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Finnish report on nuclear safety

Finnish 7th national report as referred to in Article 5 of the Convention on Nuclear Safety

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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STUK • **SÄTEILYTURVAKESKUS**
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Osoite/Address • Laippatie 4, 00880 Helsinki
Postiosoite / Postal address • PL / P.O.Box 14, FIN-00881 Helsinki, FINLAND
Puh./Tel. (09) 759 881, +358 9 759 881 • Fax (09) 759 88 500, +358 9 759 88 500 • www.stuk.fi

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Executive summary

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Seventh Review Meeting in March/April 2017.

There are two nuclear power plants operating in Finland: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two PWR units (pressurised water reactors, of VVER type), operated by Fortum Power and Heat Oy, and the Olkiluoto plant two BWR units (boiling water reactors), operated by Teollisuuden Voima Oyj. In addition, a new nuclear power plant unit (PWR) is under construction at the Olkiluoto site. At both sites there are interim storages for spent fuel as well as disposal facilities for low and intermediate level nuclear wastes. Posiva, a joint company by Fortum and TVO, submitted a construction licence application for the spent nuclear fuel repository in the end of 2012. The construction licence was granted for Posiva by the Government in November 2015.

Finland is currently reviewing a construction licence application for Fennovoima Hanhikivi unit 1 in Pyhäjoki (VVER type design). Since the review is underway, Hanhikivi unit 1 is discussed in this report mainly with regard to the licensing process and siting (see Articles 7 and 17 and Annex 5).

Furthermore, there is a Triga Mark II research reactor, FiR 1 in Espoo licensed to VTT Technical Research Centre of Finland Ltd. The operating licence for the research reactor FiR 1 is valid until the end of 2023. However, VTT Technical Research Centre of Finland Ltd has decided to shut down and decommission the reactor earlier due to economical reasons. This will be the first decommissioned nuclear facility in Finland representing a new challenge for the utility and the regulatory body.

In this report, latest development in the various topics of the Convention on Nuclear Safety is described. Major safety reviews and plant modernisations are explained including safety assessment methods and key results. Safety performance of the Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered.

Major developments in Finland since the Sixth Review Meeting are as follows: updating of legislative and regulatory framework, implementation of the renewed regulatory guides at the operating nuclear power plants completed, periodic safety review carried out at the Loviisa nuclear power plant in 2015-2016, and IRRS follow-up mission (IAEA's Integrated Regulatory Review Service) carried out in Finland. Furthermore, construction of the new nuclear power plant unit continued and progressed to the operating licence phase, one

new unit has entered into construction licence phase and construction licence for Olkiluoto Spent Nuclear Fuel encapsulation and disposal facility was granted. Latest development in the various topics of the Convention on Nuclear Safety is described in relevant articles.

Finland continues the hosting and participation in the international peer reviews and the Government of Finland has requested the IAEA to carry out four OSART missions in Finland between 2017–2022:

- Olkiluoto 1&2 OSART mission will be conducted from 27 February until 16 March 2017
- Loviisa NPP OSART mission would take place in March 2018.
- Pre-Operational OSART mission for Olkiluoto 3 before the first fuel loading (according to current schedule in April 2018)
- Pre-Operational OSART mission for Fennovoima (Hanhikivi unit 1) would take place in 2022.

In the report, the implementation of each of the Articles 6 to 19 of the Convention is separately evaluated. Based on the evaluation, the following features emphasising Finnish safety management practices in the field of nuclear safety can be concluded:

- During the recent years Finnish legislation and regulatory guidance have been further developed and the revision of regulatory guide system was finalised in 2013. The overall revision of the regulatory guides took into account international guidance such as IAEA safety standards and WENRA (Western European Regulators' Association) safety reference levels for existing reactors and safety objectives for new reactors. In addition, the lessons learnt from the TEPCO Fukushima Dai-ichi accident are taken into account. No deviation from the convention obligations has been identified in the Finnish regulatory infrastructure including nuclear and radiation safety regulations.
- The revised regulatory guides were published at the end of 2013. The revised guides are applied as such for new nuclear facilities. For the existing facilities and facilities under construction separate facility specific implementation decisions are made. In the end of 2014 the licensees of operating NPPs submitted to STUK assessments on the fulfilment of the revised regulatory guides. In 2015, STUK evaluated the assessments and made decisions on how to further improve safety. Regular update and implementation of regulatory guides, particularly with regard to nuclear power plants in operation, are unique measures on the international perspective.
- The licensees have shown good safety performance and rigorous safety management practices in carrying out their safety related responsibilities in the operation and modernisation of existing NPPs. During recent years, only minor operational events (INES 1 and below) have taken place and no major safety problems have appeared. The licensees' practices are considered to comply with the Convention obligations.
- Safety assessment is a continuous process and living full scope level 1 and 2 probabilistic risk assessment (PRA) practices are effectively used for the further development of safety. Periodic safety review of the Loviisa plant was carried out in 2015–2016, and the periodic safety review of the Olkiluoto plant was carried out in 2007–2009. The decisions how to apply the revised regulatory guides at the operating NPPs were made by STUK in 2015. Several plant modifications have been carried out at the operating NPPs during the recent years to further improve the safety. Some of these modifications are originating from the Fukushima Dai-ichi accident.
- The resources of the Radiation and Nuclear Safety Authority (STUK) have been increased to meet the needs to oversee the construction of the new plants in Finland. The reports of the recent IRRS mission and follow-up mission have been published on STUK's website and mission results have been and will be used to further improve

regulatory guidance and practices. VTT Technical Research Centre of Finland Ltd supports effectively the regulatory body in the safety assessment work providing safety analysis capabilities and tools and performing safety analyses. There are also national research programmes which support and develop the competencies in nuclear safety and waste management of VTT as well as in the universities participating in the research programmes.
- The Nuclear Energy Act was amended in 2015. The Act was revised to broaden STUK's legal mandate to issue binding regulations. This was one of the recommendations from IRRS mission to Finland in 2012. Based on the amended Act, STUK published the new binding regulations concerning nuclear safety, security, emergency preparedness and waste management, as well as uranium and thorium mining in the beginning of 2016. Furthermore, based on changes in the Act the Government has to take into account the proposals included in the STUK's statements when considering the conditions of the Decision-in-Principle and licences for nuclear facilities.
- In January 2013 the Ministry of Employment and the Economy set up a working group to prepare a research and development strategy for the safe use of nuclear energy. The working group emphasized the importance of the research in the competence building. The Ministry of the Employment and Economy has started the implementation of the recommendations. In 2015 the Nuclear Energy Act was changed to ensure the financing for the enhancement of the nuclear safety research infrastructure.

The Sixth Review Meeting in 2014 identified some challenges and recorded some planned measures to improve nuclear safety in Finland. These issues are included and responded in this seventh national report of Finland. Some of these topics are discussed also below. These items were (in brackets the Articles, in which the issues are addressed):
- regulatory oversight of existing NPP's: ageing management (see Article 14)
- challenges in new NPP construction project (Olkiluoto unit 3); oversight of contractors and subcontractors, operating licence application review, digital I&C (see Articles 10, 11, 12, 13, 18 and Annex 4)
- preparation for the new build (see Annex 5)
- maintaining and improving competence and responding to the growing needs for professional staff (see Articles 8 and 11)
- continuous improvement of plant design: natural hazards, ultimate heat sink, I&C, electrical systems, spent fuel storage, emergency control room, replacement of diesel generators (see Articles 14, 17, 18 and Annexes 2, 3 and 4)
- implementation of the action plan based on IRRS findings 2012, and follow-up IRRS mission in June 2015 (see Articles 7, 8, 10, 13, and Annex 6).

Still some of these issues require further development to enhance safety, i.e., including provision for plant ageing, reliability and safety demonstration of digital I&C and management of competence taking into account the new build projects and retirement of experts. Other important issues cover new technologies, security arrangements and the growing need for new research and development programmes. These are generic issues that require international attention in all countries using nuclear energy.

Implementation of the updated ageing management requirements is underway for NPPs in operation and some specific challenges to fulfil these requirements have been met. For instance the revised regulatory guide has a requirement on the availability and operability as well as monitoring the condition of spare parts. Inspections have revealed that the amount of spare parts can be inadequate for keeping the plant in a safe state also during prolonged transients and accidents, and that some of the spare parts in the storage have either aged or obsoleted. Another challenge has to do with knowledge and resources allocated for ensuring appropriate ageing management programme at NPPs. Inspections have revealed that the licensees have challenges to implement knowledge management to ensure that in the event of personnel changes information and knowledge necessary for discharging the duties involved is transferred to the successors. Additional challenge is to conduct relevant research to both educate personnel and to identify new ageing mechanisms to develop new inspection or monitoring technologies to detect degradation early enough.

The expected lifetime of the existing nuclear power plants requires renewal of systems, structures and components and modernisation of technologies. The regulation of the existing nuclear power plants emphasises the management of ageing and the quality of plant operations. The modernisation of I&C and other systems at the Loviisa and Olkiluoto plants are either undergoing or under planning, and therefore extra care is needed to ensure that operational safety will be maintained notwithstanding the plant modifications. Operating experience has shown that special attention has to be paid on the meticulous planning and controlled implementation and testing of the plant modifications and STUK is following this in its regulatory inspections.

A generic lesson learned in Finland is that the closer nuclear power plants get to the end of their design lifetime, especially due to the current market price of electricity, more difficult it is for the licensees to make decisions to modernise or modify the NPPs. Instead of renewing a system or a component, modernisation may be rejected or a partial modification is planned resulting in ageing issues in the remaining parts. Finland has successfully applied periodic safety reviews (PSR) for the operating NPPs. Practice has been that the licensee is obliged to demonstrate that the safety of the operations can be ensured and improved also during the next 10 years, and to do that the licensee has to commit to make safety improvements including major modernisations to address ageing of SSCs.

The retirement of large age groups in Finland has been affecting public administration and industry throughout, including STUK, utilities and the spent fuel management company Posiva as well as organisations providing technical support and education to them. The plans for a new NPP construction project and the above mentioned challenges and activities require additional resources and efforts from the nuclear power utilities and regulatory body as well as from technical support organisations. Thus, ensuring an adequate national supply of experts in nuclear science and technology and ensuring high quality research infrastructure are continuous challenges in Finland. For the moment, STUK has adequate resources to fulfil its oversight responsibilities. However, resources used for developing STUK's own activities may be considered to be occasionally insufficient.

The Government has been decreasing STUK's budget during the past years mostly due to reorganisation of funding and conduct of research in the government organisations. While oversight activities are charged in full from the licensees and nuclear safety research programmes are funded via waste management fund, budget cuts have not impacted the nuclear safety research or resources needed for the regulated activities. However, due to budget cuts STUK has partly terminated and also decreased significantly its radiation safety research (e.g. biological effects of radiation, biodosimetry). Since radiation safety research activities have been contributing to the maintenance and development of know how in Finland, STUK has established a national radiation safety research programme in co-operation with all universities in Finland to ensure that radiation safety research will be continued in Finland.

Since the interest in nuclear power in Finland is increasing, communication and information sharing with media and the general public on nuclear and radiation safety has become an increasingly important success factor for STUK and utilities. Regulatory processes and decisions have to be clear and understandable to general public. Due to the challenge, STUK has initiated a strategic communication development project in spring 2016 to address both changing communication environment and the use of modern communication tools. In addition, STUK has also initiated a project to develop its crisis communication capabilities. This work is based on the experience on recent events as well as past emergency exercises.

Actions taken as a result of the TEPCO Fukushima Dai-ichi accident

Following the accident at the Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011 (TEPCO Fukushima Dai-ichi accident), safety assessments were initiated in Finland immediately. In order to ensure nuclear safety, the Ministry of Employment and the Economy requested STUK to carry out a study on how the Finnish NPPs have prepared against prolonged losses of electric power supply and ultimate heat sink and extreme natural phenomena. Based on the results of the assessments conducted in Finland, it was concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. However, areas where nuclear safety can further be enhanced were identified, and accordingly, Finnish National Action Plan how to address these areas was created. The experiences from the TEPCO Fukushima Dai-ichi accident were also addressed in the renewed regulation and Finnish Regulatory Guides (YVL Guides) and in the nuclear safety research programme (SAFIR), see Articles 7 and 8.

In addition to the periodic safety reviews carried out for the nuclear power plants, an extraordinary review of site related issues was performed after the TEPCO Fukushima Dai-ichi accident in connection with the so called European stress tests. Assessment of the safety margins and effects of exceeding the design basis values have been available and utilised for all identified relevant hazards (including extreme weather conditions) in connection with external events probabilistic risk assessments (PRA) which are mandatory for the Finnish NPPs. The stress tests did not reveal any new site-related external hazards or vulnerabilities of the plants to external events. No need for immediate action was recognised, but some additional studies of external hazards and feasibility studies for plant modifications to improve robustness against external events were found justified (see Article 17). The following examples of safety improvements and additional analyses of external events can be mentioned: enhanced protection against high seawater level at the Loviisa NPP, detailed structural analysis of spent fuel pools to demonstrate integrity of the pools in the case of an earthquake with consequential boiling in the pools and seismic walk-downs of the fire extinguishing water system at the Olkiluoto NPP following with some improvement measures.

The systems needed for residual heat removal from the reactor, containment and spent fuel pools require external power at both Finnish NPPs. At both sites, the ultimate heat sink is the sea. A reliable supply of electrical power to the systems providing for basic safety functions at the Finnish NPPs is ensured by the Defence-in-Depth (DiD) concept. As a result of multiple and diversified electrical power sources at different DiD levels, the probability of loss of all electrical supply systems is considered very low at the Finnish NPPs. However, as a result of the studies made after the TEPCO Fukushima Dai-ichi accident, further changes are under planning or implemented at the both NPPs (see Articles 6 and 18). For example at the Loviisa NPP the independent air-cooled cooling units have been installed for decay heat removal from the reactor core and from the spent fuel pools in case of the loss of sea as an ultimate heat sink. These cooling units were considered already before the TEPCO Fukushima Dai-ichi accident due to the increased risks related to transporting of oil on the Finnish Gulf. Safety improvements at the Olkiluoto units 1 and 2 include ensuring cooling of the reactor core in case of total loss of AC systems, ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water systems, and diverse cooling of the spent fuel pools. The emergency diesel generators will be replaced within the next few years. The new emergency diesel generators will be provided with alternative air and seawater cooling, while the existing diesels have only seawater cooling.

A comprehensive severe accident management (SAM) strategy has been developed and implemented at the operating Finnish NPPs during 1980's and 1990's after the accidents in TMI and Chernobyl (see Annexes 2 and 3). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation. As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary for severe accident management. However, the licensees are expected to consider ensuring the cooling of spent fuel pools in the SAM procedures (see Article 19). In addition, there are many actions related to the update of the emergency plans (see Article 16). Both NPPs were required to clarify and update their emergency preparedness plans with respect to issues like the possibility of several reactor units' simultaneous accident, evaluation of the number and the suitability of emergency response personnel to their duties, management of access control and contamination control in the case when the normal arrangements are out of function and restoring the access routes and connections to the site in case of massive destruction of the infrastructure.

Concerning the off-site emergency preparedness and response (see Article 16), no needs for major changes were identified. However, some improvements were identified and implemented that are for instance improved accessibility to the site in case of extreme natural hazards, ensured sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services and improved the communication arrangements between emergency centers of NPPs, STUK, and Rescue Service. In 2014 Loviisa NPP exercised for the first time a two reactor unit's simultaneous accident scenario. Furthermore, during the national full command post exercise OLKI-14 actions and decision making of the intermediate phase of the severe accident were exercised for the first time.

Most of the Fukushima Dai-ichi related safety improvements presented in the Finnish national action plan have already been implemented. A few ongoing measures will still be completed in the next few years. Further information related to the actions taken in Finland following the accident at the Fukushima Dai-ichi nuclear power plant are described in more detail under Articles 16, 17, 18, 19 and Annexes 2, 3 and 4.

The challenges identified by the Special Rapporteur in the Sixth Review Meeting

How to minimize gaps between Contracting Parties' safety improvements? The Finnish policy is to participate actively in the international work on developing safety standards and adopt or adapt the new safety requirements into national regulations. STUK participated WENRA's work on the update of the Safety Reference Levels after the Fukushima accident and most of the updated Reference Levels were already taken into account in the finalisation of the revised YVL guides. In addition, Finland has bilateral agreements with several foreign countries and regulatory bodies. See more details under Article 7 and Annexes 2, 3 and 6.

How to achieve harmonized emergency plans and response measures? Nordic countries have published two joint documents that detail the cooperation arrangements in case of an radiological emergency. Nordic Manual and Nordic Flag Book ensure that the response to any nuclear or radiological emergency in Nordic countries is harmonised and consistent between the countries. Furthermore, Finland participates actively in the international co-operation in the field of emergency preparedness, such as IAEA, OECD/NEA and EU/EC (WENRA and HERCA). See more details under Article 16.

How to make better use of operating and regulatory experience, and international peer review services? Finland supports activities to improve peer review services and has participated in the development of IAEA's peer review services (e.g. IRRS, IPPAS and the OSART missions). Finland continues both hosting and providing experts to the international peer reviews. The latest peer reviews in Finland are described in Annex 6. STUK has also participated in co-operation between international organisations such as the IAEA, the OECD/NEA and the EU (Clearinghouse), which exchange information on safety issues, operating events and regulatory experience. Other forums that STUK uses to obtain information are WENRA, MDEP and its working groups, the VVER Regulators' Forum as well as some bilateral agreements. See more details under Articles 8 and 19 and Annex 6.

How to improve regulators' independence, safety culture, transparency and openness? The regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. STUK's role and responsibilities have been assessed by a peer reviews (IRRT mission in 2001, follow-up in 2003 and IRRS mission in 2012, follow-up in 2015). STUK's Safety and Quality Policy was fully renewed in 2014 as a result of the recommendation from the IRRS mission. STUK has also updated its management system and included self-assessment of safety culture into annual self-assessment programme. The IRRS mission also recommended that the Government should seek to modify the Nuclear Energy Act so that the law clearly and unambiguously stipulates STUK's legal authorities in the authorisation process for safety. Based on the recommendation, the Act was amended in

2015 to broaden STUK's legal mandate to issue binding regulations. Furthermore, the Government has to take into account the proposals included in the STUK's statements when considering the conditions of the Decision-in-Principle and licences for nuclear facilities. See more details under Articles 8 and 10.

How to engage all countries to commit and participate in international cooperation? STUK participates in international cooperation in several working groups of the IAEA, the OECD/NEA and the EU. For example, the OECD/NEA/CNRA working groups WGOE (Operating Experience) and WGRNR (Regulation of New Reactors) improve nuclear safety by sharing experience and lessons learnt from nuclear installations in operation and under construction. Other forums that STUK uses to obtain information are WENRA, MDEP and its working groups, the VVER Regulators' Forum as well as some bilateral agreements. For example, exchange of information between Rostechnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants is an ongoing activity. The similar information exchange is arranged also to Sweden (SSM) and France (ASN). Furthermore, Finland has bilateral agreements with Sweden, Norway, Russia, Ukraine, Denmark and Germany on early notification of nuclear or radiological emergencies and exchange of information on nuclear facilities. In addition, STUK has bilateral arrangements with several foreign regulatory bodies, which cover generally the exchange of information on safety regulations, operational experiences, waste management etc. Such an arrangement have been made with NRC (USA), ASN (France), FANR (United Arab Emirates), NSSC and KINS (Republic of Korea), TAEK (Turkey), ENSI (Switzerland), SUJB (Czech Republic), Rostechnadzor (Russian Federation), CNSC (Canada), AERB (India), ONR (Great Britain), HAEA (Hungary), NNR (South Africa), NRA (Japan) and SSM (Sweden). STUK has also formed a strategic partnership with King Abdullah City for Atomic and Renewable Energy (K.A.CARE) to develop the necessary infrastructure for the establishment of a national authority dedicated to regulate and monitor nuclear safety in Saudi Arabia. See more details under Annex 6.

Consideration of the Vienna Declaration on Nuclear Safety

The Vienna Declaration on Nuclear Safety was adopted by the Contracting Parties by consensus at the Diplomatic Conference on 9 February 2015. The Vienna Declaration contains three principles to guide the Contracting Parties.

The first principle concerning the safety goal for new nuclear power plant design, siting, construction and operation is included in the Finnish regulations (see Articles 17 and 18). Furthermore, the Nuclear Energy Decree stipulates that the release of radioactive substances arising from a severe accident at a nuclear power plant shall not necessitate large scale protective measures for the population nor any long-term restrictions on the use of extensive areas of land and water. In order to limit the long term effects, the limit for atmospheric releases of cesium-137 is 100 terabecquerel. The possibility of exceeding the set limit and of a release in the early stages of an accident requiring measures to protect the population shall be extremely small.

Regarding the second principle, on the implementation of safety improvements at the operating NPPs to meet, as far as reasonably practicable, the safety goal of the first principle, Finnish regulations state that periodic safety review (PSR) shall be conducted at least every ten years. In addition, the Nuclear Energy Act states that the safety shall be maintained as high as practically possible and for further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology. Hence, the implementation of safety improvements has been a continuing process at both Finnish NPPs since their commissioning. The most significant plant modifications and modernisation projects carried out at the Finnish NPPs during the plant life time including backfitting of severe accident management systems during 1980's and 1990's are described in Annexes 2 and 3.

Regarding the third principle of the Vienna Declaration requiring that national regulations need to take into account the relevant IAEA safety standards and, as appropriate, other good practices, the Finnish nuclear safety regulations are regularly updated taking into account operating and construction experience, safety research and advances in science and technology. The overall revision of the regulatory guides in end of 2013 took into account international guidance (e.g. IAEA safety standards and WENRA safety reference levels) and the lessons learnt from the Fukushima Dai-ichi accident.

