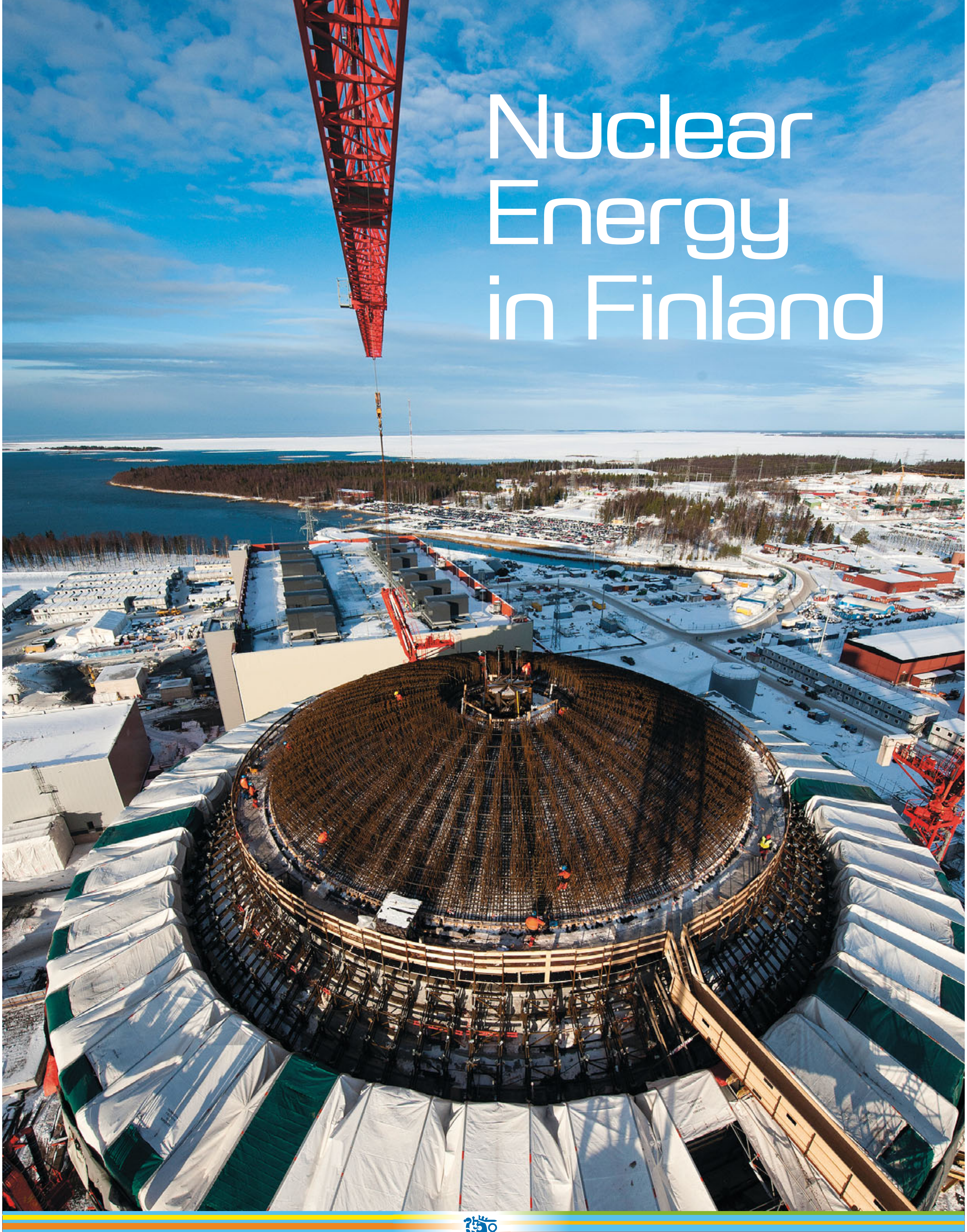
Nuclear Energy in Finland



TYÖ- JA ELINKEINOMINISTERIÖ
ARBETS- OCH NÄRINGSMINISTERIET
MINISTRY OF EMPLOYMENT AND THE ECONOMY

Profile of Finland

Independent republic since 1917

Member State of the European Union since 1995

Capital: Helsinki

Neighbouring countries: Estonia, Norway, Russia and Sweden

Area: 338,000 km²

Population: 5.4 million

Population density: 15.9 persons per km²

Monetary unit: euro (EUR)

GDP *per capita (2010):* EUR 33,600

Total primary energy consumption (2010): 34.5 Mtoe

Energy consumption per capita (2010): 6.5 toe

Total electricity consumption (2010): 87.5 TWh

Electricity consumption per capita (2010): 16,500 kWh

Share of nuclear energy in Finland (2010):

25.0 per cent of total electricity consumption

28.4 per cent of domestic electricity production

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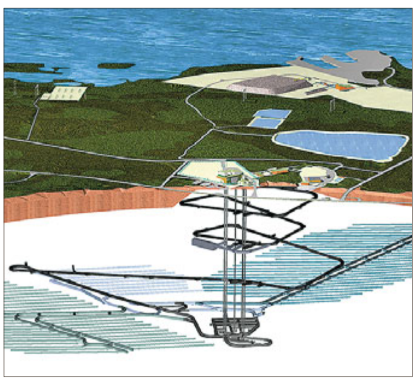


WASTE MANAGEMENT:

- Repositories for LLW & MLW in operation at Olkiluoto and Loviisa
- Initial Decision in principle for spent fuel repository at Olkiluoto ratified by Parliament in 2001
- Confirming underground rock characterisation studies underway in ONKALO facility at Olkiluoto

OLKILUOTO, EURAJOKI

Owner: Teollisuuden Voima Oyj
Reactor units 1&2: BWR 2 x 880 MWe (net)
Operation started: 1979, 1982
Production: 14.2 TWh (2010)
Load factor: 93.5 per cent (2010)

Under construction
Olkiluoto 3: EPR (PWR) 1600 MWe

Planned: Olkiluoto 4

SIMO OR PYHÄJOKI

Owner: Fennovoima Oy
Planned: Fennovoima 1
Site Alternatives: Simo and Pyhäjoki

HÄSTHOLMEN, LOVIISA

Owner: Fortum
Reactor units 1&2: PWR 2 x 488 MWe
Operation started: 1977, 1981
Production: 7.7 TWh (2010)
Load factor: 91.1 per cent (2010)

To the reader

Nuclear energy has played a major role in Finnish electricity production since the beginning of the 1980s. In 2010, the proportion of nuclear electricity totalled 25 per cent of total electricity consumption and 28.4 per cent of domestic production. Finland can be proud of the high load factors of its nuclear power plants, the low price of its nuclear electricity and its low levels of radioactive emissions. Largely owing to nuclear electricity, Finland can also take pride in its low level of carbon dioxide emissions in total electricity generation.

The construction licence for building Finland's fifth reactor, Olkiluoto 3, was granted by the Government in early 2005, subsequent to a Decision in Principle ratified by Parliament in 2002. In 2010, two additional Decisions in Principle for two new reactor units were approved by Parliament. These decisions to expand the Finnish nuclear power programme have markedly increased the attractiveness of working in the nuclear energy sector as a career. Efforts devoted to postgraduate training have been strongly intensified and are being conducted through close cooperation between key organisations in Finland. Increased nuclear power production is expected to play an important role in meeting greenhouse gas emission targets.

In addition, nuclear waste management and the disposal of spent fuel are progressing according to long-term plans. A site for the spent fuel disposal facility has been approved by a Government Decision in Principle, which was ratified by Parliament in 2001. According to current plans, the construction licence application for the spent fuel encapsulation and disposal facility will be submitted to the Ministry of Employment and the Economy by the end of 2012. Furthermore, financial arrangements for nuclear waste management and decommissioning are clearly defined in legislation.

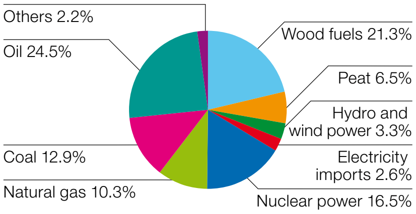
Amendments to Finland's nuclear energy legislation have taken place, among others in order to meet the general requirements defined under constitutional law. In addition, a major renewal process is underway for the system of detailed regulatory guides by the regulatory authority.

For Finland, the deregulation of the electricity market has meant increasing trade and cooperation, both with other Nordic countries and other EU member states. Open markets also mean more cooperation at the political level. International decision-making, cooperation and agreements, as well as the political climate, will play an increasingly important role in the future of nuclear power worldwide.

Based on the initiative of the Ministry of Employment and the Economy shortly after the Fukushima reactor accident, the Radiation and Nuclear Safety Authority STUK requested Finnish nuclear utilities to present their perspectives on possible required measures and safety improvements. Based on the responses and its own initial assessment, STUK has prepared a report on how Finnish nuclear power plants are prepared for the impacts that floods and other extreme natural phenomena may have on the functioning of the facilities. The ongoing assessments cover both national and joint efforts within the European Union. The next step will be to consider improvements in power plant safety and safety regulations in more detail.

The purpose of this booklet is to provide an up-to-date overview of the use of nuclear energy in Finland as well as future plans regarding the nuclear energy sector. It is intended for people working in the nuclear energy or other energy sectors in other countries, as well as for those international audiences and decision-makers who would like to have extra information on this particular energy sector. Nuclear energy is described as part of the Finnish electricity market.

Helsinki, September 2011
MINISTRY OF EMPLOYMENT AND THE ECONOMY
ENERGY DEPARTMENT



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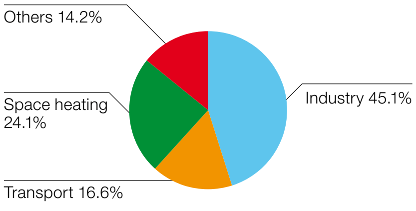

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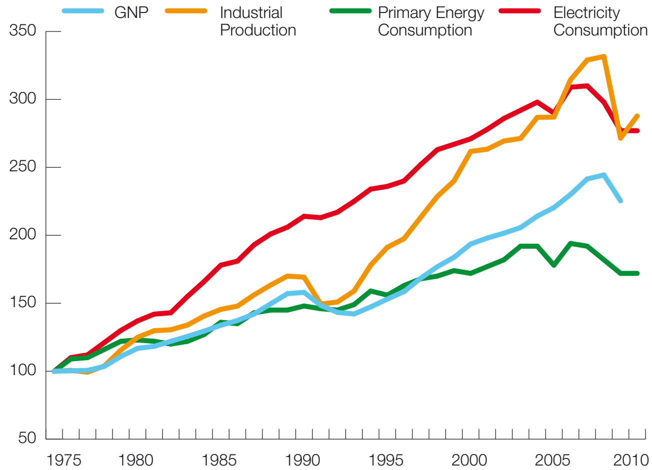
01 Primary energy sources in Finland in 2010, 34.5 Mtoe (1445 PJ) in total. [Statistics Finland]

02 Final energy consumption by sector in Finland in 2010, 1130 PJ in total. [Statistics Finland]

03 Normalised primary energy consumption, electricity consumption, industrial production and gross national product 1975–2010 (1975 = 100).



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Energy consumption and production in Finland

Energy production and consumption are among the basic functions of society. For industry, energy is an important production factor, especially with respect to many Finnish export products. Since energy consumption per capita in Finland is high and the proportion of indigenous energy sources is low, energy, its price and its efficient use are more significant than in most other countries.

In 2010, primary energy consumption in Finland totalled 34.5 Mtoe (million tonnes of oil equivalent). The calculated annual energy consumption per person, 6.5 tonnes of oil, is one of the highest in Western countries. Finland's high energy consumption is attributable to the energy-intensive structure of its industry, its high standard of living, cold climate and long distances between population centres.

Energy consumption

In 2010, industry accounted for 45.1 per cent of all final energy consumed in Finland, space heating for 24.1 per cent and transport for 16.6 per cent. The remaining 14.2 per cent of final energy use is divided between public and private services, agriculture and households. The Finnish manufacturing industry's heavy consumption of energy is due to its production structure. The forest industry alone accounted for roughly 54 per cent in 2010 and the metal and chemical industries together for about one third of all industrial energy consumption.

The share of electricity of all energy consumed in Finland is exceptionally high and electricity generation and its share of primary energy consumption have been increasing. Moreover, the high efficiency of electricity generation is mainly based on the high proportion (35.2 per cent in 2009) of combined heat and power production in all domestic power production.

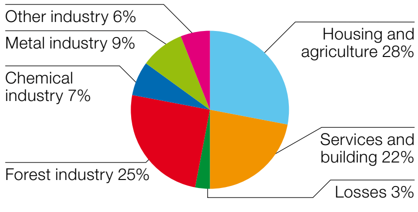
Energy supply

Finland is highly dependent on imported energy, which in 2010 accounted for two thirds of all primary energy consumption in Finland. Although its share has long been in decline, oil has maintained its position as the most important fuel. In 1973, oil accounted for as much as 58 per cent of all energy consumption, whereas in 2010 its proportion was only 24.5 per cent.

In the early 1980s, the share of coal in electricity generation fell sharply, when new nuclear power plant units replaced production by coal-fired power plants. In 2010, coal and coke accounted for 12.9 per cent of all Finnish primary energy consumption. Imports of natural gas from Russia (then the Soviet Union) began in 1974. In 2010, natural gas represented 10.3 per cent of Finland's energy consumption and the share of nuclear power of all energy consumption was 16.5 per cent. Net electricity imports comprised 2.6 per cent of primary energy consumption.

The proportion of indigenous energy sources was about one third of total energy production in 2010. This has fundamentally influenced energy policy in Finland and will continue to do so in the future. The principal indigenous energy sources are wood, waste liquor from the forest industry, peat and hydropower. The share of wood fuels of all energy consumption totalled 21.3 per cent in 2010.

With respect to renewable energy sources in Finland, investments are being made in the further use of bioenergy in particular, but efforts are also being made to increase the proportion of wind power and other renewable energy sources. The majority of Finnish hydropower resources have already been utilised. Most of the remaining unharnessed, economically exploitable rivers are protected by law. Small-scale hydropower production can be increased, and some old hydropower plants can be modernised and their capacity extended.



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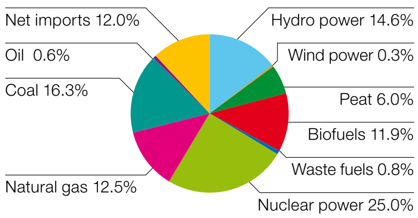

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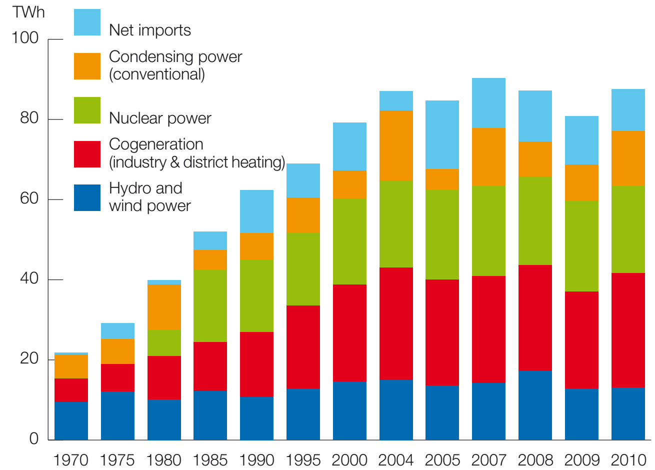
04 Electricity consumption in 2010, 87.5 TWh in total. [Finnish Energy Industries]

05 Electricity supply in 2010, 87.5 TWh in total. [Finnish Energy Industries]

06 Supply of electricity by energy source 1970–2010 [Statistics Finland & Finnish Energy Industries]



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Open electricity market

Almost all of the activities of a modern society are based on a secure supply of electricity. Finland's highly functional and economical electricity supply has played a key role in making the country one of the world's wealthiest nations. The modern information-based society, the so-called New Economy, is more dependent on electricity than ever before.

The Finnish electricity generation and distribution system is economical and efficient. Correspondingly, the price of electricity is relatively low, despite the fact that electricity generation is mainly based on imported fuels. The deregulation of the electricity market in Finland in the late 1990s further enhanced the functioning of the markets and lowered the price of electricity for all consumer groups.

On the other hand, increased competition and the uncertainty of the direction of EU climate policy have made it more challenging for power companies to make investment decisions. These factors have also increased concerns, particularly among large scale electricity consumers, regarding future power supply and electricity prices.

In fact, the EU energy and climate policies set the framework for national energy policy. In particular, the so-called 20/20/20 strategy includes binding targets for both greenhouse gas emissions and renewable energy sources (in Finland 38 per cent of final energy consumption by 2020). Electricity and gas internal markets are also increasingly regulated by the EU, as will be energy efficiency issues.

Electricity consumption

The 1980s were a period of growth in Finland, and electricity consumption increased by a total of over 50 per cent. This growth decelerated during the recession of the early 1990s, but electricity consumption increased again by around 27 per cent in the 1990s as a whole. In 2010, consumption totalled 87.5 TWh (billion kWh), around 16,500 kWh per capita.

Industry's share of total electricity consumption in Finland is exceptionally high, at around 47 per cent of all consumption. Households and agriculture consume about a quarter, and services and the public sector less than one-fifth of all electricity. Transmission and distribution losses account for a few per cent. About 665,000 dwellings were heated by electricity at the end of 2007. For new dwellings, two-thirds of families building a new single-family house plan to use electricity as their form of heating based either on direct heating or on the application of heat pumps.

Electricity generation

Total simultaneously available electricity generation capacity (net) in Finland was around 13,300 MW at the beginning of 2011. There are around 400 power plants in total, half of which are hydropower plants. Around 120 companies are involved in electricity distribution.

In the early 1960s, Finland's electricity generation was still mainly based on hydropower. Most of the potential cost-effective hydropower has already been harnessed, and over the last couple of decades the share of hydropower in electricity generation has fallen from two-thirds to less than one-sixth. In 2010, nuclear power plants generated 25 per cent and bio-fuelled plants about 12 per cent of Finland's electricity demand. Net imports accounted for 12 per cent.

