimensioning the plant unit's safety systems. In order to ensure sufficient safety margins, the analyses make assumptions about the values of physical quantities and the operation of the safety systems that have an adverse impact on the course of events.

In the potential plant alternatives, criticality accidents are practically possible only during refueling outages. The risk is mainly associated with incorrect transfers of fuel. Also during outages, exceptionally incorrect movement of control rods in boiling water reactors and unplanned dilution of the boron concentration of the coolant in pressurised water reactors may lead to unwanted criticality. Human activities play a larger role in outage-time risks than during power operation. To make the possibility of a criticality accident infinitesimal, the technical protective measures of the reactor are supplemented with strict administrative restrictions during outages.

In addition to level 1 and 2 postulated accidents, so-called design extension conditions must be observed with regard to the potential new plant unit. These constitute either events in which a common-cause failure of safety systems occurs in connection with an initiating event that is relatively moderate (see Section 3.2.6), or events that involve a complex combination of faults. With regard to the latter, the examination usually extends to complete loss of electrical power and loss of the ultimate heat sink, which refers to seawater cooling. According to the requirement, the plant must overcome such situations without substantial fuel damage. If recovery from such situations requires action by operations personnel, it is required that adequate time for consideration and implementation is available for such action and that the adequacy is proven.

### *4.2.4. Ensuring primary circuit integrity*

In addition to appropriate design and sufficient design margins, ensuring primary circuit integrity is based on care in manufacturing and the use of top-quality materials. This makes it possible to ensure that the magnitude of a flaw leading to a sudden crack in a pressure-bearing device in the primary circuit must be so large that it can either be detected as a leak during plant unit operation or discovered in periodic inspections before the occurrence of an actual accident. The periodic inspection programme therefore plays an important role in ensuring primary circuit integrity.

Primary circuit design also accounts for radiation embrittlement of the reactor pressure vessel wall caused by fast neutrons. Due to the phenomenon, the reactor pressure vessel is designed and constructed in a way that minimises the number of welded seams in the area close to the reactor core. The development of radiation embrittlement is also monitored within the pressure vessel periodic inspection programme.

Failures that prevent steam from being driven into the turbine condenser or cause reactor shutdown to fail may lead to increased pressure in the primary circuit. In such situations, primary circuit pressure is limited to an acceptable level using relief and safety valves. In boiling water reactors, these valves discharge steam directly from the primary circuit to a condensation pool in the containment, in which the discharged steam is condensed into water. In pressurised water reactors, primary circuit pressure can be regulated by means of the pressure on the secondary side of the steam generators. Therefore most of the relief and safety valve capacity in pressurised water reactor plants is located on the secondary side. Because the secondary side water is normally not radioactive, the discharge from these safety valves goes directly to the outside atmosphere. According to the design bases, no anticipated operational transient should require the opening of the primary circuit safety valves.

The reactor protection and scram system also contributes to the limitation of pressure in the primary circuit. The design pressure for the primary circuit of the plant unit will not be exceeded during anticipated operational transients if reactor scram operates as intended. The design pressure is 10 per cent to 20 per cent higher than normal operating pressure. In postulated accidents, the design pressure may be exceeded by a maximum of 10 per cent, and in cases where reactor scram fails it may be exceeded by a maximum of 30 per cent. The pressure vessel can endure substantially higher pressure without failing.

The overpressure protection analyses on which the dimensioning of the overpressure protection system has been based use very disadvantageous or conservative assumptions: for example, it is assumed that approximately one in four valves fails to open and that the scram limit that is exceeded first is not tripped. Thanks to this conservativeness, the overpressure protection system will have significant overcapacity.

The boiling water reactor alternatives only use valves for controlling the initial stage of a pressure transient. After this, an isolation condenser is used for pressure control, which does not require coolant to be released outside the primary circuit.

### *4.2.5. Ensuring containment building integrity*

The essential properties of containment buildings for PWR and BWR plants have been discussed above in Section 4.2.2 “Technical barriers for preventing the dispersion of radioactive materials”.

Of all postulated accidents, primary circuit pipe breaks inside the containment building cause the most significant loads on the containment building. These include pressure and temperature loads due to the release of hot water and steam, as well as the dynamic effects of pipe failures, which include jet forces and impacts of missiles. In the case of a pressurised water reactor plant, the dimensioning of the containment building in provision for pipe break accidents is essentially based on the large volume of the full-pressure containment building. This means that the containment building can simply be dimensioned to bear the maximum pressure that the evaporation of water discharged from the primary circuit may cause. In the pressure suppression containment used at boiling water reactor plants, steam discharged from the primary circuit is conducted to a special condensation pool in which it is condensed. This allows the volume of a pressure suppression containment to be relatively small, and the maximum pressure achieved does not depend on the amount of steam discharged from the primary circuit to any significant extent. On the other hand, the volume relations and flow resistances between the different subvolumes are important for the design of such a containment building.

The requirement that the containment must also be able to prevent the dispersion of radioactive materials to the environment in connection with so-called severe accidents has a significant effect on the design of the containment building for the plant unit.

It is the task of nuclear power plant safety systems to ensure that the reactor can be shut down after all postulated accidents, the decay heat generated in the fuel can be removed from the reactor and the dispersion of radioactive materials into the environment can be efficiently prevented or at least limited to a very low level. The aim is to make the reliability of these functions as good as possible, for example by multiplying the number of systems with safety functions, making the parallel systems independent of each other, backing up the power supply of the parallel systems from mutually independent sources and utilising passive safety systems.

In principle, the simultaneous inoperability of all parallel and all in-depth systems is possible with an extremely low probability. Should the safety systems completely fail, for example in connection with a primary circuit leak, the supply of water into the reactor could be prevented. The consequence might be core meltdown caused by decay heat power from the disintegration of radioactive materials in the reactor core, which is a severe accident. As a consequence of a severe accident, the molten core mass might be relocated to the bottom of the reactor pressure vessel, the bottom of the vessel could be damaged, and molten material could be discharged into the containment building.

The starting point for the design of the potential plant alternatives is that even in the case of severe accidents, the release of radioactive materials must be limited so that it does not cause immediate health effects to the population around the nuclear power plants or any long-term restrictions to the use of large areas of water and land.

There are two main approaches to the management of such a severe accident. In the first one, the containment, and particularly its bottom section, is designed to deal with the molten core mass without losing its tightness due to the mass. In the second one, in-vessel cooling of the molten core material is ensured directly through the bottom of the pressure vessel, preventing the molten core from being discharged from the pressure vessel. Filling the bottom section of the containment with water plays a central role in both cases.

In the BWR alternatives, the possibility that hydrogen created by reactions between metal and water might explode is prevented through the lack of oxygen in the containment; during operation, the building is filled with nitrogen. In the PWR alternatives, hydrogen is removed from the containment atmosphere in a controlled manner using igniters or catalytic methods during an accident situation.

The long-term integrity of the containment building is ensured by a filtered venting system or an independent decay heat removal system and recombination of non-condensable gases.

The containment buildings of all of the plant alternatives also involve a filtered venting system. In the long term, it can be used to limit the pressure increase arising from the formation of non-condensable gases and boiling due to the molten core to a level that the containment can endure. However, the containment building is designed so that depressurization will not be required in any circumstances during the first 24 hours from the beginning of the accident. This aims at providing opportunities for initiating decay heat removal and thus eliminating the need for releases completely. Radioactive particles are removed from the gases released from the containment building by a filter with a high degree of retention, more than 99.9 per cent. The removal of particles from the emissions prevents the creation of any radioactive fallout that would contaminate the soil.

Independent decay heat removal from the containment may be passive or there may be a separate active cooling system independent of other safety systems. This can prevent an increase in containment pressure due to decay heat generated by the reactor. Furthermore, the air-filled containments of pressurised water reactor plants use passive catalytic recombination of hydrogen and oxygen, which also makes it possible to eliminate pressure increases due to the formation of non-condensable gases.

### *4.2.6. Ensuring safety functions*

One of the most important design requirements for a modern light water reactor is that it must inherently resist changes in reactor power. Among other things, this means that increases in the temperature of the fuel and coolant or increases in the steam content of the coolant must decrease the reactivity of the reactor core. This allows the reactor operation to remain stable without continuous operation of the control systems. This will significantly reduce the plant's sensitivity to disturbances and, correspondingly, reduce the number of situations that require the operation of the reactor protection system. This also means that severe reactivity accidents cannot be initiated by any operating disturbance. All of the plant alternatives in question fulfill this requirement of inherent reactor stability.

The purpose of the protection systems is to detect accident situations and start the required safety systems and, after the accident, ensure that the plant remains in a safe state for a long enough period until the operators intervene with the course of events. The protection systems have been designed so that in each situation where automatic protection is needed, the system is started on the basis of at least two mutually independent parameters.

Generally, the protection function that is required first is rapid shutdown or scram. There are two mutually independent systems for this, one based on the use of control rods and one based on pumping or passively injecting a boron solution into the reactor. Each of these systems alone is able to shut down the reactor.

After shutdown, the safety systems cater for functions such as the water supply to the reactor and decay heat removal. The safety systems of the different plant alternatives apply the principle of inherent safety or passive operation to a varying degree. This means that the system does not need external power for fulfilling its safety function. However, most safety systems are still active, which means that safety is ensured using other means than passive operation.

The safety systems have been designed in accordance with the principle of redundancy, which refers to parallel subsystems. For example, the emergency core cooling systems of several plant alternatives have four parallel subsystems, two of which are sufficient to ensure cooling of the fuel during accidents that involve major pipe breaks in the primary circuit (4 x 50 per cent system). Another alternative is to use three parallel subsystems, each of which is capable of fulfilling the safety function of the system alone if necessary (3 x 100 per cent system). This allows the systems to fulfil their safety function even if one of the parallel subsystems was inoperable due to maintenance or repair and another subsystem had a fault preventing its operation. The parallel subsystems have been designed in accordance with electrical and physical separation. The latter is also associated with fire compartmentalization.

Each of the plant alternatives has a backup power system whose task is to ensure the supply of electrical power to the plant during loss of off-site power using diesel generators or gas turbines and accumulators. The backup power system is divided into parallel mutually independent subsystems. All the parallel trains of each safety system receive their power supply from different subsystems of the backup power system.

Another principle observed in the design of safety systems and safety functions is diversity. This means that it must be possible to implement a particular safety function using two systems based on different principles of operation. The two independent reactor shutdown systems mentioned above constitute an example of diversity. Diversity makes it possible to reduce the risk for core damage caused by the inoperability of safety systems due to common-cause failures.

To the extent possible, the so-called fail-safe principle has also been observed in the design of equipment important for safety. This means that the device goes into a state advantageous for safety upon loss of external driving power.

The new draft for a Council of State's Decree concerning the safety of nuclear power plants further emphasises the significance of diversity. According to the draft Decree, the impacts of common-cause failures of safety systems on plant safety shall be minor. This requirement is applicable to the new plant alternatives so that in connection with the most common initiating events, it must be assumed that the operation of the protection or safety system primarily intended to cope with the event fails completely. In such a case, some kind of a backup system must be available to bring the plant unit to a safe state without substantial fuel damage. Such cases of common-cause failure must be analysed as so-called design extension conditions (See Section 4.2.3).

The diversity requirement applies to actual safety systems as well as auxiliary systems necessary for their operation and protection automation systems responsible for starting them at the right time. Because common-cause failures of protection and safety systems are very improbable, the diversity requirement does not apply to initiating events that are infrequent as such.

#### *4.2.7. Avoiding human errors*

The possibility of human errors is reduced by means of appropriate instructions, procedures and training, as well as an efficient quality management system. Ensuring competence is a crucial part of managing the human factor during design, construction and operation. Any errors and deficient procedures shall be corrected immediately when observed, and shall be used as learning opportunities to prevent any recurrence of similar events. This is supported by an advanced quality management system and reporting practices.

Human errors at the design stage can be divided into random and systematic errors. A random error is a single error, for example an incorrect figure. Random design errors will be detected in a multi-stage inspection. Furthermore, modern design tools have certain functions for preventing or detecting errors. A systematic error can be a deficiency or error in a safety requirement specification, for example. These are prevented through a systematic hierarchical system of safety requirements (safety analysis report at the construction stage, system requirements, component-level requirements, as well as environmental requirements common to several systems and components), the application of which will ensure (prove and verify) that upper-level safety requirements have been correctly and comprehensively implemented in the design prerequisites for systems, components and the like. Through the OL3 project, TVO has accumulated experience and competence in the implementation of such systematics in practical projects, including managing supply chain.

Human factors are managed at the construction stage using common nuclear power industry procedures, such as the quality management system. The detection of errors is also supported by the fact that components and structures are manufactured in accordance with approved plans and subjected to tests and inspections specified in advance (the results must fulfill acceptance criteria specified in advance). Furthermore, the activities produce traceable documentation that can be used to prove that manufacturing and construction have been carried out according to plans. QA and QC constitute an important part of nuclear safety. TVO's competence in the field has become even stronger through the implementation of the OL3 project.