In conclusion, Finland has implemented the obligations of the Convention and also the objectives of the Convention, including the principles of the Vienna Declaration on Nuclear Safety, are complied with. Safety improvements have been implemented at the Loviisa and Olkiluoto plants since their commissioning. Legislation and regulatory guidance have been further developed. Additional safety assessments and implementation plans for safety improvements have been made at the Loviisa and Olkiluoto plants based on the lessons learnt from the Fukushima Dai-ichi accident. IRRS mission (IAEA's Integrated Regulatory Review Team) was carried out in October 2012 and the follow-up mission in 2015. STUK has been implementing its action plan for improvement on the basis of the IRRS missions results and the self-assessment. There exists no urgent need for additional improvements to upgrade the safety of the Finnish nuclear power plants in the context of the Convention.

Contents

1 Introduction

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Seventh Review Meeting in March/April 2017.

In Chapter 2 of this report, the measures related to each of the Articles 6 to 19 of the Convention are separately evaluated. The evaluation is based on the Finnish legislation and regulations as well as on the situation at the Finnish nuclear power plants. The reference is made to the IAEA Safety Requirements and other safety standards as appropriate. IAEA's Information Circular 572, Rev. 5, 16 January 2015, was used as a guideline for the context of the report. Furthermore, the guidance "Additional Recommendations for the Preparation of National Reports" prepared by the 6th Review Meeting President has been taken into account.

In the report, latest safety reviews and plant modernisations are explained in detail including safety assessment methods and key results. Safety performance of Finnish nuclear power plants is also presented by using representative indicators. The actions taken with regard to lessons learnt from the TEPCO Fukushima Dai-ichi accident are discussed under applicable Articles. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered in detail. The results of the latest IRRS mission (IAEA's Integrated Regulatory Review Service) and the follow-up mission carried out in Finland in October 2012 and in June 2015 are described under Article 8 and detailed actions related to recommendations and suggestions under applicable Articles.

This seventh National Report is aimed to be a stand-alone document and does not require familiarisation with the earlier reports. The fulfilment of the obligations of the Convention is described in general and the latest development since the Sixth Review Meeting is specifically described.

2 Compliance with Articles 6 to 19 – Article-by-article review

Article 6. Existing nuclear installations

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

In Finland, there are presently two nuclear power plants: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two PWR units (pressurised water reactors, of VVER type), operated by Fortum Power and Heat Oy (Fortum), and the Olkiluoto plant of two BWR units operated by Teollisuuden Voima Oyj (TVO). TVO is constructing a new plant unit of nominal reactor thermal power 4300 MW at the Olkiluoto site (Olkiluoto unit 3). At both sites there are fresh and spent fuel storage facilities, and facilities for storage and treatment of low and intermediate level radioactive wastes. Other existing nuclear installations in Finland are the repositories for low and intermediate level nuclear waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and the facility at Loviisa in 1998.

Construction licence application for the fifth nuclear power plant unit in Finland on the Olkiluoto site was submitted by TVO to the Ministry of Trade and Industry (predecessor of the Ministry of Employment and the Economy) in January 2004. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. Commissioning work is presently under way and TVO submitted operating licence application to the Ministry of Employment and the Economy in April 2016.

For taking care of the spent fuel disposal, a joint company Posiva Oy has been established in 1995 by Fortum and TVO. Research, development and planning work as well as construction for spent fuel disposal are in progress and the disposal facility is envisaged to be operational in early 2020's. The Decision-in-Principle (DiP) on the spent fuel disposal facility in deep crystalline bedrock was made by the Government in 2000 and ratified by the Parliament in 2001. In the connection of approving the DiP in May 2002 for the construction of the fifth power reactor in Finland, the Parliament also approved the DiP for expanding the capacity of the planned spent fuel disposal facility in Olkiluoto to also include the spent fuel from this new reactor unit. The repository will be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility (ONKALO) was commenced in 2004. The excavation of ONKALO was almost completed during 2015, but some extensions will be excavated during 2016. Posiva submitted a construction licence application for the spent nuclear fuel facility to the Ministry of Employment and Economy in the end of 2012. The detailed technical documentation of the application was reviewed by STUK during 2013-2014 and based on the review STUK gave a statement and safety assessment for the Ministry of Employment and Economy in February 2015. The construction licence was granted for Posiva by the Government in November 2015.

Finland is currently reviewing a construction licence application for Fennovoima's NPP in Pyhäjoki. According to the set dead line in DiP, Fennovoima filed a construction licence application for Hanhikivi unit 1 (ROSATOM AES-2006 plant design) in June 2015 to the Government and submitted according to the Nuclear Energy Decree safety, security and safeguards documentation to STUK for regulatory review and assessment. It was noted that Fennovoima was not able to submit a complete licensing documentation to the regulatory review and assessment at same time. Fennovoima will complement its documentation during the years 2015-2017 according to a licensing plan. The Government has requested STUK to give its statement and safety assessment during the year 2017, if possible (see more details under Annex 5).

Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in the use of a research reactor. In Finland, there is one TRIGA Mark II research reactor (250 kW), FiR 1, situated in Espoo. The research reactor was taken into operation in 1962, and it is operated by VTT Technical Research Centre of Finland Ltd (VTT). In 2012, VTT decided to commence the activities related to the planning of the decommissioning of the research reactor due to economical reasons. The preparation of the programme for the environmental impact assessment (EIA) procedure for the decommissioning of FiR 1 was started in May 2013 and the EIA programme was submitted to the Ministry of Employment and the Economy in November 2013. STUK submitted a statement on the EIA programme to the Ministry in January 2014. Based on the EIA programme, VTT prepared an EIA report, and STUK issued its statement on the report in December 2014. In its statements, STUK paid special attention to more specific planning of the demolition and more specific planning of nuclear waste management during the decommissioning stage. In April 2015 STUK gave a statement on VTT's action plan for the permanent shut down of FiR 1. The reactor was then permanently shut down in the end of June 2015. VTT is planning to apply for an updated operating license for the decommissioning of FiR 1 by 2017. This will be the first decommissioned nuclear facility in Finland representing a new challenge for the utility and the regulatory body.

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Nuclear Energy Act states that *the safety of nuclear energy use shall be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology.* The implementation of safety improvements has been a continuing process at both Finnish nuclear power plants since their commissioning and there exists no urgent need to upgrade the safety of these plants in the context of the Convention, or Vienna Declaration on Nuclear Safety.

Loviisa NPP units 1 and 2

The reactor units at the Loviisa nuclear power plant were connected to the electrical grid in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original power of 1375 MW). The increase of the power level was implemented and licensed in 1998.

The operating licences of the units are valid until the end of 2027 (unit 1) and 2030 (unit 2). The relicensing of the plant took place in 2005–2007. The Loviisa plant reached its original design age in 2007–2010, but the technical, safe and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. The review was completed in July 2007 when STUK provided the Ministry of

Figure 1. Loviisa nuclear power plant units 1 and 2. Source: Fortum.

Employment and the Economy with its statement on the safety of the plant. The Finnish Government granted in July 2007 to the licensee Fortum new operating licences for unit 1 until the end of 2027 and for unit 2 until the end of 2030. The length of the operating licences corresponds to the current goal for the plant's lifetime, which is 50 years. According to the conditions of the operating licences, two periodic safety reviews are required to be carried out by the licensee (by the end of the year 2015 and 2023). STUK's assessment of the first periodic safety review has been completed during the year 2016. Based on the assessment, STUK considered that the Loviisa Nuclear Power Plant meets the set safety requirements for operational nuclear power plants. Further information about periodic safety reviews at the Loviisa NPP is presented in Annex 2.

Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (see Article 14). For continued safe operation, plant improvement projects are still necessary. The largest ongoing improvement is the renewal of the plant I&C system, where the safety classified parts of the project are intended to be completed in 2018.

Due to the TEPCO Fukushima Dai-ichi accident, safety improvements have been initiated at the Loviisa NPP. Improvements implemented, under planning and implementation for the Loviisa plant include among other things:

- Installation of independent air-cooled cooling units for decay heat removal from the reactor core and from the spent fuel pools. The cooling units provide an alternative ultimate heat sink in case of loss of sea water cooling. The units have been taken into use in 2014-2015.
- Flood protection. The utility has estimated the effects of high sea water level to the plant safety. The utility has submitted a detailed plan of improved flood protection in 2015. The plan is based on strengthening of flood protection of the buildings most important to safety. The plan will be implemented by 2018 (protection during annual maintenance shutdown already partly implemented).
- Installation of diverse water supply to the spent fuel pools. STUK has approved the design plans. The plant modifications will be completed by 2017.
- The licensee has conducted an evaluation of the availability of cooling water and emergency diesel fuel in case of accidents at both units. The volumes on site have been considered adequate. Furthermore, the diesel fuel distribution capabilities (connections between different fuel tanks) have been improved.

Fukushima related modifications, as well as other latest ongoing improvements at the Loviisa NPP are described in more detail in Article 18 and in Annex 2. Furthermore, the most significant plant modifications and modernisation projects carried out at the Loviisa nuclear power plant during the plant lifetime and STUK's safety reviews are as well described in more detail in Article 18 and in Annex 2. During recent years, only minor operational events have taken place and no major safety issues have appeared (see also Article 19).

Plant lifetime management includes credible procedures for the follow-up of the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively. One specific issue with Loviisa plant units is the risk of reactor pressure vessel brittle fracture. Several modifications have been made at both units to reduce the risk. Fortum submitted during the latest operating licence renewal process a comprehensive analysis based on which the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The permit renewal for the use of the reactor pressure vessels was carried out at the Loviisa unit 2 in 2010 and at the Loviisa unit 1 in 2012. STUK approved the applications to extend the operation of the pressure vessels at the both units to the end of the operating licence, i.e. until the end of 2027 for the Loviisa unit 1 and until the end of 2030 for the Loviisa unit 2.

In addition to the regulatory oversight and safety assessment, there have been independent safety reviews conducted by international organisations such as IAEA and WANO (World Association of Nuclear Operators). IAEA OSART (Operational Safety Review Team) missions have been organised at the Loviisa power plant in November 1990 and in March 2007 with a latest follow-up review in July 2008. The next OSART mission will be organised during the year 2017. The pre-visit of the mission was carried out in 2016.The WANO peer reviews have been carried out at the Loviisa nuclear power plant at the beginning of 2001, in March 2010 with a follow-up review in 2012, and in March 2015. The WANO review 2015 included also the WANO corporate review in January 2016. The WANO follow-up review will be carried out in 2017.

In 2013, the net production of the Loviisa unit 1 was 4000 GWh, the load factor was 92,2% and the refuelling and maintenance outage lasted 19 days. The net production of the Loviisa unit 2 was 4040 GWh, the load factor was 93.1%, and the refuelling and maintenance outage lasted 17 days. The collective radiation doses in 2013 were 0.33 manSv for the Loviisa unit 1 and 0.21 manSv for the Loviisa unit 2.

In 2014, the net production of the Loviisa unit 1 was 4011 GWh, the load factor was 92,5% and the refuelling and maintenance outage lasted 21 days. The net production of the Loviisa unit 2 was 3873 GWh, the load factor was 89,3%, and the refuelling and maintenance outage lasted 35 days. The collective radiation doses in 2014 were 0.32 manSv for the Loviisa unit 1 and 0.53 manSv for the Loviisa unit 2.

In 2015, the net production of the Loviisa unit 1 was 4026 GWh, the load factor was 92,7% and the refuelling and maintenance outage lasted 21 days. The net production of the Loviisa unit 2 was 4039 GWh, the load factor was 93.1%, and the refuelling and maintenance outage lasted 17 days. The collective radiation doses in 2015 were 0.27 manSv for the Loviisa unit 1 and 0.25 manSv for the Loviisa unit 2.

Olkiluoto NPP units 1 and 2

The Olkiluoto nuclear power plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018.

The latest periodic safety review (PSR) of the Olkiluoto plant took place in 2007–2009. STUK made a decision concerning the PSR in October 2009. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK. The next periodic safety review will be carried out in 2016-2017 in connection with the renewal of operating licence for Olkiluoto NPP. STUK has started preparations for the safety assessment for the operating licence renewal and has actively held meetings with the licensee. During 2015-2017 the safety of the Olkiluoto plant is assessed more intensively and extensively than usual due to the licence renewal and extension of the original design lifetime which was 40 years. The safety documentation will be submitted to STUK at the end of 2016 and the review is planned to be made during 2017. The key issues in the licence renewal are ageing management, organisational issues, deterministic and probabilistic safety analyses, fatigue analyses, status of the safety improvements as well as matters relating to the environment, nuclear waste and nuclear fuel.

Safety improvements due to the TEPCO Fukushima Dai-ichi accident under planning and implemented at the Olkiluoto NPP units 1 and 2 include among other things:

- Assessing possibilities to ensure cooling of the reactor core in case of total loss of AC supplies and systems. The arrangement will consist of high and low pressure systems. The high pressure system is based on a steam driven turbine. The low pressure system pumps coolant into the core from the fire fighting system. STUK has approved the design plans. The systems will be implemented in 2017–2018.
- Ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water cooling systems. The modification

Figure 2. Olkiluoto nuclear power plant units 1 and 2. Source: TVO.

has been implemented at Olkiluoto 1 in 2014. Abnormal vibration and pressure oscillations have been observed during the testing of one subsystem and the reasons are under investigation. The modification will be implemented at Olkiluoto 2 when the issue has been resolved.

- Diverse cooling water supply to the spent fuel pools have been completed in 2015. To improve monitoring of the water temperature and level in the spent fuel pools is in progress and will be completed in 2016.
- The utility has acquired new mobile equipment (aggregates, pumps).
- The utility has evaluated the availability of cooling water and emergency diesel fuel in case of accidents at multiple reactor units and other nuclear facilities at the same site.

Fukushima related modifications, as well as other latest ongoing improvements at the Olkiluoto NPP are described in more detail in Article 18 and in Annex 3. Furthermore, the most significant plant modifications and modernisation projects carried out at the Olkiluoto nuclear power plant during the plant lifetime and STUK's safety reviews are as well described in more detail in Article 18 and in Annex 3. During recent years, only minor operational events have taken place and no major safety issues have appeared (see also Article 19).

In addition to the regulatory oversight and safety assessment, there have been independent safety reviews conducted by international organisations. IAEA OSART mission has been organised at Olkiluoto in March 1986. The next OSART mission will be conducted from 27 February till 16 March 2017. The WANO peer reviews have been carried out at the Olkiluoto nuclear power plant in 1999, in 2006 with a follow-up review in 2009, and in 2012 with a follow-up review in 2014. The next WANO peer review will be carried out in October 2016. The WANO review 2016 will also include the WANO corporate review.

In 2013, net production at the Olkiluoto unit 1 was 7470 GWh and the load factor 97.1%. The annual refuelling and maintenance outage of the Olkiluoto unit 1 lasted 8 days. The net production of the Olkiluoto unit 2 was 7163 GWh and the load factor was 93,1%. The annual refuelling and maintenance outage of the Olkiluoto unit 2 lasted 17 days. The collective radiation doses in 2013 were 0.14 manSv for the Olkiluoto unit 1 and 0.51 manSv for the Olkiluoto unit 2.

In 2014, net production at the Olkiluoto unit 1 was 7266 GWh and the load factor 94.5%. The annual refuelling and maintenance outage of the Olkiluoto unit 1 lasted 17 days. The net production of the Olkiluoto unit 2 was 7497 GWh and the load factor was 97,4%. The annual refuelling and maintenance outage of the Olkiluoto unit 2 lasted 7 days. The collective radiation doses in 2014 were 0.40 manSv for the Olkiluoto unit 1 and 0.24 manSv for the Olkiluoto unit 2.

In 2015, net production at the Olkiluoto unit 1 was 7397 GWh and the load factor was 96,2%. The annual refuelling and maintenance outage of the Olkiluoto unit 1 lasted 10 days. The net production of the Olkiluoto unit 2 was 6864 GWh and the load factor was 89,2%. The annual refuelling and maintenance outage of the Olkiluoto unit 2 lasted 17 days. The collective radiation doses in 2015 were 0.24 manSv for the Olkiluoto unit 1 and 0.51 manSv for the Olkiluoto unit 2.

Olkiluoto NPP unit 3

Construction licence for the fifth nuclear power plant unit in Finland on the Olkiluoto site was granted in February 2005. Olkiluoto 3 unit is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens.

Construction work is almost completed and commissioning phase has started. TVO submitted the operating licence application in April 2016 to the Ministry of Employment and the Economy. Operating licence is needed prior to loading nuclear fuel into the reactor core. STUK has started reviewing the operating licence application documents and the safety assessment by STUK is expected to be completed before the end of 2017. IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP before the fuel loading. Also, the WANO pre-startup peer review will be carried out before the fuel loading. Licensing and construction of the Olkiluoto unit 3 is described in more detail in Annex 4.

Due to the TEPCO Fukushima Dai-ichi accident, additional safety improvements have also been initiated for the Olkiluoto NPP unit 3. These include e.g. the possibility to add water to the steam generator secondary side and to fuel pools from fire water distribution system as well as the possibility to move diesel fuel from emergency diesel generator storage tanks to station blackout diesel storage tanks. Additional mobile pumps to provide water injection into the fire fighting water system are to be acquired before the start of operation of the Olkiluoto unit 3. With the mobile pumps, water can also be added directly to fuel pools with hoses. Preparations have also been made to enable restoring the AC distribution system functionality by replacing the internals of damaged cabinets in case of full loss of all electrical power.

In conclusion, Finnish regulations and practices are in compliance with Article 6.

Article 7. Legislative and regulatory framework

1. ***Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.***
2. ***The legislative and regulatory framework shall provide for:***
   - *i.* ***the establishment of applicable national safety requirements and regulations;***
   - *ii.* ***a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;***
   - *iii.* ***a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;***
   - *iv.* ***the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.***

Legislative and regulatory framework

The current nuclear energy legislation in Finland (see Annex 1) is based on the Nuclear Energy Act originally from 1987. The Act has been amended over twenty times during the years it has been in force: most changes are minor and originate from changes to EU or other Finnish legislation. In 2008, nuclear energy legislation was updated to correspond to current level of safety requirements and the new Finnish Constitution which came into force in 2000. Together with a supporting Nuclear Energy Decree originally from 1988, the scope of this legislation covers e.g.

- the construction and operation of nuclear facilities; nuclear facilities refer to facilities for producing nuclear energy, including research reactors, facilities for extensive disposal of nuclear wastes, and facilities used for extensive fabrication, production, use, handling or storage of nuclear materials or nuclear wastes
- the possession, fabrication, production, transfer, handling, use, storage, transport, export and import of nuclear materials and nuclear wastes as well as the export and import of ores and ore concentrates containing uranium or thorium.

In 2012, the Finnish regulatory framework for nuclear and radiation safety was reviewed in the IRRS (Integrated Regulatory Review Service) peer review process. According to the IRRS recommendations, some amendments were made to the legis-

Figure 3. Olkiluoto NPP unit 3 in construction phase in autumn 2015. Source: TVO.

lation aimed to increase the independence of STUK and to extend its authorities. The Nuclear Energy Act was amended in 2015 giving STUK a mandate to issue binding STUK Regulations concerning the areas of previous Government Decrees, and a new area concerning mining and milling operations aimed to produce uranium or thorium. Based on the mandate, STUK issued on 1st January 2016 the regulations listed below. There were still issues, such as limits for radiation exposure of workers and population and radioactive releases and requirements for other governmental agencies, which must still be provided by the Radiation Act and the Nuclear Energy Decree causing an amendment of the Decree.

- STUK Regulation on the Safety of Nuclear Power Plants (STUK Y/1/2016)
- STUK Regulation on Emergency Response Arrangements at Nuclear Power Plants (STUK Y/2/2016)
- STUK Regulation on the Security in the Use of Nuclear Energy (STUK Y/3/2016)
- STUK Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2016)
- STUK Regulation on the Safety of Mining and Milling Operations aimed at Producing Uranium or Thorium (STUK Y/5/2016).

The current radiation protection legislation is based on the Radiation Act and Decree, both of which are from 1991 and take into account the ICRP Publication 60 (1990 Recommendations of the International Commission on Radiological Protection). Section 2, General principles, and Chapter 9, Radiation work, of the Act are applied to the use of nuclear energy. The radiation protection legislation is currently under overall reform caused by implementation of revised Basic Safety Standard Directive (2013/59/EURATOM) among other things.

As mentioned, nuclear legislation has been amended several times and therefore the Ministry of Employment and the Economy has decided to start a more comprehensive update of the legislation. The update includes for instance the implementation of the following EU Directives: the amendment of Nuclear Safety Directive (2014/87/EURATOM, amending Directive 2009/71/EURATOM), Basic Safety Standard Directive (2013/59/EURATOM), and amendment (2014/52/EU) of Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment.

At the same time with the international negotiations to update the Paris and Brussels Conventions on Nuclear Liability also the Finnish Nuclear Liability Act was reviewed by a special governmental committee already in 2002. The financial provisions to cover the possible damage and resulting costs caused by a nuclear accident have been arranged according to the Paris and Brussels Conventions. A remarkable increase in the sum available for compensation of nuclear damages is expected in the future since international negotiations about the revision of the Paris/Brussels agreements on nuclear liability were successfully completed in 2004. In addition to the revised agreements, Finland decided to enact unlimited licensee liability by law. This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and also the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1500 million) has been exhausted. The revised law will also have some other improvements, like extending the claiming period up to 30 years for victims of nuclear accidents (personal injuries). The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by Government Decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force.

As the ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million by the operator. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect. In Finland, the finishing off the international ratification process of the convention amendments without any undue delay is considered to be extremely important.

Provision of regulatory guidance

According to Section 7 r of the Nuclear Energy Act, STUK shall specify detailed safety requirements concerning the implementation of safety level in accordance with the Act. These requirements are presented in regulatory guides which are called YVL Guides. STUK shall specify the safety requirements it sets and publish them as part of the regulations issued by the STUK.