Finland is one of the leading countries in combined heat and power production. This technique is applied extensively in energy-intensive industries and district heating plants. Electricity produced through combined heat and power production meets about one-third of Finland's total power demand.

The Electricity Market Act

The Electricity Market Act, which came into force in 1995, has set great challenges for the Finnish electricity market. Since the beginning of 1997, the markets have been deregulated for

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all consumers, and the three million-plus electricity consumers in Finland are now able to purchase their electricity from any supplier they choose.

Deregulation of the electricity market has resulted in considerable changes in companies in the sector and in their ownership structures. In order to rationalise their operations, companies have, for example, established joint ventures for both electricity supply and sales.

The Finnish Power Exchange (EL-EX) for buying and selling electricity started operations in August 1996. The Nordic Power Exchange, Nord Pool, is a marketplace for trading electric power in the Nordic countries. Established in 1993, Nord Pool is the world's first multinational commodity exchange for electric power.

Demand for new generating capacity

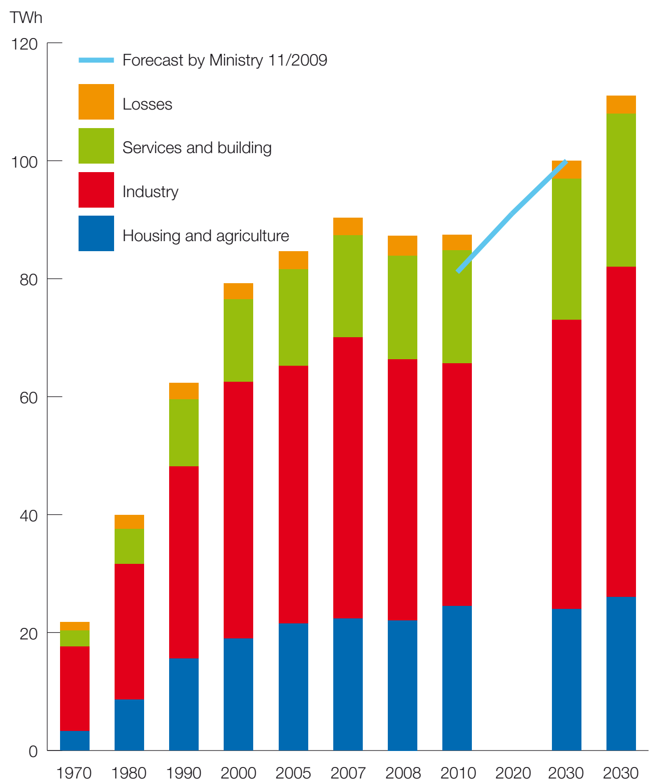
The Government has drafted a new national Climate and Energy Strategy, which was presented to Parliament in November 2008. This new strategy includes intensified energy efficiency measures as well as strong promotion of renewable energy sources. These measures will affect all elements of the future of Finnish energy system.

Developments within the Nordic electricity market indicate that the possibility of importing electricity from the other Nordic countries will decline significantly. Although the new 800 MW/500 kV direct current electricity transmission connection between Finland and Sweden (Fenno-Skan 2) is expected to begin commercial operation by the end of 2011, a considerable amount of new electricity production capacity will be required to meet increased demand for power and compensate for the retirement of older plants.

An increase in the production of combined heat and power production would cover part of the increased demand, but separate electricity generation is also needed in order to meet the demand for electricity. Capacity can only be increased significantly through nuclear power, biofuels and natural gas. Finland's relatively weak wind conditions limit the share of wind power compared with many other countries.

07 Olkiluoto 3 construction site in May 2011. Source: TVO/Hannu Huovila.

08 Electricity consumption between 1970 and 2010 and projected electricity demand up to 2030 estimated by the industry [Confederation of Finnish Industries and Finnish Energy Industries, 2009] and by the Ministry of Employment and the Economy in November 2009.



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09 Loviisa power plant on the island of Hästholmen in Loviisa. Source: Fortum.

Nuclear energy in electricity production

Finnish nuclear power plants meet the constant need for base-load power. The decision to include nuclear power in the Finnish energy system was made in the late 1960s, and the construction of the current nuclear power plants was agreed at the turn of the 1960s and 1970s. The first unit became operational in 1977, and all four units had been taken into commercial use by the early 1980s. As a result of good operating experiences and safety improvements, a power uprating for all four units was carried out in the 1990s.

Steadily improving performance figures have been achieved, and since the mid-1980s the Finnish nuclear power plants' annual and cumulative load factors have been among the best in the world. The most important elements affecting the availability of a nuclear power plant are the duration of annual refuelling outages and undisturbed operation. Therefore, special attention is paid to the planning and technical implementation of annual refuelling outages and the reliability of plant systems.

Almost without exception, the average annual load factor has been over 90 per cent since 1983. The operation of the Finnish reactors has been safe and undisturbed. Furthermore, their commercial profitability has been boosted further by extensive modernisations, including the considerable upratings, carried out on all units in the late 1990s.

Loviisa Nuclear Power Plant

Finland's first nuclear power plant is located on the island of Hästholmen, about 10 km from the centre of Loviisa and around 100 km east of Helsinki. The plant is owned by Fortum Power and Heat Oy. The Loviisa nuclear power plant comprises two Russian design pressurised water reactors of the VVER-440 type, both with a net electrical capacity of 488 MW after an uprating of some 9 per cent, which was carried out between 1996 and 1998.

Loviisa's main components, such as the reactor pressure vessel, steam generators, main piping and turbogenerators, are part of the original Russian delivery. The western safety philosophy was applied to the implementation of the plant from the very beginning. Both units at Loviisa are equipped with Western safety automation systems that have been extended from the original ones and with a containment building that restricts emissions.

As a result of operating experiences, research results and lessons learnt from reactor incidents and accidents that have taken place elsewhere, the safety of the plant has been improved by modifying, for example, the safety systems, automation systems, fire safety arrangements and plant instructions. In Finland, nuclear power plants must also be prepared for the unlikely event of a core meltdown accident. On the basis of research carried out on such accidents, safety systems restricting releases into the environment have been added to the Loviisa plant, including a spray system outside the steel containment for the removal of heat from the containment in the event of a severe accident. Some of the safety modifications designed for the Loviisa plant have also been reproduced and implemented at other VVER plants.

Expertise in nuclear safety accumulated in support of the operation and modernisation of the Loviisa plant by Fortum Power and Heat Oy is also being sold to foreign customers. According to the current plans, the operating lifetime target for both reactor units is at least 50 years. Since the operating licences of the Loviisa 1 & 2 reactor units would have expired at the end of 2007, the operating licence renewal application was submitted to the authorities for a regulatory review in the autumn of 2006 and, in July 2007, the Government granted the renewal of the operating licences of Loviisa 1 & 2 up to 2027 and 2030, respectively. As part of the automation renewal (LARA project), the I&C systems of the plant will be renewed gradually; there will be four stages per plant unit. The first system commissioning took place in 2007 and the last stage will be carried out in 2014.

Nuclear fuel for the Loviisa plant has been supplied by Russia under long-term contracts. During the period 2001 to

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Main characteristics of the Finnish nuclear power plants

Reactor unit	Capacity Gross/net MW	Fuel Amount of uranium (tU)/number of fuel elements)	Start of commercial operation	Cumulative load factor by the end of 2010 (*) per cent
Power plants in operation				
Loviisa 1	510/488	38/313	1977	86.5
Loviisa 2	510/488	38/313	1981	88.8
Olkiluoto 1	910/880	90/500	1979	92.1
Olkiluoto 2	910/880	90/500	1982	93.4
All units	2840/2736			90.9
Power plants under construction				
Olkiluoto 3	1600	128/241	2013	
Decisions in Principle for new reactor units in 2010				
TVO; OL4	1,000 – 1,800		Early 2020s	
Fennovoima 1	up to 1,800		Early 2020s	

(*) From the beginning of commercial operation, the mean value is calculated by weighting with gross capacities

10 Olkiluoto nuclear power plant on the island of Olkiluoto in Eurajoki. Source: TVO/Korpi-Hallila.

2005, fuel was also supplied to Loviisa 1 by a British manufacturer. A repository for low and intermediate-level operating waste from the Loviisa plant has been excavated in the bedrock at the plant site and it has been in operation since 1997. There are also plans to extend the facility for the final disposal of the plants' decommissioning waste in due course. The final disposal of spent fuel will be implemented by Posiva Oy at Olkiluoto.

Electricity production at the Loviisa power plant amounted to 7.7 TWh (net) in 2010. The load factor of Loviisa 1 was 93.1 per cent and that of Loviisa 2 89.1 per cent.

Olkiluoto Nuclear Power Plant

The Olkiluoto nuclear power plant, owned by Teollisuuden Voima Oyj, is located in the municipality of Eurajoki, about 20 km north of the town of Rauma. It comprises two boiling water reactors of Swedish design. Their original net electrical capacity of 660 MW has been increased to the present capacities in four main stages, first as upratings between 1982 and 1984 and secondly between 1995 and 1998 in connection with a major modernisation programme of the plant. A third phase took place between 2005 and 2006, with the modernisation of the high-pressure turbines. A further increase in the net capacities of the reactor units will be achieved through efficiency improvements made to the turbine plant.

The current operating licences of Olkiluoto 1 & 2 are valid until 2018 and they required that a comprehensive periodic safety review (PSR) be carried out by the end of 2008. This PSR was submitted to the safety authority, STUK, for its approval. STUK reviewed the documentation provided for PSR by TVO in 2009 and gave some recommendations to TVO in its final review report, published in 2010. Furthermore, TVO has preliminary plans to further increase capacity, up to 2 x 1,000 MW, in connection with the application for the renewal of the operation licence required after 2018.

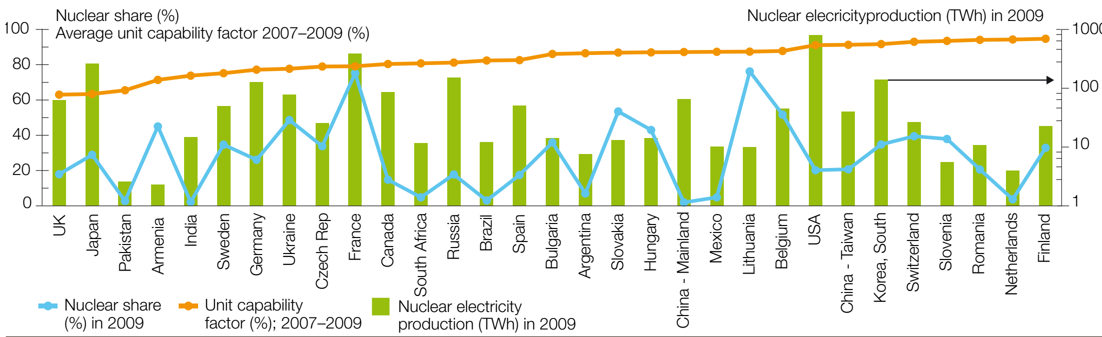
Construction works for the third reactor unit at Olkiluoto began in February 2005 after the Government had granted the related construction licence. The unit is expected to begin commercial operation in 2013. According to current plans, the target for the operating lifetimes of the existing reactor units and the unit under construction is at least 60 years.

The Olkiluoto power plant units have been kept constantly up-to-date in respect of their technology. Operating experiences and safety requirements that have become stricter over the years have been taken into account in these technological improvements. In the late 1980s, the containment buildings of the Olkiluoto units were equipped with severe accident management systems for mitigating the off-site consequences of any possible, albeit extremely unlikely, core meltdown accidents.

Nowadays, uranium for the Olkiluoto units is supplied under long-term contracts, mainly from Canada and Australia. This uranium is enriched in Russia and the EU area. Fuel assemblies delivered to Olkiluoto are made in Germany, Spain and Sweden.

The repository for reactor operating waste, excavated into the bedrock, was commissioned at Olkiluoto in 1992. There are plans to expand the facility for the final disposal of decommissioning waste in due course. Posiva Oy is planning a final disposal facility for spent fuel, which will be situated at Olkiluoto.

In 2010, electricity production at the Olkiluoto power plant amounted to 14.2 TWh (net). The load factor of Olkiluoto 1 was 91.8 per cent, despite extensive maintenance work including the exchange of all low-pressure turbines and the upgrading of the generator cooling system. The improvement in the efficiency of the turbine plant increased the net electrical output of the Olkiluoto 1 unit by 20 MW from 1 July 2010. Similar large maintenance outages for the second unit took place in spring 2011 and the net electrical output of Olkiluoto 2 was also increased to 880 MW. The load factor of Olkiluoto 2 was 95.2 per cent in 2010.



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11 Performance of the Finnish nuclear power plants in comparison with operating experience in other countries: (1) nuclear share (per cent) in power production in 2009, (2) average unit capability factor 2007–2009, and (3) nuclear electricity production (TWh) in 2009 [IAEA, WNA].

FENNOVOIMA

Fennovoima Oy is a new Finnish nuclear power company established in 2007 that aims to construct a new up to 1,800 MW capacity nuclear power plant in Finland to produce power cost-effectively to its 69 Finnish share-holding companies. The operation of the plant is scheduled to begin at the end of this decade or early next decade.

Fennovoima will produce electricity for its owners' needs on a production cost basis (the so-called Mankala principle). Each owner will receive the share of capacity proportional to its ownership in the company. Owners of Fennovoima include enterprises in industry, trade and services, as well as regional and local energy companies. With its 34 per cent share, the nuclear expert E.ON Kärnkraft Finland is a minority shareholder in the company. E.ON will offer its nuclear expertise for utilisation in the project.

Fennovoima has conducted the Environmental Impact Assessment procedure for three sites and the Decision in Principle including two site alternatives, Simo and Pyhäjoki in northern Finland, was made by the Government on 6 May 2010. This was ratified by Parliament on 1 July 2010. In 2011 Fennovoima will choose one of the sites as the location of the plant.

Fortum

Fortum Oyj is a leading energy company in the Nordic countries and other parts of the Baltic Rim. Fortum's activities cover the generation, distribution and sale of electricity and heat, the operation and maintenance of power plants and energy-related services.

Fortum Power and Heat Oy is engaged in nuclear energy activities. In addition to the Loviisa nuclear power plant, Fortum owns minority shares in the Olkiluoto nuclear power plant and the Swedish Forsmark and Oskarshamn nuclear power plants.

Fortum Corporation was listed on the Helsinki Exchanges in December 1998. At the end of 2010 the Finnish state owned 50.8 per cent of its shares. In 2010, the sales of Fortum Group amounted to EUR 6,300 million, power generation in EU and Norway totalled 53.7 TWh, of which the share of nuclear power was 41 per cent. At the end of 2010 the company employed around 10,600 people, of which around 2,600 were in Finland.

TVO

Teollisuuden Voima Oyj (TVO) produces electricity for its shareholders on a production cost basis at the Olkiluoto nuclear power plant in Eurajoki and at the Meri-Pori coal-fired power plant.

TVO's principal task is to secure economical, safe and environmentally-friendly electricity generation for its shareholders at Olkiluoto's current plant units. The company's objective is to maintain the plant units as good as new and in excellent condition, and to ensure the development of the personnel's expertise.

TVO has six shareholder companies and three share series: A. existing units (OL1 & 2), B. the Meripori coal-fired plant, and C. the new reactor unit under construction (Olkiluoto 3). TVO forms part of the PVO Group, whose parent company is Pohjolan Voima Oy. The power produced by TVO is delivered to the shareholders at production cost basis (the so-called Mankala principle).

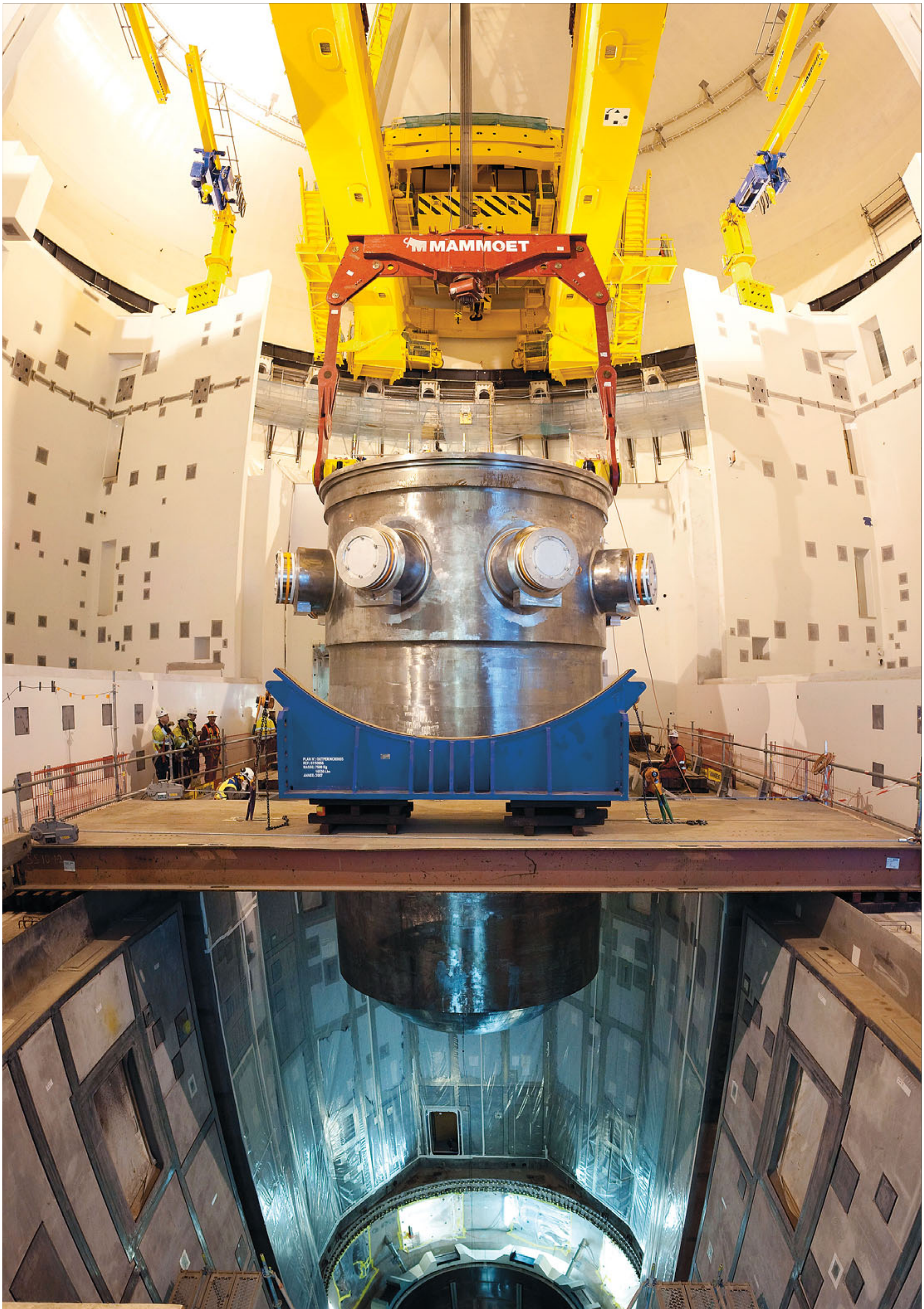
In 2010, the company's net sales amounted to EUR 363 million and it sold 14.1 TWh of electricity produced by nuclear power. In 2010 TVO had an average of around 837 permanent employees. The Decision in Principle for the Olkiluoto 4 reactor unit was made by the Government on 6 May 2010 and ratified by Parliament on 1 July 2010.