The foundations for managing human factors at the operating stage are created at the design stage. At that stage, human factors are taken into account as a potential cause of failures or disturbances. This is done through factors such as the following: single failure tolerance of systems, taking human actions into account in the probabilistic safety analysis (PRA/PSA), consideration of the simultaneous occurrence of preventive maintenance and a potential single failure (the N-2 principle), as well as designing safety functions and associated instrumentation, control and protection systems so that the operators will have enough time to consider the correct actions (the so-called 30-minute rule).

The impact of the human factor at the operating stage can roughly be divided into three: management of plant modifications, maintenance and operations. The management of human factors associated in the management of plant modifications is based on accurate documentation, maintenance and management of the design bases of the plant. The foundation for this is created at the design and construction stages. TVO also uses a comprehensive plant modification management procedure embedding the principle of multi-stage verification and ending at a comprehensive documented procedure for the testing and validation of the effects of changes.

In maintenance operations, the management of the human factor is based on administrative routines and procedures. An example of this is that when work is planned and work management controlled, work permits concerning safety systems will only be issued for one subsystem at a time. Furthermore, equipment and systems are subjected to comprehensive tests after the completion of work. In very uncommon cases, human errors may cause common-cause failures but in addition to diversification, the possibility has been further reduced through the distribution of work and the development of testing procedures.

In addition to the above foundation, the human factor is taken into account in operating activities through precisely defined competence requirements for personnel and supervision of these. Training simulators specific to the type of plant constitute a part of this.

At the existing plant units, TVO has introduced procedures aimed at reducing, detecting and correcting human errors (so called error-prevention tools), such as peer review, clear communications, independent verification and pre-job briefings. Development related to these is constantly carried out as part of operating activities.

#### *4.2.8. Protection against external events and fires*

The design of the potential plant alternatives allows them to endure extreme weather conditions that are estimated to be very rare or improbable at the site, including high and low temperatures, wind, snowload, sea water level, ice conditions and thunder. Furthermore, the possibility of an earthquake is taken into account in the design of plant unit parts important to safety.

Physical separation of the safety systems and their location in well-protected spaces is aimed at protecting the safety functions so that an external event cannot make all of them inoperable simultaneously. Correspondingly, parallel safety systems are located in different fire compartments so that a fire cannot damage them all. Physical separation can protect the parallel parts of safety systems also against other internal events within the plant unit. Such events may include pipe breaks, tank ruptures, explosions and floods.

The design of the new plant unit will also take into account potential damage to the plant from a large airplane crash or from illegal activities.

### *4.2.9. Safety classification*

Safety classification ensures that the structures, systems and components are developed, manufactured and installed so that their quality level and the inspections and tests required to verify their quality level are in correct proportion to any item's safety significance. The safety class provides a starting point for specifying the requirements to be made for the design, manufacture, installation, inspection, testing, operation and quality assurance of a structure, system or component.

The safety classification of structures, systems and components, as well as the quality assurance procedures and their foundations will be submitted to the regulatory authorities for approval.

### *4.2.10. Monitoring and control of the nuclear power plant unit*

The main control room of the plant unit contains equipment that provides information on the current state of the plant unit. Any significant deviations from the normal operating state and failures of systems and equipment are indicated by alarms.

It has already been noted that one of the design bases for the protection system of the new plant alternatives is the so-called 30-minute rule. However, this rule is only valid on the precondition that the safety systems operate automatically at least at their planned minimum capacity. If this is not the case, operator actions may be needed earlier than 30 minutes after the beginning of the accident. Emergency operating procedures will be prepared for such situations, and in the case of a disturbance more severe than the design basis, the operating personnel can use these to bring the plant unit to a safe state.

An operator support system will be developed for disturbances and accidents, with information specially compiled and grouped to facilitate the application of the emergency procedures.

The plant design also includes provisions for the loss of the main control room, for example due to fire or sabotage. Each of the potential plant alternatives has an emergency control post independent of the main control room, which can be used for shutting down the reactor and bringing the plant unit to a safe state.

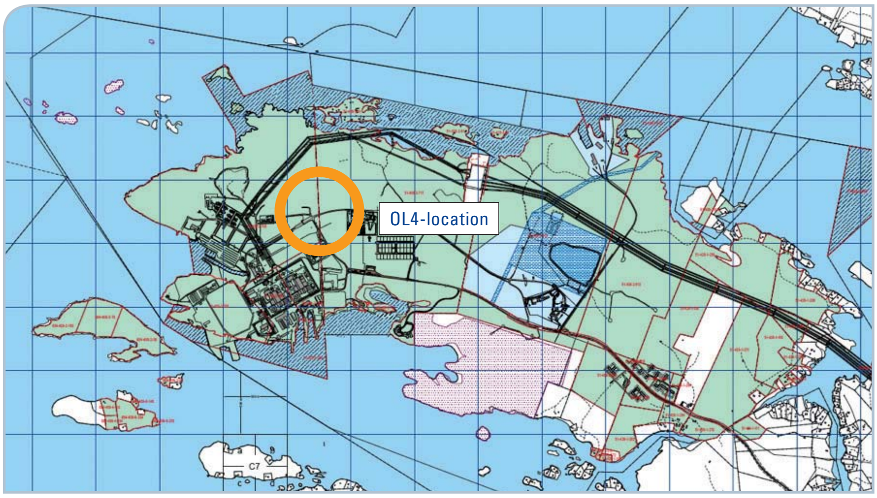
# OUTLINE OF THE OWNERSHIP AND OCCUPATION OF THE SITE PLANNED FOR THE NUCLEAR FACILITY

CONTENTS

## 1. GENERAL

The intention is to build the new nuclear power plant unit in the Olkiluoto nuclear power plant area located in the western part of Olkiluoto Island. The power plant area houses the applicant's two operating nuclear power plant units and one nuclear power plant unit under construction.

***Figure 9–1*** *Areas owned by the applicant.*



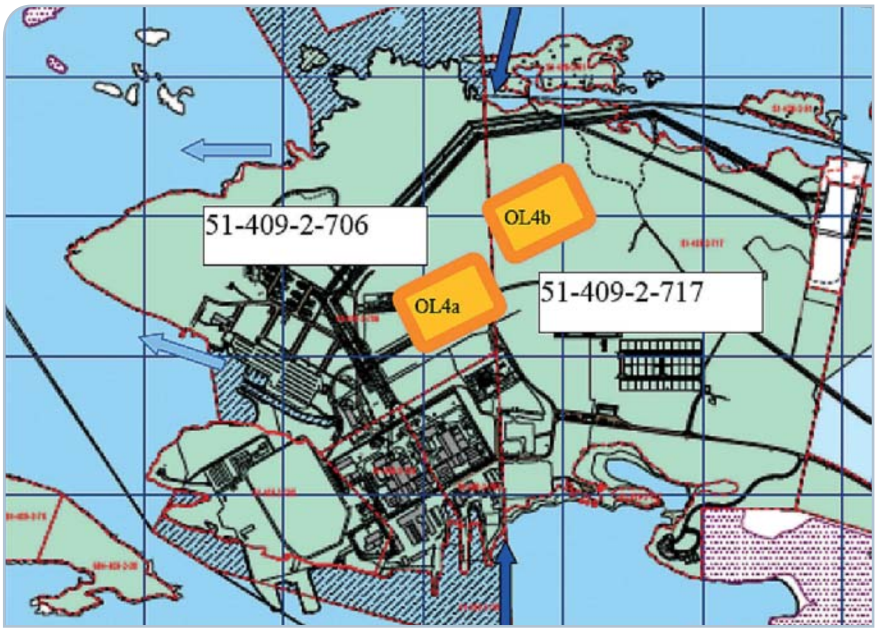

The applicant owns most of Olkiluoto Island, approximately 745 ha (green area in Figure 9–1), which corresponds to approximately 85 per cent of the entire area of the island. The areas in private ownership in the eastern part of Olkiluoto Island (white area) mostly contain holiday properties. 180 ha (halftone area) of the waters around Olkiluoto are controlled by the applicant, with additional parts held through joint ownership. The area marked in purple is a nature conservation area owned by the Metsähallitus State Enterprise.

The extensive areas owned by the applicant at Olkiluoto provide good preconditions for the placement of nuclear power plant units. Extensive ownership provides flexibility of the use of the area and an opportunity to ensure and further develop area security.

## 2. OWNERSHIP AND OCCUPATION OF THE LOCATION

The alternative locations of the new nuclear power plant unit at Olkiluoto are within properties owned and occupied by the applicant, registration numbers 51-409-2-706 and 51-409-2-717. The new plant unit will be located in the western part of Olkiluoto Island between the existing transmission line area and the existing plant units.

***Figure 9–2*** *The alternative locations for the plant unit and the overground structures for their cooling water passages are located within two properties owned by the applicant (51-409-2-706 and 51-409-2-717).*




The applicant's operating nuclear power plant units Olkiluoto 1 and Olkiluoto 2, as well as the Olkiluoto 3 nuclear power plant unit under construction, are located close to these locations on properties having the registration numbers 51-409-2-703, 704 and 705.

In the eastern part of Olkiluoto Island and other islands bordered by the eastern part, there are holiday homes and empty holiday home sites, as well as a few privately-owned larger areas. The Liiklankari conservation area located in the southern part of Olkiluoto Island is owned and governed by Metsähallitus.

The applicant also owns the island called Kuusisenmaa off Olkiluoto, as well as properties on islands called Lippo and Leppäkarta. There are no buildings on Kuusisenmaa. Lippo and Leppäkarta also have some holiday properties in private ownership.

In the waters around Olkiluoto, the applicant fully owns 180 ha, in addition to which the applicant has holdings in jointly owned water areas, approximately 70 per cent of the the Olkiluoto and Orjasaari water rights (51-428-876/1) and approximately 40 per cent of the Munakari joint area (51-876-13-0).

# DESCRIPTION OF SETTLEMENT AND OTHER ACTIVITIES AND PLANNING ARRANGEMENTS AT THE PLANNED NUCLEAR FACILITY SITE AND IN ITS IMMEDIATE VICINITY

CONTENTS

## 1. GENERAL

Certain requirements are imposed on the location of a nuclear power plant in order to ensure the safety of the plant units and the environment. As a location for a nuclear power plant unit, Olkiluoto is well compliant with the requirements set by the authorities and TVO.

The valid land use plan at the location and the planned amendment allow the construction of a new nuclear power plant unit. The amendment to the plan will also reserve areas for the disposal of spent nuclear fuel originating from the new nuclear power plant unit. The plan is in harmony with provincial land use.

## 2. COMMUNITIES

***Figure 10–1*** *There is no dense settlement referred to in YVL Guide 1.10 by the Radiation and Nuclear Safety Authority within 5 kilometres of Olkiluoto.*


Eurajoki is a municipality on the coast of the Gulf of Bothnia and belongs to the economic zone of Rauma. The municipality of Eurajoki has a population of slightly more than 6,000. The municipal centre is located just over 10 kilometres north of the centre of Rauma and almost 40 kilometres south of Pori along highway 8. Daily commuter traffic between Olkiluoto, Eurajoki and Rauma is intense.

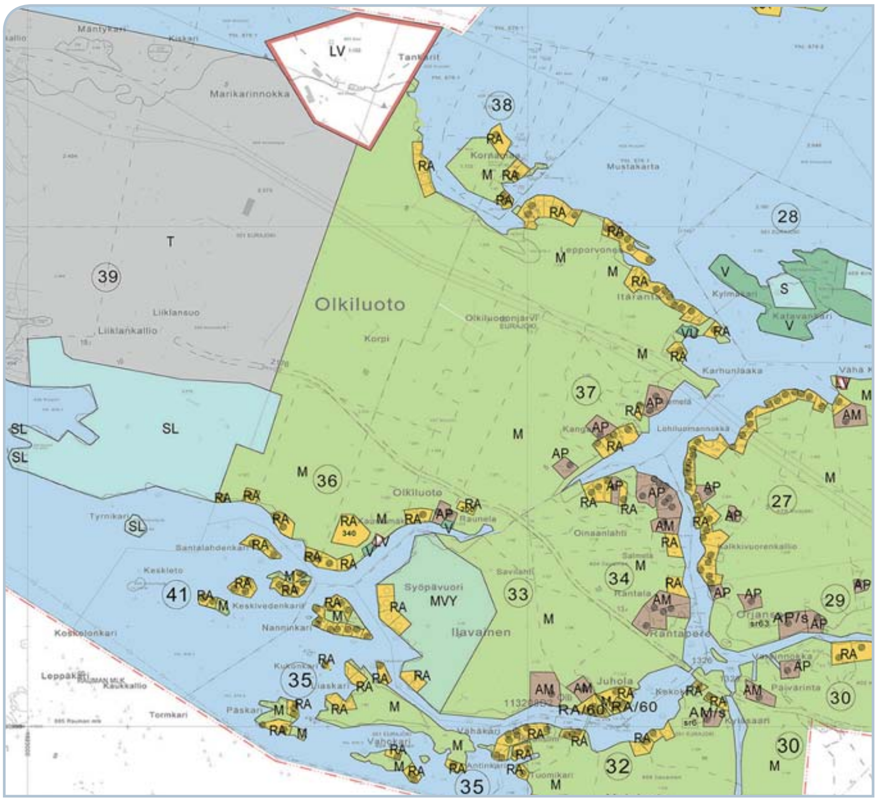
The neighbouring municipalities are
- Rauma (approximate population 38,000),
- Lappi (approximate population 3,400),
- Eura (approximate population 9,600),
- Kiukainen (approximate population 3,700),
- Luvia (approximate population 3,300),
- Nakkila (approximate population 6,200).