The safety requirements in YVL Guides are binding on the licensee, while preserving the licensee's right to propose an alternative procedure or solution to that provided for in the regulations. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety level in accordance with the Nuclear Energy Act, STUK may approve this procedure or solution.

New YVL Guides are applied to new nuclear facilities as such. The procedure to apply new guides to existing nuclear facilities and to facilities under construction is such that the publication of an YVL Guide does not, as such, alter any previous decisions made by STUK. Before an implementation decision is made by STUK the licensees are requested to evaluate the compliance with the new guide. In case of non-compliances the licensee has

Structure of the new YVL Guides

A Safety management of a nuclear facility

- A.1 Regulatory oversight of safety in the use of nuclear energy
- A.2 Site for a nuclear facility
- A.3 Management system for a nuclear facility
- A.4 Organisation and personnel of a nuclear facility
- A.5 Construction and commissioning of a nuclear facility
- A.6 Conduct of operations at a nuclear power plant
- A.7 Probabilistic risk assessment and risk management of a nuclear power plant
- A.8 Ageing management of a nuclear facility
- A.9 Regular reporting on the operation of a nuclear facility
- A.10 Operating experience feedback of a nuclear facility
- A.11 Security of a nuclear facility
- A.12 Control of information security on a nuclear facility

B Plant and system design

- B.1 Safety design of a nuclear power plant
- B.2 Classification of systems, structures and components of a nuclear facility
- B.3 Deterministic safety analyses for a nuclear power plant
- B.4 Nuclear fuel and reactor
- B.5 Reactor coolant circuit of a nuclear power plant
- B.6 Containment of a nuclear power plant
- B.7 Provisions for internal and external hazards at a nuclear facility
- B.8 Fire protection at a nuclear facility

C Radiation safety of a nuclear facility and environment

- C.1 Structural radiation safety and radiation monitoring of a nuclear facility
- C.2 Radiation protection and dose control of the personnel of a nuclear facility
- C.3 Control and measuring of radioactive releases to the environment of a nuclear facility
- C.4 Radiological control of the environment of a nuclear facility
- C.5 Emergency arrangements of a nuclear power plant
- C.6 Radiation monitoring at a nuclear facility
- C.7 Radiological monitoring of the environment of a nuclear facility

D Nuclear materials and waste

- D.1 Regulatory control of nuclear safeguards
- D.2 Transport of nuclear materials and nuclear waste
- D.3 Handling and storage of nuclear fuel
- D.4 Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility
- D.5 Disposal of nuclear waste
- D.6 Production of uranium and torium in mining and milling activities
- D.7 Barriers and rock engineering of nuclear waste disposal facility

E Structures and equipment of a nuclear facility

- E.1 Authorised inspection body and the licensee's in-house inspection organisation
- E.2 Procurement and operation of nuclear fuel
- E.3 Pressure vessels and pipings of a nuclear facility
- E.4 Strength analyses of nuclear power plant pressure equipment
- E.5 In-service inspection of nuclear facility pressure equipment with non-destructive testing methods
- E.6 Buildings and structures of a nuclear facility
- E.7 Electrical and I&C equipment of a nuclear facility
- E.8 Valves of a nuclear facility
- E.9 Pumps of a nuclear facility
- E.10 Emergency power supplies of a nuclear facility
- E.11 Hoisting and transfer equipment of a nuclear facility
- E.12 Testing organisations for mechanical components and structures of a nuclear facility

Collected definitions of YVL Guides: same data is shown both as the collection and within the guides.

Figure 4. The re-structured system of regulatory YVL Guides.

to propose plans for improvement and schedules for achieving compliance. After having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction, and to licensee's operational activities as well as to other nuclear facilities related to nuclear waste management and disposal and to the research reactor. STUK can approve exemptions from new requirements if it is not technically or economically reasonable to implement respective modifications and if safety justification is considered adequate. This is case by case decision.

In compliance with the national strategy and with expectations of IAEA the most important references considered in the Finnish regulations for nuclear safety are the IAEA safety standards, especially the Safety Requirements. Finland as a member of WENRA (Western European Nuclear Regulators' Association) has committed itself to implement Safety Reference Levels published by WENRA. Also the WENRA Safety Objectives for new reactors and the WENRA positions on some key technical issues are considered. Other sources of safety information are worldwide co-operation with other countries using nuclear energy, e.g. OECD/NEA, MDEP (Multinational Design Evaluation Programme) and VVER Forum. The Finnish policy is to participate actively in the international work on developing safety standards and adopt or adapt the new safety requirements into national regulations. The regulatory guides are updated based on advances in science and technology, results of safety research and on analysis of operational experience.

The regulatory guides are continuously re-evaluated for updating. If there is not any immediate need for corrections or updates of YVL guides (e.g. new international requirements or update of pertinent national legislation) there are criteria for the review and updating of the regulations. The preparation process of the regulatory guides includes internal hearings and external hearings of the stakeholders and STUK's relevant advisory commissions and committees. The public participation is made possible through the website of STUK where the drafts for external hearings and all the regulations are also available.

After amending the nuclear energy legislation in 2008, also the revision of all YVL Guides was commenced to reflect the enhanced safety requirements. The thorough revision and update of the YVL Guides aimed at more goal-based and more user-friendly set of requirements. The updating integrated the lessons learnt from the regulatory oversight especially the lessons learnt from the Olkiluoto unit 3 project. The set of YVL Guides covers safety, security and safeguards.

Considering the WENRA Safety Reference Levels published in 2007 and 2008, the Finnish policy was to include all of them in the revised regulatory guide system. This was done during the work through a systematic approach to earmark all the Reference Levels to certain guides.

After the TEPCO Fukushima Dai-ichi accident it was decided to include lessons learnt from the accident into the revised YVL Guides, which delayed the completion of the new guides. The most important changes that were included in the new YVL Guides due to the TEPCO Fukushima accident deal with the design of NPPs and spent fuel storages, consideration of severe external hazards and with the requirements concerning onsite emergency preparedness including multi-unit accidents. STUK participated WENRA's work on the update of the Safety Reference Levels after the Fukushima accident and most of the updated Reference Levels were already taken into account in the finalisation of the revised YVL guides.

The new set of YVL guides was published 1st December 2013 (see Annex 1). The publication of 2 guides out of 45 guides takes place during 2016. These were left to wait for publication due to the needed changes in the legislation and upper level regulations. Translations of YVL Guides into English are also published. Justification memorandums are published in connection of each guide in Finnish and will be translation into English is ongoing.

Systematic training on application of new YVL Guides has been provided to the licensees by STUK's personnel involved in preparation of guides. Furthermore several training courses on YVL Guides directed for stakeholders, have been arranged also in English and are scheduled to be repeated in English also in future.

The guidance has now a new structure: guides are grouped under 5 topical areas. Single guides have a standard format and compact presentation of numbered requirements. Descriptive text in requirements is avoided. Additional clarification of requirements is written in justification memorandums (separately for each guide). Guides use consistent terminology, in Finnish and in English, which is collected into a glossary.

After publishing the new YVL guides STUK asked in January 2014 licensees to make their assessments concerning fulfilment of requirements: requirement by requirement assessment, justifications for the fulfilment and references to plant documentation. Requests for these assessments concerned separately the operating NPP units, the unit under construction and the research reactor as well. Deadlines for submittals were for operating nuclear power plants by the end of 2014 and for the unit under construction the operating licence application (April 2016).

STUK established a project for the implementation of the revised YVL Guides. Project target was to create a common view on application of requirements in new YVL Guides for existing nuclear facilities. Another target was that information was stored in the requirement management system to be utilised in STUK's oversight activities in future. The implementation decisions were given by the 1st of October 2015 for operating plants and by the 1st of January 2016 for the research reactor. STUK has started the evaluation work for Olkiluoto unit 3 together with the review of the operating licence application.

According to STUK's evaluation, the revised guides do not contain notable technical modification needs with regard to operating facilities since several plant improvements were already initiated after the Fukushima accident (Fukushima related improvement measures are in line with the updated requirements). Several plant modifications have also been implemented during last decades or are still under implementation based on previously updated regulatory requirements, PRA results and periodic safety review (PSR) results. Operating NPPs must nevertheless, during the next few years, expand the scope of their accident analyses, improve measures related to the facilities' ageing management and develop facility documentation that advances the traceability of modification plans.

After the renewal of YVL Guides nearly all IAEA Safety Requirements documents have been revised. Just because of TEPCO Fukushima Daiichi accident IAEA has updated Requirements documents concerning site selection, design, operation, safety analysis, and regulatory oversight of nuclear power plants, and additionally General Safety Requirements on response to emergencies. The updated WENRA Safety Reference Levels for Existing Reactors taking into account the lessons learnt and the insight from the EU stress tests were published in fall 2014. WENRA has also published Safety Reference Levels for Waste and Spent Fuel Storages in 2014, and both for Radioactive Waste Disposal Facilities and De-commissioning in 2015. The national regulators have made a commitment to improve and harmonize their national regulatory systems by implementing the new Safety Reference Levels until the end of 2017.

The updated international requirements are reviewed and assessed by STUK to clarify the need for further modifications of STUK's regulations (STUK Regulations and Regulatory Guides (YVL Guides), see Annex 1). In this connection also the new requirements of Council Directive (2014/87/Euratom) amending Nuclear Safety Directive (2009/71/Euratom) and BSS directive (Basic Safety Standards Directive, 2013/59/ Euratom) are reviewed and assessed their impact on the Finnish nuclear energy regulations; the laws and STUK's regulations. STUK has an action plant to update STUK's Regulations by 15th August 2017 and the YVL Guides by the end of 2017.

System of licensing

The licensing process is defined in the Finnish legislation. The construction and operation of a nuclear facility is not allowed without a licence. The licences are prepared by the Ministry of Employment and the Economy and granted by the Government. The conditions for granting a licence are prescribed in the Nuclear Energy Act (Sections 18-20). For a nuclear power plant, nuclear waste disposal facility, or another significant nuclear facility the process consists of three steps (see Figures 5 and 6):

- Decion-in-Principle – made by the Government and ratified by the Parliament
- Construction licence – granted by the Government
- Operating licence – granted by the Government.

Before a construction licence for a nuclear power plant, nuclear waste disposal facility, or other significant nuclear facility can be applied for, a Decision-in-Principle by the Government and a subsequent ratification of the DiP by the Parliament are required. An Environmental Impact Assessment (EIA) procedure has to be conducted prior to the application of the DiP and the EIA report has to be annexed to the DiP application. A condition for granting the Decision-in-Principle is that the construction of the facility in question is in line with the overall good of society. Further conditions are as follows: the municipality of the intended site of the nuclear facility has to be in favour of constructing the facility and no factors have appeared which indicate that the proposed facility could not be constructed and operated in a safe manner.

The entry into force of the Decision-in-Principle further requires ratification by the Parliament. The Parliament can not make any changes to the Decision; it can only approve it or reject it as it is. The stakeholders involved in the Decision-in-Principle process and their tasks are described in Figure 6. In Decision-in-Principle phase STUK prepares a statement on safety and preliminary safety assessment concerning the applicant, the proposed plant designs and plant sites. STUK asks also a statements e.g. from the Advisory Commission on Nuclear Safety and from the Ministry of the Interior concerning the emergency preparedness and physical protection arrangements.

For the construction and operating licence application, the Ministry of Employment and the Economy asks STUK's statement on safety. Construction and operating licence documents to be submitted to STUK for approval in this phase are defined in Sections 35 and 36 of the Nuclear Energy Decree. STUK asks also statements e.g. from the Advisory Commission on Nuclear Safety and from the Ministry of the Interior. After receiving all statements for the construction or operating licence, the Government will make its decision. In the construction and operating licence phases the acceptance of the Parliament and the host municipality are no more needed.

The Finnish process of licensing was assessed in the IRRS mission conducted in Finland in October 2012. The IRRS team gave a recommendation that the Finnish Government should seek to modify the Nuclear Energy Act so that the law clearly and unambiguously stipulates STUK's legal authorities in the authorization process for safety. In particular, the changes should ensure that STUK has the legal authority to specify any licence conditions necessary for safety. Due to the recommendations, the Nuclear Energy Act was amended in 2015. Based on these changes the Government has to take into account the proposals included in the STUK's statements when con-

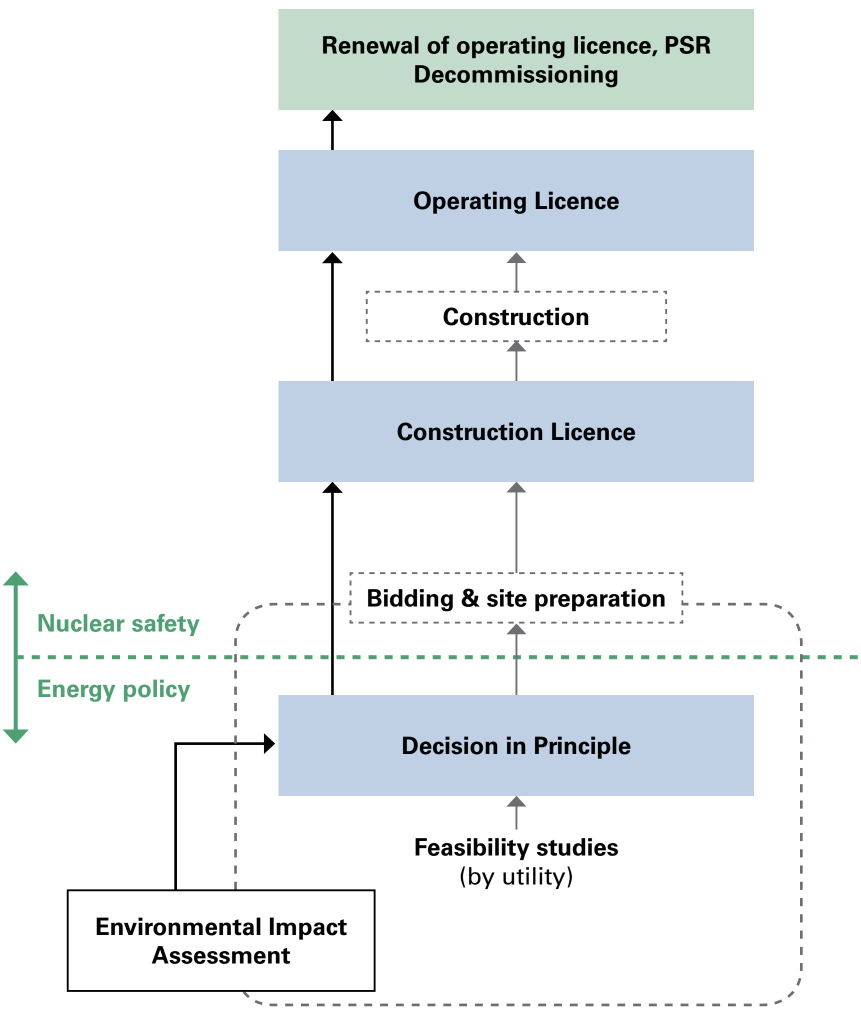


Figure 5. Three steps of licensing of nuclear facilities.

sidering the conditions of the Decision-in-Principle and licences for nuclear facilities.

The Decision-in-Principle procedure has been applied several times. The first DiP concerning the encapsulation and disposal facility for spent fuel in Olkiluoto was ratified by the Parliament in May 2001. Most recently the DiP procedure was applied during the period April 2008 – July 2010 when three applications for new nuclear power plants (Fennovoima Oy, Fortum Power and Heat Oy and TVO), and two applications for expanding the planned capacity of the future spent fuel disposal facility in Olkiluoto were handled by the Government. The Government approved TVO's and Fennovoima's applications but Fortum's application regarding the proposed new Loviisa unit 3 and the corresponding DiP application to expand the capacity of the spent fuel disposal facility were not approved. The DiP set a schedule for Fennovoima and TVO to submit the construction licence applications to the Government by mid 2015. In March 2014 Fennovoima started a complementary DiP process to introduce a new plant alternative (AES 2006), which was not mentioned in Fennovoima's original DiP application in 2009. The Government approved the application and the Parliament ratified it at the end of 2014 and Fennovoima submitted the construction licence application according the conditions by the end of June 2015.

In May 2014, also TVO started a complementary process with the Ministry of Employment and the Economy in order to extend the schedule for the submission of the construction licence application. The Government did not grant the requested extension of time to Olkiluoto unit 4 project and the project ended in June 2015.

In accordance with Section 108 of the Nuclear Energy Decree, the different phases of construction of a nuclear facility may be begun only after STUK has, on the basis of the construction licence application documents and other detailed plans and documents it requires, verified in respect of each phase that the safety-related factors and safety regulations have been given sufficient consideration.

Review of the detailed design of structures and equipment can be begun after STUK has found during the construction licence phase that the

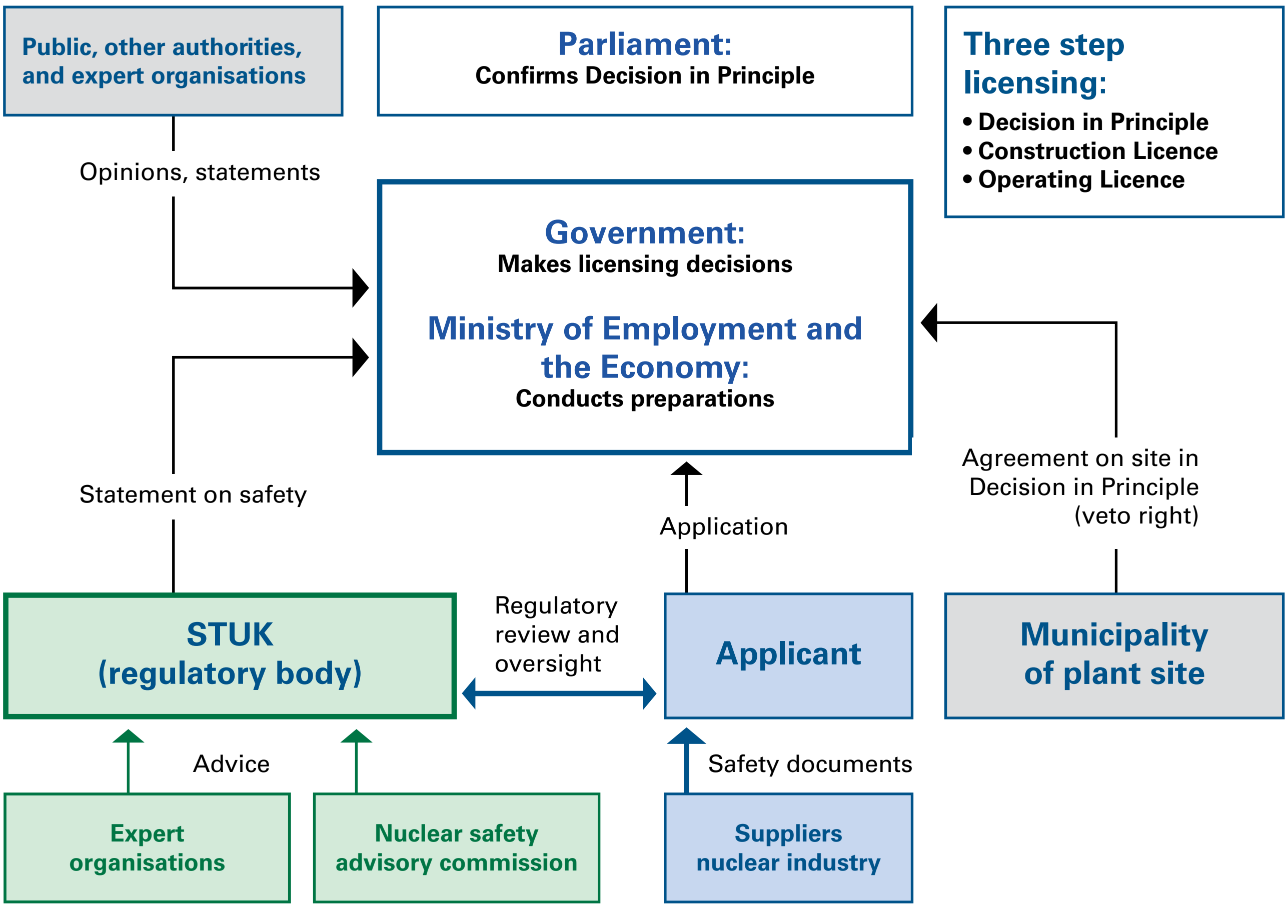


Figure 6. Licensing of nuclear facilities in Finland.

system-level design data of the system concerned are sufficient and acceptable.

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. The purpose is to ensure that the safety and quality requirements, regulations for pressure equipment and approved plans are complied with and that the nuclear facility is constructed in other respects in accordance with the regulations. In particular, the oversight is aimed to verify that working methods ensuring high quality are employed for the construction.

Before loading fuel into the reactor, an operating licence is needed. The operating licences are granted for a limited period of time, generally for 10-20 years. In case the operating licence is granted for a longer period than 10 years, a periodic safety review (PSR) is required to be presented to STUK. The periodic re-licensing or review has allowed good opportunities for a comprehensive, periodic safety review. Current operating licences of the Loviisa and Olkiluoto units are valid for about 20 years, but PSRs at least every ten years are required in the licenses as a condition of continued operation.

In addition, the Nuclear Energy Decree (Section 112) requires that if the licensee intends to carry out such modifications to the nuclear facility systems, structures, nuclear fuel or the way the facility is operated, which influence safety and involve changes in the plans or documents approved by the STUK, the licensee shall obtain approval from STUK for such modifications before they are carried out. Correspondingly, STUK shall approve measures related to the decommissioning of a nuclear facility. The licensee shall ensure that the documents mentioned in Sections 35 and 36 are revised accordingly.