POSIVA

Posiva Oy is responsible for the characterisation of the site for the final disposal of spent fuel and for the technical planning and safety assessment of the repository and, at a later date, the construction and operation of the final disposal facility. In addition, Posiva's line of business includes other expert services in the field of nuclear waste management provided for the two owner companies and other customers.

At the end of 2010, Posiva employed around 92 people working in the field of nuclear waste management. Posiva utilises not only Finnish expertise in the field but also contracts international research institutes. Research connected with nuclear waste management is carried out in universities, research institutes and consulting companies representing expertise in different fields.

Posiva is owned by TVO (60 per cent) and Fortum Power and Heat Oy (40 per cent). The company had a turnover of some EUR 60.5 million in 2010 and is headquartered in Olkiluoto in the municipality of Eurajoki.


MAMMOET

12 Installation of pressure vessel of Olkiluoto 3 reactor unit. Source: TVO/ Hannu Huovila.

New Finnish reactor unit, Olkiluoto 3, under construction

In May 2002, the Finnish Parliament ratified the Government's earlier favourable Decision in Principle (DiP) on the fifth nuclear power plant unit. TVO chose Olkiluoto as the location of the unit in October 2003 and, in December 2003, made the investment decision to choose the European Pressurised Water Reactor (EPR) with a net electrical output of around 1,600 MW. The plant's supplier is a consortium composed of Areva NP and Siemens AG. Nuclear power capacity is being increased, mainly in an effort to restrict the use of fossil fuels in order to counter climate change. Furthermore, positive experiences of the existing nuclear power plants, the steady price of nuclear electricity and Finland's small indigenous energy resources were additional contributing factors. In addition, the general public has adopted a relatively positive attitude towards an increase in nuclear power production in Finland.

Finnish nuclear power companies had closely followed the development of nuclear technology in the 1990s and had participated in certain plant concept development projects. In 1998 the Finnish nuclear power companies, Fortum and TVO, separately launched the environmental impact assessment (EIA) procedures in compliance with the legislation in force, in order to study the environmental effects of a new nuclear power plant unit built in either Loviisa or Olkiluoto. The environmental impact assessment procedures were completed in February 2000, when the former Ministry of Trade and Industry issued its final statement on the reports, concluding that the environmental impacts had been studied with sufficiently comprehensive scope.

In November 2000, TVO filed an application to the Government for a DiP concerning the construction of a new nuclear power plant unit. In the application, the size of the new unit was defined at 1,000–1,600 MW with a technical operating lifetime of 60 years. The locations, Loviisa and Olkiluoto, competed as equal alternatives, as did the boiling water and pressurised water technologies as technical alternatives. The application also included the nuclear facilities required for the handling, storage and final disposal of operating waste.

The Government made its favourable DiP on the fifth nuclear power unit in January 2002. In May 2002, Parliament decided to ratify the DiP by a vote of 107–92. Thus, TVO was authorised to continue preparations for the construction of a new nuclear reactor unit.

TVO initiated an invitation to tender for the project in the autumn of 2002 and received tenders for the new plant unit in March 2003. After the evaluation of the tenders, TVO chose Olkiluoto as the location of the plant in October 2003 and continued contract negotiations with the supplier consortium, comprising the German company Framatome ANP GmbH, the French Framatome ANP SAS (now Areva NP) and the German Siemens AG. The investment decision on the construction of the Olkiluoto 3 nuclear power plant unit was made in December 2003.

In January 2004, TVO submitted a licence application to the Government for the construction of a nuclear power plant unit called Olkiluoto 3 in the municipality of Eurajoki on the Olkiluoto nuclear power plant site.

In accordance with the Nuclear Energy Act and the Nuclear Energy Decree, the then Ministry of Trade and Industry handled the application on behalf of the Government. The Ministry invited statements from the Finnish Radiation and Nuclear Safety Authority (STUK) and several other authorities and organisations. In addition, the Ministry sent the construction licence application for information to several other institutions with a view to obtaining possible statements from them.

The Statement of Position of the Finnish Radiation and Nuclear Safety Authority (STUK) was submitted to the Ministry in January 2005. According to STUK´s overall assessment, the Olkiluoto 3 nuclear power plant unit can be built

Phases of the Olkiluoto 3 project. (Status in August 2011)

Phase of the Project	Started	Completed
Environmental Impact Assessment procedure (FIN5)	June 1998	February 2000
Application for Decision in Principle (DiP) for FIN5	November 2000	
Decision in Principle (DiP) by Government		January 2002
DiP ratified by Parliament		May 2002
Bidding process	September 2002	March 2003
Investment decision and main contract signed for OL3		December 2003
Construction licence application submitted	January 2004	
Excavations started	February 2004	
Construction licence granted		February 2005
Construction of the plant	March 2005	
Application of operating licence	2011/2012	
Granting of operation licence		2013
Commercial operation		2013

safely, fulfilling the requirements set by the Nuclear Energy Act. Furthermore, in its Statement of Position, STUK presented some specifying comments and restrictions. In February 2005, the Government granted the licence for constructing the Olkiluoto 3 unit. The reactor's thermal output will be 4,300 MW and electric output about 1,600 MW.

The construction of the reactor started in summer of 2005 and by the end of 2010 the civil construction works had been completed to a large extent. Several major components, such as the reactor pressure vessel, pressuriser and three steam generators, have been installed. Installation and pipeline welding works continued at the plant. The turnkey supplier Areva has informed TVO that most of the work at the plant will be completed in 2012. According to Areva, commissioning will take about eight months, which means that operation could start during the latter half of 2013. There have been some problems in the design and construction work and the project has been delayed by approximately four years when compared to the original schedule.

The next step in the licensing process will be the handling of the application for an operating licence. This application is expected to be submitted to the Government by the end of 2011 or early in 2012. Its processing is expected to take at least one year. Consequently, the commercial operation of Olkiluoto 3 will probably begin towards the end of 2013.

In May 2002, simultaneously with the DiP on the fifth Finnish reactor unit, Parliament also unanimously ratified a separate DiP on the final disposal of the spent nuclear fuel of the fifth nuclear power unit. According to this decision, the spent fuel of the fifth nuclear power unit would also be disposed of in the bedrock at Olkiluoto, like the spent nuclear fuel of the present nuclear power plants.

13

Planning of new nuclear power plant

In the spring of 2007, both TVO and Fortum announced that they had begun the environmental impact assessment (EIA) procedure for a new nuclear power plant unit (1,000–1,800 MW) at either the Olkiluoto or the Loviisa sites, respectively. The EIA report is an obligatory attachment of an application for a Decision in Principle (DiP) to the Government. TVO filed its DiP application in April 2008. However, the Companies had not made any firm investment decisions with respect to constructing a new power plant unit.

In the early summer of 2007, a new Finnish energy company, Fennovoima, was established, also with the intention of constructing one or two reactor units in Finland. The shareholders of Fennovoima are Finnish trade, industry and service companies, regional and local energy companies, as well as E.ON which, as a minority shareholder, offers its expertise in nuclear technology to Fennovoima's project.

At the end of May 2007, TVO submitted the programme of the Environmental Impact Assessment (EIA) procedure for a planned fourth reactor unit at Olkiluoto in Eurajoki and the then Ministry of Trade and Industry (now the Ministry of Employment and the Economy) issued its statement on the programme at the end of September 2007. The nuclear power plant unit may be either a boiling or pressurised water reactor plant. This EIA procedure ended in summer 2008.

At the end of June 2007, Fortum submitted the EIA programme for a planned third reactor unit at the Loviisa site and the Ministry issued its statement on the programme in the middle of October 2007. This EIA procedure was completed during the autumn of 2008.

In 1997–1999, Posiva conducted an EIA procedure covering 9,000 tU (tons of uranium) of spent fuel. Posiva updated the previously performed investigations for the EIA report in 2008, and the company filed a DiP application in April 2008 concerning the spent fuel from the proposed Olkiluoto 4 unit. The total disposal capacity will thereby be increased to

13 An animated photograph of the location of the reactor units Olkiluoto 1–3 and the planned fourth reactor unit on the island of Olkiluoto in Eurajoki. Source: TVO.

14 An animated photograph of the location of Fennovoima's planned reactor unit at the Karsikko site alternative in Simo. The second site alternative (Hanhikivi) of Fennovoima is located in the Pyhäjoki community. Source: Fennovoima.

14

units

Phases of the initiatives of TVO, Fortum and Fennovoima with respect to building additional nuclear power plant unit(s) in Finland. (Status in August 2011)

Phase of the Project	Started	Completed
TVO delivers EIA programme of OL4 for review by Ministry	May 2007	
Ministry submits statement on EIA programme for OL4		September 2007
Preparation of EIA report for OL4	September 2007	February 2008
Application filed by TVO for DiP for OL4 unit	April 2008	
Ministry submits statement on EIA report by TVO		June 2008
Government makes positive DiP		May 6, 2010
DiP ratified by the Parliament		July 1, 2010
Fortum delivers EIA programme of Lo3 for review by Ministry	June 2007	
Ministry submits statement on EIA programme for Lo 3		October 2007
Preparation of EIA report for Lo 3	October 2007	April 2008
Ministry submits statement on EIA report by Fortum		August 2008
Application from Fortum for DiP for Lo3 unit	February 2009	
Government makes negative DiP		May 6, 2010
Fennovoima delivers EIA programme of new plant for review by MEE	January 2008	
MEE submits statement on EIA programme by Fennovoima		May 2008
Preparation of EIA report by Fennovoima	May 2008	October 2008
MEE submits statement on EIA report by Fennovoima		February 2009
Application for DiP for new reactor units by Fennovoima	January 2009	
Government makes positive DiP		May 6, 2010
DiP ratified by the Parliament		July 1, 2010

9,000 tU. The further increase up to 12,000 tU required a new EIA procedure that was completed in March 2009.

In the first phase of Fennovoima's project, during the summer of 2007, the company surveyed potential nuclear power plant sites in various parts of Finland. Following negotiations with several municipalities, the company began the EIA procedure in four municipalities and conducted assessments in three sites (Pyhäjoki, Ruotsinpyhtää and Simo). In January 2008, Fennovoima submitted the EIA Programme to the Ministry of Employment and the Economy for review, and submitted an EIA Report to the Ministry in October. The entire procedure was completed in February 2009. In January 2009 the company filed a DiP application for the planned reactor unit(s). The application included two alternative sites, Pyhäjoki and Simo.

The submitted DiP applications were subsequently handled according to the requirements of the Nuclear Energy Act under the leadership of the Ministry of Employment and the Economy. The Ministry processed all five DiP applications in 2009-2010 and the Government made its decisions in May 2010. All applications fulfilled all safety and environmental requirements. As specified by the Nuclear Energy Act, decisions on all DiPs were based on the project's overall benefit to society and the projected national energy needs in 2020 that limit nuclear power development to two new nuclear power plant units at this time.

The Olkiluoto 4 and Fennovoima's new build project received positive DiPs by the Government as did Posiva's plan for repository enlargement project for Olkiluoto 4 spent fuel. Loviisa 3 was issued a negative DiP, as was Posiva's proposal to further expand ONKALO to accommodate spent fuel from Loviisa 3. The three positive DiPs were ratified in Parliament on 1 July 2010.

Positive DiPs were issued to the two utility companies (TVO and Fennovoima) that will produce cost-price electricity for the needs of Finnish industries that are funding these new build projects. The Government took also into account Fortum's stake (about 25 per cent) in TVO when deciding upon the DiPs.

During the EIA and DiP processes, Fennovoima narrowed down the site list to Simo and Pyhäjoki from the original four sites under consideration. Both municipalities have stated, at the request of the Ministry of Employment and the Economy, that they are willing to host Fennovoima's plant and STUK has found both of these greenfield sites suitable for a nuclear power plant. Fennovoima is expected to choose the site in the autumn of 2011.

TVO and Fennovoima have preliminarily planned to issue the call for tenders within about two years after the granting of the DiPs.

Environmental impact and radiation exposure

The release limits for the most important groups of radioactive substances have been determined and calculated separately for atmospheric and aquatic releases. Releases are monitored regularly: the radiation levels in the areas surrounding the nuclear power plants are monitored and measuring samples are taken from the environment. The releases and the radiation doses of nuclear power plant personnel and the residents of nearby areas have been clearly below the authorised limits.

Finns are annually exposed to an average of 3.7 millisieverts (mSv) of radiation, mostly (3 mSv) arising from natural background radiation, including radiation from elevated indoor radon levels. According to the authorised limits for releases from the Finnish nuclear power plants, the additional radiation dose of individuals in the most exposed population group in the immediate surroundings of the plant may not exceed 0.1 mSv per year.

Environmental impacts during operation

Before the nuclear power plants were constructed, a basic survey was carried out in the areas surrounding the plants. During plant operation, samples have been taken continuously, for example, from flora, milk and seabed sediments. The air and rainwater are also monitored, as is a sample group of nearby residents.

The radiation exposure arising from the releases can be calculated using measurement data on releases into air and water, meteorological statistics and dispersion data, and data on the ecological and biological behaviour of various substances. Determining the releases from nuclear power plants is facilitated by the fact that it is easier to observe releases of radioactive substances in the environment than many other substances in industrial effluents. The estimates for annual doses thus derived are around 0.0001 mSv for individuals in the most exposed population groups in the vicinity of the plants.

Such minute increases in exposure cannot be distinguished from natural background radiation by any direct measuring technique.

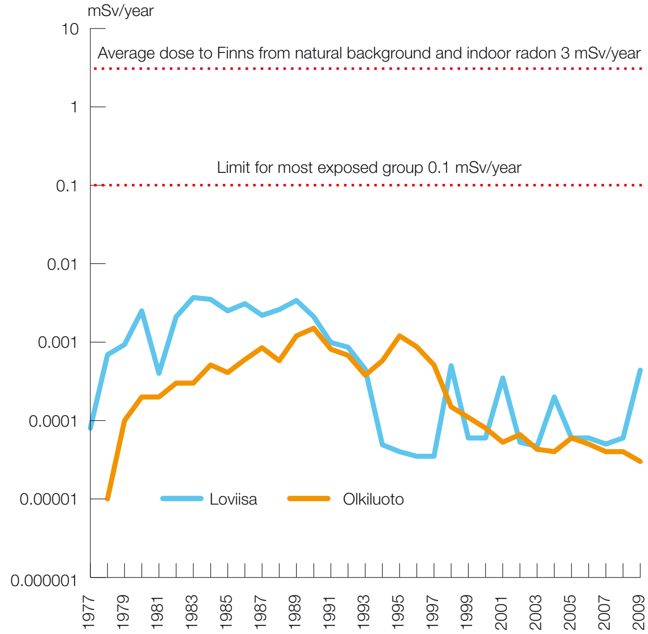
The most significant environmental impacts of the Finnish nuclear power plants are related to the warming of seawater, since the plants use seawater for condensing, like other thermal power plants. The seawater temperature increases by 11–13°C during its passage through the plant, but it cools rapidly when it returns to the open sea. This warmer water prevents a sea area of a varying size from freezing; the ice around this area remains brittle, which makes movement on the ice difficult.

Occupational radiation exposure

The average annual dose of all Finnish employees exposed to radiation at Finnish NPPS was around 0.6 mSv in 2010. About 99.4 per cent of the annual exposures of individual workers remained below 10 mSv. Most of the radiation doses are received during the annual refuelling outages of the nuclear power plants. The statutory limit for the annual radiation dose is 50 mSv and the five-year average may not exceed 20 mSv a year. In 2009 the highest individual worker dose at Finnish nuclear power plants was 13.5 mSv.

For the collective occupational dose, the statutory limits are expressed per net electricity capacity, so that the average over two years of collective exposure of plant personnel may not exceed 2.5 manSv per 1000 MW. Consequently, the limits for the Loviisa (2 x 488 MW) and Olkiluoto (2 x 880 MW) nuclear power plants are 1.22 and 2.2 manSv per reactor unit. In Finland, the Radiation and Nuclear Safety Authority (STUK) sets the statutory limits for collective doses.

In 2010, the radiation doses of personnel at the Loviisa power plant totalled 1.57 manSv and those of the Olkiluoto power plant 0.9 manSv.