The economic zone of Rauma, including the municipalities of Eura, Eurajoki, Kiukainen, Lappi and Rauma, has some 60,000 inhabitants. Pori, which is located some 32 km from Olkiluoto to the northeast, has some 76,600 inhabitants.

Services, secondary production, agriculture and forestry play a major role in the economic structure of the municipality of Eurajoki. TVO is the largest employer in the municipality. The applicant has some 700 employees at the nuclear power plant, in addition to which more than 300 people work for subcontractors at Olkiluoto. Annual outages usually employ some 1,000 people in addition to the normal workforce at the power plant. The work site for the Olkiluoto 3 plant unit currently under construction employs almost 3,000 people.

## 3. SETTLEMENT AT OLKILUOTO

***Figure 10–2*** *Holiday homes to the east of Olkiluoto Island in accordance with the partial shore master plan.*



Agriculture is only practised in the vicinity of the power plant area at Olkiluoto to a minor extent, mostly constituting field cultivation in the eastern part of Olkiluoto Island. Fishing is practised in the nearby waters both professionally and as a hobby.

The nearest residential buildings are located approximately three kilometres from the power plant site. There are three residences intended for permanent use on Olkiluoto Island. The village of Ilavainen located to the east of Olkiluoto Island has several residences intended for permanent use.

There are approximately 30 privately owned holiday properties on Olkiluoto Island, located in the eastern end. There are approximately 550 holiday properties within an approximate distance of five kilometres from the power plant site, mostly located on nearby islands and in the villages of Ilavainen and Orjasaari.

## 4. OTHER OPERATIONS

There is a harbour in general operation on the northern shore of Olkiluoto Island located on property owned by the applicant, and a 6-metre navigable passage maintained by the Finnish Maritime Administration leads to the harbour. The harbour area currently also houses an engineering workshop serving the construction of the OL3 nuclear power plant unit.

The holiday home area in the eastern part of Olkiluoto includes the old Raunela estate which TVO is restoring and developing as a heritage farm to represent the history of Olkiluoto before the nuclear power plant.

Olkiluoto currently has temporary accommodation facilities for approximately 1,000 people working at the nuclear power plant, and the capacity can be increased by approximately 500 accommodation units if necessary.

Operations in the villages of Ilavainen and Orjasaari to the east of Olkiluoto Island (within 5 kilometres) and the new plant site's impact on them are minor. However, traffic to Olkiluoto through the villages will increase.

Operations located within the actual power plant area are discussed in Appendix 11.

## 5. LAND USE PLANNING

The licensing procedure and construction of the new nuclear power plant unit do not require changes in the valid land use plan at Olkiluoto. The valid plan ensures the prerequisites for long-term safe operation of nuclear power plant units at Olkiluoto.

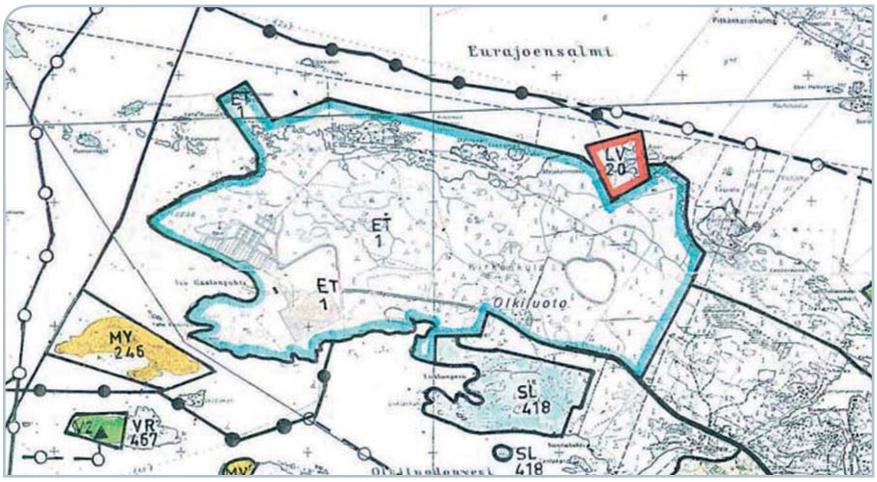
The land use planning at Olkiluoto is being updated to correspond to the contentual requirements of the new Land Use and Planning Act and to observe the requirements set for the disposal facility for spent nuclear fuel.

The Regional Plan 5 will be replaced by a provincial plan prepared by the Satakunta Regional Council, taking into account the objectives set by the State authorities on land use planning at Olkiluoto and the requirements imposed by nuclear waste management.

## 5.1. The current regional plan

The Regional Plan 5 is based on building legislation, and its primary purpose is to guide more detailed planning of the use of areas.

***Figure 10–3*** *In the Regional Plan 5, the Olkiluoto power plant area is designated as a community management zone (ET).*




The Satakunta Regional Plan 5, which was approved by the Satakunta Regional Council in 1996 and ratified by the Ministry of the Environment in 1999, is in force at Eurajoki. In the regional plan, the Olkiluoto power plant site is designated as a community management zone. According to the special provisions concerning the zone, detailed planning and design must pay special attention to environmental protection, and the handling and storage of radioactive waste must be arranged in a completely safe manner. Furthermore, the regional plan also allows other energy production besides the nuclear power plant units, as well as other industry based on the energy production in the area.

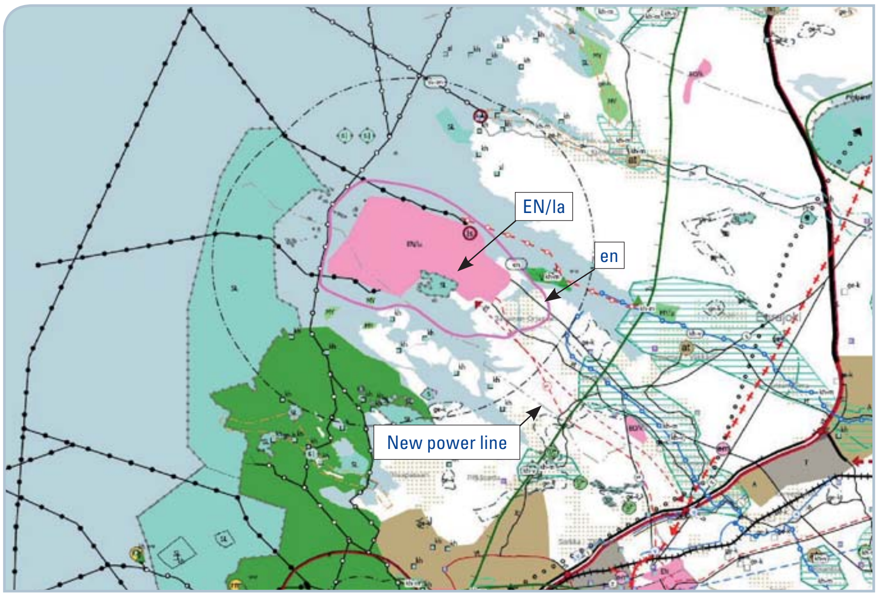
The Liiklankari area is designated as a nature conservation area in the Regional Plan 5.

The Regional Plan 5 indicates a remote protection zone around the nuclear power plant with restrictions on land use. The zone surrounds the nuclear power plant area at a distance of approximately 5 to 7 kilometres. The zone must not be used for the planning and placement of any large residential areas or facilities with a large number of employees or patients, food processing plants or any facilities or equipment that could be a danger to the nuclear power plant, such as explosives factories, warehouses or airports.

## 5.2. Provincial plan in preparation

The Satakunta Regional Council is preparing a provincial plan that will replace the current Regional Plan 5. The objectives for the use of areas in the Satakunta provincial plan are based on approved national land use objectives that became legally valid in 2001.

***Figure 10–4*** *National land use objectives related to operations at Olkiluoto are taken into account in the draft provincial plan shown here.*



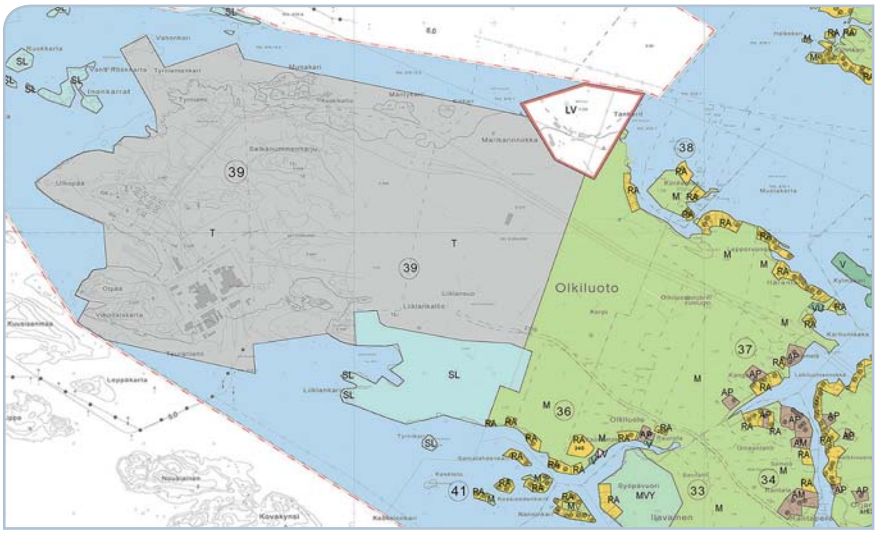

The draft provincial plan designates an energy supply plant zone (EN/1a) at Olkiluoto, which is reserved for facilities, buildings or structures that serve energy production, as well as facilities and buildings for carrying out final disposal of spent nuclear fuel. The surroundings of the plant zone are designated as the vicinity of a plant zone reserved for energy supply (en) which, due to nationally significant operations, is subject to development needs related to land use.

The draft provincial plan also designates the power line routes leaving the area, a regional road, navigable passages for ships and boats, and conservation areas.

The preparation of the provincial plan started in February 2003. The draft should be available for public viewing during 2008.

## 5.3. Master plan

*Figure 10–5 Partial shore master plan currently valid at Olkiluoto.*




No ratified local master plan exists for the Olkiluoto area within the municipality of Eurajoki, but there is a master structural plan approved by the Eurajoki municipal council in 1988.

In June 1999, the Eurajoki municipal council approved a master shore plan covering the sea shores of Eurajoki. The Southwest Finland Regional Environment Centre ratified the master shore plan with some modifications in October 2000.

The partial master plan for the northern shores of Rauma ratified on 23 December 1999 is valid in the coastal areas of Rauma.

The Eurajoki municipal council approved an amendment to the master shore plan on 12 December 2005, assigning an accommodation village and other functions serving energy production to the southeastern part of Olkiluoto.

## 5.4. Amendment to the partial master plan

The Olkiluoto partial master plan and an amendment to the partial master plan for the northern shores of Rauma are under preparation in the Olkiluoto area.

The primary objective is to maintain the prerequisites for land use at the largest energy production site in Finland and reserve areas for implementing a final disposal facility for spent nuclear fuel in compliance with Finnish legislation and the requirements set for the safety of the operations.

The work for amending the Olkiluoto partial master plan and the partial master plan for the northern shores of Rauma started in 2006. The work is progressing according to plan. The plan proposals will probably be approved in 2008.

## 5.5. The current local detailed plan of Olkiluoto

The current local detailed plan of Olkiluoto comprises 6.45 million $m^3$ of construction rights in the zone designated as a nuclear power plant area, almost 4 million $m^3$ of which remains available for power plant construction. The power plant area is located at the western end of Olkiluoto Island.

Local plans ratified in 1974 and 1997 are valid in the area of the existing nuclear power plant units, the unit under construction and the planned OL4 plant unit. The power plant site is designated as a zone for industrial and warehouse buildings allowed for nuclear power plants, other facilities and equipment intended for the production, distribution and transmission of power, as well as buildings, structures and equipment associated with these, unless otherwise restricted.