System of regulatory inspection and assessment

The legislation provides the regulatory control system for the use of nuclear energy. According to the Nuclear Energy Act, STUK is responsible for the regulatory oversight of the safety of the use of nuclear energy. The rights and responsibilities of STUK are provided in the Nuclear Energy Act. Safety review and assessment as well as inspection activities are covered by the regulatory oversight.

Oversight during operation

STUK's oversight during plant operation includes periodic inspection programme, continuous oversight performed by STUK's resident inspectors, regular reporting and reporting of events and oversight performed at the plant site during operation and maintenance outages.

STUK's periodic inspection programme is focused on the licensee's main working processes and covers the most relevant areas of nuclear power plant safety. The objective of the inspection programme is to assess the safety level at the plants as well as safety management. Possible problems at the plants and in procedures of the operating organisations are to be recognised.

STUK has put special emphasis on the management of the entire inspection programme, including the timely conduct, resource allocation and accurate reporting of results, but there are some issues which can be further improved. Periodic inspection programme was assessed in the IRRS mission conducted in Finland in October 2012. The IRRS mission team suggested that STUK can further enhance the effectiveness of its inspection activities by enhancing the focus of inspection on the most safety-significant areas, by defining more concrete criteria for reactive inspections and conducting higher number of unannounced inspections.

STUK has modified the inspection programme during the years. Latest changes were made in 2015, when the whole inspection programme was re-assessed and the internal guidance was updated taking into account the recommendations and suggestions of IRRS mission. Each year STUK defines the programme for the next year, including additional inspections as necessary. According to updated internal guide, many of the yearly conducted inspections have been decided to be carried out every two years. The inspections focused on the most safety-significant areas are still carried out annually. In addition, reactive inspections can be carried out based on the oversight results and proactive inspections can be added focusing on ongoing or coming activities at the plant. The aim is to have more flexible inspection programme to optimize its effectiveness and focus and to be able to conduct inspections in the areas and at times considered necessary. In addition, unannounced inspections are included in the annual inspection programme, e.g. inspection focusing on the conduct of operations is always carried out unannounced.

In the event review, the safety significance of the event is first evaluated based on the information given by the operator and STUK's resident inspectors. Later operating experience is reported to STUK as an event report, which STUK evaluates and may require additional information or actions. STUK maintains internal database for events which disseminates operating experiences and provides easy access to operational event reports. STUK may assign own investigation team for events deemed to have special safety importance, especially when the operations at the nuclear power plant have not been performed as planned or expected. It is also possible to nominate an investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. These inspections are usually conducted by a leadership of the STUK's event investigation manager, and an investigation team includes normally 3–5 experts from STUK or from external organisations nominated on case-by-case basis.

Numbers of operational events are followed through STUK's plant performance indicator system. Risk significance of operational events is followed by PRA based indicators.

STUK's oversight and safety assessment concerning plant modifications is described under Article 14.

Oversight during construction

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. Oversight consists of inspections within the frame of the Construction Inspection Programme and inspections on manufacturing and construction of systems, structures and components important to safety. In addition, STUK has four resident inspectors overseeing the construction, installations and commissioning work at the Olkiluoto site. Licensee reports regularly about the progress of the construction.

To oversee the licensee's performance in a construction project, STUK has established a Construction Inspection Programme. The purpose of the programme is to verify that the performance and organisation of the licensee ensure high-quality construction and implementation in accordance with the approved designs while complying with the regulations and official decisions. The Construction Inspection Programme is divided into two main levels: the upper level assesses the licensee's general operations to manage the construction, such as safety management and safety culture, organisation, corrective actions programme, the licensee's expertise and use of expertise and project quality management. The next level, known as the operation level, assesses e.g. project quality assurance, training of the operating personnel, utilization of the PRA, radiation safety issues, and licensee's review and assessment process for system, structure and component-specific design reviews and inspections in the various fields of technology. Furthermore, the emergency response arrangements during construction, physical protection, fire protection and nuclear waste treatment are subjects of the Construction Inspection Programme as far as the scope is considered necessary by STUK. In addition to the above-mentioned inspections, of which the licensee is informed in advance, STUK carries out inspections without prior notice at its discretion. Construction Inspection Programme was also assessed in the IRRS mission and the recommendations and suggestions given for the periodic inspection programme of the operating plants concern also the Construction Inspection Programme. STUK has updated the internal guidance of the Construction Inspection Programme in 2014 to take into account the recommendations of IRRS mission, and again in 2015 and 2016 in order to cover e.g. changes in STUK's organization.

STUK performs construction inspections of pressure equipment, mechanical components as well as steel and concrete structures as specified in the YVL Guides. These inspections are performed according to structure or component specific construction plans that have been assessed and approved before start of manufacturing. The objective of the inspections is to verify that manufacturer, vendor and the licensee have performed their duties as expected and that QC results of manufacturing and construction are acceptable. The licensee is responsible for inviting STUK to perform the inspection at a right time.

In addition, STUK performs inspections on installation and commissioning of systems, structures and components. Safety significance of systems, structures and components are taken into account when determining the scope of inspections. STUK inspects safety class 1 and most safety important cases in safety class 2–3. Authorised Inspection Organisations (AIO) performs other inspections in safety class 2–3.

Enforcement

The Nuclear Energy Act defines the enforcement system and rules for suspension, modification or revocation of a licence. The enforcement system includes provisions for executive assistance if needed and for sanctions in case the law is violated. The enforcement tools and procedures of the regulator are considered to fully meet the needs.

In practice, STUK's enforcement tools include: oral notice or written request for action by the inspector, and written notice or order for actions by STUK. Actions can include stopping the plant operation immediately or decrease of reactor power for unlimited time. Legally stronger instruments would be 1) setting a conditional imposition of a fine, 2) threatening with interruption or limiting the operation and, 3) threatening that STUK enforces the neglected action to be made at the licensee's expense.

The repertoire of these tools together with some practical examples for implementing them has been presented in an internal policy document as part of STUK's Quality System.

In conclusion, Finnish regulations and practices are in compliance with Article 7.

Article 8. Regulatory body

1. ***Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.***
2. ***Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.***

STUK in the regulatory framework

According to the Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Employment and the Economy. The Ministry prepares matters concerning nuclear energy to the Government for decision-making. Among other duties, the Ministry of Employment and the Economy is responsible for the formulation of a national energy policy.

The mission of the Radiation and Nuclear Safety Authority (STUK) is 'to protect people, society, environment, and future generations from harmful effects of radiation'. STUK is an independent governmental organisation for the regulatory control of radiation and nuclear safety as well as nuclear security and nuclear materials. STUK is administratively under the Ministry of Social Affairs and Health. Interfaces to ministries and governmental organisations are described in Figure 7. It is emphasised that the regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. No Ministry can take for its decision-making a matter that has been defined by law to be on the responsibility of STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

The current Act on STUK was given in 1983 and the Decree in 1997. According to the Decree, STUK has the following duties:

- regulatory oversight of safety of the use of nuclear energy, emergency preparedness, security and nuclear materials
- regulatory control of the use of radiation and other radiation practices
- monitoring of the radiation situation in Finland, and maintaining of preparedness for abnormal radiation situations
- maintaining national metrological standards in its field of activity
- research and development work for enhancing radiation and nuclear safety
- informing on radiation and nuclear safety issues, and participating in training activities in the field
- producing expert services in the field of its activity
- making proposals for developing the legislation in the field, and issuing general guides concerning radiation and nuclear safety

- participating in international co-operation in the field, and taking care of international control, contact or reporting activities as enacted or defined.

STUK has the legal authority to carry out regulatory oversight. The responsibilities and rights of STUK, as regards the regulation of the use of nuclear energy, are provided in the Nuclear Energy Act. They cover the safety review and assessment of licence applications, and the regulatory oversight of the construction, operation and decommissioning of a nuclear facility. The regulatory oversight of nuclear power plants is described in detail in the Guide YVL A.1. STUK has e.g. legal rights to require modifications to nuclear power plants, to limit the power of plants and to require shutdown of a plant when necessary for safety reasons, as described in Article 7. Furthermore, the Nuclear Energy Act was amended in 2015 to give STUK a legal authority to carry out environmental monitoring as a regulatory activity. This change was based on the recommendation given in the IRRS mission in 2012.

STUK does not grant construction or operating licences for nuclear facilities. However, in practice no such licence would be issued without STUK's statement where the fulfilment of the safety regulations is confirmed as described in Article 7.

STUK's Advisory Committee was established in March 2008. Advisory Committee helps STUK to develop its functions as a regulatory, research and expert organisation in such a way that the activities are in balance with the society's expectations and the needs of the citizens. Advisory Committee can also make assessments of the STUK's actions and give recommendations to STUK.

An Advisory Commission on Nuclear Safety has been established in 1988 by a Decree. This Commission gives advice to STUK on important safety issues and regulations. The Commission also gives its statements on licence applications. The Commission has now two international committees, one for reactor safety and one for waste safety issues. In addition, an Advisory Committee on Radiation Safety has been established for advising the Ministry for Social Affairs and Health. The members of the Advisory Commission on Nuclear Safety and the Advisory Committee on Radiation Safety are nominated by the Government.

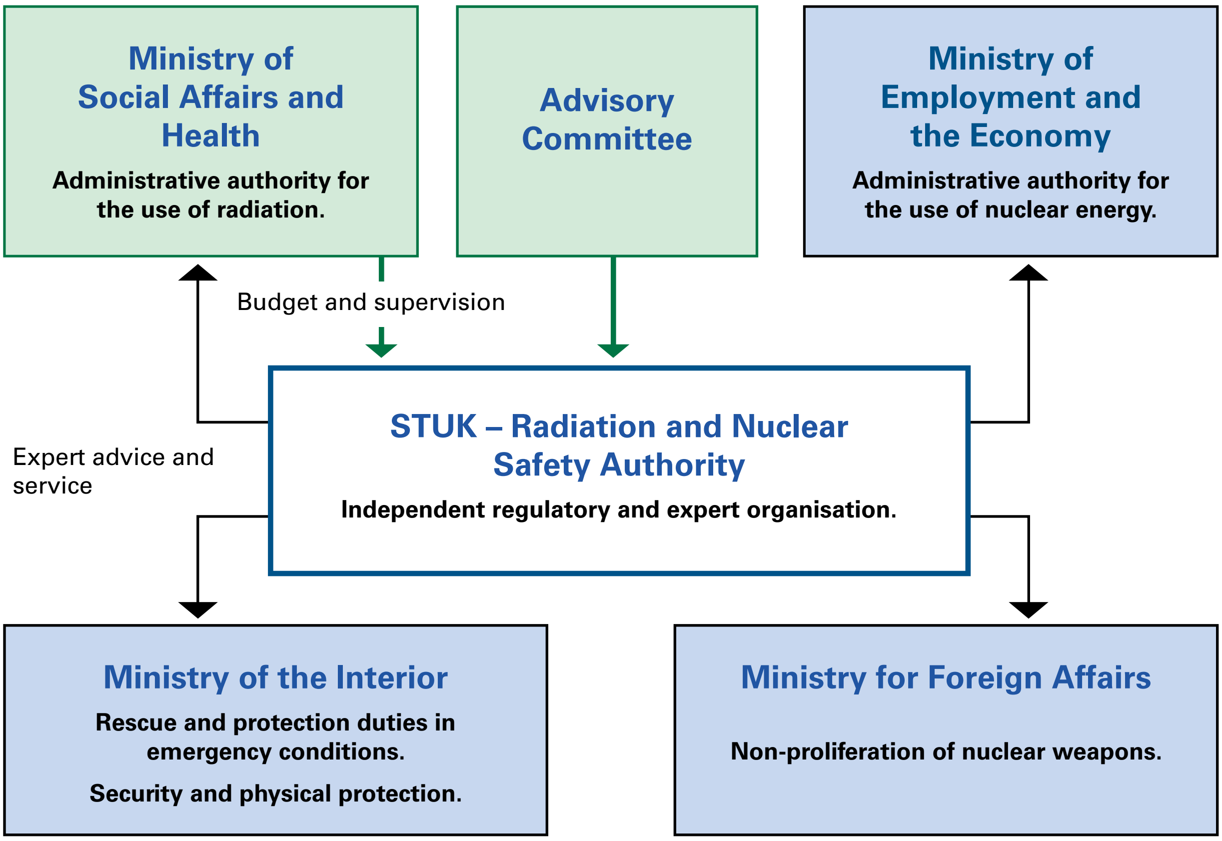


Figure 7. Co-operation and interfaces between STUK and Ministries and other organisations.

To assist STUK's work in nuclear security, an Advisory Committee on Nuclear Security was established in 2009. The members of the committee come from the various Finnish authorities, and the nuclear licensees also have their representatives as experts. The duties of the committee include the assessment of the threats in the nuclear field as well as consultation to STUK in important security issues. The committee also aims to follow and promote both the international and domestic co-operation in the field of nuclear related security issues. The members of the Advisory Committee on Nuclear Security are nominated by the Government.

STUK is responsible for informing the public and media on radiation and nuclear safety. STUK aims to communicate proactively, openly, timely and understandably. A prerequisite for successful communication is that STUK is known among media and general public and the information given by STUK is regarded as truthful. Communication is based on best available information. STUK's web site is an important tool in communication. It is important that the web pages are professionally edited and updated regularly. The information on web pages must be easy to find and understandable. Internal communication provides the personnel information about STUK's activities and supports its capability in participating in the external communication.

STUK's role and responsibilities have been assessed by a peer review. Full-scope IRRT mission (IAEA's International Regulatory Review Team) was carried out in 2000 and a follow-up mission in 2003. IRRS mission (IAEA's Integrated Regulatory Review Service) was carried out in October 2012 and the follow-up mission in June 2015.

In June 2015 the follow-up mission, 5 international experts and 4 IAEA staff members reviewed regulatory activities in Finland on the basis of IAEA Safety Standards, international best practices and experiences and lessons learned from the TEPCO Fukushima Dai-ichi accident. The purpose of the IRRS follow-up was to review the measures undertaken following the recommendations and suggestions of the 2012 IRRS mission. The scope of the follow-up mission was the same as in 2012 i.e. nuclear facilities, except the research reactor FiR 1 (due to decision of decommissioning), radiation sources and transport.

As the result of the follow-up mission the review team concluded that the recommendations and suggestions from the 2012 IRRS missions have been taken into account systematically by a comprehensive action plan. Significant progress has been made in most areas and many improvements have been implemented in accordance with the action plan. The IRRS team determined that 7 out of 8 recommendations and 19 of 21 suggestions made by the 2012 IRRS mission had been effectively addressed and therefore could be considered closed.

One of the recommendations left open deals with the STUK's position in the Government which will be discussed further in Finland. STUK's current position administratively under the Ministry of Social Affairs and Health continues to have the potential for STUK's decision-making to be unduly influenced by an entity that has interests in the medical applications of radiation. One of the suggestions left open is related to STUK's manage-

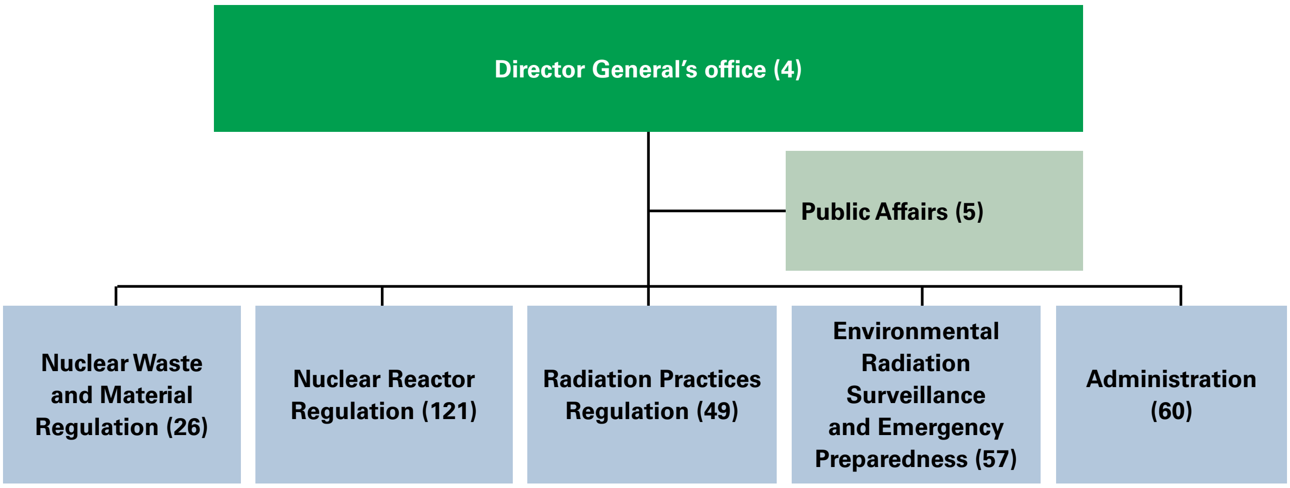


Figure 8. Organisation of STUK. The total number of staff at the end of 2015 was 323.

ment system. According to the IRRS team in 2012, STUK should consider further improving its management system. The IRRS follow-up team found that while STUK has initiated a number of actions, work still has to be undertaken for further enhancing its integrated management system.

Two new recommendations were raised to amend the legislation to clarify that decommissioning of a nuclear installation and closure of a disposal facility require a licence amendment; and to address the arrangements for research in radiation safety. STUK has updated its action plan and taken actions to complete the open issues (see Reference 6).

IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009 and the follow-up in 2012.

Finance and resources of STUK

The organisational structure and the responsibilities within STUK are described in the Management System of STUK. Also processes for regulatory oversight and other activities of STUK are presented in the Management System. The organisation of STUK is described in the Figure 8.

STUK receives about 34% of its financial resources through the government budget. However, the costs of regulatory oversight are charged in full to the licensees. The model of financing the regulatory work is called net-budgeting model and it has been applied since 2000. In this model the licensees pay the regulatory oversight fees directly to STUK. In 2015, the costs of the regulatory oversight of nuclear safety were 19 million €.

STUK has adequate resources to fulfil its responsibilities. The net-budgeting model makes it possible to increase for example personnel resources based on needs in a flexible way.

At the end of 2015, number of staff in the department of Nuclear Reactor Regulation was 121. The number of staff has increased by 7 since the time of the sixth review meeting. The expertise of STUK covers all the essential areas needed in the oversight of the use of nuclear energy. As needed STUK orders independent analyses, review and assessment from technical support organisations to complement its own review and assessment work. The main technical support organisation of STUK is the VTT Technical Research Centre of Finland Ltd., but also Lappeenranta University of Technology (LUT) and Aalto University (former Helsinki University of Technology) are important. Also international technical support organisations and experts have been used, especially to support review and inspection activities related to Olkiluoto unit 3 and Fennovoima Hanhikivi unit 1.

New personnel have been recruited since 2003 mainly for the safety review and assessment and inspection activities related to the Olkiluoto unit 3. There is a plan to recruit almost 20 new staff members to the department during 2016 due the new NPP construction project (Hanhikivi unit 1). The number of personnel in the department

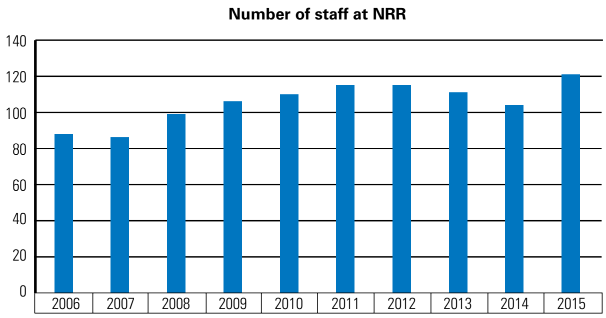


Figure 9. Number of personnel in the department of Nuclear Reactor Regulation.

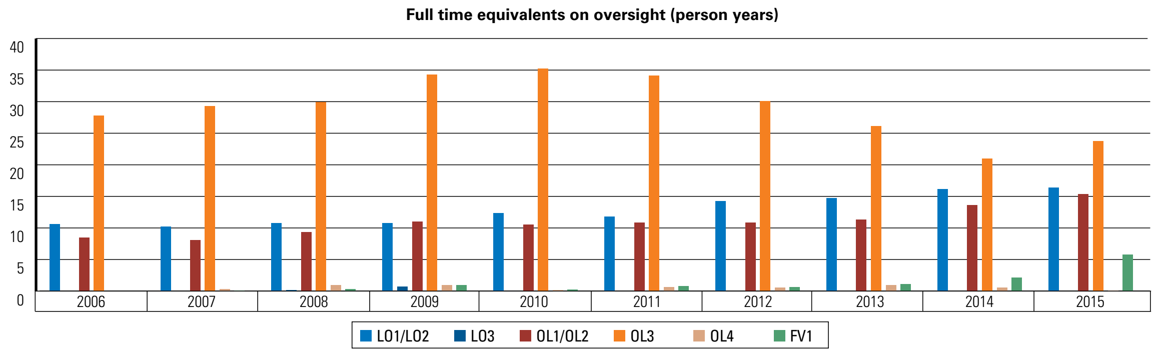


Figure 10. Resources used for the regulatory oversight in full time equivalents.

of Nuclear Reactor Regulation over the period of 2003–2015 is shown in Figure 9. The resources used for the oversight of operating nuclear power plants (Loviisa units 1 and 2 and Olkiluoto units 1 and 2), Olkiluoto unit 3 which is under construction and new plant projects (Loviisa unit 3, Olkiluoto unit 4 and Hanhikivi unit 1) are shown in Figure 10. Annual volume of the oversight of the Olkiluoto unit 3 construction was about 24 person-years in 2015. Starting from year 2003, inspection organisations have been performing construction inspections in lower safety classes.

STUK has also personnel in the areas of safeguards and nuclear waste management and disposal. The number of staff at the department of Nuclear Waste and Material Regulation was 26 at the end of 2015.