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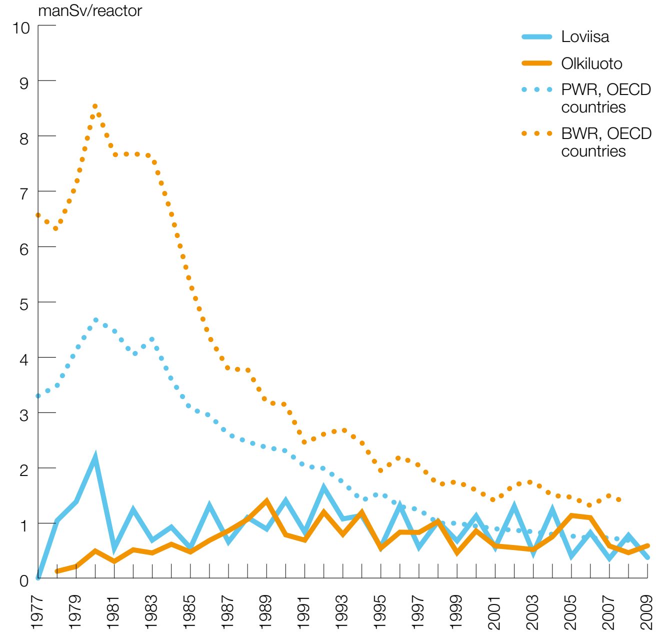

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15 Calculated annual doses[1] (mSv/year) to individuals 1977–2009 in the most exposed population groups close to Loviisa and Olkiluoto NPPs.

16 Trends in annual average occupational doses per reactor 1977–2009 at Finnish nuclear power plants in comparison with experiences of LWRs in OECD countries [OECD/NEA ISOE statistics].

Safety feedback from Fukushima accident

A few days after the accident at the Fukushima nuclear power plant in Japan in March 2011, the Ministry of Employment and the Economy requested the Radiation and Nuclear Safety Authority (STUK) to prepare a report on how Finnish nuclear power plants are prepared for the effects of floods and other extreme natural phenomena on the functionality of plants, and how plants have ensured the availability of electricity during various fault and malfunction situations. Following this request STUK asked the Finnish nuclear utilities to present viewpoints on possible required measures and safety improvements.

Based on the responses received from utilities and its own initial assessment, STUK submitted a summary report containing proposals on enhancing the safety of the Finnish nuclear power plants in mid-May 2011. At a general level, STUK's exhaustive report underlines that Finnish nuclear power plants have high safety levels. STUK states that although there is no need for immediate safety improvements, there is cause for power companies to continue investigations into preparedness for certain exceptional natural conditions. Companies will carry out additional investigations into the effects of an extremely unlikely high flood situation in Loviisa, for example.

At the same time, companies will investigate how some of the plants' systems would function following an earthquake which would be more intense than any earthquake considered possible in Finland until now. In addition, companies will investigate the functionality of power plant systems which ensure the electricity supply required during accident situations. Investigations and plans for safety improvements can be compiled in connection with and on the same time schedule during 2011 as stress tests carried out at the request of the European Council.

1 Sievert (Sv) indicates the amount of radiation dose absorbed in tissue, taking into account the biological effects of radiation using a factor corresponding to the radiation type. Generally speaking, one-thousandth, mSv (millisievert), or one-millionth, μSv (microsievert), of a Sievert is used. ManSv is the sum of radiation doses received by individuals within a certain group of people, the so-called collective radiation dose (in this case, the collective radiation dose received by the entire personnel of a power plant).

17

17 The Talvivaara Ni-Zn-Cu-Co mine in Sotkamo in eastern Finland is planned to be exploited also for uranium extraction with annual capacity of 350 to 500 tU. Source: Talvivaara Sotkamo Oy.

Plans for prospecting and mining for uranium in Finland

Finnish bedrock contains uranium, and its abundance in some places appeals to exploring companies. Owing to recent uranium price hikes, international uranium prospecting companies have shown an interest in Finland. Environmental impact assessment procedure is applied to all uranium mining projects, without any limitations on the annual amount of the extracted resource or on the area of an opencast mine.

In addition to the licensing based on the Mining Act and on other legislation (Environmental Protection, Nature Conservation, Protection of Wilderness Reserves, Land Use and Building, Occupational Safety and Health, Radiation), the production of uranium or thorium also needs a licence from the Government according to the Nuclear Energy Act.

The Ministry of Employment and the Economy promotes the use of mineral resources by securing a favourable operating environment for mineral exploration and mining activities. The Ministry has been responsible for the revision of mining legislation in recent years. The new Mining Act was accepted by Parliament in March 2011, to enter into force in July 2011. An amendment to the Nuclear Energy Act was also included.

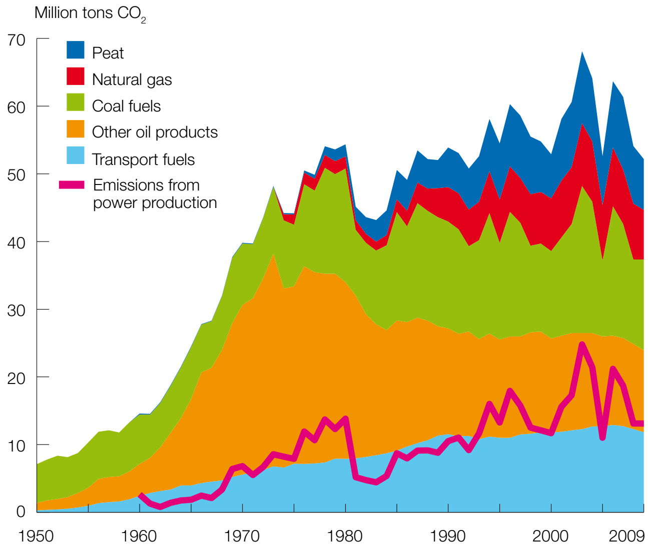
While securing the preconditions for mining and exploration, the Mining Act of 2011 takes account of environmental issues, citizens' fundamental rights, landowners' rights and municipalities' opportunities to influence decision-making. One of the changes is that the duties of the mining authority are transferred from the Ministry to a lower administrative level, the Safety Technology Authority (Tukes). With the responsibility for granting permits and supervising compliance with legislation, this new mining authority office of Tukes has been established in Rovaniemi, northern Finland.

In the Mining Act of 2011, an exploration licence is required for uranium exploration (e.g. drilling, trenching). Permit applications concerning a uranium mine under the Mining Act and Nuclear Energy Act are handled jointly and are decided on in a single decision by the Government. The mining licence for a uranium mine requires that the mining project activities are aligned with the overall interests of society, the municipality in question has given its consent, and safety requirements are being complied with.

There are several pending claim applications for uranium exploration and there were three accepted claims in force in late 2010. The pending claim applications were filed between 2007 and 2010. The uranium exploration licences are subject to more extensive hearings than those for other commodities. For the claim decisions for uranium given by the MEE in 2009 and 2010, the licensing procedure took two to three years. For the moment, Mawson Energi AB, the Swedish subsidiary of Mawson, is the only active uranium exploration company in Finland and its current main target is the Rompas Au-U prospect at Ylitornio, northern Finland.

Operated by Talvivaara Mining Company Plc., the Talvivaara Ni-Zn-Cu-Co mine in Sotkamo, eastern Finland, is one of the largest sulphide nickel deposits in Europe. The company applies bioheapleaching to extract the metals from black schist-hosted ore. Although the average uranium grade is very low (0.0017 per cent), the pregnant leach solution contains 15 to 25 mg/l U, sufficient for exploitation. Talvivaara released its plans to build a solvent extraction circuit for by-product recovery of uranium in February 2010. Annual uranium production is expected to be about 350 to 500 tU. Proceeding with construction and operation of the uranium circuit requires a number of permits from the regulators. Planning and licensing have been ongoing throughout 2010 and 2011, and the environmental impact assessment procedure was completed in March 2011. The company has also submitted an application for considering the requirements contained in the Nuclear Energy Act.

Cameco Corporation is providing technical assistance to Talvivaara in the design, construction, commissioning and operation of the uranium extraction circuit. Cameco and Talvivaara signed agreements in February 2011 for an up-front investment to cover the construction costs and for the purchase of the uranium concentrates produced at Sotkamo until 2027.



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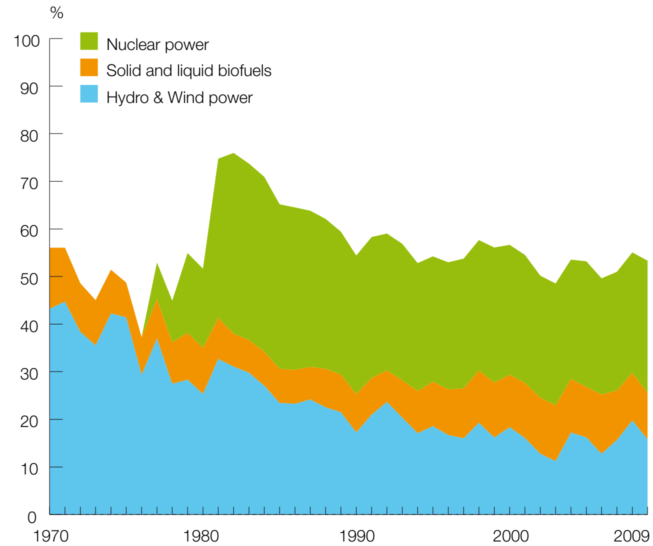

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Climate change and air pollution

18 Annual carbon dioxide emissions in Finland 1950–2009 from fuel combustion, by fuel type.

19 Percentage of CO_2-neutral electricity generation of total electricity consumption.

Finland has been successful in reducing its amounts of sulphur dioxide and nitrogen dioxide emissions that acidify the environment. However, preventing the growth of carbon dioxide emissions remains a very challenging task. The most important emissions reduction options are energy conservation, the use of renewable energy sources, nuclear power and natural gas. Energy-efficiency is at a very high level in Finland, and any significant further increase in energy conservation could prove expensive.

In accordance with the targets for reducing greenhouse gas emissions, as agreed in the Kyoto Protocol, EU member states have committed themselves to reducing their greenhouse gas emissions by a total of 8 per cent from the 1990 level, by the first commitment period of 2008–2012. In accordance with burden sharing within the EU, Finland's commitment is to return its emissions to their 1990 level. Meeting emission targets cost-effectively – especially those of carbon dioxide – will prove a challenging task without the expanded use of nuclear power and renewable energy sources.

Between 1991 and 1993, CO_2 emissions decreased slightly below the 1990 level and exceeded it only slightly in 2000, when hydropower production and net electricity imports had a large share in electricity production. On the other hand, in 2003 CO_2 emissions from fuel combustion were at their highest (30 per cent above the reference level) due to the lowest hydropower production in Finland since 1970, and much lower net electricity imports.

In 2005, emissions again dropped fleetingly below the Kyoto target, owing to the high share of net electricity imports and long strikes and trade union disputes in the forest industry. Thereafter, emissions temporarily grew above the target but dropped again below the Kyoto target during the economic recession period 2008–2009. During 2010 the emissions from the energy sector returned to 2001 levels. The EU Emissions Trading Scheme started in 2005 and it gives flexibility to the emissions trading sector, i.e. power production and industry. Instead of stiff national targets there is an EU-target for the EU-wide umbrella covering the total emissions trading sector in the EU.

The main activities in Finland which have aimed at restricting emissions growth have been increasing the use of wood-based fuels, wind power and natural gas as a substitute for coal, as well as upgrading nuclear power plants. Energy efficiency has also played a role.

National Climate and Energy Strategy

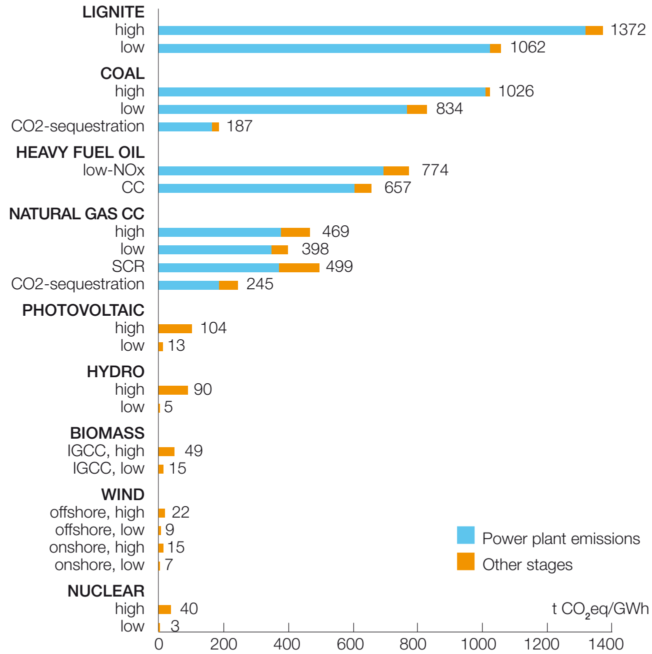
Since the energy sector accounts for nearly 80 per cent of greenhouse gas emissions, the greatest potential for reductions in these emissions will be found in this sector. Greenhouse gas emissions will also have to be reduced in other sectors. Finland's present Energy and Climate Strategy was presented by the Government in November 2008 to Parliament. The National Climate and Energy Strategy and its supplementary programmes determine the energy policy lines to be followed. While drafting the Climate and Energy Strategy, the principles underlying energy policy were taken into account. According to the Strategy, Finland should continue to rely on a diverse supply of energy sources, ensuring maximum self-sufficiency. All emission-free, low emission or emission-neutral production methods will be considered in decision-making on future capacity.

The EU's role in steering energy policy has increased in recent years. The core framework of Europe's Energy and

20 Greenhouse Gas emissions ($t\ CO_2eq/GWh$) for alternative electricity generation systems [IPCC Climate Change 2007: Mitigation; based on special report by World Energy Council in 2004].

21 Trends in greenhouse gas emissions in EU15 countries relative to the targets (=100) set in the burden sharing and GHG emission trends in new member states [European Environment Agency, Statistics Finland].

22 Specific CO_2 emissions (g/kWh) from electricity production in Europe in 1990, 2000, 2006 and 2007 [Eurelectric, EURPROG].



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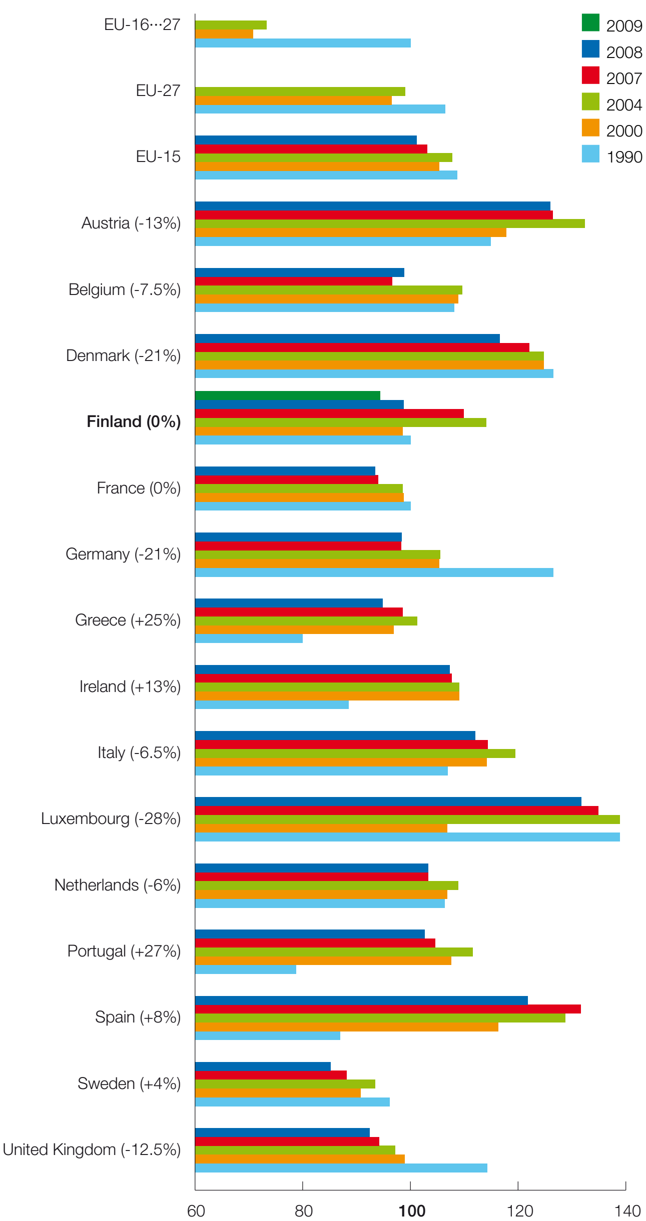

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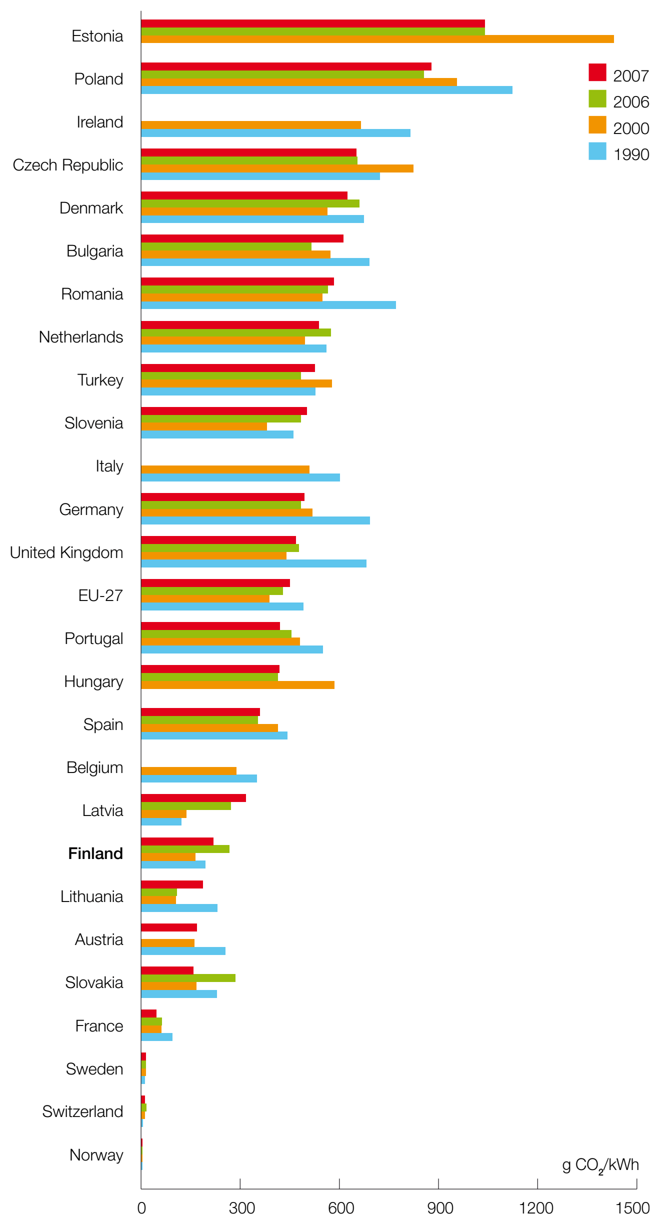

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Climate Policy is based on decisions taken in December 2008. These include reducing greenhouse gas emissions by 20 per cent, raising the share of renewable energy to an average of one-fifth of total consumption (38 per cent for Finland), while improving energy efficiency by 20 per cent by 2020.