Most of the water areas included in the building plan are approved for the purposes of power plants, and landing places and other structures required for power plant purposes may be constructed on and off the shore of the industrial and warehouse areas. The building plan also indicates water areas where filling and embankment operations are allowed.

The Olkiluoto area also has plans for a zone for accommodation buildings serving energy production approved on 12 December 2005, as well as ratified local shore plans to the east of Olkiluoto Island.

*Figure 10–6 Local plan valid at Olkiluoto in which the area designated for nuclear power plants is marked with purple.*

## 5.6. Amendment to the Olkiluoto local plan

The Olkiluoto partial master plan guides the amendment to the local plan that is currently underway. Within the municipality of Eurajoki, the amendment to the local plan comprises Olkiluoto, the small islands to its north and northwest, as well as the waters surrounding these islands. Within the town of Rauma, the area covered by the plan includes the islands to the southwest of Olkiluoto, as well as the waters surrounding these islands. The plan will retain the current construction rights designated for nuclear power plants and incorporate regulations and construction rights for the spent fuel final disposal facility.

The amendment process began at the end of 2007. The plans are expected to be approved in late 2008.

# ASSESSMENT OF SUITABILITY OF THE PLANNED SITE FOR ITS PURPOSE AND OF LAND USE RESTRICTIONS IN PLANT SURROUNDINGS CAUSED BY THE SITING OF THE NUCLEAR FACILITY

CONTENTS

## 1. GENERAL

Olkiluoto at Eurajoki fulfils the requirements set for a plant site. Land use planning has made preparations and will make further preparations for the additional construction of power plant units. The site of a large power plant unit must also have a sufficient supply of cooling and service water, good traffic connections, a sufficiently large area and suitable geological and topographical conditions. These preconditions are fulfilled well at Olkiluoto.

The Olkiluoto area has been in nuclear power plant use for approximately 30 years and has been proven very suitable for the purpose. The land use of the site of the new plant unit is in harmony with other land use on Olkiluoto Island and relies on the existing Olkiluoto infrastructure. The new plant unit can utilise functions supporting the operation of the existing plant units, as well as premises and structures built for them. The new plant unit will not cause any land use restrictions additional to those caused by the existing plant units.

The impact on the environment is minor and limited mainly to the local warm-up of seawater and changed flow conditions caused by the cooling water requirement of the plant units.

## 2. SUITABILITY OF THE SITE

The new plant unit OL4 will be located in the immediate vicinity of the existing nuclear power plant units OL1 and OL2, as well as the OL3 unit now under construction. In the valid building plan, the power plant site is designated for industrial and warehouse buildings and, according to the planning regulations, may be used for the construction of nuclear power plants and other facilities, equipment and components intended for power production, distribution and transmission, as well as other buildings, constructions and structures related to these unless otherwise restricted. The plan also indicates water areas that may be filled or banked up and in which landing places, other structures and equipment needed by the power plants may be built. The construction of the new power plant unit does not require any amendments to the building plan.

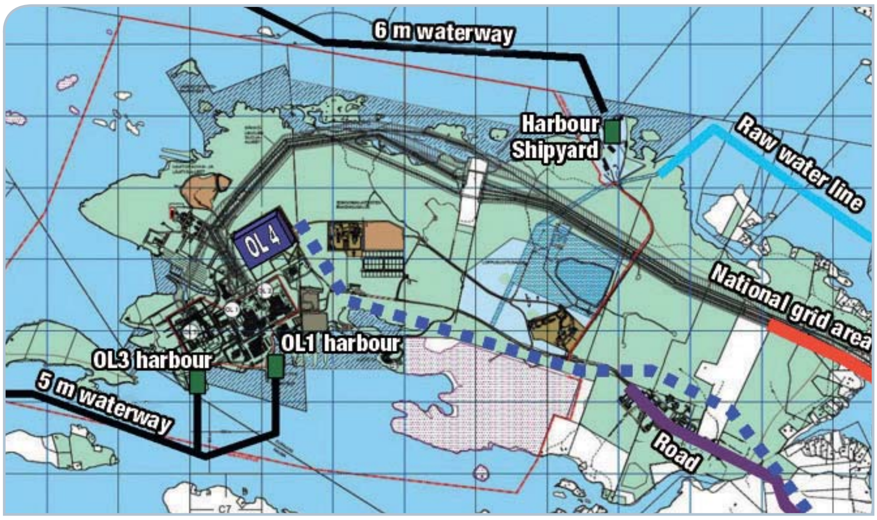
The existing power plant site at Olkiluoto already has the infrastructure required for nuclear power production. The new plant unit will mostly rely on this infrastructure. The construction of the new power plant unit will cause some rearrangements in the power plant area, for example with regard to fencing, access connections and the intake and discharge of cooling water. The new unit will also require the establishment of a new transmission line area and the construction of a new power line separate from the existing transmission line area at Olkiluoto and its immediate vicinity.

The eastern part of Olkiluoto Island has an agriculture and forestry zone in accordance with the current shore master plan, and there are holiday homes on the eastern shore. The intention is to secure the existence of holiday homes at Olkiluoto in any upcoming plans. In the partial master plan under preparation, the holiday properties are located in a green zone that disallows any other construction. The middle and eastern parts of the island, at a distance from the holiday home area, mostly house the overground structures for the spent fuel disposal facilities such as vent stacks and structures required for the handling of fuel. Due to the distance and the nature of the operations, they will have a negligible impact on the holiday homes. The power plant unit OL4 to be sited in the western part of Olkiluoto will not cause any negative impact on the holiday home area as such. Additional construction will somewhat increase traffic to Olkiluoto.

Studies have shown that the impact of OL4 on Natura areas located in the vicinity will be minor.

## 2.1. External infrastructure

***Figure 11–1** The existing external infrastructure at Olkiluoto will also be available to OL4, and substantial extensions and changes will only be needed with regard to power transmission. The location of the power transmission line is shown with a blue dashed line.*

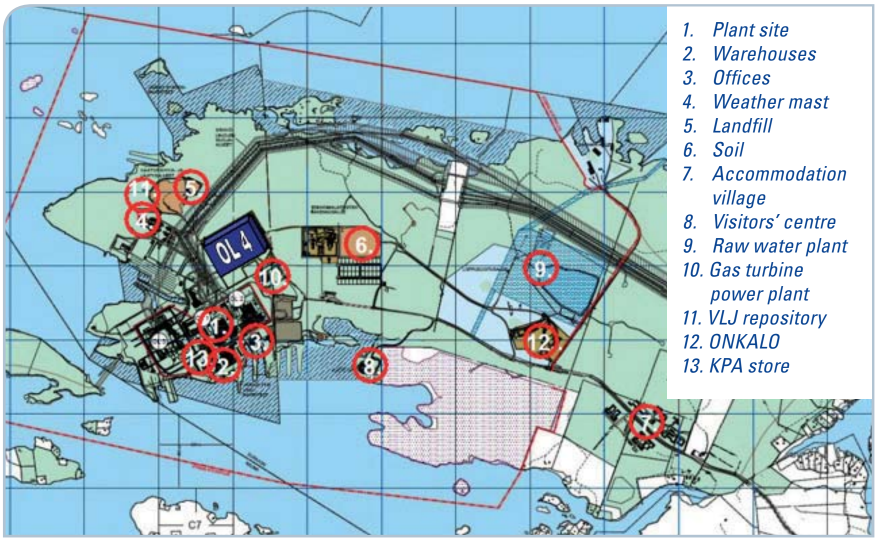



The external infrastructure required for the OL4 plant unit consists of traffic connections, the conveyance of raw water and the transmission of power to the national grid. Most of this infrastructure already exists.

For the purpose of power transmission from the new nuclear power plant unit, a new transmission line connection from Olkiluoto to Rauma through the southern part of the island, separate from the current lines, has been planned. The location of the new line is accommodated in the pending provincial plan and the Olkiluoto local plan.

## 2.2. Internal infrastructure

***Figure 11–2*** *The internal infrastructure at Olkiluoto can be easily extended to serve the construction and operation of the OL4 plant unit.*




The new plant unit will be able to efficiently utilise the infrastructure built for the needs of the existing plant units at Olkiluoto. Among other facilities, the site contains administrative buildings, a training centre and a visitors' centre, warehouses, repair shops, a back-up heating plant, a raw water tank, a raw water treatment plant, a demineralisation plant, a sanitary water treatment plant, a landfill, a contractors' area, accommodation villages and a gas turbine plant.

TVO has overall responsibility for all handling and storage of radioactive waste at Olkiluoto. Buildings and facilities for waste management include interim storage for spent fuel (KPA Store), interim storage for low-level and intermediate-level operating waste (MAJ and KAJ Storage), a final disposal facility for operating waste (VLJ Repository), and the spent fuel final disposal research facility ONKALO currently under construction by Posiva Oy. These facilities can be used for the needs of nuclear waste management associated with OL4 either as such or with certain changes.

The area has functional traffic connections with a harbour, roads and parking lots.

## 2.3. Final disposal of spent nuclear fuel

Spent nuclear fuel originating from the applicant's operations will be disposed of at Olkiluoto. A research facility for final disposal operations called ONKALO is under construction in the middle part of Olkiluoto Island, to the south of the Korvensuo basin and to the north of the Liiklankari conservation area, for the purpose of studying the bedrock conditions for disposal of spent nuclear fuel. ONKALO is planned to constitute a part of the final disposal facilities. When implemented, the area of disposal facilities may extend to a large part of Olkiluoto Island and nearby waters.

## 3. LAND USE RESTRICTIONS IN PLANT SURROUNDINGS

The normal operation of the nuclear power plant or anticipated operational transients does not limit land use off-site. However, in the vicinity of the nuclear power plant, precautions for the possibility of a severe accident are taken by preparing plans for the use of nearby areas and for civil defence.

YVL Guide 1.10 by the Radiation and Nuclear Safety Authority defines a nuclear power plant site as an area where only power plant related activities are allowed as a rule. However, the plant site, which comprises both land and water, may be used for fishing, hiking and other recreational activities, provided that the operator of the nuclear power plant is able to supervise the area. The intention has been to extend the plant site to approximately one kilometre from the plant fence but the value is indicative and decided separately in each special case.

Preparations for the safety of the Olkiluoto site have been made through only allowing restricted use of everyman's rights within the Olkiluoto land area and nearby waters. The plant site according to YVL Guide 1.10 is affected by access restrictions in accordance with a decision by the Ministry of the Interior subject to separate application. According to the same Guide, the number of permanent inhabitants within five kilometres of the plant should not be in excess of 200. The number of persons taking part in recreational activities may be higher, provided that an appropriate rescue plan can be drawn up for the area.

The plant site is surrounded by a protective zone shown in the regional plan, which extends to about five kilometres' distance from the facility. Land use restrictions are in force within the protective zone. Dense settlement and hospitals or facilities inhabited or visited by a considerable number of people are not allowed within the protective zone. The zone may not contain such significant productive activities that could be affected by an accident at the nuclear power plant.

# ASSESSMENT REPORT DRAWN UP IN ACCORDANCE WITH THE ACT ON ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE AND AN ACCOUNT FOR THE DESIGN CRITERIA THE APPLICANT INTENDS TO APPLY IN ORDER TO AVOID ENVIRONMENTAL DAMAGE AND TO LIMIT ENVIRONMENTAL BURDENS

CONTENTS

# 1. ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) is a systematic process used in preparations for decision-making, with the aim of providing a uniform and comprehensive picture of the venture and its alternatives already in the early stage. Another objective of the EIA procedure is to increase the opportunities for citizens to receive information, become involved in the planning of ventures and express their opinion.

The Olkiluoto area has a long tradition of comprehensive environmental surveys. When constructing a nuclear power plant unit at a site with existing nuclear power plant units in operation, previous experience of construction and operation can be directly applied to the assessment of the new unit's environmental impact.

An environmental impact assessment in accordance with the EIA Act has been conducted on the new nuclear power plant unit planned for the Olkiluoto plant site. When assessing the environmental impacts of the Olkiluoto nuclear power plant extension venture, the present state of the environment was first examined, and after that, the changes caused by the ventures as well as their significance were assessed, taking into account the combined impacts of the operations at Olkiluoto. The environmental impact assessment for the planned nuclear power plant unit covers the entire life cycle of the plant unit. The results are presented in the environmental impact assessment report. The report is included in the application materials as Appendix 12.1. This Appendix 12 provides a brief description of the environmental impact of the new nuclear power plant unit and the design criteria used to avoid environmental damage and to restrict the burden on the environment. The environmental impact will be discussed in detail when applying for an environmental permit for the new plant unit.

TVO operates an environmental management system that has been certified to comply with the requirements of international standard ISO 14001:2004. In addition, the Olkiluoto power plant holds EMAS registration based on an EU Regulation. TVO's environmental management system includes the consideration of environmental aspects over the entire life cycle of nuclear energy production and the principle of constantly improving the standard of environmental protection.