Ensuring competence

The management of STUK highlights the need for competent workforce. STUK has adopted a competence management system and nuclear safety and regulatory competencies are also emphasised in STUK's strategy. Implementation of the strategy is reflected into the annual training programmes, on the job training and new re-cruitments. The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organisations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and tools for regulatory oversight, and for the second ensuring the on-line transfer of the research results to the organisations participating in the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

Most of the professional staff of STUK conducting safety assessments and inspections has a university level degree. The average experience of the staff is about 15 years in the nuclear field. The competence analysis is carried out on regular basis and the results are used as the basis for the training programmes and the new recruitments. The training programme includes internal courses as well as courses organised by external organisations. On an average 5 % of the annual working hours has been used to enhance the competence.

An induction programme is set up at STUK for all new recruited inspectors. In addition to administrative issues, the induction programme includes familiarisation with legislation, regulatory guidance and regulatory oversight practices. Programme is tailored to each new inspector and its implementation is followed by the superior of the person. STUK has also participated in the preparation and execution of a basic professional training course on nuclear safety with other Finnish organisations in the field (described in more detail in Article 11).

National research programmes

In Finland, VTT Technical Research Centre of Finland Ltd is the largest research organisation in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy, about half of them full-time. The total volume of the nuclear energy research in Finland in the year 2012 was over 75 million € (estimate of the Ministry of Employment and the Economy). This figure includes research related to use of nuclear energy conducted in all the stakeholder organisations. Two thirds of the research is focused on the disposal of the spent fuel. The largest individual organizations are VTT, LUT (Lappeenranta University of Technology), GTK (Geological Survey of Finland), and Aalto University (former Helsinki University of Technology, HUT).

The Nuclear Energy Act was amended in 2003 to ensure funding for a long-term nuclear safety and nuclear waste management research in Finland. Funds are collected annually from the licence holders to a special fund. Regarding nuclear safety research the amount of money is proportional to the actual thermal power of the licensed power plants or the thermal power presented in the Decision-in-Principle. For the nuclear waste research, the annual funding payments are proportional to the current fund holdings for the future waste management activities. In 2016 the Nuclear Energy Act was amended and the temporary increase of the money collected to the nuclear safety research fund was introduced. The purpose of temporary increase of the research funding is to renew the ageing infrastructure for the nuclear energy related research. The increased funding is collected in between the years 2016 and 2025. At the first stage the additional funding is allocated for the new hot cell at VTT Center of Nuclear Safety (CNS) and at the second stage for the thermohydraulic laboratory at Lappeenranta University of Technology. The estimated investment for the VTT CNS hot cell capacity is about 18 million €.

The research projects are selected so that they support and develop the competences in nuclear safety and to create preparedness for the regulator to be able to respond on emerging and urgent safety issues. These national safety research programmes are called SAFIR and KYT. The structure for SAFIR2018 was renewed to enhance multidisciplinary co-operation within the research programme. Research areas are 1) Plant Safety and Systems Engineering, 2) Reactor Safety and 3) Structural Safety and Material. The key topics of the recent nuclear safety research programme (SAFIR2018) are automation, organisation and human factors, severe accidents and risk analysis, fuel and reactor physics, thermal hydraulics, structural integrity and development of research infrastructure. The amount of money collected from the licensees in year 2016 was about 9 million € for nuclear safety research. 4 million € is used to research projects and the rest is for the enhancement of the infrastructure. The decision by TVO to terminate the Olkiluoto unit 4 project in 2015 decreased the funding by 24 % for the SAFIR2018 research projects. The research projects have also additional funding from other sources. The total volume of the programme in 2016 was 6.4 million €.

The objective of KYT2018 (Finnish Research Programme on Nuclear Waste Management) is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods. Likewise the previous programme also KYT2018 is divided into three main categories:

- new and alternative technologies in nuclear waste management
- safety research in nuclear waste management and
- social science studies related to nuclear waste management.

The main emphasis in the research programme will continue to be devoted to safety related research. The funding of the research programme is provided mainly by the State Nuclear Waste Management Fund (VYR) into which those responsible for nuclear waste management pay annually 0.08 % of their respective assessed liability. The current level of annual funding is 1.8 million €.

In conclusion, Finnish regulations and practices are in compliance with Article 8.

Article 9. Responsibility of the licence holder

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

The responsibility for the safety rests with the licensee as prescribed in the Nuclear Energy Act. According to Section 9 of the Act, it shall be the licensee's obligation to assure safe use of nuclear energy. That responsibility cannot be delegated or transferred to another party. Furthermore, it shall be the licensee's obligation to assure such physical protection and emergency planning and other arrangements, necessary to ensure limitation of nuclear damage, which do not rest with the authorities. In addition, a licensee whose operations generate or have generated nuclear waste shall be responsible for all nuclear waste management measures and their appropriate preparation, as well as for their costs.

It is the responsibility of the regulatory body to verify that the licensees fulfil the regulations. This verification is carried out through continuous oversight, safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasises the licensee's commitment to the strong safety culture. The obvious elements of licensee's actions to meet these responsibilities are strict adherence of regulations, prompt, timely and open actions towards the regulator in unusual situations, active role in developing the safety based on improvements of technology and science as well as effective exploitation of experience feedback. In addition to inspections and safety assessment, the follow-up of licensee's efforts in achieving results is based on safety indicators. This system includes indicators e.g. for plant availability, incidents, probabilistic risk assessment results, safety system operability, radiation doses to personnel as well as releases to the environment and resulting radiation exposures to the general public.

Based on the Chapter 7 of the Nuclear Energy Act, to ensure that the financial liability for the future management and disposal of nuclear wastes and for the decommissioning of nuclear facilities is covered, the nuclear power companies are every third year obliged to present estimates for future costs of these operations and take care that the required amount of money is set aside to the State Nuclear Waste Management Fund. In order to provide for the insolvency of the nuclear utilities, they shall provide securities to the Ministry of Employment and Economy for the part of financial liability which is not yet covered by the Fund. At the end of 2015, the fund contained approximately 2 450 million euros (see also Article 11).

The arrangements for the nuclear waste management liabilities related to the Olkiluoto unit 3 will follow the same lines after the start of the operation. The licensee with a waste management obligation shall submit the waste management scheme and the calculations of waste management costs, which are based on the scheme, to the Ministry of Employment and the Economy for approval for the first time early enough before beginning the operations producing nuclear waste, and at the latest in connection with the operating licence application. The waste management scheme shall cover all phases of waste management including the decommissioning of the nuclear facilities and the disposal of all arising nuclear wastes. The scheme must be sufficiently detailed to allow the calculations for the assessed liability.

The financial provisions to cover the possible damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of the Paris and Brussels Conventions in 2004, Finland has decided to enact unlimited licensee's liability by law (see Article 7). The revised law will also have some other modifications, such as extending the claiming period up to 30 years for victims of nuclear accidents. As the international ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect after the international ratification of the Paris and Brussels Conventions.

In conclusion, Finnish regulations and practices are in compliance with Article 9.

Article 10. Priority to safety

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

Regulatory requirements regarding safety culture and safety management

The importance of a good safety culture is emphasised in the Nuclear Energy Act and in the STUK Regulation (STUK Y/1/2016) Section 25, which states that when designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture shall be maintained by making sure that the decisions and activities of the entire organisation reflect commitment to operational practices and solutions that promote safety. Licensee has to ensure that these requirements are applied in all organisations that participate in safety significant activities. An open working atmosphere must be promoted to encourage identification, reporting and elimination of factors endangering safety, and the personnel must be given opportunity to contribute to the continuous enhancement of safety. According to the Nuclear Energy Act, a responsible director has to be appointed for the construction and operation of a nuclear power plant. The appointment is subject to approval by STUK. The responsible director has a duty to ensure the safe use of nuclear energy and to see that the arrangements for physical protection and emergency preparedness and the safeguards control are complied with.

STUK's Guide YVL A.3 sets general requirements for management systems. The new guide YVL A.3 is based on IAEA GS-R-3, and it includes detailed requirements for promoting good safety culture. The management system must support the characteristics of the organisational culture that promote good safety culture, and the management must express its commitment to safety. Safety culture expertise must be available for developing the safety culture. The development of the safety culture must be target oriented and systematic.

The procedures used must strengthen a vigilant, questioning and initiative attitude at all levels of the organisation. The licensee has to also establish a process to measure, assess and improve its safety culture.

STUK has published in the end of 2013 a new Guide YVL A.5 concerning nuclear facility construction, commissioning and modifications. Also in this guide there are requirements concerning safety culture and risk management. During construction and modification projects at existing NPPs the licensee must ensure that the contributing parties are able to perform according to safety requirements and there must be training on safety culture issues for the personnel taking part in the activities. The licensee must have procedures for evaluating and developing the safety culture of the contributing parties.

TEPCO Fukushima Dai-ichi accident has highlighted the importance of safety culture and its continuous assessment and improvement. The Diet report in 2012 concluded that *"fundamental causes of the accident are to be found in the ingrained conventions of Japanese culture; our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity"*. These ingrained conventions were seen as factors preventing necessary stakeholders (Licensee, Regulatory Body and Government) to take needed actions to ensure safety and therefore also contradicting with good safety culture. The influence of ingrained conventions in national culture was considered in Finland to be one of the key messages in the Diet report. To better understand the ingrained conventions in the Finnish culture and their possible positive and/or negative impacts on safety culture, STUK facilitated a research project touching this topic as part of the Finnish nuclear research program SAFIR (the SISIANS project).

Measures taken by licence holders

Loviisa NPP

Loviisa power plant is operated by Fortum Power and Heat Ltd, which is part of a large Fortum corporation. In 2015 Fortum renewed the quality and safety policy for the Nuclear Operations. The policy emphasises the priority of safety and requires commitment to high level safety culture from all parties involved in the activities. Fortum has also strengthened its internal Nuclear Safety Oversight function in its latest reorganisation. Loviisa NPP has a unit especially dedicated for operational experience and safety culture. In addition, the Loviisa NPP has an independent advisory body for safety issues, i.e., a nuclear safety committee with external expert members.

Fortum has continued having international peer reviews and evaluations at the Loviisa NPP in order to improve its own operations. In the beginning of 2016 a WANO Corporate Peer Review was carried out for the first time in order to evaluate corporate support functions to Loviisa NPP. The latest WANO Peer Review was performed in March 2015.

The licensee has continuously developed the self assessment procedure for the safety culture. As part of a periodic safety review the licensee conducted a safety culture self assessment in 2014 which concluded that their safety culture complies with the requirements. During 2013-2016 there has been annual Safety Culture Survey and several evaluations and development projects that have led to development of competences, instructions and support materials such as e.g. Human Performance Tools -training (HUP-training). Loviisa NPP is presently developing a safety culture improvement programme with which to coordinate and communicate the activities done in the area of safety culture improvement.

Fortum has continued the special training programme for the Loviisa NPP contractors, with which the licensee aims to ensure the right attitudes and safety culture and capabilities to safe operations among the contractors working at the NPP. Fortum is also going to train their contractors on Human Performance tools. In the training, Fortum communicates the safety-first-principle and nuclear and radiation safety issues for contractor personnel working at the site. The contractor training is valid only for a determined time and has to be repeated when expired. All contractors and suppliers are regularly evaluated by Fortum to ensure that they can fulfil the regulatory and safety requirements. Fortum has developed procedures for ensuring appropriate competencies for the auditors conducting contractor evaluations and audits.

Olkiluoto NPP

TVO, the licensee operating the Olkiluoto NPP has a corporate policy which shows commitment to create conditions to produce electricity in a safe manner. The corporate policy also emphasises commitment to high level safety culture. TVO carries out regular safety culture surveys and more in-depth safety culture self assessments to ensure that their safety culture is on a good level. TVO reorganised its activities in 2015 and conducted pre- and post reorganisation safety evaluations.

TVO has a safety culture team that is independent from operations and construction. This team meets regularly about 10 times a year and the mission is to form a comprehensive view of the safety culture situation in TVO and report and give suggestions to the top management. The NPP has a safety culture specialist who facilitates the safety culture self assessments and coordinates the safety culture improvement programme. TVO has a Corrective Actions Group (CAP) that works independently from line organisation and consists of specialists from quality, nuclear safety, risk management, human resource and occupational health areas. The objective for the CAP group is to support the continuous improvement of TVO's performance by giving recommendations to the management.

TVO has undergone peer reviews by the WANO. The next peer review will be conducted in October 2016. Furthermore, the WANO review 2016 will also include the WANO corporate review.

TVO carries out safety culture monitoring and continual development also at the construction site of Olkiluoto unit 3. Safety culture of the construction site is assessed through a questionnaire, interviews and analysis of safety observations, authority inspections and non-conformance records. Safety culture promotion methods include e.g. continual dialogue between the site workers and dedicated safety culture ambassadors, and regular safety culture meetings with the supplier. A strong safety culture is also essential during the commissioning phase, which has been taken into account in cooperation with the commissioning personnel.

TVO follows up the competence of contractors that work at the plant regularly or for longer terms. These contractors have to complete the same basic training as NPP's own personnel as appropriate. Introductory nuclear and radiation safety training is a prerequisite for all persons working at the site. Priority to safety is addressed in the training. TVO regularly audits and evaluates contractors and suppliers to ensure that they fulfil the regulatory and safety requirements.

Regulatory oversight

STUK has continued to regularly inspect the management systems of both licensees (Fortum and TVO) to ensure that they are fulfilling the requirements of the legislations and the Guide YVL 1.4 and since the end of 2015 according to the new Guide YVL A.3. The Guide YVL A.3 has more detailed requirements for management of a supply chain and for safety culture. Based on the inspections, there is still need for development actions to fulfil the requirements concerning both the process based management system and supply chain management.

STUK carries out safety culture oversight by collecting observations from resident inspectors, documents, events, and from other interactions with the licensee. STUK also conducts specific inspections focusing on Leadership and Safety culture. Further, STUK has utilised its TSO VTT to carry out independent safety culture assessments at the licensee organisations. Independent safety culture assessments were done at both Loviisa (2014) and Olkiluoto (2015-2016) NPPs to support STUK in the processes of periodic safety review of Loviisa NPP and the Licence Renewal of Olkiluoto 1 and 2.

During 2014–2016 specific safety culture inspections have dealt with safety culture evaluation methods and management commitment for safety culture and the responsibility for the management to define and communicate the requirement for a good safety culture. Additionally, safety culture topics are included in quality assurance audits. Safety culture related findings from different inspections are discussed in regular meetings in STUK and between the top management of the nuclear power plants and the regulatory body.

The event investigation that STUK conducted 2010-2011 concerning the Emergency Diesel Generator procurement for Olkiluoto NPP unit 3 underlined the importance of strict supply chain management. This was an important input for developing the Finnish regulatory requirements concerning the topic in e.g. the Guides YVL A.3 and YVL A.5.

STUK has developed a tool (HAKE-Polarion database) for gathering information about issues related to Human and Organisational Factors (HOF) from all oversight activities at all licensees or licensee applicants. The tool was implemented during 2015. STUK has also developed the process to create an overall picture of the licensee's overall safety including HOF topics. The HAKE-Polarion tool and the developed process for creating the picture of the overall safety at licensee organisations are responding to the IRRS mission team's suggestion to have a more systematic method for collection and assessment of indications of the licensee's safety culture. STUK is continuing the improvement of the process by development projects.

STUK co-operates with VTT Technical Research Centre of Finland Ltd on safety culture related research and VTT has continued with re-assessments on safety culture at the Olkiluoto unit 3 construction site. Safety culture and supply chain management related seminars have also been arranged together with both VTT and the licensees, and vendors.

Means used by regulatory body in its own activities

Safety is emphasised in STUK's Management System as well as in the framework contract between STUK and its technical support organisation VTT Technical Research Centre of Finland Ltd. STUK's Safety and Quality Policy was fully renewed in 2014 as a result of the recommendation from the IRRS mission in 2012. The policy includes STUK's values that give the highest priority to keeping the radiation exposure of people as low as reasonably achievable and preventing radiation and nuclear accidents. STUK has taken an active role in this area and both developed its own culture and taken the initiative in the assessment of cultures of the licensee organisations. The IRRS mission was carried out in fall 2012 and the reviewers suggested that STUK could emphasize safety culture also in its quality manual in a more detailed way as well as to assure the safety consciousness of the staff. To meet this suggestion, STUK decided to update its management system and to include self-assessment of safety culture into annual self-assessment programme. In addition STUK has provided training of safety culture to its personnel.

STUK conducts self-assessments and personnel questionnaires to follow up the internal opinions regarding the priority devoted to different topics of nuclear safety. STUK arranges regularly training for the inspectors and an introduction programme is set up for all new recruited inspectors.

In conclusion, Finnish regulations and practices are in compliance with Article 10.

Article 11. Financial and human resources

1. ***Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.***

Financial resources

Nuclear Energy Act defines as a condition for granting a construction or operating licence that the applicant has sufficient financial resources, necessary expertise and, in particular, that the operating organisation and the competence of the operating staff are appropriate. According to the Nuclear Energy Act, the licensee shall also have adequate financial resources to take care of the safety of the plant. In addition, Nuclear Energy Act provides detailed regulations for the financial arrangements for taking care of nuclear waste management and decommissioning. The Act on Third Party Liability provides regulations on financial arrangements for nuclear accidents, taking into account that Finland is a party to the Paris and Brussels conventions.

The financial preconditions are primarily assessed by authorities other than STUK (mainly by the Ministry of Employment and the Economy). The financial position and business environment of the licensee also affect the safety of plants, and STUK therefore follows licensees' plans to improve safety of nuclear power plants, as well as organisational reforms, safety research conducted by licensees, the number of employees and the competence of personnel. The annual reports of Fortum

Corporation and Teollisuuden Voima Oyj provide financial information on the utilities. Both utilities have annually invested typically about 40–50 M€ for maintaining the plant and improving safety. For example, TVO has recently made a decision to renew all emergency diesel generators where the overall investment is more than 100 M€.

A financing system for the costs of future waste management and decommissioning exists to ensure that the producers of nuclear waste bear their full financial liability on the coverage of those costs and that the costs can be covered even in case of insolvency of the waste generator. The pertinent licence-holders submit every three years for regulatory review the technical plans and cost calculations on which the liability estimates are based. After confirmation of the financial liabilities, the licensees pay fees to a State controlled Nuclear Waste Management Fund and provide securities for the liability not yet covered by the funded money. At the end of 2015, the fund contains approximately 2 450 million euros.

Human resources

The licensee has the prime responsibility for ensuring that all the employees are qualified and authorised to their jobs. The regulatory requirements for human resources are stated in the Nuclear Energy Act (Sections 7 and 20), the STUK Regulation (STUK Y/1/2016) and Guide YVL A.4. The Nuclear Energy Act Section 7 was modified during 2012 with a demand to appoint also deputies for the responsible persons for emergency preparedness, security and safeguards. According to Section 25 of the STUK Regulation (STUK Y/1/2016), significant functions with respect to safety within nuclear power plants must be designated, and training programmes shall be prepared for developing and maintaining of the professional qualifications of the persons working in such positions. Adequate command of the functions in question must also be verified. The Guide YVL A.4 sets requirements for training and qualifications of personnel working in functions that are important for plant safety and the Appendix E in this Guide sets requirements for NPP operator competence. This new YVL guide has more specific requirements for safety critical positions, e.g. for responsible director and persons responsible for safeguards, emergency preparedness and security (Appendix A–D). The guide also has specific requirements on management and leadership competencies.

Human resource planning at the Loviisa NPP is based on a ten-year plan, which is subject to annual management review and updating. Loviisa NPP has a project management procedure which includes a resource management approach that will support the NPP in evaluating and following up the resources needed for accomplishing the projects.

The training activities and procedures at the Loviisa NPP are constantly developing. Much responsibility is given to the line manager and the individual defining the qualification and training needs. The training unit can support the line organisation with their expertise, but the responsibility for developing the specialist competence lies on the line organisation. The training unit's main responsibility is to develop the human resource management procedures and organise the general training sessions. The training organisation has recently been strengthened with experts in behavioural sciences. Fortum has a procedure for setting up individual development plans for all newcomers and for persons changing positions. Qualification needs for different positions are based on evaluations performed by line managers. According to the requirements in the Guide YVL A.4 Loviisa NPP has started to develop tools and procedures for a more efficient competence management to be able to ensure the resources needed for also in the long-term. STUK has identified by inspections the needs for human resource development in, for example, quality assurance and safety cultural issues. Loviisa NPP has during 2013-2016 faced several organisational changes. Every organisational change is evaluated from safety point of view and the evaluation report is sent to STUK for review.

TVO has updated the personnel plan regularly according to the phases of Olkiluoto NPP unit 3 construction. TVO made a big organisational change during 2015 where the business model was changed, the organisation completely reorganised and also some personnel were laid off. This organisational change has been assessed by external specialists and has been challenging for the organisation. TVO decided to stop the planning of the Olkiluoto unit 4 project to concentrate on finalising Olkiluoto 3 project and integrate the project organisation smoothly to the operating organisation. Some administrative organisational parts of Posiva, which is a company responsible for the disposal project in Olkiluoto, were integrated to be part of TVO corporate group organisation.

TVO has a training program and procedures taking into account the commissioning of the Olkiluoto unit 3. TVO uses an IT-system that supports the managers e.g. in defining and following up individual development plans. TVO has defined training requirements for each position or job that automatically will be included in the new recruited person's development plan.

Personnel and human resources related issues are included in STUK's periodic and construction inspection programmes at the nuclear power plants. A top level inspection of the periodic inspection programme, "Human Resources and Competence", includes assessment of human resource management, competence development and training programmes. It also covers the licensee's procedures for managing human resources and competence of suppliers, sub-suppliers and other partners participating in functions affecting safety. During the years 2014-2016 STUK has paid attention especially to personnel planning and ensuring resources in development and modification projects. STUK also participates in examinations of shift personnel, where the operators working in the control rooms show that they are conversant with all salient matters related to plant operation and safety. STUK further approves the appointment of certain key personnel, such as the responsible director and his/her deputies.