According to the trend outlined in the strategy, the share of indigenous energy, and that of renewable energy in particular, will increase markedly over current levels. The share of renewable energy will increase to 38 per cent of total final energy consumption, the efficiency of the energy system will improve, and greenhouse gas emissions will begin to fall on a permanent basis. Furthermore, the share of coal and oil on the Finnish energy balance sheet will decrease, and the diversity of our energy system will further improve, while the risk to our energy supply posed by crises originating outside our country will diminish. To an extent, our energy system will be based on greater use of electricity than before.

Meeting increasing demand for energy and replacing fossil fuel-fired power plants with entirely renewable energy sources may prove difficult. The Government will see to it that energy production in Finland remains diverse and as self-sufficient as possible. No emission-free, low-emission or other form of generation that is neutral with respect to emissions and also sustainable and cost-efficient can be ruled out, including nuclear power. On the contrary, all forms of energy must be assessed on the basis of the overall interests of society.

However, the CO_2 emissions from electricity generation alone are relatively small, owing to the significant share of combined heat and power production, and the use of biofuels, hydropower and nuclear power. In 2009 the specific emissions of CO_2 arising from power production (69.2 TWh) in Finland were 189 g/kWh.

Renewable energy and energy efficiency

In November 2008, the Government accepted a long-term climate and energy strategy that includes the long-term target to stop the growth of final energy consumption and turn it into a decreasing trend. The objective is to decrease the final energy consumption by 37 TWh by 2020, meaning a decrease of 11 per cent as compared to the projected situation without the implementation of the new energy efficiency improvement measures.

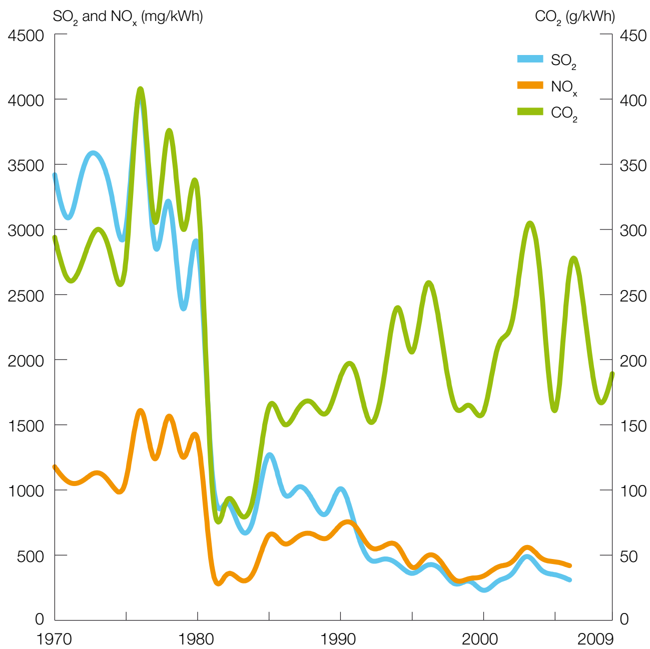
The broad-based Energy Efficiency Committee, appointed by the Ministry of Employment and the Economy, presented its proposal in summer 2009 regarding the required measures to achieve the above target for improving the energy efficiency. In February 2010, the Government passed a resolution on energy saving and energy efficiency measures for implementation during the current decade.

Electricity taxation

The current Finnish energy taxation system levies a tax on the end use of electricity (EUR 6.9/MWh for industry and EUR 16.9/MWh for other consumers). There is also a Precautionary Stock Fee of 0.013 cent/kWh for all customers. Value added tax on electricity has been in effect in Finland since August 1986. The current rate is 23 per cent although it is recoverable by industrial customers. In comparison, the minimum tax levels in the EC directive for electricity tax for industry and other consumption are EUR 0.5/MWh and EUR 1/MWh, respectively.

In heating fuel taxation a new structure based on two components was introduced in 2011. It takes into account energy content of the product (energy content tax (€/MJ)) and CO_2 emissions of the product (CO_2 tax (€/MJ), based on 30 €/tCO_2.

CO_2 tax for fossil fuels used in Combined Heat and Power Production (CHP) is halved to avoid overlap with the Emission



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23 Specific emissions of CO_2, SO_2 and NO_x in electricity production, 1970–2009 [Finnish Energy Industries/ Enprima Oy].

Trading Scheme (ETS) and to improve the competitiveness of CHP compared to separate heat production.

Role of nuclear power in mitigating climate change

Carbon dioxide emissions were reduced significantly in the early 1980s, when the current Finnish nuclear power plants were commissioned in 1977–1982. Nuclear power replaced condensing power production, which was mainly based on coal. To curb greenhouse gas emissions, the Government published a new Climate and Energy Strategy in November 2008, which took account of developments since the first and second climate strategies of 2001 and 2005, such as the Emissions Trading Directive and the entry into force of the Kyoto Protocol. In parallel with domestic emission-cutting measures, Finland will also explore the use of the Kyoto mechanisms as part of the new strategy. The variability of Finnish emissions is high for climatic reasons (i.e. hydropower availability and space heating needs in the winter).

Considerable emission cuts are expected from the new nuclear power plant, which is expected to be commissioned in 2013. Because the plant is delayed as per the original schedule, Finnish producers in general need to buy emission allowances on the EU market. Emission trading prices in the EU area have been rather volatile. Initially, prices were much higher than expected but settled at rather modest values. With the realisation of the Kyoto emission reductions during the second period, between 2008 and 2012, prices are expected to increase from the low level that prevailed up to the end of 2007. Emission trading has thus created a competitive advantage for carbon-free energy production forms, as intended.

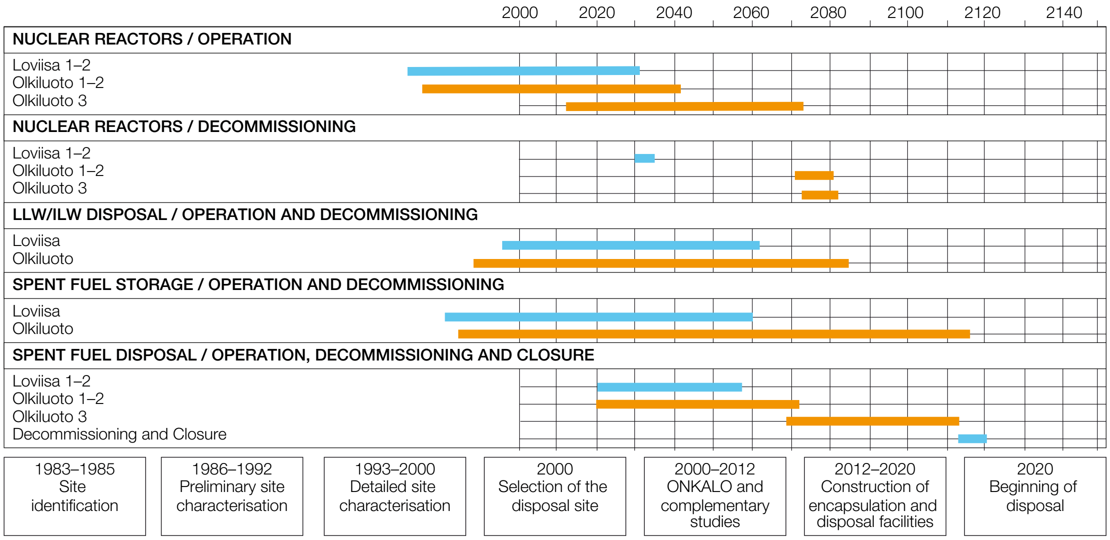
However, it remains unclear how emissions trading will affect decisions on investment in low or zero-carbon energy sources. Emissions trading will bring competitive advantages to carbon-free energy production forms. On the other hand, the present emissions trading system, with specifications extending only a few years into the future, has considerably increased levels of uncertainty over investment decisions. In most EU countries, the basis on which emission-free allowances will be allocated to operators in the next phases of the system remains unknown. There is a concrete risk that emission reductions realised during the first phase of the system will decrease the amount of free emission allowances obtained in the second phase.

Through the EU emissions trading system, the benefits for all carbon-free or low-carbon electricity producers selling electricity to the stock market will increase. In Finland, nuclear energy produced by Teollisuuden Voima Oyj (TVO) is sold to its shareholders at production cost price. Thus, emissions trading brings a competitive advantage to TVO's shareholders in the form of cheaper electricity.

Acidifying emissions

The impact of the use of nuclear power on the level of emissions of acidifying substances is also significant. In particular, the level of sulphur dioxide (SO_2) emissions significantly reduced in the early 1980s, which was mainly attributable to the commissioning of nuclear power plants and the use of low-sulphur fuels in traffic. The reduction in the amount of SO_2 emissions continued during the period 1985–1995 through intensified flue-gas desulphurisation, the use of low-sulphur coal and oil, and improvements and structural changes in industrial processes.

The effect of the use of nuclear power on nitrogen oxide (NO_x) emissions is also noticeable, but reductions have been smaller than those of SO_2, since the proportion of NO_x emissions caused by electricity generation is rather small. Around 65 per cent of NO_x emissions in Finland emanate from the transport sector.



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24 Timetable for the disposal of spent nuclear fuel from the nuclear power plants at Loviisa and Olkiluoto.

Nuclear waste management

The use of nuclear power in electricity generation produces two kinds of radioactive waste: highly radioactive spent fuel and low- and intermediate-level operational waste. About 75 tonnes of spent nuclear fuel is produced in Finland's four nuclear power plant units every year. Operational waste is produced at power plants within process water cleaning systems and during maintenance and repair work. When the operation of the power plants is winded up, their dismantling produces decommissioning waste, which is similar to operational waste by nature.

Arrangements for the safe management of radioactive waste produced by Finnish nuclear power plants have been in place ever since the plants' construction phase in the 1970s. As early as 1983, the Government made a policy decision on the objectives and schedules of the national nuclear waste management programme in Finland. Since then, the former Ministry of Trade and Industry (now the Ministry of Employment and the Economy) has specified the objectives and updated the schedule.

According to the Nuclear Energy Act, all nuclear waste generated in connection with the use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland. Another legislative basis for nuclear waste management is the "polluter pays" principle, by which responsibility for nuclear waste management lies with its producers. This means that nuclear power companies are responsible for both technical measures and the required R&D associated with waste management, including final disposal and the costs incurred. It is the task of the authorities to ensure that waste management is implemented in compliance with safety and other regulations.

Low- and intermediate-level waste

After treatment, low- and intermediate-level waste generated during the operation of a nuclear power plant is initially stored at the plant. After interim storage, the waste is transferred to a repository for low- and intermediate-level waste on the plant site. At Olkiluoto, the disposal of waste in the repository began in 1992 and in Loviisa in 1997.

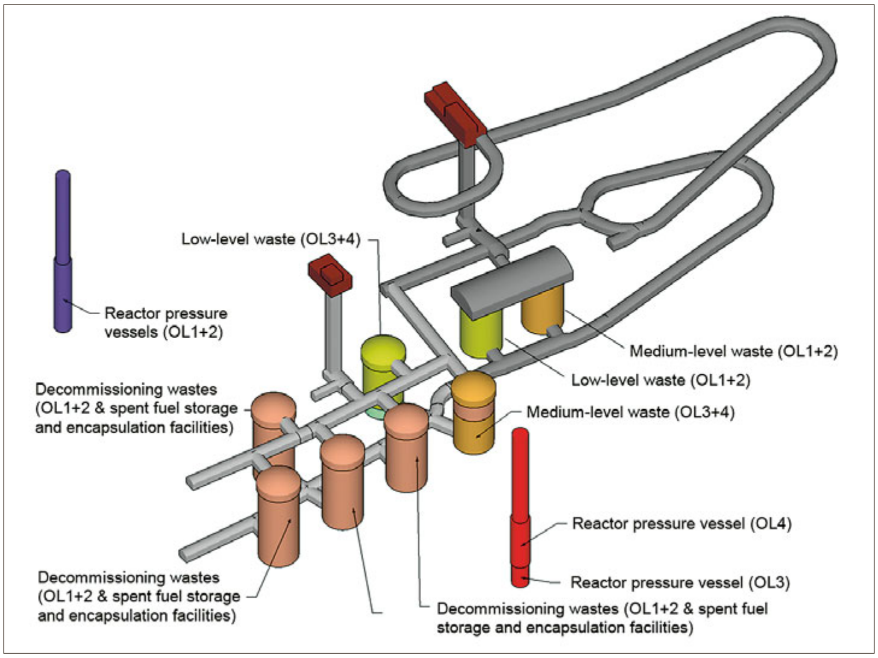
The repositories for low- and intermediate-level waste are located in the bedrock, at a depth of 60–110 metres. These repositories have separate silos or tunnels for low and intermediate-level waste, and have been dimensioned to house all radioactive operational waste produced during the operative life of the present Olkiluoto and Loviisa units. Once all waste has been disposed of, the tunnels and shafts leading to the repositories will be filled and sealed.

Plant decommissioning

Plans are in place for the extension of the repositories for low- and intermediate-level operational waste, in order to enable the disposal of decommissioning waste as well. These decommissioning plans are updated every six years and the plants will be decommissioned after an operating life of around 50–60 years. Structures that have been either activated or contaminated during operation will be dismantled and taken into the final disposal facility. Such dismantling can be implemented fairly soon after decommissioning or after a few decades, in order to reduce radiation levels and thus facilitate the handling of the structures. After dismantling, the plant site can be used for other operations or, for example, as a site for a new power plant.

Interim storage of spent fuel

Spent nuclear fuel from NPPs is stored at the power plant sites until its disposal. In addition to the storage pools in the reactor buildings, the Loviisa NPP has basket-type and rack-type pool storage attached to the reactor building. Its current storage capacity will be adequate until the early 2010s, and additional capacity is planned through providing the pools with dense racks.



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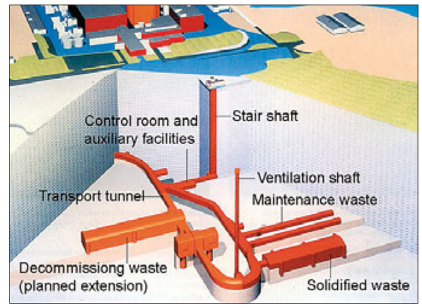
25 A cross-sectional view of the repository for low- and intermediate-level waste at Olkiluoto from the existing units and planned additional silos for Olkiluoto 3, and the possible new reactor unit Olkiluoto 4 as well as for decommissioning wastes from all units. Source: TVO.

26 A cross-sectional view of the repository for low- and intermediate-level waste in Loviisa and the planned extension for decommissioning waste. Source: Fortum.



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27 The access tunnel to the disposal facility for spent nuclear fuel under construction at Olkiluoto with the reactor units in the background. Source: Posiva.

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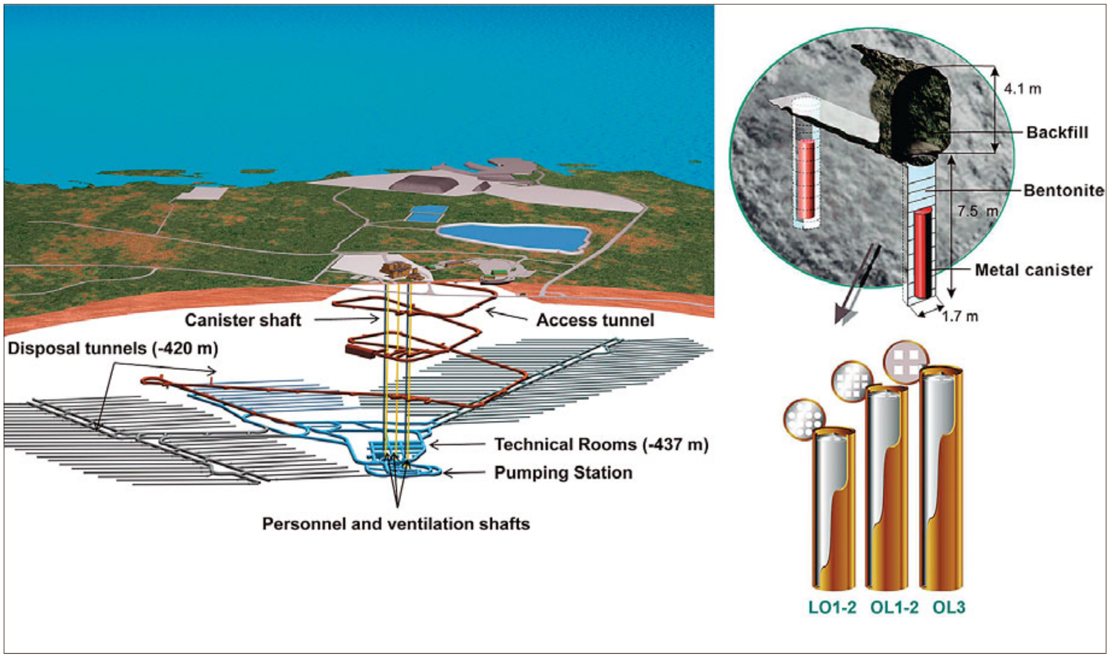

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28 An animated photograph of the repository for spent fuel at Olkiluoto. A schematic view of a final disposal tunnel for spent fuel at a depth of 500 metres. The canister alternatives for Loviisa 1–2, Olkiluoto 1–2 and Olkiluoto 3. The outer diameter of the canister is about one metre and its length 3.4, 4.4 or 5.2 metres. Source: Posiva.