# 2. RADIOACTIVE MATERIALS

## 2.1. Isolation principle

The heat production process in a nuclear power plant is based on the fission of uranium nuclei in the nuclear reactor fuel. This process generates radioactive materials that are isolated from the environment by several layers of protection within each other.

The fuel is sealed in gas-tight cladding within the reactor pressure vessel. The fuel cladding and the reactor pressure vessel with the associated cooling water circulation circuit form two layers of protection around the fuel and within each other. The reactor containment building is the third and outermost layer of protection between the radioactivity contained in the fuel and the environment.

The volume of nuclear fuel in proportion to its energy content is very small. The operation of the heat-producing process does not need any connection with the environment. This allows for the isolation principle implemented by means of the layers of protection described above. According to the principle, the radioactive materials generated in the fuel, which constitute the major part of the total amount of activity originating in the nuclear power plant process, are kept within a restricted small volume inside the plant.

In comparison with the radioactivity in the fuel, a minor amount of radioactive material is created in the cooling water inside the reactor when it flows through the reactor core. Any material released from the fuel through leaks in the fuel claddings will also end up in the reactor cooling water. This activity will either stay in the reactor system or be removed from it into other closed systems, such as the reactor coolant cleaning system, after which the radioactive materials will be treated using radioactive waste management methods.

The same principle of isolation applies to waste management at a nuclear power plant. Radioactive waste is packed and stored under supervision so that it does not release any emissions to the environment. Waste is disposed of in a final repository in the bedrock. The waste containers and surrounding technical protection layers ensure that they are isolated from the living environment for a long time. Even though the technical protection layers lose their integrity over an extended period of time, the activity of the waste has been reduced to a fraction of the original and the amounts of activity released into the environment are minor in terms of the radiation burden. The waste management for the new plant unit is discussed in Appendix 14 to the application.

## 2.2. Releases during normal operation and operating disturbances

Releases of radioactive material during operation originate in the processing of water removed from the reactor cooling system or gases in cleaning systems. The activity of gaseous substances is reduced before their release into the environment mainly on the basis of delay, meaning that short-lived radionuclides have already lost most of their activity by the time they are released into the environment.

In order to reduce the activity of water releases, any water released into the environment is cleaned by filtration or evaporation.

All systems containing radioactivity are located in rooms within the radiation controlled area. The leakage and sewage waters from the controlled area are piped to collection tanks from where they can be taken for cleaning or, if the activity is low enough, released into the environment. A ventilation system maintains underpressure in the controlled area in comparison with outdoor air. The exhaust flow from ventilation is filtered if necessary and conveyed to the ventilation stack where the activity level of the exhaust air is monitored.

The arrangements for handling and cleaning radioactive materials are implemented so that any releases during normal operation and anticipated operating transients can be kept so low that the radiation dose from the releases into the surrounding population is only a fraction of the limits specified in the Government Decision on the general regulations for the safety of nuclear power plants (GD 395/91). The limit for releases during normal operation is 0.1 millisieverts per year. The limit applicable to anticipated operating transients is the same, 0.1 millisieverts per year. The draft Government Decree that will replace GD 395/91 specifies the same limits. The allowed limits for radioactive releases from plant units at the same site are specified so that the total emissions do not cause a dose that would exceed the limit.

The radiation dose to the nearby population from the releases during normal operation of the planned plant unit is estimated to be less than 0.001 millisieverts per year, which is in the same order of magnitude as the dose caused by the existing units. The dose is less than 1 per cent of the limit and less than 0.03 per cent of the average annual radiation dose received by Finns from other sources of radiation. The Finns receive an average annual radiation dose of 3.7 millisieverts. Most of this originates in natural sources of radiation, the most significant being radioactive radon gas released to indoor air from the soil. Other exposure mostly originates in background radiation from space and the soil, foodstuffs, construction materials and medical procedures. The radiation dose originating in natural background radiation varies by region. For example, the dose caused by external radiation from the soil and buildings varies between 0.17 and 1.0 millisieverts in different parts of Finland.

The annual radiation dose of less than 0.001 millisieverts caused by the new plant unit to the nearby population poses a theoretical risk of cancer that is insignificant in comparison with the level of risk caused by the average annual dose of 3 millisieverts from natural radiation and its regional variation.

One can summarise that the amounts of radioactive materials released from the new power plant unit into the environment are so minor that they do not have any significance for human health.

## 2.3. Releases during accidents

In order to prevent accidents and limit their consequences, the safety principles and regulations described in Appendix 8 to the application are observed in the design, construction and operation of the plant unit.

The postulated accidents that serve as a basis for the design of the plant unit examine, among other things, situations where a leak develops in the reactor cooling system and the safety systems operate as designed. In these accident situations, there is no need to impose any restrictions on living and the use of foodstuffs in the vicinity or any other restrictions. The radiation dose caused to the nearby population may not exceed the limit for a postulated accident specified in GD 395/91, which is 5 millisieverts. The limit concerns the dose accumulated by an individual during a period of one year from the accident. The dose limit corresponds to the dose received by an average Finn from other sources over a period of just over a year. If the average Finn receives a dose corresponding to the limit for a postulated accident once in his life, his lifetime radiation burden increases by approximately 2 per cent. The change is minor in comparison with the variations in the lifetime dose from natural radioactivity in different regions of Finland.

In the case of a severe accident, it is assumed that the safety systems of the plant are not operational in a situation caused by a reactor system leak or some other damage. This may lead to severe damage to the reactor core, releasing a major part of the radioactive materials in the fuel into the containment building. According to the design requirements, the containment building must keep the amount of radioactivity released into the environment below the limit specified in GD 395/91. The prescribed limit is such that even in the case of a severe accident, the discharge does not cause immediate health hazards to the surrounding population or any long-term restrictions to the use of large areas of land.

In connection with the application for a construction licence and an operating licence, detailed analyses are used to prove that the plant fulfils the requirements set for accident situations in GD 395/91 and the draft Government Decree that will ultimately replace it. This also includes proving the fact that the possibility of exceeding the limit for a severe accident is extremely minor.

## 2.4. Environmental impact analysis methods

Established calculation models exist for estimating the conveyance of radioactive materials in the water environment, the atmosphere, the food chain etc. These allow radiation doses to the environment to be calculated on the basis of measured and predicted release amounts. The models pay attention to all the important routes through which the release of radioactive materials may affect people. The information on the environment and the lifestyles of the population required for the models has been determined by means of local surveys in the area surrounding the power plant. The plant site is equipped with weather monitoring equipment that continuously registers meteorological data for the calculation of conveyance in the atmosphere.

Due to the great variation of the variables related to the environment and its exploitation, the dose calculation model is unable to achieve high accuracy. This is compensated by choosing the numerical values of the variables so that they increase the radiation dose calculated on the basis of releases. This so-called conservative approach, which overestimates the doses, is intended to ensure that the actual doses to people are always lower than the calculated values.

## 2.5. Measures to reduce environmental impact

The minimisation of the environmental impact from radioactive releases is based on the minimisation of releases in accordance with the isolation principle described above. The water treatment systems and off-gas systems of the plant will be designed with this in mind.

The waters and gases released into the environment are efficiently cleaned by separating the radioactivity into filters, for example, which are stored as solid nuclear waste isolated from the environment. The amount of activity released into the environment during operation is so minor that its impact as a radiation dose to the environment is negligible.

The aim of the plant's safety systems is to ensure that releases can be controlled even in accident situations. However, preparations have also been made for measures to avoid an unnecessary radiation burden on the population in an accident situation. The power plant operator's own emergency response organisation is prepared to carry out the required radiation measurements at the plant site and its vicinity, issue the required alarms to the nearby area and the authorities, and to assess the impact of potential releases caused by the accident as radiation doses to the environment. The official rescue organisation is responsible for any measures to protect the population that may be deemed necessary in an accident situation.

## 2.6. Monitoring programme

Emissions of radioactive materials from the nuclear power plant take place through monitored emission routes. The total activity and nuclide composition of the emissions are measured. The doses caused by the emissions cannot be directly measured in the environment, as they are very minor compared to natural background radiation and its variations. The amounts of radioactivity caused by emissions are monitored by means of an environmental radiation monitoring programme that includes, for example, measurements of the radioactivity in more than 300 environmental samples each year.

## 3. COOLING AND WASTE WATER

### 3.1. Load

The thermal load to be conducted from the nuclear power plant unit to the sea depends on the power and efficiency of the plant unit. A nuclear power plant with an electrical power of 1,000 to 1,800 MW requires approximately 40 to 60 $m^3$ of cooling water per second. The water flows in the pipelines through the turbine condenser and is returned to the sea after a temperature gain of approximately 12 °C. The overall efficiency of the new plant unit is some 35 per cent to 40 per cent.

Waste water generated on the power plant site includes water from the raw water treatment and demineralisation plant, water from the liquid waste treatment plant, water used for flushing the travelling band screens, sanitary waste water and laundry waste water. The waste water fractions are processed appropriately by mechanical, chemical or biological means or a combination of these before being discharged to the sea. The waste water causes minor nitrogen and phosphorus load and oxygen-consuming load in the sea.

***Figure 12–1*** *Photomontage of the Olkiluoto area. The OL3 plant unit is in the front left. OL4 will be behind the existing plant units OL1 and OL2 and, in the photo, is located at plant site alternative 1. In the photo, the cooling water is taken from the southern side of Olkiluoto Island, to the right of the intakes of the existing plant units, and discharged at the existing discharge point to the west of the island.*

***Figure 12–2*** *Photomontage of the Olkiluoto area in which OL4 is located at plant site alternative 2 and cooling water is taken from Eurajoki strait to the north of Olkiluoto Island and discharged to the northwest of the island.*

## 3.2. Environmental impact of the load

The water areas surrounding the plant site allow for an adequate supply of cooling water for the new plant unit and the discharge of cooling water back to the sea. OL4 will increase the amount of cooling water, which will expand the size of the warmed-up sea area and the area unfrozen in winter approximately in direct proportion to the thermal power conducted to the sea.

The increase in water temperature caused by cooling water and the size of the warmed-up area varies by weather, season and the utilisation rate of the power plant. An increase of 1 °C in water temperature due to the combined impact of four plant units can be observed in surface waters at an approximate distance of 10 kilometres from the discharge point. Significant increases in temperature are limited to waters in the immediate vicinity of the discharge point. The most significant impact of the cooling water is caused in the winter to the ice conditions around the plant site.

According to experience, the impact of the cooling water on other properties of sea water is minor. The oxygen conditions in the sea area off Olkiluoto have also been good close to the bottom and almost without exception, and the situation is not estimated to change substantially due to the increased thermal load. The biological impact of the thermal load is evident from the extended growing season in the expanded unfrozen area and from increased total production.

The impact of cooling water on fish populations in the area is expected to remain similar to the present. The most substantial impact of cooling water with regard to fishing takes place in the winter season when the area of unfrozen water and weak ice off Olkiluoto limits fishing from the ice. Cooling water as a whole is not estimated to impose any substantial or extensive harmful effects on the fish populations of the area. Cooling water and its consequences are not estimated to have any effect on the usability of fish.

The increased waste water load is expected to remain so small that the impact probably cannot be distinguished from other nutrient and solid matter loads in the area.

## 3.3. Environmental impact analysis methods

Model calculations on the dispersal of cooling water and an estimate of the impact of thermal load on the temperatures and the ice conditions in the vicinity of the discharge point have been prepared using a three-dimensional flow model developed at the Environmental Impact Assessment Centre of Finland Ltd (EIA Ltd). The modelling has examined the differences between the intake and discharge point options. The detailed dispersal calculations, obtained as a result of the above, have been used as the basis of the impact assessments. The surveys have included cooling waters for the existing plant units, cooling waters for OL3 under construction and cooling waters for the planned OL4 plant unit.

## 3.4. Measures to reduce environmental impact

Based on experience from the operation of the existing plant units and results from the flow model referred to in the above, Olkiluoto is a suitable location for the new plant unit. The discharge of cooling water towards the open sea provides for efficient mixing, which helps in keeping the warmed-up sea area as small as possible. This can be implemented at Olkiluoto with short cooling water passages, which minimises the impact from their construction and from energy consumed for pumping the water. The cooling water passages for the new plant unit can be located close to those of the existing plant units, which will minimise the extent of the area losing its natural state. The new plant unit will not increase the temperature of cooling water going into the sea compared to the present situation. The cooling water passages will be located so as to minimise the recirculation of warm discharge water to the cooling water intake side. The cooling water arrangements will be discussed in more detail during the environmental permit procedure for the new plant unit.

The volume of waste water generated shall be minimised through water use planning and recycling. The waste water processing capacity will also cover the duration of construction of the new plant unit, at which time the volume of waste water will be greater than at the operating stage.