Strengthen and maintain competence building in Finland

Ensuring an adequate national supply of experts in nuclear science and technology and high quality research infrastructure is recognised as a continuous challenge in Finland because of the ongoing Olkiluoto unit 3 construction project and the new reactor project Hanhikivi unit 1.

During 2012–2015, the three Universities Aalto, Helsinki University and Lappeenranta University of Technology set up a Doctoral programme YTERA (Doctoral Programme for Nuclear Engineering and Radiochemistry), which was funded by the Academy of Finland, the universities and the industry (the NPP utilities and Posiva). The aim was to ensure supply of high-level expertise of nuclear engineering and radiochemistry and to create a permanent network for nuclear post-graduate education. The programme covered all fields of nuclear engineering and radiochemistry and it involved close collaboration with Finnish research bodies, industry and authorities that deal with nuclear energy generation. In general, the YTERA doctoral programme has reached its goals. During the programme 21 new doctors have been graduated. The future challenge is to sustain the nationwide activities within the domestic network.

The main organisations in the nuclear energy area in Finland develop and organise the basic professional training course on nuclear safety, which is a annually held approximately 6-week training programme for students and staff members of the participating organisations (STUK, the licensees, VTT, Aalto University and Lappeenranta University of Technology, Ministry of Employment and the Economy). The first course commenced in September 2003 and the 14th basic professional training course will commence in autumn 2016. At the moment, over 800 newcomers and junior experts have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants.

During 2010-2012 a committee set up by the Ministry of Employment and the Economy worked on a report aiming at giving recommendations and steps to be taken until the 2020's for ensuring competence and resources needed for the nuclear sector. STUK was an active part in this committee. One of the recommendations of the committee was that the future needs and focus areas of Finnish nuclear energy sector research must be accurately defined and a long-term strategy drawn up for further development of research activities. This calls for a separate joint project among research organisations and other stakeholders in the field. The update of the competence review is planned to be carried on in 2017 to reflect the current changes in the operating environment.

At the end of January 2013 the Ministry of Employment and the Economy set up a working group to prepare a research and development strategy with in the use of nuclear energy. The working group was chaired by a representative of the Ministry of Employment and the Economy. The nominated members of the working group include experts from STUK, VTT, Finnish Academy, Aalto University, Technical University of Lappeenranta, University of Helsinki, Fortum, TVO and Posiva. Results of the research and development strategy work have been published at the end of April 2014. The report "Nuclear Energy Research strategy" emphasizes the importance of the research in the competence building. The recommendations of the working group are the following: 1) The areas of focus in nuclear energy research must be compiled into wide-ranging national programmes. 2) The scientific level of Finnish nuclear energy research needs to be raised. 3) Active participation is needed on international research that is important for Finland through broad-based national multidisciplinary collaboration. 4) To secure the quality and quantity of researcher education, a broad and comprehensive doctoral programme network needs to be established for the nuclear energy field. 5) Building, maintaining, and utilizing infrastructure requires coordination at the national level. Financing needs to be considered strategically and the roles of national financiers need to be clarified. 6) In research activities input is needed into the development of innovations. The growth of business operations and internationalisation are supported by bringing the players together under Team Finland. 7) It is proposed that an advisory committee be set up in connection with the Ministry of Employment and the Economy linked with nuclear energy research and co-operation as a permanent expert body to support decision-making in national questions related to the nuclear energy.

The ministry of the Employment and Economy has started the implementation of the recommendations. In 2015 the Nuclear Energy Act was changed to ensure the financing for the enhancement of the nuclear safety research infrastructure.

In conclusion, Finnish regulations and practices are in compliance with Article 11.

Article 12. Human factors

Each Contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

Regulatory requirements regarding human factors

Human reliability in the plant operations is largely based on good plant design and proper procedures, training and recruitment. According to Section 6 of the STUK Regulation (STUK Y/1/2016), attention shall be paid to the avoidance, detection and correction of human errors affecting safety and the limiting of their effects throughout the service life of the nuclear power plant. The possibility of human error shall be taken into account in the design of the nuclear power plant and in the planning of its operations and maintenance, so that human errors and deviations from normal plant operations due to human error do not endanger plant safety or lead to common cause failures.

According to Section 16 of the STUK Regulation (STUK Y/1/2016), the control rooms of a nuclear power plant shall contain equipment that provides information on the state of the nuclear power plant and any deviations from normal operation. Furthermore, the nuclear power plant shall be equipped with automatic systems that actuate safety functions as required, and that control and supervise their functioning during operational occurrences to prevent accidents and during accidents to mitigate their consequences. These automatic systems shall be capable of maintaining the plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions. The nuclear power plant shall have a supplementary control room independent of the main control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing decay heat from the fuel in the nuclear reactor and the spent fuel stored at the plant.

Measures taken by licence holders

Loviisa nuclear power plant

In 2015 Loviisa plant made a big investment in Human Performance training. Every person working at the plant attained a very practical two day training which focused on a few important Human Performance working methods that may by efficient usage effectively decrease human errors in activities at the plant. These methods include pre-job-briefing, de-briefing, peer checking and clear communication. Measures at the Loviisa plant to ensure adequate human performance have also focused on development of operating procedures. Large part of plant's emergency operating procedures (EOPs) has been modified into flowchart format. These EOPs include symptom based identification which guides operators to event based procedures. Complex accident sequences and core melt accidents lead to symptom based operation. Human redundancy is provided by independent on-duty safety engineer. These emergency operating procedures have gone through a comprehensive set of verification and validation activities which include background analysis of the plant behaviour. Loviisa plant is equipped with a full scope training simulator which is used for operator training, including accident situations.

Fortum evaluates human reliability as part of the probabilistic risk assessment (PRA). For analysing hidden defects influencing the course of a possible transient or accident, Fortum has evaluated regularly different types of duties performed at the plant. In the analysis such operational and maintenance mistakes have been evaluated which may act as an initiating event of a transient or an accident. Different plant states and duties related to them have been evaluated in detail.

For preventing human errors it is important, that the operating events are carefully evaluated and, if necessary, procedures of the nuclear power plant are developed to prevent similar mistakes. Fortum has developed the utilisation of operating experiences and conducts the root cause analyses out of most significant events.

The protection systems of the plant initiate the safety systems automatically when needed so that the operators will have enough time to consider actions according to operating and emergency procedures. Due to the inherent characteristics of the Loviisa plant, e.g. large water volumes both in the primary and secondary circuits, the operators will have more time for consideration in a transient situation than usually at other nuclear power plants. The Loviisa units 1 and 2 have their own independent main control rooms where the needed process information is available and control actions can be performed. Alarm signals from the separate interim spent fuel storage are also available in the Loviisa unit 2 main control room. The process computer gives process information in an illustrative format for the use of the operators.

In addition to the main control room, the shutdown of the reactor as well as the control and monitoring actions necessary for safety can be performed by means of a so-called emergency control post. For severe accidents there is a separate dedicated control room shared by both units.

The I&C systems are currently being renewed at the Loviisa plant. Human performance is taken into account in the modification. This automation renewal project has a dedicated control room design team, which is in charge of the human factors engineering (HFE).

Olkiluoto nuclear power plant

Basis for safe operation has been laid already in design phase. The so-called 30-minute rule has been the design basis for the protection system at the Olkiluoto units 1 and 2. Important protection measures and safety systems start up automatically so, that no actions of operating personnel are needed during the first thirty minutes after the beginning of the operational transient or postulated accident. Proper emergency and transient situation procedures as well as training for those situations reduce the possibility of human errors further.

Olkiluoto reactor units 1 and 2 have their own independent control rooms, where the necessary process information is available, and from where all necessary control measures can be conducted. The alarms covering the separate interim storage facility for spent fuel are also available in the control room of the Olkiluoto unit 1. The technical solutions of the main control rooms are based on the proven control room technology. During the renewal of turbine automation system several new computerised operator workstations and a large screen display system were installed into the main control room. Process information is presented by the indicating measuring equipment installed in the steering desks and panels as well as with several computer display units. Conventional and computer aided alarm systems are used to facilitate the management of main processes and other sub and auxiliary processes. The alarms are indicated primarily by the alarm lamp panels. The parallel alarms received through the computer are seen on the monitors. In addition, the event and state data as well as deviations from warning/alarm limits are printed on the alarm printers. A safety parameter display system (SPDS), which improves the performance capability of the operating personnel in controlling transient and accident situations, is in use at the Olkiluoto plant units. Main control room can now be described as a hybrid control room. All the main control room related modifications are tested at the training simulator, and operators are trained for managing the modified systems prior to the modifications are installed.

Currently both Olkiluoto plant units have an emergency control room that has been redesigned and relocated to provide better co-ordination and control for plant shutdown and safety function monitoring. Cooling the reactor down to a safe cold state can be carried out after the shutdown by using emergency control room and some local control posts.

There are methods for preventing human errors during operation. Main areas to be considered are operation, maintenance and modification projects. Human reliability can be enhanced in every day activities with special methods. These methods include pre-job-briefing, de-briefing, peer checking, independent verification and clear communication. TVO has trained and introduced these methods in feasible activities. Proper work planning and Permit-to-Work-system in addition to up-to-date procedures are key methods in maintenance related activities to ensure safety during maintenance. Checking and approval requirements are also considered when requalifying systems back into operation. This work is part of a company wide project called "Human Performance 2012" which incorporates also other measures to improve human performance. The aim is to support managers and the personnel in managing human performance to avoid as many human mistakes as possible.

Human Factor issues are taken into account in all events. Lessons learned from the events are taken into account in the corrective action plans and lessons learned are used in internal training and organisational development. TVO has utilised operating experience and results of root cause analyses in the development of human aspects in the operating procedures. Errors related to the maintenance actions have also been examined and measures have been developed to avoid corresponding errors. Fatigue has been identified as an important factor to be managed.

TVO has conducted a probabilistic risk assessment (PRA) where the consequences of human errors have been studied. Latent maintenance and testing errors have been studied in connection with the system analyses related to the PRA. In addition to the human factor experts, experienced staff members from the operating and maintenance personnel have participated in assessing the possibility of errors. The identified error possibilities have been classified into groups according to their importance and the most important ones have been modelled in the PRA study to clarify the risks related to errors. The reliability of operator actions conducted during accident conditions was assessed as a part of the PRA analysis. The diagnostic errors that may be made in connection with accidents have also been assessed. Based on the results of the analyses concerning the human errors, a few additions and modifications have been made on the emergency and operating procedures of the Olkiluoto units 1 and 2. Emergency operating procedures have been recently re-evaluated in order to identify any previously unnoticed errors. Some clarifications have been made into procedures based on these talk/walk-throughs and simulator tests.

For the Olkiluoto unit 3, human factors engineering has been part of the design phase. Concept of operation is taken from existing units and reference plants. Main control room has operational I&C system with operating terminals and large screen displays. This interface can be used in all plant conditions. Additional information can be integrated into this system, e.g. alarm systems and operating procedures. Safety related I&C system has own traditional operating panels which are diverse control method for operational I&C. These safety panels include also hardwired controls which are additional back-up for all I&C systems. Olkiluoto unit 3 has also remote shutdown station. Feasibility of human factors engineering will be demonstrated in validation studies. Integrated validation will be done at a full scope simulator before plant commissioning.

Regulatory oversight

Human factors have to be taken into account in the design and analysed in the failure analyses of plant safety systems and in probabilistic risk assessments. Such analyses have been completed for both Finnish nuclear power plants. In addition to this high level licensing documentation, individual system design needs to be reviewed by STUK. Main emphasis is on the control room design approvals and verification and validation procedures for normal and emergency operations. Design documentation needs to reflect proper human factors design and design shall be coordinated with Human Factors Engineering -program and according to quality plans, change processes and verification/validation plans. Finally licensee shall demonstrate the safety with integrated system validation and analyse the results. Human error discrepancies need to be addressed if there are major findings, before commissioning of the control room systems can proceed.

In conclusion, Finnish regulations and practices are in compliance with Article 12.

Article 13. Quality assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

Regulatory requirements regarding management systems

According to Section 25 of STUK Regulation (STUK Y/1/2016), the organisations participating in the design, construction, operation, and decommissioning of a nuclear power plant are required to employ a management system. The quality management system must cover all functions influencing plant safety, and the licensees are further required to ensure that all their suppliers, sub-suppliers and other partners participating in functions that affect nuclear and radiation safety adhere to the quality management system. Along with the management system, the STUK Regulation sets requirements for the documentation of the lines of management and monitoring of the operations.

STUK's Guide YVL A.3 sets general requirements for management systems. Guide YVL A.3 adheres to IAEA Safety Standard GS-R-3 on management systems. Requirements for quality management of system design are established in the new Guide YVL B.1. The quality management requirements related to specific technical areas are presented in the corresponding technical guides. STUK also has a new YVL guide concerning nuclear facility construction and modifications, i.e., Guide YVL A.5. In this new guide, there are requirements for example on project management and supplier management. The management systems of the licensees and applicants are subject to approval by STUK. According to the Guide YVL A.3, any safety-significant revisions to the management system must be submitted for approval to STUK, but minor revisions are only submitted for information prior to their use.

Measures taken by licence holders

Loviisa nuclear power plant

Fortum's Policy Commitment to Quality in the Nuclear Power Operations was revised and confirmed by the management of Fortum in 2015. The development of Loviisa NPP's quality management system is based on the principle of continuous improvement in accordance with the observations and remarks made in quality audits and quality assessments. The environmental management system of the plant is compatible with the ISO 14001 and OHSAS 18001 standards.

Fortum has developed their management system, according to the guide YVL 1.4 requirements and in 2014 Fortum started a development project aiming at fulfilling the new Guide YVL A.3 requirements concerning the process based management system. This project concerns Fortum's Nuclear operations and Loviisa NPP and will continue. The quality management system of Fortum Power & Heat Oy for the Loviisa NPP complies with the requirements of the Guide YVL A.3 in most respects, but some deviations still remain of which the most significant is the process based management approach. Other areas where there still are development needs are the quality management in procurement and supply management. Fortum conducted an independent evaluation of the purchasing activities at the Loviisa NPP in the end of 2012 and the evaluation resulted in a development program. Also the implementation phase of the Guides YVL A.3 and A.5 resulted in additional development needs and actions that are still ongoing. Loviisa NPP has clearly defined the responsibilities for developing the management system and reformed the procedures for reviewing the management system. Loviisa NPP has had special training sessions for defined personnel on the management system and the Guide YVL A.3. Loviisa has reformed also the quality assurance (QA) personnel qualification demands and procedures for evaluating and developing the QA-competence.

Olkiluoto nuclear power plant

TVO's quality management system is described in the Quality Management Manual. It takes into account the requirements from YVL A.3, IAEA GS-R-3 and ISO 9001:2000. TVO is actively developing the management system towards a process based management system due to the growing organisation and the need for systematic and efficient operations throughout the organisation. The Management System guides all TVO's operations and provides each staff member with procedures for the safe, economical, high-quality and environmentally friendly generation of electricity. TVO's company-level policies are nuclear safety and quality policy, social responsibility policy, production policy and corporate security policy. The functions and responsibilities of TVO's organisations and personnel are described in detail in the TVO's Administrative Rules, in the Organisational Manual and in the manuals and instructions of individual organisational units. For the Olkiluoto unit 3 construction phase, STUK has approved "The Quality Plan for Olkiluoto 3 Project". The review of document as well as review of the QM systems of plant vendor and major suppliers has been carried out by STUK. STUK has also asked external QM experts' opinions on the QM systems.

The quality management system of TVO for the Olkiluoto units 1 and 2 mainly complies with the requirements of the Guide YVL A.3. The most significant development need concerns the process management and process descriptions. TVO also needs to develop the purchasing processes and the quality assurance competence in procurement. The Guide YVL A.3 was implemented to the Olkiluoto units 1 and 2 during 2015 and the implementation for the Olkiluoto unit 3 will be carried out during the evaluation of the operating licence application.

Regulatory oversight

STUK has followed up the implementation of the Guide YVL A.3 requirements in the management systems of the licensees during the periodic inspection program. The top level inspection of the STUK's periodic inspection programme, "Functioning of the Management System", includes assessment of functioning, development and assessment of the management system as well as assessment of the organisation for quality management. The "Management and Safety Culture" inspection (see Article 10) also contains items concerning management systems. During 2014-2016 the management system inspections have especially dealt with the process management, follow up of corrective actions, quality assurance competence in procurement and supply management. The management systems of the main suppliers are also reviewed and assessed and their implementation is verified through inspections and audits mainly by the licensee where STUK is taking part as an observer.

Concerning the Olkiluoto unit 3 construction project, STUK has performed two quality management and quality assurance inspections every year as a part of the construction inspection programme. In addition, STUK has participated as an observer in the licensee's and vendor's quality audits at the subcontractors. STUK's inspections have been focussed on the ongoing integration of the management system of Olkiluoto unit 3 to TVO's management system.

Management system of the regulatory body

STUK has an own Quality Manual that includes safety and quality policy, description of the quality system, organisation and management, roles and responsibilities, main and supporting working processes and personnel policy. The results of management reviews, internal audits, self-assessments and international evaluations are used as inputs for the enhancement projects of the Quality Management System at STUK. In addition to STUK's Quality Manual, all main functions of STUK have their own more detailed Quality Manuals.

STUK's management system will be further developed during the next years according to the suggestions of the IRRS mission and its follow-up. For example, STUK will continue reviewing and revising the existing Quality Manuals and guidance documents for consistency and improve overall descriptions of the processes including sub-processes and their interdependency. STUK has developed further a systematic long-term programme for self-assessments, internal and external audits and evaluations on the effectiveness of the processes. In addition, STUK has developed new more formalised principles of using graded approach in its oversight activities as a response to IRRS mission findings. STUK will continue developing more detailed procedures for the use of graded approach in the authorisation of systems, structures and components and in the planning and conducting inspections.

In conclusion, Finnish regulations and practices are in compliance with Article 13.

Article 14. Assessment and verification of safety

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;***

ii. ***verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.***

Regulatory approach to safety assessment

The prerequisite of the construction and operating licences is that the licence applicant has made its own safety assessment on the facility and in particular how the facility meets Finnish safety requirements. The fulfilment of the safety requirements is demonstrated in the construction and operating licence documentation. STUK makes an independent safety assessment concerning the application and STUK's assessment is required in the Nuclear Energy Act. Conditions for granting a licence are provided in the Nuclear Energy Act. In Section 20 of the Act it is further stated that the operation of the nuclear facility shall not be started until STUK has ascertained that the nuclear facility meets the prescribed safety requirements.

The Nuclear Energy Decree requires that when applying for a construction licence, the applicant must submit to STUK the following documents: a Preliminary Safety Analysis Report, a design phase Probabilistic Risk Assessment, a proposal for a safety classification document, a description of Quality Management during the construction of the nuclear facility, preliminary plans for periodic inspections, for the arrangements for security and emergency preparedness, and a plan for arranging the safeguards control. For the operating licence, the applicant must submit to STUK: the Final Safety Analysis Report, the Probabilistic Risk Assessment, the safety classification document, the quality management programme for the operation of the nuclear facility, Operational Limits and Conditions, a programme for periodic inspections, security and emergency plans, a description on administrative rules for safeguards, a programme for radiation monitoring in the environment of the nuclear facility, a description of how safety requirements are met, and a programme for the management of ageing. In addition, the Decree gives STUK a possibility to ask other documents considered necessary for safety demonstration.

Design of the facility is described in the Preliminary (PSAR) and Final (FSAR) Safety Analysis Reports. As listed above, the reports have to be submitted to STUK for approval with the applications for construction and operating licences. PSAR/FSAR forms the basis to STUK´s safety assessment which is required before granting the Construction/Operation Licence (see Article 7). According to the Nuclear Energy Decree, FSAR has to be continuously updated, and changes to FSAR have to be submitted to STUK for approval. Requirements for the plant modification process are presented in the Guide YVL B.1. The main principle in plant modification process is that conceptual design plans and system-specific pre-inspection documents of Safety Class 1, 2 and 3 systems must be submitted to STUK for approval. STUK reviews and approves the modification prior to its implementation at the plant. In connection with a system modification, the Final Safety Analysis Report shall be amended accordingly without delay.

The general design bases for nuclear fuel are defined in the Guide YVL B.4. The design objective is that the probability of fuel failure is low during normal operational conditions and anticipated operational transients, and that during a postulated accident the rate of fuel failures remains low and the fuel remains in a coolable state. Detailed requirements for the design, quality management and control, handling, storage and transport of fuel are specified in the Guides YVL A.1, YVL A.5, YVL A.11, YVL D.2, YVL D.3 and YVL E.2.

According to the Nuclear Energy Act, the operating licence is granted for a fixed term. However, legislation has not prescribed the length of the term. The term is proposed by the licensee in the application, and must be justified on the basis of the ageing and planned future operation of the nuclear facility. Particular attention is paid to licensee´s processes and activities and planned safety improvements to ensure safety for the estimated duration of operation. The procedure for operating licence renewal is in general the same as in applying for an operating licence for a new nuclear facility. Specific requirements on the documents to be submitted to STUK for the renewal of the operating licence are described in the Guide YVL A.1. Renewal of the operating licence always involves a periodic safety review of the facility. If a licence is granted for a significantly longer term than ten years, STUK requires the licensee to carry out a periodic safety review within about ten years of receiving the operating licence or of conducting the previous periodic safety review. For a separate periodic safety review, STUK must be provided with similar safety-related reports as in applying for renewal of the operating licence. Periodic safety review of the Loviisa plant was carried out in 2014–2016, and the periodic safety review of the Olkiluoto plant was carried out in 2007–2009 (see Article 6).