At the Olkiluoto plant, the effective capacity (excluding reserves for repair work) of the pools in the reactor buildings is about 370 tU. Subsequently, the spent fuel is transferred to an on-site facility with three storage pools, the capacity of each being around 400 tU, with high-capacity fuel racks. The spent fuel storage facility was commissioned in 1987 and its current capacity will be adequate until the early 2010s. The construction of the extension of the interim storage facility, taking into account the storage needs of Olkiluoto 3 unit, is planned for completion during 2013.

Final disposal of spent fuel

In May 1999, Posiva Oy, which is responsible for the disposal of spent nuclear fuel, filed an application to the Government for a Decision in Principle (DiP) on the construction of a final disposal facility. In May 2001, the Finnish Parliament ratified by a clear majority the favourable DiP made by the Government in December 2000. The final disposal facility will be built on Olkiluoto, and will be used for disposing of the spent fuel from Finland's four current nuclear power plant units. In May 2002, alongside the decision on the fifth Finnish nuclear unit, Parliament also ratified a new DiP on the final disposal of the spent nuclear fuel of the fifth reactor unit. Thus, the spent fuel arising from the operation of the Olkiluoto 3 reactor will also be disposed of in the bedrock on Olkiluoto.

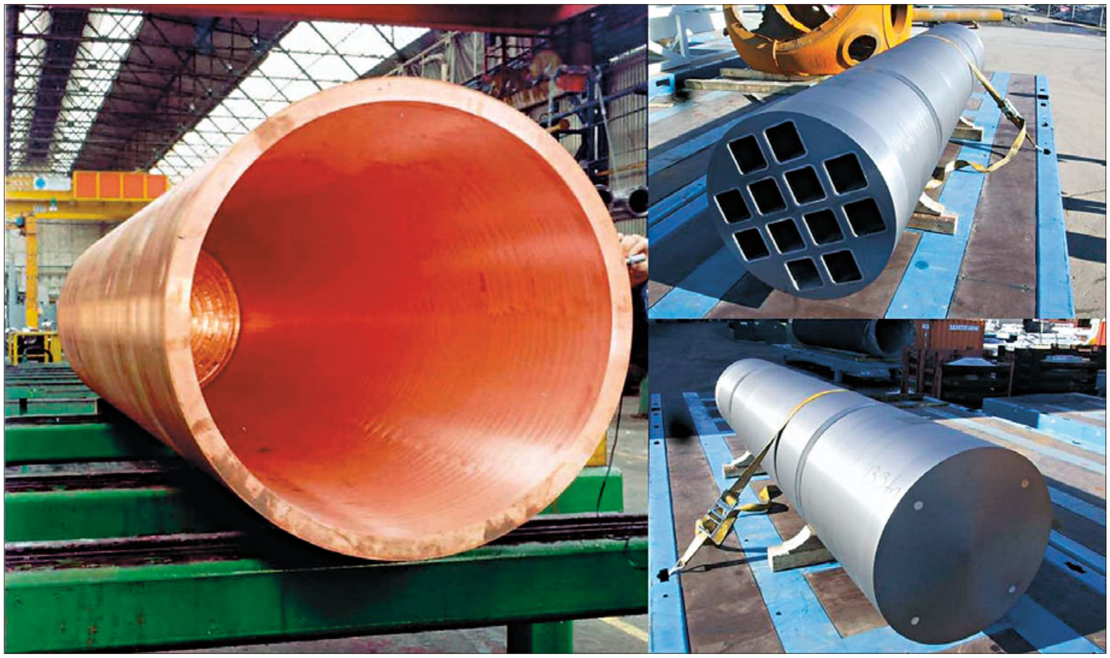
Similarly, in spring 2010 a new DiP concerning the disposal of spent fuel from the planned new reactor unit Olkiluoto 4 was made by the Government and ratified by the Parliament on 1 July 2010. Thus, the spent fuel arising from the operation of the Olkiluoto 3 and Olkiluoto 4 reactor units will also be disposed of in the bedrock on Olkiluoto. According to the present plan, Posiva Oy will submit a construction licence application for the encapsulation and geological disposal facility to be located on Olkiluoto by the end of 2012. The next licensing stage is the application and handling of the application for operation licence. The plan is to start the operation of the facility by the end of 2020.

During their 50 to 60 years in operation, the present Olkiluoto and Loviisa nuclear power units will produce a maximum of around 4,000 tonnes of spent fuel for final disposal. Spent fuel arising from the Olkiluoto 3 and Olkiluoto 4 units during their 60 year operative lifetime is estimated to total a maximum of around 2,500 tonnes each. Consequently the ratified DiPs for spent fuel arising from the operating reactors as well as from Olkiluoto reactor units 3 and 4 cover in total the disposal of some 9,000 tons of spent fuel in the spent fuel disposal facility on Olkiluoto.

The location of the encapsulation facility is presently planned to be in the same place as the underground disposal facility. In the encapsulation facility, the spent fuel rod assemblies are packed into watertight and airtight double-layered metal canisters. The fuel rod assemblies at the Olkiluoto and Loviisa reactor units differ in shape and length. However, all of the fuel element types can be packed in copper-cast iron canisters of a similar construction. The canister for Olkiluoto 1 & 2 is 4.4 metres long, the Loviisa canister 3.4 metres long and the canister for Olkiluoto 3 is 5.2 metres long. The canister diameter in each of these variants is the same.

The encapsulation plant contains a small interim storage for the canisters. Subsequently, the canisters are transferred into the repository, using either a lift with a radiation shield or via the access tunnel with a special vehicle.

The canisters can be positioned either vertically or horizontally in the repository at a depth of around 400 metres. Both options are under investigation. With the vertical option, the canisters are placed in holes drilled at the bottom of the repository tunnels, spaced a few metres from each other. They are then surrounded with bentonite clay.



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29 The components of a final disposal canister of a double-layered copper/cast iron construction. Source: Posiva.

30 Overall layout of the facility for underground rock characterisation (ONKALO).

31 Fund targets (for the existing 4 reactors) in the Nuclear Waste Management Fund and liabilities covered by securities. Beyond 2012 the data are illustrative and take into account both the use of funds for implementation and additional inputs until the closure of the reactors.

When the final disposal canisters have been placed in the repository, the encapsulation plant will be dismantled, the tunnels filled with a mixture of bentonite and crushed rock or with natural clay material, and the shafts leading to the repository closed. The underground repository will require no monitoring after it has been closed. After the facility has been closed and the above-ground structures have been dismantled, the land area can be used for new purposes.

Disposal of spent fuel is planned so that retrievability of the waste canisters is maintained. According to the plans, retrieval is possible at any stage in the final disposal process – including the phase after all the tunnels and shafts have been closed.

Underground rock characterisation facility

A deep underground rock characterisation and research facility (ONKALO) is under construction on the Olkiluoto site as part of the site confirmation investigations for spent fuel disposal. The excavation work for the ONKALO facility began in September 2004. The excavation works are now nearing completion. Unlike the generic rock laboratories, the ONKALO is being constructed at the actual repository site, and this means that the construction and operation of this facility should not cause major disturbances to the properties of bedrock that are important for the long-term safety. In addition, it should be possible to use the ONKALO later as a part of the repository. This means that the construction of the facility must comply with the rules and requirements applicable for nuclear facilities. Therefore a specific quality assurance programme has been launched for present activities.

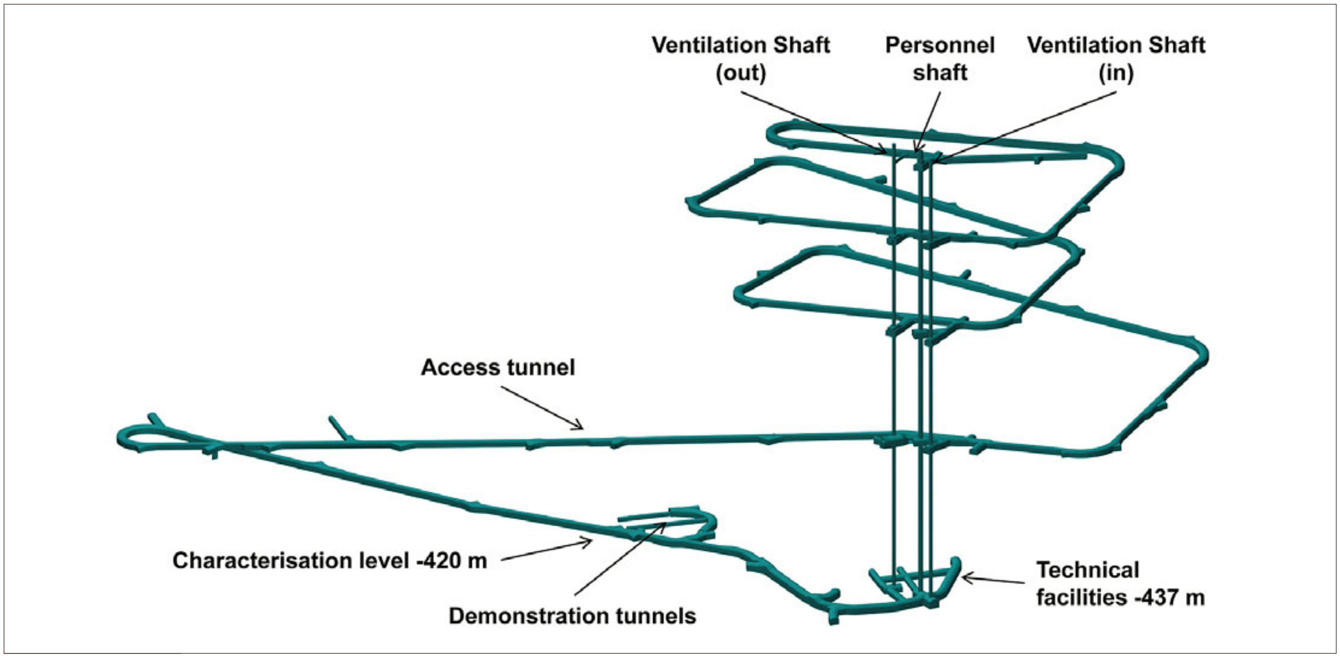
The original design and plans for the underground facility were reported in 2003. Since then, a number of changes have been made in the layout of the ONKALO access tunnel, and the number of access shafts has been increased from one to three. In addition, the layout and the depth of the auxiliary rooms at the main characterisation level have been updated to match current needs.

The main characterisation level is located at a depth of 420 metres, but some of the auxiliary rooms are deeper, at a depth of 437 metres. The excavation work will be completed by early 2012 and the rest of the construction work should be ready in 2014. The total underground volume of the ONKALO will be approximately 365,000 m³, the combined length of tunnels and shafts being 9.8 km. The access tunnel from the surface to the repository level consists of approximately 4.6 km of tunnelling with an inclination of 1:10. The shafts are excavated to the lower level. The personnel shaft will be equipped with a cage lift for personnel transport.

The plan has been drawn up for the safety case required for the application of the construction licence for a spent fuel disposal facility. According to the timetable set by the Ministry, all plans for the application will have to be finalised by 2012. The project plan aims at the phased development of the "safety case portfolio" through a number of successive report updates during the period 2005–2012, with the overall aim of having the repository operational in 2020.

The construction of the ONKALO underground rock characterisation facility is well underway. In April 2011, the tunnel length was 4,665 metres. The ventilation and personnel shafts have been raise-bored to a depth of 290 metres. Key challenges in the ONKALO work concern the limitation of disturbance to the host rock due to the excavation. A special programme has been launched to address the control of hydraulic disturbance and a new low-pH cementitious grouting material has been developed and tested and, depending on the outcome of the ongoing review process, will be used as a grouting material to limit the groundwater inflow to the tunnel and shafts.

In the joint SKB - Posiva project on the horizontal variant of KBS-3 ("KBS3H"), the testing and development of this



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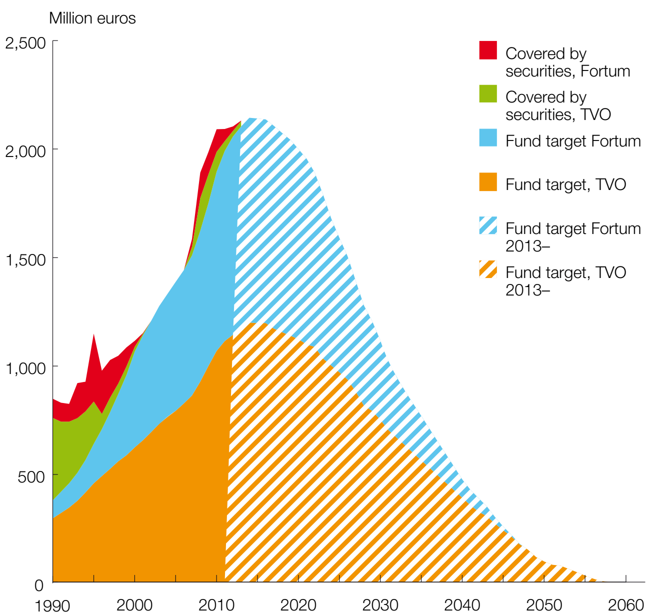

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alternative to the vertical reference concept ("KBS3V") is focusing on detailed design issues.

At the end of 2009, a number of important reports were submitted for review by the authorities. These included the new three-year RTD programme for 2009–2012 ("TKS2009"). A majority of the RTD work to be carried out during this three-year period will involve the disposal of spent nuclear fuel. The work includes the completion of the investigations for site confirmation conducted at the Olkiluoto repository site, the design of required facilities, and the development of the selected disposal technology to the level required for the construction licence application. It also includes the generation of a safety case relating to long-term safety for attachment to the construction licence application.

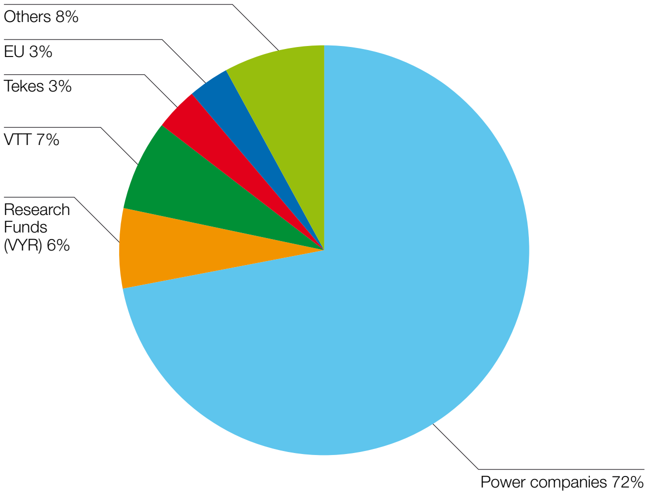
Simultaneously, the preparation of documents required for the licence application has commenced. Additionally, the surveys and studies carried out in the ONKALO underground research facility will expand to the areas surrounding the repository host rock. Several investigation niches will be excavated in ONKALO to enable the conduct of studies and tests at the disposal depth. The studies and tests conducted at the investigation site, above ground and in ONKALO, support not only site modelling but usually also the establishment of features specific to the investigation site.

A total of five investigation niches have been excavated in ONKALO for special experiments and characterisation efforts. The investigations to be conducted in the niches cover, among other things, the following topics: bentonite studies, the properties of the excavation damage zone (EDZ), rock mechanics investigations, detailed hydrogeological investigations, and investigation into the retention properties of intact rock.

The cost of nuclear waste management

To ensure that the financial liability is covered, each year the utility companies must present cost estimates for the future management of nuclear waste. At the end of 2010, the total liability of the utilities was around EUR 2,100 million and the total fund target for 2010, based on existing waste quantities and including the decommissioning of NPPs, amounted to around EUR 1,900 million with no discounting.

The utility companies are obliged to set aside a certain amount of money each year for the State Nuclear Waste Management Fund. At the end of 2010, the funding covered most of the liability and around EUR 220 million was covered by securities. The administrative procedures are described in detail within the nuclear energy legislation in force. Roughly speaking, the cost of nuclear waste management, including the disposal of all arising waste and the dismantling of the power plants and other nuclear facilities, is around 10 per cent of the total power production cost.



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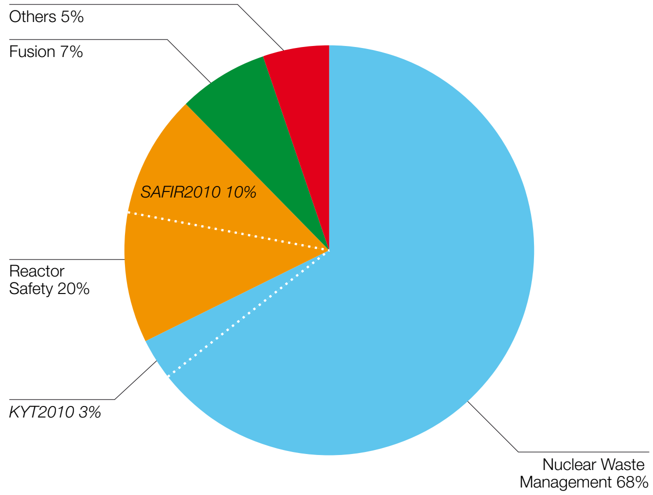

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R&D and education

Finnish nuclear energy research has been decentralised among several research units and groups, which operate within different state research institutes, universities, and in utilities and consultancy companies. The focus of nuclear R&D is on the safety and operational performance of the power plants, and the management and disposal of waste. Publicly funded nuclear energy research, on the other hand, provides impartial expertise in nuclear energy issues, contributes to maintaining the necessary personnel and equipment for research and development, and has established a framework for international collaboration.