### 3.5. Monitoring programme

An environmental permit pursuant to the Environmental Protection Act will be obtained for the operations of the new power plant unit, and a permit pursuant to the Water Act will be obtained for taking water from the water system to the power plant. Detailed environmental impact monitoring programmes will be prepared on the basis of the permit regulations.

The impact of environmental loads on the water system will be monitored in accordance with a programme approved by the permit authority. The monitoring programme includes temperature measurements, physical and chemical monitoring of water, monitoring of the biological state of water, as well as monitoring of fish populations and fishing conditions. Furthermore, the ice conditions are supervised in the winter and people are warned about weakened ice. The operation of the waste water treatment plant is supervised by monitoring the treatment efficiency.

## 4. OTHER ENVIRONMENTAL EFFECTS

The new power plant will be located within the Olkiluoto power plant site and will utilise the existing infrastructure of the area. In the landscape view, the construction of a new unit will add one new building resembling the existing plant units to the power plant complex.

***Figure 12–3*** *Photomontage of Olkiluoto Island viewed from the sea. OL4 on the left, the OL1 and OL2 units in the middle, and OL3 on the right.*

The environmental impact of the power transmission lines for the new plant unit in the Olkiluoto area is assessed in the attached environmental impact assessment report. Fingrid Oyj will initiate environmental impact assessments concerning power lines supporting the nuclear power plant unit's grid connection during 2008 and 2009, as well as the EIA procedures concerning the plant site power lines and the required reserve power capacity after the decision-in-principle.

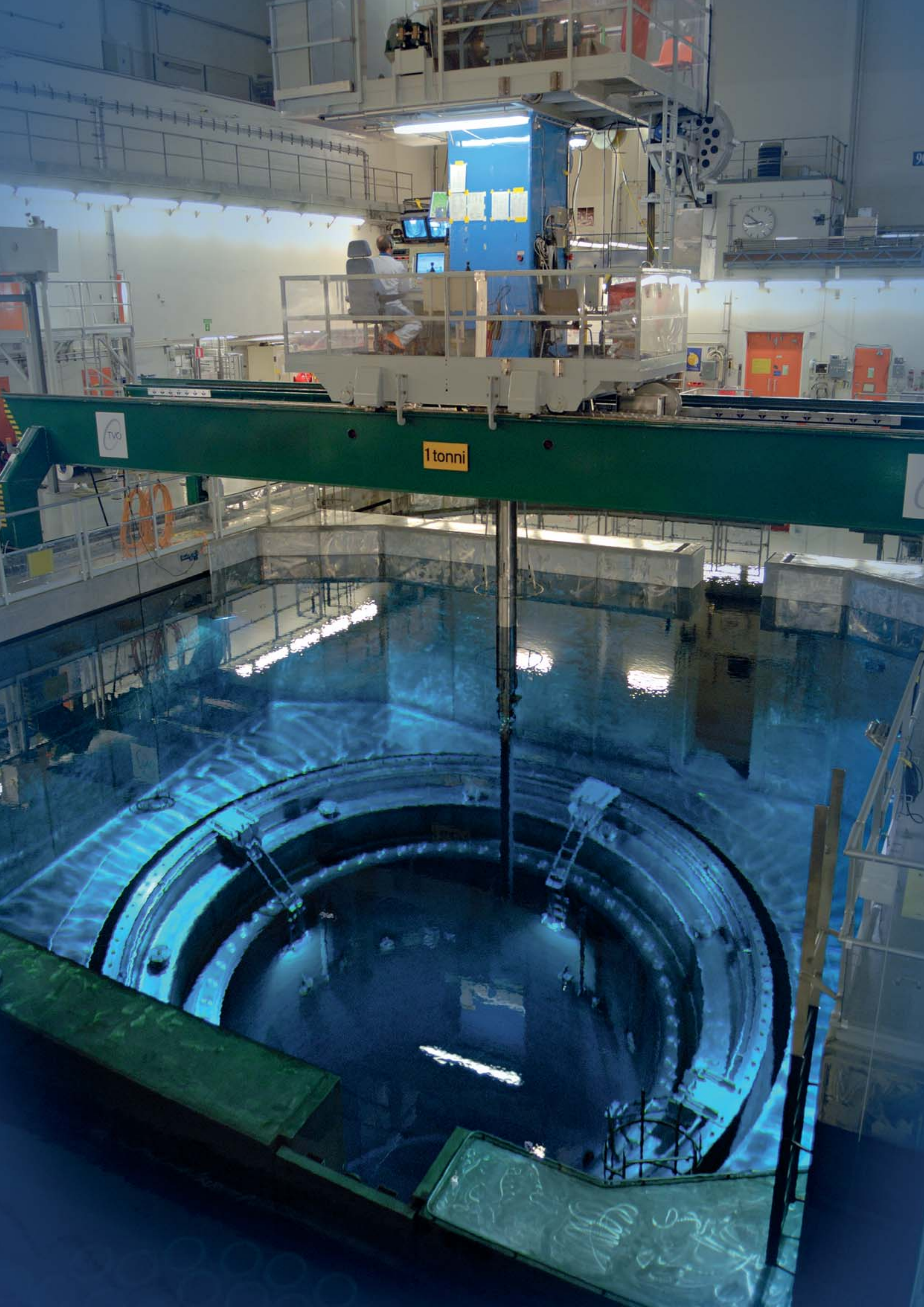
Traffic on the road to the plant site will increase during construction, which will increase the risk of traffic accidents and the nuisance caused by traffic noise along the road. The increase in traffic caused by the operation of the new plant unit is so minor that the impact is also minor.

The combined noise from the new plant unit and existing operations at Olkiluoto will not exceed the directive values set by Council of State for noise in the nearest affected location.

Low and intermediate level operating waste and conventional waste originating from the new plant unit will be processed similarly to the existing plant units. Low and intermediate level operating waste will be placed in a final disposal facility for operating waste located within the area (VLJ Repository). Conventional waste will be sorted and delivered for recovery. Waste that is unsuitable for recovery will be placed in a landfill within the area. When properly handled, waste will not cause any adverse environmental impact.

## 5. CONCLUSIONS

An extensive environmental impact assessment of the nuclear power plant venture has been conducted on the basis of statutory requirements. The environmental impact assessment did not find any adverse environmental impact of such significance arising from the construction or operation of the nuclear power plant unit that it could not be accepted or mitigated to an acceptable level. Due to careful compliance with the isolation principle, releases of radioactivity during the operation of the nuclear power plant are so minor that they do not have any impact on the environment or the surrounding population. The releases in accident situations will also be so minor that their environmental impact will be small and will not prevent normal use of the environment. According to investigations carried out, the cooling water from the new power plant unit is not considered to cause any unreasonable impact on thewater system.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APPENDIX 13

# OUTLINE PLAN ON NUCLEAR FUEL MANAGEMENT

CONTENTS

## 1. GENERAL

This Appendix describes how nuclear fuel management can be arranged for the new plant unit. The management of spent fuel is described in Appendix 14.

The stages of nuclear fuel procurement are the production uranium concentrates, conversion, enrichment and manufacturing into fuel elements or fuel assemblies.

The manufacturing of fuel is usually procured separately for each unit. However, purchases can be made simultaneously for several plant units. Enrichment, conversion and uranium concentrates can also be procured and competitive bidding can be arranged simultaneously.

## 2. REQUIRED AMOUNTS

TVO's existing power plant units OL1 and OL2 each consume approximately 20 tonnes of enriched uranium annually, the production of which requires approximately 130 tonnes of natural uranium in uranium concentrates and approximately 110 tonnes of enrichment work.

The OL3 plant unit under construction will use slightly more than 30 tonnes of enriched uranium annually. The enrichment requires approximately 210 tonnes of natural uranium concentrates and 180 tonnes of enrichment work. The need for uranium concentrates and enrichment work for OL3 in relation to kilowatt-hours produced is approximately 15 per cent lower compared to OL1 and OL2. This is particularly attributable to the better efficiency of the turbine generator but also to the better neutron economy of the new reactor. The need for uranium at OL1 and OL2 has also been reduced quite a lot over the years as a consequence of fuel development.

As the size of the new plant unit will be 1,000 to 1,800 MW, its estimated annual fuel requirement based on OL3's consumption will be in the order of 20 to 32 tonnes of uranium, corresponding to 120 to 220 tonnes of natural uranium in uranium concentrates.

## 3. AVAILABILITY OF URANIUM CONCENTRATES AND SOURCES OF PRODUCTION

The sufficiency of uranium will not impose any obstacle to the production of nuclear fuel over the next 70 to 100 years. The annual global demand for uranium is approximately 70,000 tonnes of natural uranium, also known as uranium concentrates. Identified and inferred uranium resources having a production cost of less than USD 130 per kilogram amounted to some 5 million tonnes in 2005, and additional resources of this category that will probably be found amounted to some 10 million tonnes. At current consumption, the resources will last for 70 years, and with probable resources included, more than 200 years.

The demand will increase to an estimated 100,000 tonnes by 2020 and continue to increase until nuclear fuel is recycled as necessary or other emissions-free sources of energy that are more economical than nuclear power are introduced. There is also the possibility of using uranium that is twice as expensive as the cost limit for existing uranium resources; according to a geological estimate, this would increase the resources approximately tenfold. This does not play a great role with regard to the profitability of nuclear power as it would only increase the production costs by some EUR 2 per MWh.

Experience shows that more uranium resources are being found in accordance with demand. This was also the case in the 1970s when the initial amount of known inexpensive resources was only one million tonnes. After a long quiet period, prospecting has become more active again, and the IAEA has announced that their statistics to be published in 2008 show 17 per cent more resources than two years earlier. A lot more uranium has already been found after the data for the new statistics were compiled. For example, the ore resources of a single large mine, Olympic Dam in Australia (which is a copper mine with uranium as a by-product) have been surveyed through extensive drilling and found to be almost quadruple in comparison to original estimates, including some two million tonnes of uranium.

The sales of stocks and the introduction of diluted weapons-grade uranium into the market caused a long-term drop in the price and prospecting for uranium. The price has been high from 2005 to 2007, and prospecting for uranium has become more active. At present, dozens or hundreds of enterprises are prospecting for uranium all around the world.

The largest known uranium deposits are in Australia, North America, Kazakhstan, Russia, South Africa, Niger and Namibia. The latest discovered deposits of uranium, particularly in Canada and Australia, have been rich, which means that they allow uranium to be produced at a reasonable cost. The following is a description of the development of the industry in Canada, Australia and Kazakhstan, which will produce most of the world's uranium within the next few years.

The first batch of uranium ever procured by TVO was produced at the Beaverlodge mine in Canada, where the ore contained approximately 0.1 per cent of uranium. Beaverlodge was shut down when richer ore bodies were discovered. Next, uranium was procured from Rabbit Lake (concentration 1 per cent) and Key Lake (2 per cent). At the newest mine McArthur River, the concentration in the ore is approximately 20 per cent, which is also the case at the Cigar Lake mine under construction. Several other rich deposits have been discovered recently in Canada in addition to the above. By the year 2005, one-half of all uranium purchased by TVO has been procured from Canadian uranium suppliers.

In Australia, TVO procures uranium from the Olympic Dam copper mine that produces uranium, gold and silver as by-products. The production capacity is almost 4,000 tonnes of uranium annually. The present proprietor BHP Billiton is investigating the feasibility of an expansion, potentially to 700,000 tonnes of copper and 20,000 tonnes of uranium annually.

Kazakhstan's uranium production in 2004 was 3,600 tonnes, with the 2007 estimate being 7,000 tonnes. The announced targets are approximately 18,000 tonnes of uranium in 2015 and as much as 27,000 tonnes in 2025. There are many well-known companies operating in Kazakhstan. In Kazakhstan uranium can be extracted directly from the soil using drilled wells and the so-called in-situ leach process.

New deposits have also been found in Africa, and uranium production is being expanded to some new countries. The production of uranium as a by-product of gold is also being planned, as is the separation of uranium from phosphate fertilisers. There is a programme for expanding uranium production in Russia, and furthermore, spent uranium is reprocessed and recycled into new fuel both in Russia and France.

Substantial amounts of uranium are still kept in stocks. There is a lot of waste uranium of different types, such as old stocks of depleted uranium, and it can be recycled using new enrichment technology.

Deliveries of diluted weapons-grade uranium from Russia to the USA started in 1994 and will continue until 2013, and will cover approximately one-half of the demand of the United States' one hundred reactors during said 20 years. The entire amount is 500 tonnes of weapons-grade uranium. It is obtained from 20,000 nuclear warheads and corresponds to 150,000 tonnes of natural uranium. Russia will still have weapons-grade uranium after this, and the remaining amount is estimated to exceed the 500 tonnes going to the USA. Weapons uranium has also been diluted for civilian use in the USA, and the US Government has announced in late 2007 that the number of US nuclear warheads will be further reduced.