According to the STUK Regulation (STUK Y/1/2016), nuclear power plant safety and the technical solutions of its safety systems shall be assessed and substantiated analytically and, if necessary, experimentally. The analyses shall be maintained and revised as necessary, taking into account operating experience from the plant itself and from other nuclear power plants, the results of safety research, plant modifications, and the advancement of calculation methods. The analytical methods employed to demonstrate compliance with the safety requirements shall be reliable, verified and qualified for the purpose. The analyses shall demonstrate the conformity with the safety requirements with high certainty. Any uncertainty in the results shall be considered when assessing the meeting of the safety requirements.

Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL B.3. Requirements for probabilistic risk assessments are given in the Guide YVL A.7. Acceptance criteria for the analyses are presented in Guides YVL B.4, YVL B.5 and YVL B.6. Acceptance criteria for limitation of public exposure in the environment of a nuclear power plant or other nuclear facility and limitation of radioactive releases from the plant are given in the Nuclear Energy Act 1988/161.

Deterministic safety assessment

As mentioned above, detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL B.3. YVL B.3 was revised together with other YVL Guides and was published 1st December 2013. New features of YVL B.3 compared with previous guides were inclusion of design extension conditions as an event category to be analysed and the possibility to utilise the so-called Best Estimate plus Uncertainty analysis method as an alternative to conservative approach. The event categories used in the Guide YVL B.3 are shown in the Table 1.

The acceptance criteria considering doses and releases in case of severe accidents are determined in the Nuclear Energy Decree. Other acceptance criteria are given in the B-series of YVL Guides for plant and system design.

Fortum submitted with the licence renewal documentation in 2005–2007 the revised Final Safety Analysis Report, including the transient and accident analyses of the Loviisa units 1 and 2. The analyses presented in the Safety Analysis Report cover anticipated operational transients,

Table 1. Event categories used in Guide YVL B.3.

DiD level	Event category	Frequency	Acceptance criterion (doses)
Level 1	Normal operation (DBC1)		0.1 mSv
Level 2	Anticipated operational occurrences (DBC2)	$f > 10^{-2}/a$	0.1 mSv
Level 3a	Postulated accidents Class 1 (DBC3)	$10^{-2}/a > f > 10^{-3}/a$	1 mSv
	Postulated accidents Class 2 (DBC4)	$f < 10^{-3}/a$	5 mSv
Level 3b	Design extension conditions (DEC)	Multiple failures DEC A – CCF combined with DBC2 / DBC3 DEC B – Complex failure combination DEC C – Very rare external event	20 mSv
Level 4	Severe accidents (SA)		Release limit

category 1 and 2 accidents, and severe accidents. The analyses cover comprehensively different operating states and include accident analyses for the storages of spent fuel and reactor operational wastes. Fortum will supplemented the deterministic safety analyses by analyses of type A and B design extension conditions, as required by YVL B.3, in association with the plant I&C renewal project by the end of 2018. Deterministic DEC C analyses will be submitted to STUK in 2019. Extreme external events have already been included in the plant PRA analyses. STUK reviewed the analyses for the Loviisa NPP license renewal and methods applied in the analyses. STUK contracted VTT Technical Research Centre of Finland to carry out independent analyses to verify the results given in the licence renewal documentation and to conduct sensitivity analyses. STUK concluded that the plant behaviour in different transient and accident situations has been analysed comprehensively and that the methods used in the analyses are properly validated to describe the operation of the Loviisa plant.

Accident and transient analyses of the Olkiluoto units 1 and 2, as well as the analysis methods, have been updated and developed throughout the operation of the plant. TVO revised completely the accident and transient analyses in conjunction with the application for the renewal of its operating licence in 1995–1998. The analyses were at that time carried out for nuclear fuel that is no longer being used at the NPP units. For the periodic safety review in 2007–2009, TVO updated the accident analyses using the SVEA-96 Optima 2 as a reference fuel. The plant modifications carried out after the renewal of the operating licence in 1998 were also taken into account in the update. Since the periodic safety review, YVL Guides have been revised and requirements regarding analyses of design extension conditions have been introduced. TVO will updated its safety analyses taking into account the new regulation in connection with the renewal of operating licence for Olkiluoto units 1 and 2 in 2017.

The calculation methods used for analysing the plant normal operating conditions, transients and postulated accidents were developed by the supplier of the Olkiluoto plant units. The methods have been qualified to an extent corresponding to a good level from the international perspective. STUK reviewed the analyses updated for the periodic safety review and the calculation methods used. The conclusion was that the analyses of transients and accidents of the Olkiluoto units 1 and 2 were conducted as referred to in the Government Decree (733/2008) in force at the time of the review. STUK required updating of the loss of coolant analyses which TVO submitted in 2010.

The preliminary analyses of Olkiluoto unit 3 were presented to STUK in PSAR and the Topical Reports appended to PSAR with the application for the construction licence. STUK contracted technical support organisations to carry out independent analyses to verify the results. STUK approved the PSAR of Olkiluoto unit 3 in January 2005 just before the construction licence was granted by the Government. TVO has submitted updated analyses for the Final Safety Analysis Report in 2008–2015. The analyses will be reviewed as a part of the Olkiluoto unit 3 operating licence application.

Probabilistic risk assessment

Regulatory requirements on PRA

In the Nuclear Energy Decree, probabilistic risk assessment (PRA) has been included since 1988 in the list of documents to be submitted to STUK for the review of the operating licence application. Since 2008 the design phase PRA has been in the list of documents to be submitted to STUK for the review of the construction licence application according to the Nuclear Energy Decree, but a limited preliminary PRA has been required in Regulatory YVL Guides since 1996. PRA for construction licence application is based on preliminary design information and generic reliability data for components. PRA for operating licence application is based on essentially final design information and vendor specific component reliability data, where available, and more detailed modelling of systems.

According to the STUK Regulation (STUK Y/1/2016), nuclear power plant safety and the technical solutions of its safety systems shall be assessed and substantiated analytically and, if necessary, experimentally. The analyses shall be maintained and revised as necessary, taking into account operating experience from the plant itself and from other nuclear power plants, the results of safety research, plant modifications, and the advancement of calculation methods. The detailed requirements on the use of PRA are set forth in the Regulatory Guide YVL A.7. Detailed requirements on risk-informed applications are included in several other YVL Guides.

STUK required in 1984 that the Finnish utilities Fortum (former Imatran Voima Oy) and TVO shall make extensive probabilistic risk assessments for the Loviisa and Olkiluoto nuclear power plants. The objective of these assessments was to determine the plant-specific risk topographies of the essential accident sequences. Another important objective was to enhance the plant personnel's understanding of the plant and its behaviour in different situations. Therefore STUK also required that the PRAs are performed mainly by the utility personnel and external consultants are used only for special topics.

In 1987 STUK published the Regulatory Guide YVL 2.8 on PRA. The Guide was updated in 1996 and 2003. In Nov. 2013 it was replaced by the new Regulatory Guide YVL A.7. Currently the Guide requires a full-scope (including internal events, fires, floods, seismic events, harsh weather and other external events) PRA for power operation and low-power and shut-down states. PRA shall cover the analysis of the probability of core damage (Level 1) and large release of radioactive substances (Level 2). PRA shall be updated continuously to reflect plant and procedure modifications and changes in reliability data.

Guide YVL A.7 includes the following probabilistic safety goals:

- Core damage frequency less than $1 \cdot 10^{-5}$/year
- Large radioactive release (> 100 TBq Cs-137) frequency less than $5 \cdot 10^{-7}$/year.

These safety goals apply as such to new NPP units. For operating units, instead of the numerical safety goals, the SAHARA (safety as high as reasonably achievable) principle and the principle of continuous improvement are applied.

Guide YVL A.7 also includes requirements on several risk informed applications, such as analysis of plant modifications, risk-informed in-service inspections and testing, development of emergency operating procedures and training programmes and review of safety classification and Operational Limits and Conditions.

For a new NPP unit, a preliminary PRA covering Levels 1 and 2 shall be submitted to STUK for the review of the construction licence application (design phase PRA) and the updated and complemented PRA (Levels 1 and 2) shall be submitted for the review of the operating licence application.

PRA's computer models shall be submitted to STUK. PRA is routinely used by STUK to support its decision making, for example, in the review of plant modifications and applications for exemption from Operational Limits and Conditions and in the analysis of operating events.

Main developments in risk informed regulation and safety management during the reporting period

During the reporting period the role of risk informed regulation and safety management has been further strengthened by STUK and the licensees. The following activities can be given as examples of the increased role of risk informed methods:

- Unit-specific PRA models have been completed for Loviisa NPP unit 2 and Olkiluoto NPP unit 2.

- TVO and Fortum have applied PRA in support of the review of safety classification of the operating units.
- The finalisation of the PRA for Olkiluoto unit 3 under construction is still ongoing. Risk informed applications have been used in the design of the unit and the risk informed applications for the operating phase are under development in accordance with the YVL Guides. PRA is also used in the planning of commissioning testing programmes.
- Risk informed methods have been used to support ageing management, for example, trend analysis of failure data. In connection with the life extension of Loviisa NPP unit 1 reactor pressure vessel, the probabilistic analysis of pressurised thermal shock was used to evaluate the safety significance of radiation induced embrittlement of weld seams.
- Risk informed approach has been used also for inspections of Loviisa reactor vessel internals. Preliminary results show that risk reduction could be gained by doubling the inspection interval, which would decrease the risk due to heavy load drop significantly.

The use of PRA in several well-established applications has been continued and the methods have been further refined.

In addition to the risk informed applications based on regulatory requirements, the licensees use PRA in applications supporting their operating activities, for example availability analysis and reliability centered maintenance.

Further development of the PRA computer code software developed at STUK has been continued in a joint project with VTT Technical Research Centre of Finland. The software is used in the review of the PRAs submitted by the licensees and in support of risk informed decision making at STUK.

Probabilistic risk assessment of the Loviisa NPP

Fortum provided STUK with Level 1 PRA in 1989. Since 1990 Fortum has extended PRA by analysing risks related to fires, floods, earthquakes, severe weather conditions and outages, as well as by conducting Level 2 PRA. Plant modifications have been carried out continuously at the Loviisa NPP, including safety system improvements, fire safety improvements, implementation of Severe Accident Management systems and a major modernisation programme in mid 1990's (see Annex 2). By means of these modifications risks have been decreased and the risk topography of the plant has been balanced. Technical solutions of the modifications have also been often justified with PRA.

The development of the core damage frequency since 2000 is shown in Figure 11. Until year 2014, PRA was done only for Loviisa NPP unit 1 and the small differences between the NPP units were assessed on case by case basis. Thereafter unit-specific PRA models have been kept up-to-date reflecting the small differences between unit 1 and unit 2. At the end of year 2015 the calculated estimate for the total probability of reactor core damage was about 1.7·10 5 per reactor year for unit 1 and 2.0·10 5 per reactor year for unit 2. The relative contribution to the annual core damage frequency from different groups of initiating events is shown for NPP unit 1 in Figure 12. There are no major differences between unit 1 and unit 2 risk profiles.

Fortum has also provided STUK with the Level 2 PRA, in which the integrity of the containment and the release of radioactive materials from the plant to the environment are evaluated. In the latest update in 2015, it was estimated that the total probability of a large release to the environment is about $9.3 \cdot 10^{-6}$ per reactor year. The estimate includes all initiating event groups, except for seismic events. The following modifications have

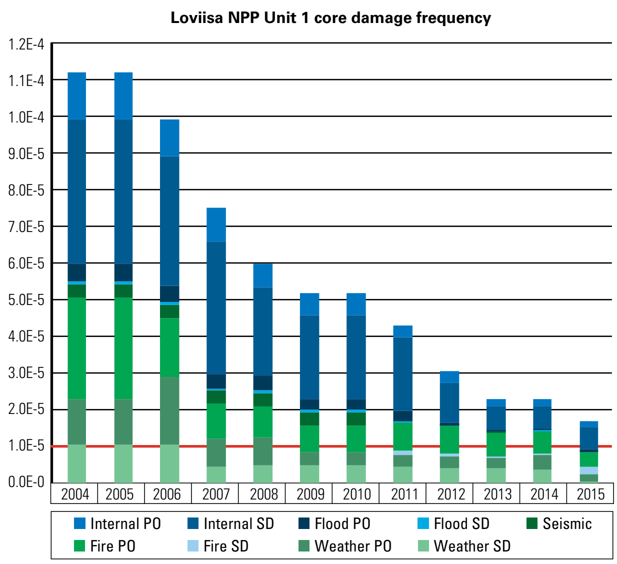


Figure 11. Development of the estimate of annual core damage frequency of the Loviisa NPP in 2004–2015.

decreased core damage frequency and large release frequency: the independent air-cooled cooling units for decay heat removal from the reactor core and from the spent fuel pools, enhanced protection against extreme high seawater level, renewal of auxiliary service water system, modifications in power distribution for some containment systems, renewal of Pressuriser Overpressure Protection Valve (PORV), renewal of pressuriser spray system and new procedures for sump recirculation in shutdown states.

The results of STUK's review show that Fortum has applied in its analyses commonly accepted methods in modelling transient and accident situations of the plant and in collecting and analysing reliability data. The reviews also show that the assessments provide an adequate basis for risk informed decision making.

PRA has been used by the licensee in the risk-informed applications as required by YVL Guides, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme, risk informed review of the Operational Limits and Conditions, including optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times). The Loviisa NPP has also introduced a Risk-Informed In-Service Inspection programme for piping. The number of inspections was increased but the focus shifted from high safety classes to lower safety classes. This shift is due to the fact that some lower safety class pipings have relatively large risk significance as they belong to vital support systems, or leaks in lower class pipelines may lead to consequential damage to safety systems. The radiation doses to inspection personnel will decrease as a result of the new inspection programme.

Probabilistic risk assessment of the Olkiluoto units 1 and 2

TVO submitted to STUK the first version of Level 1 PRA in 1989. Since then, the PRA has been updated several times and the scope has been extended. TVO has now practically full-scope PRA covering levels 1 and 2 for full power operation and for low power and shutdown states.

Annual core damage frequency since 2000 is shown in Figure 13. Plant modifications have been carried out continuously at the Olkiluoto plant, including backfitting with severe accident management systems and power uprate and modernisa-

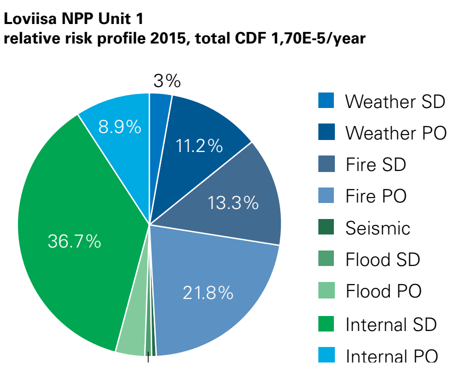


Figure 12. Relative contribution of different initiating event types to the annual core damage frequency in 2015 for Loviisa NPP unit 1. The most significant initiating events at full power (power operation, PO) are fires in the control building and in the turbine hall, and loss of off-site power due to strong wind combined with heavy snow fall or algae in the sea water intake. At shutdown (SD) the most significant initiating events are drop of heavy loads and various fire events. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

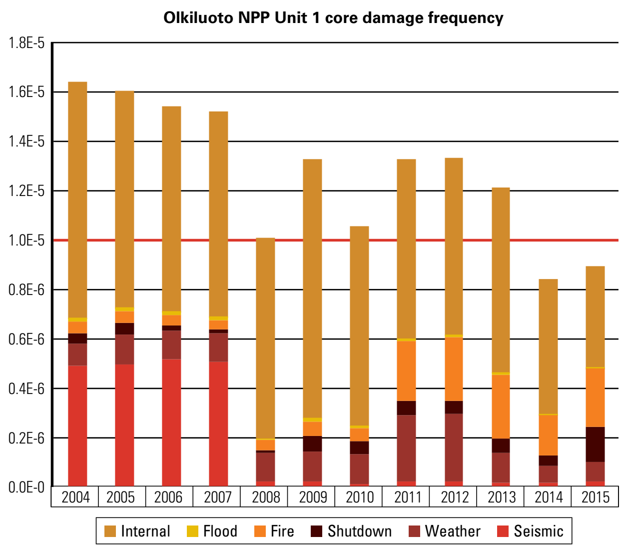


Figure 13. Development of the estimate of annual core damage frequency for Olkiluoto unit 1 in 2004–2015. The risk estimate increase in 2009 is due to a more detailed analysis of the capacity of decay heat removal by diverse systems. The risk estimate increase in 2011 is due to the change of the method used to determine fire ignition frequencies and update of external hazards study that contains a new man-made hazard "marine oil-spill". Risk increase in 2015 estimate is due to more realistic modelling of operator and operating staff actions during shutdown.

tion in the 1990's (see Annex 2). Until year 2013, PRA model was done only for Olkiluoto unit 1 and the small differences between NPP units 1 and 2 were assessed on case by case basis. Thereafter unit-specific PRA models have been kept up-to-date reflecting the differences between Olkiluoto unit 1 and unit 2.

At the end of 2015 the overall core damage frequency was approximately $9.0 \cdot 10^{-6}$ per reactor year for Unit 1 and $1.5 \cdot 10^{-5}$ per reactor year for unit 2, including all operating states and all groups of initiating events. The higher risk for unit 2 can mainly be explained by the fact that plant modifications that improve safety are not implemented at the same time. In 2014, a new recirculation line modification in auxiliary feedwater system was implemented. The modification reduced the system's dependence on seawater cooling. A similar modification has not been implemented at unit 2 yet. The relative contributions to annual core damage frequency from different groups of initiating events are shown in Figure 14.

In 1996, TVO submitted to STUK the Level 2 PRA. The analysis has been updated a few times since then. According to the latest PRA model the frequency of the large release to the environment (>100 TBq Cs-137) is $2.6 \cdot 10^{-6}$ per reactor year, which was approximately one tenth of the core damage frequency. The large release frequency has decreased in the updates mainly due to the decrease of the core damage frequency, but the severity of the release has decreased significantly mainly due to modifications in procedures.

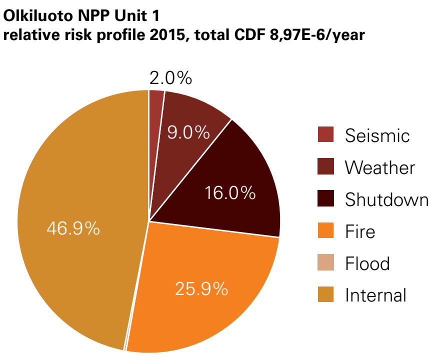


Figure 14. Relative contribution of different initiating event types to the annual core damage frequency in 2015 for Olkiluoto unit 1. The most significant internal initiating events at full power are the loss of off-site power and loss of feedwater. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

TVO has used PRA in the risk-informed applications required by the Guide YVL A.7, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times).

Probabilistic risk assessment of Olkiluoto unit 3

The vendor of Olkiluoto unit 3 conducted a design phase PRA, which TVO submitted in 2004 to STUK for the review of the construction licence application as required by the Nuclear Energy Decree. The design phase PRA already included analysis of internal initiating events, internal hazards and external hazards for power operation and refuelling outage. STUK approved the Olkiluoto unit 3 PRA for the construction licence in January 2005. The PRA of Olkiluoto unit 3 has been continuously updated by the plant vendor during the construction phase and STUK has closely followed the completion of the PRA.

The PRA for operating licence application was submitted to STUK in April 2016. The modelling has been improved in several areas taking into account the detailed design information. Main improvements are related to the modelling of internal fires and the extension of the PRA to cover seismic events. PRA review is ongoing and will be finalised in 2017.

Olkiluoto unit 3 Level 1 and Level 2 PRA covers transients and LOCAs as well as internal and external hazards in all operating modes, as required by YVL Guides. Level 3 PRA, which assesses the potential risk to people and the environment, is not required in Finland.

According to the Level 1 PRA results (under review), Olkiluoto unit 3 fulfils with a wide margin the probabilistic safety goals. The total core damage frequency estimate is approximately 3.0·10–6 per reactor year.

Results of the Level 2 PRA show that large release frequency of Olkiluoto unit 3 is very small, approximately $1.0 \cdot 10^{-7}$ per reactor year. Level 2 covers both the reactor core and the spent fuel pool.

PRA has been used by TVO and plant vendor in the risk-informed applications in accordance with YVL Guide requirements, for example in evaluation of system design, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, optimisation of Operational Limits and Conditions (allowable outage times), and planning of plant commissioning tests.

Assessment of safety as a result of TEPCO Fukushima Dai-ichi accident

Following the accident at the Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessments in Finland were initiated after STUK received a letter from the Ministry of Employment and the Economy on 15 March 2011. The Ministry asked STUK to carry out a study on how the Finnish NPPs have prepared against loss of electric power supply and extreme natural phenomena in order to ensure nuclear safety. STUK asked the licensees to carry out assessments and submitted the study report to the Ministry of Employment and the Economy on 16 May 2011. Although immediate actions to ensure safety of public and environment were not considered necessary, STUK required the licensees to carry out additional assessments and present action plans for safety improvements. Assessments were conducted and reported by the Finnish licensees to STUK on 15 December 2011. STUK reviewed the results of national assessments, and made licensee specific decisions on 19 July 2012 on the suggested safety improvements and additional analyses.

Finland also participated in the EU Stress Tests and submitted the national report to European Commission at the end of 2011. An EU level peer review on the report was completed by April 2012. The recommendations of the EU peer review have been taken into account in the regulatory decisions as well as included in the development of national regulations. A National Action Plan was prepared addressing the measures initiated on a national level and at the nuclear power plants as a result of the TEPCO Fukushima Daiichi accident. The National Action Plan was sent to the European Nuclear Regulators Group (ENSREG) and peer reviewed in April 2013 and April 2015. In addition, Finland participated in the second Extraordinary Meeting of the Convention of Nuclear Safety (CNS) in August 2012 and prepared a report introducing all Fukushima related actions. All STUK's related decisions, the national report to European Commission, the report to the Extraordinary CNS, and the Finnish National Action Plan have been published on STUK's website.