The total annual funding (in 2011) of Finnish research into nuclear fission and fusion energy is estimated at about EUR 73.5 million. In late 2003, the Nuclear Energy Act was amended to secure funding for long-term nuclear safety and nuclear waste management research in Finland. The necessary financing is collected annually from licence holders, and is allocated to two special funds devoted to this purpose. These research funds are aimed at ensuring a high scientific-technical level for national safety research and maintaining national competencies in the long run. For reactor safety research, the amount of finance is proportional to the thermal power of the licensed plant, the thermal power presented in the Decision in Principle application or the construction licence application. For waste research, payments are proportional to the fund targets in the Nuclear Waste Management Fund. The total annual volume of these research funds for reactor safety and nuclear waste management is currently around EUR 7 million.

In 2010 the Ministry of Employment and the Economy initiated a working group to address nuclear energy-related human resource and infrastructure questions in Finland. The group will publish its report in October 2011, in Finnish and English. A query posed by the working group shows that the number of nuclear safety specialists in 2011 is 1,600 persons,

32 FUNDING SOURCES The annual funding (2010) for national nuclear energy research is about EUR 73.5 million in total. Financing paid into funds for reactor safety and nuclear waste management research is collected from the operators of the nuclear power plants.

33 RESEARCH AREAS Funding (2010) for different research areas of nuclear energy research (around EUR 73.5 million in total per year). The shares of the national research programmes, funded to a large extent from the dedicated research funds, are indicated for reactor safety (SAFIR2014) and nuclear waste management (KYT2014). The sector 'others' includes environmental impacts, research reactor and radiation protection.

whereas in 2000 there were 500. The ongoing nuclear projects are behind this sharp increase in human resources.

Research institutes and units

Finland has no institutes dedicated solely to nuclear research. Most research takes place at VTT Technical Research Centre of Finland. Other major research institutes include Aalto University and Lappeenranta University of Technology (LUT), the Geological Survey of Finland (GTK), the Finnish Meteorological Institute and the universities of Helsinki and Jyväskylä and Tampere University of Technology. In addition, the Radiation and Nuclear Safety Authority (STUK) and the power companies Fortum, TVO and Posiva Oy carry out internal research, or finance research at research institutes or universities.

The versatile array of research subjects at research institutes and universities promotes spin-off and spin-in relationships with other industries. Spin-offs include simulation technologies, reliability engineering, fracture mechanics, and non-destructive testing, while spin-in benefits have been enjoyed in areas such as human factors, digital automation systems and computational fluid dynamics.

Research programmes

The Finnish public nuclear energy research is organised into national research programmes. These research programmes mainly operate on the basis of funding provided by the dedicated funds (for reactor safety and nuclear waste management) described above. Additional funding is provided by Tekes, the Finnish Funding Agency for Technology and Innovation, VTT's basic funding and the European Union.

The main objective of these programmes is to provide the authorities with high-standard expertise and research outcomes relevant to the safety of nuclear power plants and waste management and disposal, and to support the various activities of the authorities. In addition, these programmes train new nuclear experts and promote technology and information transfer.

The current national research programmes on nuclear energy are as follows:

- National Nuclear Power Plant Safety Research (SAFIR2014), 2011–2014
- Finnish Research Programme on Nuclear Waste Management (KYT2014), 2011–2014
- Euratom – Tekes Fusion Energy Cooperation, 2007–2011

SAFIR2014 is the Finnish public research programme (http://safir2014.vtt.fi) on nuclear power plant safety coordinated by VTT Technical Research Centre of Finland. The programme has been divided into nine research areas: 1. Man, Organisation and Society, 2. Automation and Control Room, 3. Fuel Research and Reactor Analysis, 4. Thermal Hydraulics, 5. Severe Accidents, 6. Structural Safety of Reactor Circuits, 7. Construction Safety, 8. Probabilistic Risk Analysis (PRA) and 9. Development of Research Infrastructure.

The framework plan for SAFIR2014 covers the period 2011–2014 in particular, but it is based on safety challenges identified for a longer time span as well. Olkiluoto 3, the new nuclear power plant unit under construction and new Decisions in Principle have also been taken into account in the plan. The safety challenges set by the existing plants and the new projects, as well as the ensuing research needs do, however, converge to a great extent. The construction of new power plant units will increase the need for experts in the field in Finland. At the same time, of course, the retirement of existing experts continues. These factors combined will call for more education and training, in which active research efforts play a key role. This situation also provides long-term safety research with a great challenge. The annual volume of SAFIR 2014 in 2011 is 64 person-years and the total funding EUR 9.6 million.

KYT2014 is the Finnish public research programme (http://kyt2014.vtt.fi) on nuclear waste management coordinated by VTT Technical Research Centre of Finland. The contents of the KYT2014 Research Programme comprise key research subjects in terms of national expertise. These include new and alternative nuclear waste management technologies, research into the safety of nuclear waste management and sociological research related to the issue. Through this research programme, the aim is to assemble extensive, coordinated safety research wholes, particularly with respect to research on the capacity of buffer and backfilling materials in final disposal, the long-term durability of the final disposal canister, and the safety case. The annual volume of KYT 2014 in 2011 is about 24 person-years and the total funding EUR 2.8 million.

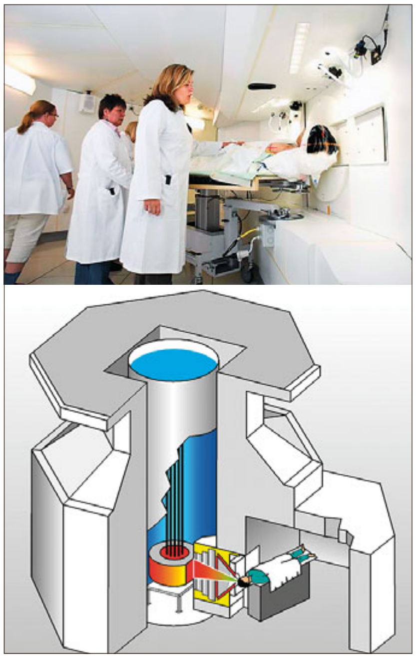
Studies directly related to licensing issues are excluded from this programme in order not to jeopardise the expected neutrality of the research. Outside this programme, the industry is conducting or financing separate R&D activities on a much larger scale on nuclear waste management, especially on spent fuel disposal.

The Ministry of Employment and the Economy (MEE) nominates separate steering groups for the SAFIR2014 and KYT2014 programmes. The total annual volume of these national research programmes on nuclear fission energy is about 90 person-years during 2011. Nuclear fusion research comprises about 50 person-years annually.

Tekes is funding the Euratom – Tekes Fusion Energy Cooperation to the tune of around EUR 22 million in total for the period 2007–2011. From this, the yearly allocation for research will be EUR 1.4 million, the rest being intended for the support of industrial activities and coordination. This work is intended to cover all fusion energy research in Finland. These research activities are fully integrated with the European Fusion Programme through the Contract of Association between Tekes and Euratom. Association Euratom – Tekes is one of the 23 Fusion Associations of the European Fusion Programme in the EU Framework Programme. The Multilateral European Fusion Development Agreement (EFDA) and bilateral Contracts of Associations are the main tools for steering fusion research activities in Europe. The main research areas include: 1. Fusion Plasma Physics, 2. Plasma-Wall Interactions, 3. Reactor Materials Research, 4. Development of Superconducting Wires, 5. Remote Handling Systems, and 6. System Studies.

In the area of new generation nuclear reactor systems, VTT has participated in the EU's framework programme projects under the area of new innovative systems. One example of this is the past project "High Performance Light Water Reactor (HPLWR 1&2)". In addition, in the KYT2014 research programme, restricted activities are carried out in the area of advanced fuel cycle concepts – primarily the follow-up of research activities on partitioning and transmutation. Based on the initiative of the former Advisory Group on Nuclear Energy (YEN), the research network (GEN4FIN) on advanced nuclear energy systems was established in 2005. The aim of this research network is the further promotion of the maintenance and development of national expertise and international cooperation.

Within the Academy of Finland's research programme "Sustainable Energy (SusEn)", a joint effort "New Type Nuclear Reactors (NETNUC)" started in early 2008 by a consortium comprising the Lappeenranta University of Technology (LUT), Aalto University and VTT Technical Research Centre of Finland. Fortum is providing additional funding for this joint project. The research work aims to contribute to the validation of the following hypotheses: (1) Key phenomena affecting



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34 Boron Neutron Capture Therapy (BNCT) is used for treating head and neck tumours at the research reactor of VTT Technical Research Centre of Finland in cooperation with the Helsinki University Central Hospital (HUCH) and jointly with other associates of the Finnish BNCT Consortium.

the safety of new types of reactors are understood thoroughly, enabling the creation of systematic safety criteria that ensure the adequate safety and security of the reactors and fuel cycle facilities (Safety), (2) Advanced reactors and the associated fuel cycles can be developed that utilise more abundant natural isotopes and increase the effectiveness of fuel resource usage and produce less high-level nuclear waste (Sustainability) and (3) New types of reactors can be developed in international cooperation (SCWR, VHTR, GFR, SFR, LFR), capable of producing energy effectively and economically for electricity, process heat and hydrogen yields in cogeneration processes (Efficiency). The NETNUC research programme will be completed by the end of 2011.

VTT, TVO, Fortum and Lappeenranta University of Technology are partners in the Sustainable Nuclear Energy Technology Platform (SNE-TP). The objectives of the platform coincide with many aspects of the NETNUC project. Consequently, SAFIR2014 and NETNUC both contribute to the objectives of SNE-TP, which cover both the present and advanced light-water reactors (e.g. EPR) and fast reactors with a closed fuel cycle, which is crucial to the long-term sustainability of nuclear fuel resources. SNE-TP also covers the production of other energy carriers besides electricity. Consequently, participation in this technology platform ensures close networking with other European stakeholders and research organisations. The NETNUC project has been closely connected with EU projects (e.g. HPLWR2 for the SCWR concept and Raphael for VHTR/GFR gas-cooled concepts) and other global forums.

Another important Technology Platform is Implementing Geological Disposal of Radioactive Waste (IGD-TP). The mission of the IGD-TP is to be a tool to support confidence-building in the safety and implementation of deep geological disposal solutions. The vision of IGD-TP is that by 2025, the first geological disposal facilities for spent fuel, high-level waste and other long-lived radioactive waste will be operating safely in Europe.

Academic education in the field of nuclear energy

Annually, 10–20 students pass the basic academic degree (Master of Science) in the subject of nuclear energy. However, the need for nuclear engineer graduates will increase due to the requirement to create a new generation of experts and the development of the possible new nuclear power plant projects. Academic postgraduate degree programmes for a licentiate or doctorate degree in nuclear energy are available at four universities in Finland.

1. Aalto University, School of Science, Department of Applied Physics

The teaching of nuclear power technology at Aalto University takes place in the Department of Applied Physics. The Department educates students in 'alternative' energy sources: nuclear energy (fission and fusion) as well as renewable energy sources such as wind and solar power. The main research subjects are radiation and reactor physics and fusion technology. The unit has a radiation measurement laboratory and also makes use of the Triga Mark II training and research reactor of the VTT Technical Research Centre of Finland, located in the campus area of Otaniemi in Espoo, as well as VTT's hot cells and radiochemical laboratory.

2. Lappeenranta University of Technology, LUT Energy, Laboratory of Nuclear Engineering and Nuclear Safety Research Unit

In LUT the Degree Programme in Energy Technology aims to provide students extensive knowledge of different fields of energy industry. There is a one-of-a-kind possibility to study nuclear engineering with a wide spectrum of ten courses including e.g. reactor physics, thermal hydraulics, radiation safety, fuel cycle, reliability, waste management. Vivid international contacts prevail in the main research area of nuclear power plant safety, with a special focus on experimental thermal hydraulics as well as on numerical modelling of nuclear

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35 The eighth national training course (YK8) began in October 2010 at Lappeenranta University of Technology, Photo: Timo Mikkola, LUT.

36 Professor Riitta Kyrki-Rajamäki, LUT, Petri Peltonen, Director General of the Ministry of Employment and the Economy and Tapio Kuula, CEO of Fortum in the inauguration ceremony of the new integral test facility PWR PACTEL of the Nuclear Safety Research Unit at Lappeenranta University of Technology, 27 May 2010. Source: LUT.

power plants. In LUT there are versatile large-scale integral and separated effect test facilities available.

3. University of Helsinki, Department of Chemistry, Laboratory of Radiochemistry

Radiochemistry is one of seven branches of chemistry taught at the University of Helsinki. Students attend about three years of basic courses in inorganic, organic and physical chemistry, concluding with specialised studies in radiochemistry for a minimum of two years. The main areas of research include the management and final disposal of radioactive waste, environmental radiochemistry, the cleaning of effluents with ion exchangers and radiation chemistry.

4. University of Jyväskylä, Department of Physics

Nuclear physics is one of the main teaching and research areas at the Department of Physics. Several courses from introductory level to advanced graduate level are offered in basic and applied nuclear physics, transport problems related to nuclear waste management, radiation safety and applications of nuclear techniques in material science. In the near future, a dedicated Master's programme will be introduced in relation to nuclear energy and waste management. The department hosts a major international accelerator facility with heavy-ion and proton cyclotrons and an electrostatic accelerator, and extensive laboratory facilities for measurements of the transport of tracers in and the structural properties of (porous) media. It also participates actively in international EURATOM-supported networks on nuclear data for nuclear energy applications.

National training courses in nuclear safety (YK courses)

A key objective of the national research programmes on nuclear energy is to train new nuclear experts to meet the requirements for additional human resources owing to the Olkiluoto 3 project, the new NPPs planned to be built by TVO and Fennovoima and to the large number of experts currently in the field who will retire within the next decade. Changes in energy markets and the rapid development of technology will set new challenges with respect to the required knowledge, and this will require a special focus from all parties. Between 2003 and 2011, eight training courses on nuclear safety technology of 5–6 weeks in duration have already been provided in order to train newcomers to the nuclear field, in the form of specific cooperation between all nuclear-related organisations. Around 460 young experts and newcomers were trained through these eight courses. A decision has already been made to offer the course for the ninth time in 2011/2012. Training materials that can be used by the organisations as part of their internal training programmes are developed as appropriate.

Nuclear energy cooperation

Finland actively participates in international cooperation regarding nuclear energy as the development and deployment of the next generation of nuclear power technology is increasingly becoming an international exercise. International collaboration is expected to create considerable efficiencies in developing and deploying new technologies worldwide.

In recent years, the recognition of these trends has led to the development of several multinational initiatives, both for research and other purposes, and there is a call for still more initiatives. Major initiatives now underway or in the early stages of implementation include: the Generation IV International Forum (GIF) led by the USDoE, the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), the Global Nuclear Energy Partnership (GNEP), Multinational Design Evaluation Program (MDEP) and the Multinational Fuel Assurance Concept (MNA) proposed by the IAEA.

At a European level, the latest Nuclear Illustrative Programme (PINC) from 2007 underlines the need to develop common instruments within the framework of nuclear safety. The European Commission has already launched a number of initiatives in the field of nuclear safety, waste management and decommissioning, such as recommendations on the financing of decommissioning activities, the establishment of a Sustainable Nuclear Energy Technology Platform (SNE-TP) and the establishment of the European Nuclear Safety Regulator's Group (ENSREG), which is composed of national nuclear regulators for the further development of a common understanding and European rules in the field of nuclear safety and waste management.

As a result, Council Directive 2009/71/Euratom, which established a Community-wide framework for the safety of nuclear installations, was introduced in June 2009. In November 2010, the Commission proposed a Directive on spent fuel and radioactive waste management.

The Sustainable Nuclear Energy Technology Platform (SNE-TP), launched in September 2007, aims at coordinating research, development, demonstration and deployment (RDD&D) in the field of nuclear fission energy. It gathers together stakeholders from industry, research organisations including Technical Safety Organisations (TSO), universities and national representatives. Regarding joint infrastructures, the recently launched Jules Horowitz Reactor (JHR) material testing reactor project will, in the short term, support studies on generation II and III light water reactors on aging and life extension, safety and fuel performances, and support material and fuel developments for generation IV reactors. The reactor will be located in Cadarache, France, and VTT will be actively involved in the planning and design of this facility.

The Strategic Research Agenda and the Deployment Strategy of SNE-TP reflect a consensus among a large group of stakeholders on research priorities in the field of nuclear fission, addressing the renaissance of nuclear energy with the deployment of generation III reactors, and the development of generation IV systems, both fast neutron reactor systems with fuel multi-recycling for sustainable electricity-generating capability and (Very) High Temperature Reactors for other applications, such as the production of hydrogen or biofuels.

Important issues such as the safety of nuclear installations and the responsible management of waste are also addressed, as well as other issues which are crucial to the success of nuclear energy in the 21st century: education and training, research infrastructures, material research and numerical simulation, and funding. The Strategic Research Agenda includes a roadmap for all European nuclear fission research up to 2040.

In 2007, the European Parliament adopted the report "Conventional Energy Sources and Energy Technology". The Report

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demonstrates a growing political consensus that nuclear energy "is indispensable if Europe's medium and long-term energy needs are to be met."

In November 2007, the European Commission published the Strategic Energy Technology Plan (SET-Plan). This plan aims at increasing the use of low-carbon technologies to meet the targets set by the European Council in March 2007 of a 20 to 30 per cent CO_2 emission reduction and a 20 per cent increase in renewables by 2020. These "clean" technologies include not only renewables, but also sustainable nuclear fission energy and carbon capture and storage (CCS). The document recognises that nuclear power is a key part of EU energy policy and, alongside other low-CO_2 energy sources, contributes to forging the EU's low-carbon economy.

In January 2008, the Commission proposed a legislative package (the so-called climate and energy package) including more detailed provisions on emission targets, the emission trading scheme and the promotion of renewable energy sources.