## 4. PROCUREMENT OF URANIUM CONCENTRATES

TVO has purchased the initial core uranium as one batch but otherwise TVO diversifies the deliveries of uranium and other purchases related to fuel procurement to several suppliers for the sake of reliability of supply.

TVO's procurement strategy includes maintaining reserves of uranium concentrates for reliability of supply, and due to market fluctuations in order to avoid purchases at price peaks. The quantities stored are small, and a reserve for several years only ties up a relatively small amount of capital. The intention is to import manufactured fuel to a reserve in Finland several months before it is needed.

## 5. PROCUREMENT OF CONVERSION, ENRICHMENT AND FUEL MANUFACTURING

Three companies operate major refining and conversion facilities in the Western countries. For the time being, TVO purchases conversion from Canadian and French suppliers. Supplementary amounts are purchased from Russia in connection with the enrichment of uranium. These and a major conversion facility in the USA will also remain the most important suppliers of conversion in the near future.

TVO presently purchases enrichment of uranium from AREVA in France and from Techsnabexport in Russia and from the company Urenco that has production facilities in three EU countries. Said companies will be the most probable suppliers of enrichment also in the future. In the future they all enrich uranium using centrifuges. Also in the USA there are plans of closing down an old enrichment facility that is based on gaseous diffusion and consumes a lot of electricity, and replacing it with new centrifuge plants within a few years.

Fuel manufacturing is presently procured from Sweden, Germany and Spain. Depending on the type of power plant, some other country may come into question, usually at least the power plant supplier. In addition to the above countries, the companies have facilities in at least France, Russia, the USA, Japan and Korea.

## 6. TRANSPORTS AND STORAGE OF URANIUM AND FUEL

The transports of nuclear material between the stages of fuel procurement, as well as the transports of manufactured fuel to power plant sites, are carried out as supervised transports on conventional transport equipment. The transport packaging and arrangements are governed by EU regulations and national regulations in different countries, the starting point being the recommendations of the International Atomic Energy Agency (IAEA). The amounts being transported are small, and transports represent a small proportion of fuel costs.

The fuel is brought to Finland by sea and further from the harbour to the power plant by lorry. Ground transport from neighbouring countries can also be used. The typical need for transports is five or six full trailer combination loads per year for each reactor.

The import of fuel is subject to licences and approvals by the Radiation and Nuclear Safety Authority pertaining to import, transport routes, equipment and packaging, as well as transport arrangements with emergency preparedness and security plans. The transports fall within the scope of nuclear liability insurance. The following provides a more detailed description of transports between the stages of procurement.

Uranium is transported to the conversion plant as uranium concentrate in 200-litre industrial steel drums that are further packed into containers for ground and sea transport. Each drum contains approximately 400 kg of uranium, and one container is typically loaded with 44 drums. Uranium concentrates are also stored in these 200-litre drums.

In the conversion plant, the uranium ore concentrate will be purified and converted into “natural uranium” i.e into uranium hexafluoride, a salt, which becomes gaseous under reduced pressure when heated. Therefore, the uranium hexafluoride salt is packaged in special pressureproof transport containers. The natural uranium is transported to the enrichment facility in containers with volume of about 8 tonnes of uranium, and enriched uranium is further taken to the fuel manufacturing plant in containers containing approximately 1.5 tonnes of uranium. For transport, the enriched uranium container is packed into a protective packaging, dimensioned to protect the container in case of traffic accident or fire, for example.

Enriched uranium is transported to the manufacturing plants by road, sea and rail. At the plant, the uranium is converted to uranium oxide and further to fuel pellets that are encapsulated into fuel rods. The finished fuel assemblies or fuel elements are transported by sea, for example, to the Port of Rauma, and further transported by lorry to Olkiluoto. Fuel transports typically take place once a year, usually 5 to 6 lorry loads per plant unit. The initial core load requires some more transports.

Radiation from fresh uranium and nuclear fuel is minor. The design bases for packaging include prevention of the most significant hazard of transport, criticality in unexpected situations. In practice, the primary risk associated with the transports is a conventional traffic accident.

Fuel is stored at the power plant primarily in the dry storage of the plant unit. The dry storage facilities are included in the scope of normal safety and security supervision.

## 7. FUEL COSTS

The cost of natural uranium including conversion has typically been from EUR 1 to 3 per MWh, and the forecast is in the order of EUR 2 per MWh depending on demand and supply.

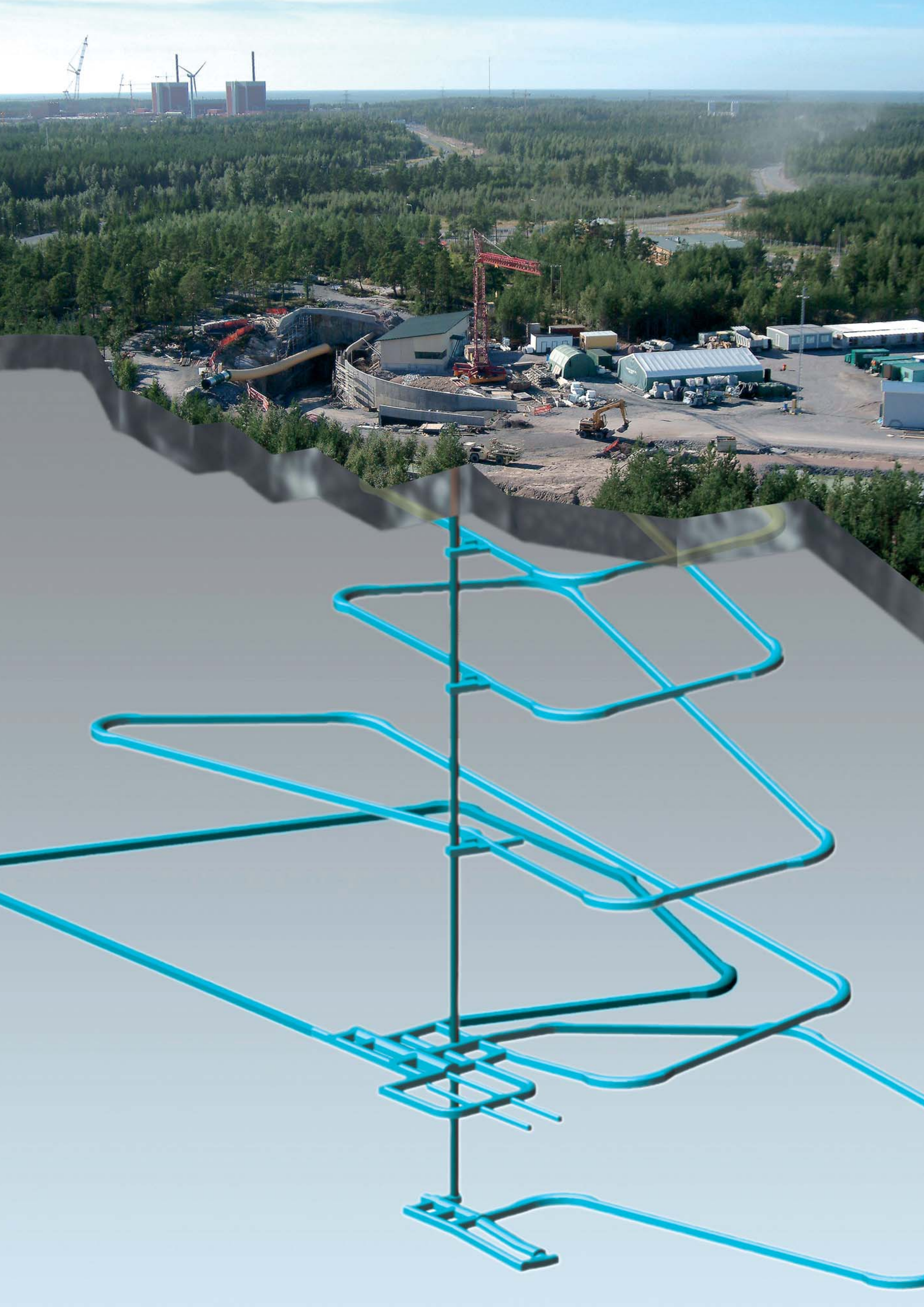
The costs of nuclear fuel manufacturing and enrichment have been relatively stable. The costs of nuclear fuel manufacturing have been slightly less than EUR 1 per MWh, while the cost of enrichment has been somewhat more than EUR 1 per MWh. The fuel costs for the annual reload of the new power plant will be approximately EUR 4 per MWh on average (EUR 3 to 5 per MWh).

The trend has been that new types of fuel produce more power per kilogram of uranium used, the real prices for conversion, enrichment and manufacturing have slightly declined due to technology development, and no increase in the real price of uranium concentrates can be seen when observed over several decades. The development of technology has reduced the costs of metal mining.

However, the price of uranium concentrates has fluctuated a lot similarly to the prices of many other metals produced in small quantities. The price dived in the 1990s when large amounts of stock uranium and diluted weapons-grade uranium was offered for sale. The price drop resulted in a closedown of a substantial share of the most expensive mining production. The price subsequently multiplied quickly from 2004 to 2007. The peak price in 2007 was in real terms equal to the price after the oil crisis from 1976 to 1979. However, after the peak price in 2007, the price fell by several dozen per cent within the same year.

The price peak was due to new speculants in the market, which had already become more tense as production and stocks had decreased but the increased demand for uranium was a reality. A sufficiently high price will ensure that there will eventually be sufficient production. Overproduction and competition between sellers in the market will then limit the price so that a connection with the costs of the most expensive production required will become apparent and the most expensive production will be closed down.

TVO has avoided the impact of great fluctuations in the price of uranium concentrates by maintaining long-term contracts diversified across several suppliers, and through a long-term storage policy. When prices have been low, reserves have been increased to cover the need for several years.



# OUTLINE OF THE APPLICANT'S PLANS AND THE AVAILABLE METHODS FOR NUCLEAR WASTE MANAGEMENT

CONTENTS

## 1. GENERAL

The operation of a nuclear power plant produces nuclear waste. In proportion to the amount of energy produced, the amount of waste and the associated space requirements are small. The management of different types of nuclear waste calls for different technologies and schedules. A part of waste management is appropriate or possible to implement only after the operating stage of the power plant.

The principle of nuclear waste management is to isolate the waste from the living environment. In addition, the final disposal of nuclear waste will be designed in a way that does not call for supervision to ensure long-term safety.

The licensee of a nuclear power plant is responsible for the implementation and costs of nuclear waste management. TVO's existing and planned nuclear waste management arrangements or similar are also appropriate for managing the nuclear waste from the new power plant unit. The company's existing and planned arrangements are appropriate for managing all nuclear waste from the existing and future plant units.

## 2. REGULATIONS AND SUPERVISION RELATED TO NUCLEAR WASTE MANAGEMENT

The central principles for arranging nuclear waste management in Finland are defined in the Nuclear Energy Act, Nuclear Energy Decree, the Government's decision-in-principle regarding the objectives for research, surveying and planning of nuclear waste management on 10 November 1983, the decisions by the Ministry of Trade and Industry on 19 March 1991 (7/815/91 MTI) and 26 September 1995 (11/815/95 MTI) on the principles to be observed in nuclear waste management for nuclear power plants, as well as the operating licences for the existing nuclear power plants. In addition, there is the MTI decision on 23 October 2003 9/815/2003, which postponed the schedule of a construction licence application from 2010 to 2012. According to these, the producer of nuclear waste shall bear the responsibility for nuclear waste management measures and their costs. According to the Nuclear Energy Act, the producer of waste is obliged to prepare for the future costs of nuclear waste management by making annual payments to the Finnish State Nuclear Waste Management Fund to the amount confirmed by the Ministry of Employment and the Economy and by depositing a security covering the difference between the total costs and the deposited funds. This ensures that nuclear power operators will pay the costs of nuclear waste management measures that are not current yet.

The above decisions by the Ministry of Trade and Industry present the principles, design criteria and schedules for the management of spent nuclear fuel, operating waste and decommissioning waste from nuclear power plants.

In accordance with the Nuclear Energy Act, the Ministry of Employment and the Economy is responsible for the highest management and supervision of nuclear waste management as well. The safety of nuclear waste management is supervised by the Radiation and Nuclear Safety Authority, which thoroughly reviews all nuclear waste management plans in advance and supervises their implementation.

The safety requirements applicable to the final disposal of nuclear waste are specified in the Government Decisions (GD), which include GD 398/91 on the general regulations for the safety of a final disposal facility for reactor waste and GD 478/99 on the safety of the final disposal of spent nuclear fuel. These GDs will eventually be replaced with a Government Decree currently at the draft stage.

## 3. TYPES OF NUCLEAR WASTE AND MANAGEMENT METHODS

Nuclear waste originating in nuclear power plants includes:
– spent nuclear fuel
– low and intermediate-level operating waste
– decommissioning waste

### 3.1. Spent nuclear fuel

After removal from the reactor, spent nuclear fuel is stored in water pools at the power plant for 3 to 10 years. The water cools the nuclear fuel and provides protection against the radiation emitted by it. Storage will continue in an interim storage facility for spent fuel which exists at Olkiluoto in Eurajoki. The existing interim storage facility can be expanded if required, or a new facility can be built for the needs of the new nuclear power plant unit. An expansion to the existing interim storage facility for spent fuel is planned to start in the early 2010s. The expansion will be implemented as to allow further additional expansion.

The activity of the nuclear fuel and the heat generated in it decrease during storage. After 20 years in interim storage, for example, the remaining activity of the nuclear fuel is to the order of a few thousandths of the initial value when removed from the reactor.

After the storage phase, the spent nuclear fuel could be reprocessed, and the remaining task would be the disposal of reprocessing waste, or it can be disposed of without reprocessing. However, the Nuclear Energy Act requires that all nuclear waste must be processed and finally disposed of in Finland. Because there are no reprocessing plants in operation or under planning in Finland, the starting point for this application is the final disposal of nuclear fuel without reprocessing.

Jointly with the company then known as Imatran Voima Oy, TVO established a separate company, Posiva Oy, for the final disposal of spent nuclear fuel. Its task is to develop the technology required for the final disposal of spent nuclear fuel from the Olkiluoto and Loviisa nuclear power plants, to carry out the safety and site surveys required for the implementation of disposal and to eventually take charge of the practical implementation of final disposal of spent nuclear fuel from its owners' nuclear power plant units existing in Finland and potentially constructed in Finland. Posiva has carried out a statutory environmental impact assessment of the disposal facility concerning 9,000 tonnes of spent nuclear fuel, and will file a separate application for a decision-in-principle concerning the final disposal of spent nuclear fuel from Olkiluoto 4.

Parliament ratified the Government's decision-in-principle concerning final disposal of spent nuclear fuel from the OL1, OL2, LO1 and LO2 plant units in accordance with the Nuclear Energy Act in 2001, followed by the decision-in-principle concerning final disposal of spent nuclear fuel from OL3 in 2002. The final disposal of spent nuclear fuel from OL4 will require a new decision-in-principle.

For the purpose of final disposal, spent nuclear fuel is packaged (encapsulated) in tight metal containers, which are placed deep into the Finnish bedrock to a depth of approximately 400 metres. The final disposal facility comprises an encapsulation plant on the ground and the final disposal facilities below it in the bedrock (Figure 14–1).

The safety of final disposal is based on the so-called multiple barriers principle, according to which spent fuel shall be isolated from the living environment inside several barriers that are as independent of each other as possible, so that any deficiencies or faults in one barrier do not essentially hamper the isolation ability of the entire system. The barriers include the actual fuel matrix, the fuel cladding, the container (canister) for fuel assemblies, the bentonite clay surrounding the container, and the bedrock.

The location of the final disposal facility is Olkiluoto in Eurajoki. The construction of a research facility (ONKALO) is currently underway at the site for the purpose of conducting research that will finally confirm the suitability of the location for final disposal, Figure 14–2.

***Figure 14–1*** *Posiva's plan for a spent nuclear fuel encapsulation plant and final repository.*

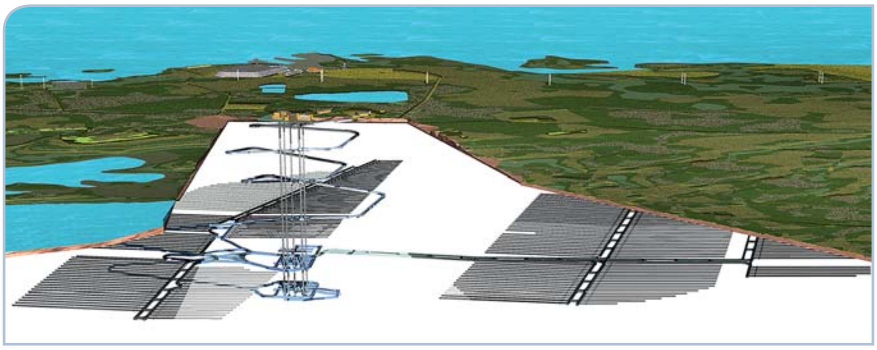


*__Figure 14–2__ Entrance of the tunnel leading to the spent fuel final disposal research facility (ONKALO) at Olkiluoto. The research facility will eventually constitute a part of the spent fuel final repository.*

Spent nuclear fuel will be transported within the Olkiluoto power plant area from the reactor buildings to interim storage and from interim storage further to the final disposal facility. All transports of fuel at Olkiluoto take place within the closed plant area, and fuel does not need to be transported on public roads.

Posiva has prepared safety analyses for the transport of spent nuclear fuel, the operation of the disposal facility and the long-term isolation ability of the final disposal solution. According to these, the total radiation burden imposed by final disposal on people and the living environment is negligible. The disposal solution complies with the safety requirements stated in the Government Decision 478/99 in terms of both operating safety and long-term safety.

The final disposal of spent nuclear fuel from the new nuclear power plant unit is planned along the same principles applicable to the existing plant units and OL3 under construction. The starting point for Posiva's plans is that spent nuclear fuel from the new plant unit will be finally disposed of in the same final disposal facility with spent nuclear fuel from the existing units. The environmental impact assessment procedure carried out by Posiva covers the amount of fuel estimated to be generated during the operation of six plant units. According to a statement by the Ministry of Trade and Industry, the final disposal of spent fuel from a sixth nuclear power plant unit is subject to a separate decision-in-principle, and the application must be accompanied with an up-to-date description of the environmental impact of the final disposal facility.

### 3.2. Operating waste

Operating waste refers to low and intermediate-level radioactive waste arising from the operation of a nuclear power plant, such as ion exchange resins used for cleaning process waters, radioactive wastewater and diverse dry waste from maintenance operations. The starting point for management operating wastes is that all waste shall be processed, stored and finally disposed of in Finland, and that the producer of waste shall be responsible for all costs of waste processing, storage and final disposal.

Most operating waste at Olkiluoto is immediately packed for processing, storage and disposal. The intermediate-level ion exchange resins used for cleaning process water are solidified into bitumen and the mixture is cast into steel drums. Some of the low-level waste (compressible diverse maintenance waste) is compressed into steel drums using a hydraulic press, while others (scrap metal and filter rods) are packed into steel and concrete boxes and steel drums as such. Drums containing compressible waste are also compressed so that the final height is approximately one-half of the original and the diameter is unchanged. Scrap metal can also be compressed before packing. Diverse liquid wastes and sludges are solidified by mixing the waste with a binding agent in a drum that becomes the packaging for the solidifying product.

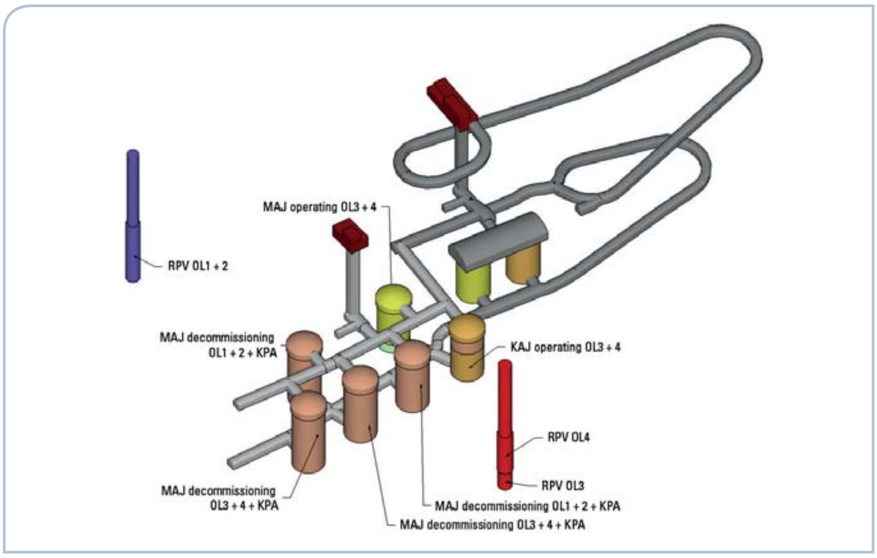
Locations for all operating waste are existing or planned within the Olkiluoto power plant site. A final disposal facility for operating waste (VLJ repository) was introduced into use at Olkiluoto in 1992. The facility is used for the final disposal of operating waste accumulated during the operation of the power plant. Very low-level waste is released from supervision and taken to a landfill or handed over to a third party for processing and recycling, for example.

The management and final disposal of operating waste from the new plant unit can be implemented on the same principles. More room for final disposal will be excavated near the existing facilities in the same manner as planned for the decommissioning waste. A principal diagram of the facilities required for operating and decommissioning waste from the four nuclear power plant units at Olkiluoto is presented in Figure 14–3.

### 3.3. Decommissioning waste

When a nuclear power plant is decommissioned, radioactive materials remain in the structures, systems and equipment as a consequence of either contamination or activation. When the power plant is no longer used, it can be brought to a safe storage state (safe enclosure) or dismantling can be started immediately. Safe enclosure would last for a few decades, after which the radioactive parts would be dismantled and disposed of. Safe enclosure facilitates dismantling work and reduces the amount of waste to be disposed of as the activity decreases. If necessary, the active parts of the nuclear power plant can be dismantled after a shorter storage period, such as one year.

***Figure 14–3** Final disposal facility for operating waste and a future final disposal facility for decommissioning waste at Olkiluoto in Eurajoki. The control building, the shaft leading down from it, the access tunnel and the two silos on the right are all parts of the existing VLJ repository. The two silos in the centre of the picture will be added during the operational life of OL3 and OL4. When plant units are decommissioned, the final disposal facility for operating waste will be further expanded by building four new silos for decommissioning waste (on the left), a process building, a shaft down from the process building, an access tunnel and two separate vertical shafts for the final disposal of reactor pressure vessels.*




The existing Finnish power plant units can be dismantled using current technology and the decommissioning waste can be safely finally disposed of in the bedrock at the plant site together with operating waste. A significant part of the decommissioning work is similar to the annual maintenance outages in terms of measures and radiation protection. The decommissioning plans are developed continuously and updated at five-year intervals. The most recently updated plans were submitted to the authorities in late 2003.

The new nuclear power plant unit will be decommissioned in accordance with the same principles approved by the authorities that have been used in the decommissioning plans for the existing plant units. The final disposal facilities constructed for operating waste at the power plant site will be extended to allow for the final disposal of decommissioning waste from the new nuclear power plant unit. The safety of the final disposal of decommissioning waste has been reviewed using safety analyses similar to those associated with the safety of the final disposal of spent nuclear fuel and operating waste.

## 4. COSTS OF NUCLEAR WASTE MANAGEMENT

Preparations are made for the costs of nuclear waste management in accordance with the Nuclear Energy Act, also with regard to the new nuclear power plant venture. The principles are the same as those applicable to the existing power plant units.

The nuclear waste management fees paid by TVO are based on annual assessments of the amount of liability, which are presented to the Ministry of Employment and the Economy for approval. The calculations are based on the updated waste management plans of the company and the amounts of waste produced.

The amount of liability covers future expenses caused by the management of nuclear waste from the nuclear power plant. The costs of spent nuclear fuel management include the costs of transports, interim storage, encapsulation and final disposal. The amount of liability also covers the costs of final disposal of operating waste, decommissioning of the power plant and final disposal of the decommissioning waste.

Preparation for the costs of nuclear waste management in accordance with the Nuclear Energy Act is based on the current amount of nuclear waste and the costs of all future actions. The Nuclear Energy Act does not allow the discounting of future costs; these must be calculated and funded in full, corresponding to the real current value. The deposits of funds can be allocated to specified years. The non-funded part must be covered with securities.

For example, the total costs of nuclear waste management for the three plant units at Olkiluoto (including past and future costs) are EUR 3.8 billion (60 years of operation). As the corresponding total amount of electric power produced by the plant is estimated to be 1,500 TWh, the average cost burden due to nuclear waste management on the price of nuclear electricity is 0.25 cents/kWh.

The construction of the new nuclear power plant unit will increase the amount of nuclear waste, which will increase the total costs but reduce the unit costs. The nuclear waste management technology and required measures will be the same as those applicable to the existing plant units.

TVO is the most significant financier of the national nuclear waste management research programme. The programme is financed with a statutory fee levied on parties obliged to answer for waste management, and its purpose is to ensure that the authorities will have the required expertise if new issues arise. TVO's annual payments to the program are approximately EUR 700,000.

## 5. CONCLUSIONS

The applicant has access to safe methods, the required locations for final disposal facilities and funding for arranging all the nuclear waste management for the new nuclear power plant unit. The planned arrangements correspond to the principles and plans currently applicable at Finnish nuclear power plants. Nuclear waste management for the new nuclear power plant unit can be implemented using existing technology.

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Eura Print Oy 2008 2,000

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