Besides the activities launched by the Commission, Finnish organisations participate actively in other efforts to further the international harmonisation of nuclear safety standards. The bases for this harmonisation should be enhanced cooperation conducted in association with the follow-up conferences on the two important IAEA conventions: the Nuclear Safety Convention and the Joint Convention on the Safety of Spent Fuel Management, as well as IAEA-published documents such as the Safety of Radioactive Waste Management and the preparation of the Nuclear Safety Guidelines. Other work currently being performed, such as that by the Western European Nuclear Regulators Association (WENRA), provides a vital additional contribution. In addition, new initiatives such as the Multinational Design Evaluation Programme (MDEP), may contribute to the convergence of national regulatory practices.

37 The Council of State (Government) holds its meetings in the Senate Building.

Nuclear safety cooperation in Eastern Europe

Political and economic changes in Eastern Europe quickly led to extensive international cooperation, in order to improve the safety of nuclear power plants based on Soviet technology. Finnish organisations have been involved in several international projects aimed at the improvement of radiation and nuclear safety and safeguards. Finland's bilateral technical and financial support has mainly been directed at its neighbouring areas. Finland's bilateral cooperation and support programme, co-ordinated by the Radiation and Nuclear Safety Authority (STUK), focuses on the safety of nuclear power plants, the control of nuclear materials and nuclear waste management.

In addition to STUK, other participants in the cooperation include Fortum, VTT Technical Research Centre of Finland and Teollisuuden Voima. Fortum has implemented commercial cooperation projects and the EU-funded improvement of nuclear safety. Other programmes funded by the Finnish Government operate in the areas of safeguards and long-term and responsible nuclear waste management. The power companies, VTT and STUK are participating in joint programmes funded by the EU in Russia, Ukraine and Armenia. These programmes aim to improve the safety of nuclear facilities in practice and to give assistance to nuclear energy authorities in these countries in developing their regulatory organisation, practices and regulations.

International agreements

Finland is a member state of the following intergovernmental organisations, among others:

- International Atomic Energy Agency (since 1958),
- Nuclear Energy Agency of the OECD (since 1976),
- International Energy Agency (since 1992).

Finland is party among others to the following international conventions (the year when the convention entered into force for Finland is given in brackets):

- Treaty on the Non-proliferation of Nuclear Weapons; adopted in London, Moscow and Washington on 1 July 1968 (1970)
- Convention on the Physical Protection of Nuclear Material; opened for signature in Vienna and New York on 3 March 1980 (1989)
- Convention on Early Notification of a Nuclear Accident; opened for signature in Vienna on 26 September 1986 (1987)
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency; opened for signature in Vienna on 26 September 1986 (1990)
- Convention on Third Party Liability in the Field of Nuclear Energy; adopted in Paris on 29 July 1960 (1972)
- Convention Supplementary to the Paris Convention of 29 July 1960 on Third Party Liability in the Field of Nuclear Energy; adopted in Brussels on 31 January 1963 (1977)
- Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material; adopted in Brussels on 17 December 1971 (1991)
- The 1988 Joint Protocol Relating to the Application of the Paris Convention and the Vienna Convention; adopted in Vienna on 21 September 1988 (1995)
- Convention on Nuclear Safety; opened for signature in Vienna on 20 September 1994 (1996)
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, adopted on 29 September 1997 in Vienna (2001)

In addition, Finland has adopted bilateral and regional agreements, for example:

- Nordic Mutual Emergency Assistance Agreement in Connection with Radiation Accidents; adopted in Vienna on 17 October 1963 (1965)
- Agreement on common Nordic guidelines on communications concerning the siting of nuclear installations in border areas; adopted on 15 November 1976 (1976)
- Agreement between Finland and Sweden on the guidelines to be followed while exporting nuclear material, technology or equipment, 4 March 1983 (FTS 20/1983)
- Agreements relating to early notification of nuclear events and exchange of information on safety of nuclear facilities with Denmark (1987), Norway (1987), Sweden (1987), Germany (1993), the Russian Federation (1996) and Ukraine (1996)
- Convention on Environmental Impact Assessments in a Transboundary Context (Espoo, 1991)

As of 1 January 1995, Finland has been a member of the European Atomic Energy Community (EAEC or Euratom). Consequently, the following agreements are applied in Finland:

- Agreement between the European Atomic Energy Community and the Government of Canada for Cooperation in the Peaceful Uses of Atomic Energy, 6 October 1959
- Agreement between the Government of Australia and the European Atomic Energy Community Concerning Transfers of Nuclear Material from Australia to the European Atomic Energy Community, 21 September 1981
- Agreement for Cooperation in the Peaceful Uses of Nuclear Energy Between the European Atomic Energy Community and the United States of America, 12 April 1996
- Agreement for Cooperation in the Peaceful Uses of Nuclear Energy Between the European Atomic Energy Community and the Government of Japan, 27 February 2006
- Agreement Between the European Atomic Energy Community and the Cabinet of Ministers of Ukraine for Cooperation in the Peaceful Uses of Nuclear Energy, 28 April 2005
- Agreement for Cooperation in the Peaceful Uses of Nuclear Energy Between the European Atomic Energy Community and the Government of the Republic of Kazakhstan, 4 December 2006
- Agreement Between the Non-nuclear Member States of the EAEC and the IAEA in connection with the Treaty on the Non-proliferation of Nuclear Weapons, 5 April 1973 (1995)
- Protocol Additional to the Agreement Between the Non-nuclear Member States of the EAEC, the EAEC and the IAEA in the implementation of Article III, (1) and (4) of the Treaty on the Non-proliferation of Nuclear Weapons, 22 September 1998.

Legislation

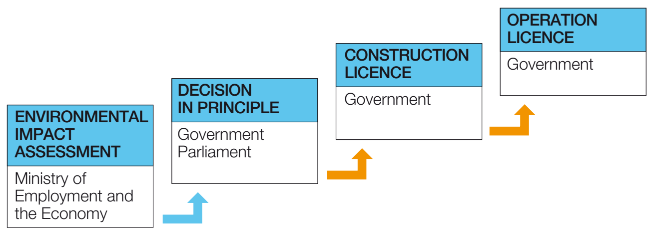
The Nuclear Energy Act (990/1987) and the Nuclear Energy Decree (161/1988) give Parliament final authorisation to permit the building of new major nuclear installations, including final disposal facilities for nuclear waste. The Act and the Decree also define the licensing procedure and conditions for the use of nuclear energy, including waste management, as well as the responsibilities and powers of the authorities. Each producer of nuclear waste in Finland is responsible for the safe handling, management and disposal of waste and for meeting the costs of the related operations. The funds required for future nuclear waste management must be raised gradually throughout the plant's operating period.

The requirements provided in the Nuclear Energy Act and Decree are specified in several general regulations laid down by specific decrees issued by the Government. During 2007–2008, major amendments to legislation related to nuclear energy were prepared. The amended Nuclear Energy Act is in force since June 2008 after the approval by the Parliament. The main reason for the changes has been the requirement under the amended constitutional law that certain key requirements be presented within the Nuclear Energy Act in place of the previous practice, based on which many of these requirements were set in lower level regulations, such as Government decisions.

These decisions have now been replaced by decrees issued by the Government under the following topics: 1. General safety regulations for nuclear power plants; 2. General regulations concerning the physical protection in the use of nuclear energy; 3. General regulations concerning emergency preparedness for nuclear power plants; 4. General safety regulations for the safety of the final disposal of nuclear waste (spent fuel and low- and intermediate-level operational and decommissioning waste from nuclear installations).

The detailed Finnish licensing requirements for nuclear installations are outlined in the STUK regulatory guidelines (YVL Guidelines). An amendment process for these regulatory guides is also underway and both the general structure of the guideline system and the topics and number of individual regulatory guidelines are undergoing major changes. The aim is to complete this amendment process by the end of 2011.

The Radiation Act (592/1991) establishes the conditions for preventing and limiting the harmful effects of radiation on the health of workers and the general public. The latest amendments to the Radiation Act and Decree were made at the end of 2005, to reflect the EU Directive on the control of high activity sealed radioactive sources.



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38 The decision-making process for the construction of a nuclear facility.

The Nuclear Liability Act (484/1972 & 588/1994) implements the Paris Convention on the Third Party Liability in the Field of Nuclear Energy and the Brussels Supplementary Convention. Furthermore, the amendment of 1994 adopts the Joint Protocol bridging the Paris and Vienna Conventions. Due to the negotiations for the updating of the Paris and Brussels Conventions on Nuclear Liability and their successful completion in early 2004, the Finnish Nuclear Liability Act was also reviewed. The review process began with the examination of amendments required by a special governmental committee and was followed by the drafting of a bill to amend the Nuclear Liability Act by the Government. The bill was approved by Parliament in the spring of 2005. These amendments include unlimited financial liability to licensees and a requirement that the licensee has to acquire insurance to cover damages of up to EUR 700 million. The entry into force of this bill has been pending the ratification by the Parties of the 2004 Protocol to Amend the Paris Convention. Meanwhile, the Finnish Parliament has approved amendments to the law, increasing the amount of insured damages up to EUR 700 million and introducing unlimited financial liability nationally. These amendments will come into force on 1 January 2012.

The Act on Environmental Impact Assessment (468/1994) provides that environmental impact assessments (EIA) be compulsory for nuclear facilities.

Several other laws under general legislation also affect nuclear power production, e.g.

- The Electricity Market Act (386/1995) opened up access to distribution networks and allows foreign ownership in electricity supply.
- The Act on Competition Restrictions (480/1992) is compatible with the EC law on competition.
- The Land Use and Building Act (132/1999) requires a land use plan for power plants and other facilities to be built on plant sites and provides guidelines for their planning.
- The Environmental Protection Act (86/2000) lays down various requirements relating to environmental protection.
- Completely revised Mining Act was accepted by Parliament on 15 March 2011 and will enter into force on 1 July 2011.

The decision-making process for the construction of a nuclear facility (e.g. a power plant or a final disposal facility) includes several stages. First, the operator carries out an environmental impact assessment (EIA) on the construction and operation of a nuclear facility. Thereafter, the operator files an application to the Government to obtain a Decision in Principle (DiP) on a new nuclear facility. The EIA report must be attached to this application. In handling the DiP application, the Government requests a preliminary safety appraisal from the Radiation and Nuclear Safety Authority (STUK) and a statement from the municipality intended as the site of the planned nuclear facility.

The municipality holds a right of decisive veto against new facilities. In addition, the Government requests statements from several other authorities and the related bodies, and organises local consultation for the residents of the local and neighbouring municipalities of the intended facility. The Ministry of Employment and the Economy is responsible for preparing the decision and the Government then prepares a DiP on whether the construction of the facility is, or is not, in line with the overall interests of society. It then submits the possible affirmative DiP to be ratified by Parliament. In cases where the DiP is affirmed, in due course the operator applies for a construction licence from the Government. The Government requests all of the relevant statements and decides on whether to issue a licence for the construction of the nuclear facility. Towards the end of the construction, the operator applies for an operating licence for the facility. After it has received the necessary official statements, the Government decides on whether to issue such an operating licence.

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Regulatory authorities

TYÖ- JA ELINKEINOMINISTERIÖ
ARBETS- OCH NÄRINGSMINISTERIET
MINISTRY OF EMPLOYMENT AND THE ECONOMY

39 Radiation and Nuclear Safety Authority in Eastern Helsinki. Source: STUK.

40 A versatile mobile measurement and analysis laboratory, Sonni, is available for the on-site surveillance of an actual radiation situation (the word 'sonni' in Finnish means 'bull'; here an abbreviation of Sophisticated On-site Nuclide Identification). Source: STUK.

Ministry of Employment and the Economy

The Ministry of Employment and the Economy (MEE) is responsible for the overall supervision of the use of nuclear energy. The drafting of legislation, the implementation of international agreements in Finland, the supervision of the planning and realisation of nuclear waste management and the administration of the State Nuclear Waste Management Fund constitute a significant part of the Ministry's duty in the nuclear field.

The Ministry supervises research and development work carried out in the field of nuclear safety. Its principal objective is to ensure a high level of safety and operating reliability at existing nuclear power plants and to support the safe and appropriately timed implementation of nuclear waste management.

The Ministry represents Finland within the European Atomic Energy Community, the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the OECD, and the Nordic Nuclear Safety Research Programme (NKS). The Energy Department of the Ministry prepares the Government's and Ministry's decrees and decisions on nuclear energy.

STUK

Radiation and Nuclear Safety Authority

The Radiation and Nuclear Safety Authority (STUK) is the authority and expert in radiation and nuclear safety in Finland. It interprets requirements laid down by law and supervises their implementation. The objective of STUK's activities is to maintain Finnish radiation and nuclear safety at a high level and to act as a trendsetter in the development of a safety culture in society in general.

The power company operating a nuclear power plant is always responsible for the plant's safety. It is the duty of STUK to supervise all activities, from the design of the plants to their decommissioning. In this its objective is to ensure the safety of nuclear facilities so that their operation does not cause a radiation hazard to the health of workers or nearby residents, or other damage to the environment or property.

The key safety and quality target of nuclear safety control is to ensure that the safety level achieved in the use of nuclear energy is at best maintained – and increased as far as possible, and to contribute to the development of an excellent safety culture in the use of nuclear energy. These targets are aspired to, for example, by formulating detailed regulations, through the continuous assessment of the safety of operations, and by making inspection visits to the plants.

STUK also supervises Posiva's research, development and planning work for the final disposal of spent nuclear fuel and the activities of the nuclear power companies in the treatment, storage and final disposal of low- and intermediate-level reactor waste. In addition, STUK controls the safety of the transportation of nuclear waste and radioactive materials.

Furthermore, STUK supervises nuclear materials in order to ensure that they are not used for anything other than peaceful purposes. Nuclear materials in Finland are also controlled by the European Union and the International Atomic Energy Agency (IAEA).

Contact information

NATIONAL NUCLEAR ENERGY AUTHORITIES

Ministry of Employment and the Economy (MEE)
Energy Department
P.O. Box 32
FI-00023 GOVERNMENT
Tel. +358 10 606 000
www.tem.fi

Radiation and Nuclear Safety Authority (STUK)
P.O. Box 14
FI-00881 HELSINKI
Tel. +358 9 759 881
www.stuk.fi/english/

NUCLEAR ADVISORY BODIES

Advisory Committee on Nuclear Safety (YTN)
c/o Radiation and Nuclear Safety Authority (STUK)
P.O. Box 14
FI-00881 HELSINKI
Tel. +358 9 759 881

Advisory Committee on Nuclear Security
c/o Radiation and Nuclear Safety Authority (STUK)
P.O. Box 14
FI-00881 HELSINKI
Tel. +358 9 759 881

OTHER NATIONAL AUTHORITIES

Ministry for Foreign Affairs
(Non-proliferation of nuclear weapons and international agreements)
www.formin.finland.fi

Ministry of Social Affairs and Health
(Administrative authority for the use of radiation)
www.stm.fi

Ministry of the Environment
(Protection of the environment in normal and accident situations)
www.ymparisto.fi

Ministry of the Interior
(Protection of population in emergency situations)
www.intermin.fi

NUCLEAR ENERGY INDUSTRY

Fortum Power and Heat Oy (FPH)
Loviisa Nuclear Power Plant
P.O. Box 23
FI-07901 LOVIISA
Tel. +358 10 455 5011
www.fortum.com/loviisa

Teollisuuden Voima Oyj (TVO)
(Operator of Olkiluoto NPP)
FI-27160 EURAJOKI
Tel. +358 2 83811
www.tvo.fi/eng

Posiva Oy
FI-27160 EURAJOKI
Tel. +358 2 837 231
www.posiva.fi/en

Fennovoima Oy
Salmisaarenaukio 1
FI-00180 HELSINKI
Tel. +358 20 757 9200
www.fennovoima.fi

Talvivaara Sotkamo Oy
FI-88120 Tuhkakylä
Tel. +358 20 712 9800
www.talvivaara.com

RESEARCH INSTITUTES

VTT Technical Research Centre of Finland
P.O. Box 1000
FI-02044 VTT
Tel. +358 20 722 111
www.vtt.fi/nuclear

Geological Survey of Finland (GTK)
P.O. Box 96
FI-02151 ESPOO
Tel. +358 20 550 11
http://en.gtk.fi

Finnish Meteorological Institute
P.O. Box 503
FI-00101 HELSINKI
Tel. +358 9 192 91
www.fmi.fi/en

UNIVERSITIES

Lappeenranta University of Technology (LUT)
P.O. Box 20
FI-53851 LAPPEENRANTA
Tel. +358 5 621 11
www.lut.fi/en

Aalto University, School of Science and Technology, Department of Applied Physics
P.O. Box 14100
FI-00076 AALTO
Tel. +358 9 47001
www.tkk.fi/English/

University of Helsinki
Laboratory of Radiochemistry (HYRL)
P.O. Box 55
FI-00014 University of Helsinki
Tel. +358 9 1915 0120
www.helsinki.fi/kemia/radiokemia/english/

University of Jyväskylä
Department of Physics
P.O. Box 35 (YFL)
FI-40014 University of Jyväskylä
Tel. +358 14 260 2350
www.jyu.fi/fysiikka/en

OTHER ORGANISATIONS

Finnish Funding Agency for Technology and Innovation (Tekes)
P.O. Box 69
FI-00101 HELSINKI
Tel. +358 10 191 480
www.tekes.fi/eng

Academy of Finland
P.O. Box 99
FI-00501 Helsinki
Tel. +358 9 774 881
www.aka.fi/eng

Finnish Energy Industries (ET)
www.energia.fi

Finnish Nuclear Society
www.ats-fns.fi

FinNuclear
c/o Prizztech Ltd
tel. +358 44 710 5336
www.finnuclear.fi/

MINISTRY OF EMPLOYMENT AND THE ECONOMY (MEE)

Energy Department
P.O. Box 32
FI-00023 GOVERNMENT
Tel. +358 10 606 000
Fax. +358 9 1606 2664

www.tem.fi

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YMPÄRISTÖMERKKI
MILJÖMÄRKT
441 002
Painotuote