Based on the results of assessments conducted in Finland to date, it is concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. However, areas where safety can be further enhanced have been identified and there are plans on how to address these areas, some of which have already been implemented. The experiences from the TEPCO Fukushima Dai-ichi accident are also taken into consideration in the renewal of the legislation and Finnish Regulatory Guides (YVL Guides) and in the nuclear safety research programme SAFIR (see Articles 7 and 8). Implemented safety improvements as well as the ones under planning and implementation due to the TEPCO Fukushima Dai-ichi accident are described more detailed under Articles 16, 17, 18 and 19, and in Annexes 2, 3 and 4.

Information collected in connection with external events PRAs has been used in the national and EU stress tests after the TEPCO Fukushima Dai-ichi NPP accident, although mainly deterministic approach has been used. Seismic events and other off-site external events have been included in the PRAs in the 1990's and the analyses have been updated regularly. The input data and plant response analyses used in the external events PRAs have been reviewed after the TEPCO Fukushima Dai-ichi NPP accident in connection with the stress tests and no essential shortcomings have been found. Further updates of the analyses and hazard estimates will be continued.

Verification of safety

Verification programmes

STUK Regulation (STUK Y/1/2016) includes several requirements which concern the verification of the physical state of a nuclear power plant. For instance, in all activities affecting the plant operation and the availability of components, a systematic approach shall be applied for ensuring the operators' continuous awareness of the state of the plant and its components. The reliable operation of systems and components shall be ensured by adequate maintenance as well as by regular in-service inspections and periodical tests. General requirements on verification programmes and procedures are provided in the YVL Guides (e.g. Guide YVL A.8 and YVL E.5).

Main programmes used for verification of the state of a nuclear power plant are

- periodic testing according to the Operational Limits and Conditions
- maintenance programme
- in-service inspection programmes for pressure retaining components
- surveillance programme of reactor pressure vessel material
- research programmes for evaluating the ageing of components and materials.

Activities for verifying the physical state of a power plant are carried out in connection with normal daily routines and with scheduled inspections, testing, preventive maintenance etc. Activities are performed by the licensee and in the case of certain inspections by contractors approved separately. Detailed programmes and procedures are established and approved by the licensee. They are also reviewed and, when needed, approved by STUK. The results of tests and inspections are documented in a systematic way and used through a feedback process to further develop the programmes. The Operational Limits and Conditions are approved by STUK. In general, the role of STUK is to verify that the licensees follow the obligations imposed on them and carry out all activities scheduled in verification programmes.

Comprehensive evaluations related to the state and operation of the Loviisa and Olkiluoto plants were carried out in the periodic safety reviews by Fortum in 2014–2016 and TVO in 2007–2009. These activities were controlled by STUK.

Inspection qualification

According to international experience and the Guide YVL E.5, STUK has recognised the qualification of non-destructive testing systems and procedures as an issue of high importance. This issue requires high priority at both present nuclear power plants. The implementation of qualified NDT systems has been started in 1990's.

General requirements on inspection qualification are provided in the Guide YVL E.5. The document "European methodology for qualification" drawn up by the European Network for Inspection and Qualification (ENIQ) shall be used as the minimum requirement level for qualification of inspection systems to be used in in-service inspection, and it shall be complemented by the ENIQ Recommended Practices. In the content of licensees' guidelines published by the qualification body, the requirements presented in the Guide YVL E.5, in the European Methodology for Qualification (EUR 17299) and in its recommendations have been taken into account.

The licensees Fortum and TVO have established the Steering Committee for Qualification and nominate members to the Committee on annual basis. The Steering Committee for Qualification is guiding and supervising the practical qualification work with the help of a separate Technical Support Group nominated and supervised by the Steering Committee.

Based on a contract with the licensees, Inspecta Certification is nominated as the qualification body for qualification management, implementation, control and assessment as well as the issuing of qualification certificates in Finland. The Finnish qualification body is a qualification body of type 1, which is an independent third party organisation as defined by ENIQ Recommended Practice 7. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications.

Most of the qualifications have already been performed by the qualification body and approved by STUK.

STUK ordered in 2009 an assessment of the current qualification activities in Finland from an independent expert organisation. The purpose was to assess whether Finnish inspection qualification practice leads to reliable and effective in-service inspection of safety critical components. Review was performed in two parts: 1) review of the inspection qualification system as specified in the Guide YVL 3.8 (in force at the time) and the national qualification guideline documents issued by the qualification body and 2) review of the inspection qualification practices. As a conclusion of the assessment it was reported that the qualification system meets the Finnish requirements, is effective and provides confidence in the inspections of safety critical components.

In-service inspections

The condition of the pressure-retaining components of the Loviisa and Olkiluoto NPPs is ensured with regular in-service inspections. The components of the primary circuit are inspected by means of non-destructive examination methods. These regularly repeated examinations are carried out during outages according to the Guide YVL E.5. The results of the in-service inspections are compared with the results of the previous inspections and of the pre-service inspections which have been carried out before the commissioning.

The in-service inspection plans are submitted to STUK for approval before each individual in-service inspection. Programmes and related inspection procedures are changed when necessary, taking into account the development of requirements and standards in the field, the advancement of examination techniques and inspection experiences as well as operating experiences in Finland and abroad.

Guide YVL E.5 and the latest revisions of the ASME Code, Section XI are applied as approval bases for the in-service inspection programmes and procedures. ASME Code, Section XI, Appendix R and ENIQ European Framework Document for Risk-informed In-service Inspection are used as approval bases for the risk-informed in-service inspection programmes.

The reliability of the non-destructive examination methods for the primary circuit piping and components has been essentially improved after the commissioning of both the Loviisa and Olkiluoto NPPs. Guide YVL E.5 calls for the qualification of the entire NDT-system; equipment, software, procedures and personnel. Most of the inspection systems are already qualified at both the plants. STUK follows the development and implementation of the plans.

A risk-informed inspection programme has been introduced and approved by STUK at the Loviisa units 1 and 2 for the in-service inspections of safety-critical pipelines. The deployment of risk-informed inspection methods for targeting inspections has been developed in Finland by STUK, Fortum, TVO and VTT. The objective of risk-informed in-service inspection programmes is to allocate inspection resources to the targets that are most critical from the point of view of risk. Using this approach, it is possible to ensure that the current inspection objects are well-justified, identify new objects and omit certain less safety-critical objects from the existing inspection programme.

The length of the inspection period of the regular inspections (e.g. ASME Code, Section XI) is normally ten years. Inspection programmes have been complemented with additional inspections as regards the reactor pressure vessel and the primary circuit piping, and the length of the inspection period of the reactor pressure vessel has been reduced to eight years. The length of the inspection period of the objects susceptible to thermal fatigue is typically three years.

At the Olkiluoto plant, attempts have been made to focus the inspections on areas where faults are most likely to emerge. These include, for example, items susceptible to fatigue due to temperature variations or items susceptible to stress corrosion cracking. The selection of inspection items is under continuous development. For this purpose, a risk-informed in-service inspection programmes have been developed for the Olkiluoto units 1 and 2. Risk informed programmes have been approved by STUK and inspection schedules are optimized. These programmes are under continues optimization and reviewed annually.

The frequency of the non-destructive examinations performed at regular intervals is usually ten years at the Olkiluoto NPP. The inspection frequency for items susceptible to thermal fatigue is three years, and the inspection frequency for items susceptible to stress corrosion cracking is two to five years.

In addition to the inspections mentioned above, physical inspections concerning the condition and reliability of pressure equipment are carried out as regular pressure equipment inspections according to the Finnish pressure equipment legislation. Such inspections are a full inspection, an internal inspection and an operational inspection. These inspections include non-destructive examinations as well as pressure and tightness tests. The inspections of piping have been defined in the system-specific monitoring programmes. These periodic inspections are dealt with in the Guides YVL E.3, YVL E.8, YVL E.9, YVL E.10 and YVL E.11. The periodic inspection programmes of the Loviisa and Olkiluoto NPPs fulfil the requirements of YVL Guides, as regards the number and techniques of inspections.

Ageing management

According to the STUK Regulation (STUK Y/1/2016), the design, construction, operation, condition monitoring and maintenance of a nuclear power plant shall provide for the ageing of systems, structures and components (SSCs) important to safety in order to ensure that they meet the design-basis requirements with necessary safety margins throughout the service life of the facility. Systematic procedures shall be in place for preventing such ageing of SSCs which may deteriorate their availability, and for the early detection of the need for their repair, modification and replacement. Safety requirements and applicability of new technology shall be periodically assessed in order to ensure that the technology applied is up to date, and the availability of the spare parts and the system support shall be monitored. Furthermore, a dedicated regulatory guide for ageing management, Guide YVL A.8, requires that when applying for an operating licence for a new nuclear facility, the licensee shall submit to STUK for approval the ageing management programme for the nuclear facility that is to be complied with during the operation of the facility.

Ageing management at the Loviisa NPP

Radiation embrittlement of the reactor pressure vessel (RPV) and the related surveillance and mitigation actions have dominated the ageing management in Loviisa NPP since the early years of operation. This was more relevant to Loviisa unit 1 whose girth weld at the level of the reactor core has a higher content of impurities. In 1996, the brittle weld joint of the Loviisa 1 reactor pressure vessel was heat-treated to improve the ductility properties of the welding material. In this connection the reactor pressure vessel was subject to thorough non-destructive tests. Embrittlement rate has been re-assessed based on the new surveillance programme representing the critical weld. STUK has granted the operating licences of the RPVs for the Loviisa units 1 and 2 until 2027 and 2030, respectively. For both units, deterministic and probabilistic safety analyses will be evaluated in the PSRs (by end of 2015 and 2023) in order to justify continued service of the RPVs. In addition, new findings from domestic and international inspection and research programmes may require updating of the RPV analysis results.

In the mid-1990's, Fortum implemented their systematic plant-wide ageing management programme. The SSCs are assigned to categories A through D based on their technical and economical replaceability. SSC failures in category A would limit plant lifetime and thus deserve a part-assembly-wise break-down of ageing related remedies. Category A comprises the main primary components. Data indicative of plant status and trends are collected with operation, maintenance and inspection IT systems, R&D activities and via experience exchange. The consequent ratings of operability, remaining service life and necessary actions for each SSC are stored on the plant database.

In 2006 the operating utility Fortum submitted to the Government an application to continue the operation of Loviisa units 1 and 2 until the end of 2027 and 2030, respectively, meaning a 20-year extension to the original design lifetime. Among the ageing-related justification were the main fatigue analyses, updated to cover the whole 50 years' life span with consideration of the environmental effects. Documents on In-Service Inspection Summary Programme, Ageing Management Programme Principles and Implementation, and SSC Status and Service Life Extensibility were also submitted. For electrical and I&C components it was noted that massive projects are underway to replace cables in containment due to its detected considerable ambient temperature rise, and for plant-wide replacing of obsolete protection and plant I&C systems and components. In its review, STUK presented a general point that the state-of-the-art permitted a quantitative life-time evaluation only in case of ageing by fatigue. However, other potential mechanisms have been identified and resources are in place to monitor, inspect, mitigate and repair as needed. The operating organisation has also strong technical support which, in the past, has convincingly resolved forthcoming ageing issues, and the history records are well preserved. The Government granted the applied operating licences on condition that two periodic safety reviews (PSR) are undertaken during the licence period. The first PSR review was done in 2014-2016 and the ageing management was one of the key issues – especially the embrittlement margins of Loviisa unit 2 reactor pressure vessel before the expected end of life in 2030 (Loviisa 1 reactor pressure vessel core area was annealed in 1996). Related to PSR assessment Fortum will send at the end of 2016 to STUK for information the documents concerning the actions to increase the embrittlement margins of unit 2 reactor pressure vessel in the future.

Ageing management at the Olkiluoto NPP

The ageing management activities at the Olkiluoto units 1 and 2 arose from wide-spread indications of inter-granular stress corrosion cracking (IGSCC) in reactor auxiliary system piping. Early replacement of entire piping systems, achievable with modest doses to maintenance staff, considerably mitigated IGSCC and led the way to the utility's strategy of seeing to the critical SSCs so that a remaining plant life-time of 40 years (design life-time) could be always demonstrated.

Since 1991, the licensee's AGE Group, with assistance of several technical discipline related expert groups, has taken care of these activities by gathering information of possibly needed future actions from several sources and by preparing and updating a table of recommended major modifications, replacements, repairs and overhauls. The modernisation and power uprating of the Olkiluoto units 1 and 2 by 16% in 1994–1996 evolved from these recommendations and was completely carried out by the utility's technical support organisation residing on plant site. The associated significant renewal campaigns of obsolete electrical and instrumentation systems and components largely contributed to current 20-year operating licence periods terminating in 2018. Efforts to enhance the reliability and good performance of the plant components, and to ensure the spare part and support service availability have continued until recent years. The major foreseeable modifications until decommissioning have been identified.

Systematic maintenance planning is an integral part of ageing management at the Olkiluoto units 1 and 2. Nominated owners of equipment groups, characterised by a common type or location, analyse the entire maintenance programme and its experiences, and assist in selection of the most effective maintenance works. Annual findings from each equipment group are stored into a relational data base on the plant computer.

STUK reviewed TVO's clarification on the actual condition and ageing implications of the main SSCs in connection to the periodic safety review (PSR) carried out in 2007–2009. Supporting assessment has been done in several periodical inspections on plant site. The main components were generally found to be in good condition, but the appearance of IGSCC in Nickel-based alloys could not be excluded and it possibly explains an indication reported from the safe-end weld of the main feedwater nozzle, made from Alloy 182. The indication has, however, remained unchanged as evaluated by NDT-inspections during annual outages (further information in Article 18). The PSR also referred to a completed pilot project for updating fatigue analyses of selected systems to incorporate the environmental effect as required in Guide YVL 3.5 (in force at the time). Based on recommendations from expert consultancy of VTT Technical Research Centre of Finland, more refined modelling is employed now that the utility is renewing all fatigue analyses to justify a prospective re-licensing of the Olkiluoto units 1 and 2 for an operating life of 60 years.

At the Olkiluoto unit 3, the ageing management is taken into account at the design and construction phase. The most severe operating conditions and long-term influences, under which an individual component is expected to serve as a part of a process system, are used to determine the design basis requirements for that component. With known design basis requirements and defined life times of SSCs, their materials, fabrication and other ageing management related issues are specified accordingly. This includes precautions against foreseeable degradation mechanisms with state-of-the art technology, and provision for inspections, overhauls, testing and replacements as needed while respecting the ALARA principle. The anticipated life-span of the main technologies and independence from single technologies are particularly considered in I&C system and component design. The design and fabrication of SSCs are verified with qualified analyses, inspections and testing, overseen by STUK, in order to demonstrate fulfilment of quality and performance requirements set by the design specifications. During Olkiluoto unit 3 operation, the ageing of SSCs and retaining the design margins will be managed by dedicated programmes and monitoring tools, and by in-service inspections to who's planning risk-informed methods are applied.

The regulatory oversight during operation

The regulatory oversight of ageing in operating plants focuses on operating licence renewals and periodic safety reviews (PSRs) where the conformance to the relevant STUK Regulations and YVL Guides, including experiences with ageing and its management, is investigated. STUK's findings from other regulatory control practices, particularly the periodic inspection programme, are used as verification.

The periodic inspections are performed on plant site according to annual planning and tackle both the technical aspects of each discipline and the process of ageing management. Possible problems at the plants and in procedures of the operating organisations are to be recognised. The dedicated plant maintenance inspection is exclusively focused on the maintenance activities and ageing management. The aim of the inspection is to evaluate the procedures the licensee has for ensuring reliable operation and integrity of SSC. STUK will also assess the implementation of the ageing management programme based on the follow-up report prepared annually by the licensee.

In addition, an expert group dedicated to ageing management has been established within STUK to oversee how the licensees perform their duties in the ageing management of SSCs. The group, which consists of mechanical, electrical, I&C, civil and human resource experts and resident inspectors, plans and coordinates STUK's regulatory duties pertaining to the ageing of nuclear facility systems, equipment and structures. If shortcomings are found, for example in condition monitoring or maintenance, the group calls the licensee for further clarifications or corrective actions. The group also follows up findings from other countries and evaluates their possible applicability to the ageing management of the Finnish nuclear power plants.

A dedicated regulatory guide for ageing management, Guide YVL A.8, apply as such for new NPPs, but also the NPPs in operation have to meet the new requirements in the new guide to the extent practicable. Implementation of the updated ageing management requirements is underway for NPPs in operation and some specific challenges to fulfil the new ageing management requirements have been met. For instance the new guide has a requirement on the availability and operability as well as monitoring the condition of spare parts. Inspections have revealed that the amount of spare parts can be inadequate for keeping the plant in a safe state also during prolonged transients and accidents, and that some of the spare parts in the storage have either aged or obsoleted. Another challenge has to do with knowledge and resources allocated for ensuring appropriate ageing management programme at NPPs. Inspections have revealed that the licensees have challenges to implement knowledge management to ensure that in the event of personnel changes information and knowledge necessary for discharging the duties involved is transferred to the successors. Additional challenge is to conduct relevant research to both educate personnel and to identify new ageing mechanisms to develop new inspection or monitoring technologies to detect degradation early enough.

A generic lesson learned in Finland is that the closer nuclear power plants get to the end of their design lifetime, more difficult it is for the licensees to make decisions to modernise or modify the NPPs. Instead of renewing a system or a component, modernisation may be rejected or a partial modification is planned resulting in ageing issues in the remaining parts. A postponed decision to renew for instance an I&C system or an electrical system may result in that later on spare parts are no longer available for the remaining systems. Both of these cases may lead to situations where the licensee may not be able to demonstrate the continued safety of operations to the regulator, or at least the views on the demonstration results may differ between the licensee and the regulator. Finland has successfully applied periodic safety reviews for the operating NPPs. Practice has been that the licensee is obliged to demonstrate that the safety of the operations can be ensured and improved also during the next 10 years, and to do that the licensee has to commit to make safety improvements including major modernisations to address ageing of SSCs.

In conclusion, Finnish regulations and practices are in compliance with Article 14.

Article 15. Radiation protection

Each contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Regulatory requirements regarding radiation protection

The main regulations governing radiation protection of Nuclear Power Plant operation are the Radiation Act (592/1991), Radiation Decree (1512/1991), STUK Regulation (STUK Y/1/2016) and YVL Guides, Group C (7 guides). Radiation Decree stipulates that the effective dose caused to a worker shall not exceed an average of 20 millisieverts (mSv) per year in any five years period, nor 50 mSv in any single year. The limit for the annual dose of an individual in the population, arising from the normal operation of a nuclear power plant, is 0.1 mSv. Based on this, STUK shall upon application confirm the release limits for radioactive materials during the normal operation of a nuclear power plant. ALARA requirements are issued in the Radiation Act and more in detail implementation requirements are given in the YVL Guides both for NPP workers and release abatement. During 2013–2015 the Guides as regards radiation protection were updated. When updating the guides the latest operation experience including the experience from Tepco Fukushima Dai-ichi accident was taken into account. However, the radiation legislation as well as the regulations and guidance of STUK is under renewal to meet the requirements stipulated e.g. in the BSS-directive.

Radiation doses of the NPP workers and the public

The most important tools to reduce radiation doses for the NPP workers and the public shall be described in an ALARA programme of a NPP.

At the Loviisa NPP the ALARA programme was updated in 2014. One of the main objectives has been that there shall be a continuous improvement in the collective dose indicator trends. The four years average of collective dose has decreased at Loviisa NPP to 0.6 manSv/reactor unit/year. The ALARA programme includes also the goal that no employee at the plant should receive a radiation dose exceeding 15 mSv per year.

The most important measure to lower the dose rates at the Loviisa NPP has been the minimisation of antimony 122 and 124 content on the primary circuit surfaces. It has been discovered that the original seals of the main coolant pumps were the main reason for the activation products of antimony 122 and 124 in the primary circuit. The activation products of antimony have contributed approximately 40% of the doses of the workers during the outages. All the reactor coolant pump seals have now been replaced with an antimony-free material. The replacement work took place in years 2012 - 2014. In the following years a positive development in dose-rates near the primary circuit is to be expected.

Another important measure has been the optimisation of the use of additional shielding in the primary coolant circuit area during outages. Also by extensive work planning and training and by timing the work between yearly outages it has also been possible to reduce some of the radiation burden.

In the ALARA programme of the Loviisa NPP the company has committed, that in the effluent control mere compliance with the limits is not enough. Efforts shall be made to keep the radioactive releases to and radiation levels in the environment arising from the operation of the plant as low as reasonably achievable. The numerical target values, well below effluent limits, were set in the programme at the beginning of 2016.

The ALARA programme of the Olkiluoto NPP contains also the major objectives and procedures regarding the reduction of the doses of the employees and the target values for the main radioactive effluents. The ALARA programme was last updated in 2016. The ALARA programme includes the goals for collective dose of the Olkiluoto 1 and Olkiluoto 2 units. For these two reactor units in a normal year the collective dose of 1 manSv should not exceed (1.5 manSv, when major additional maintenance is needed). Also no employee at the plant should receive a radiation dose exceeding 10 mSv per year. There is also a goal that the internal dose of any worker shall not exceed 0.5 mSv. For Olkiluoto unit 3 the collective dose is targeted to be low. From the first operation year of this new NPP unit the collective dose is expected to be below 0.05 manSv.

In order to minimize the doses to the population, in the ALARA programme there are target limit values for the main radioactive effluents like noble gases, iodine isotopes, water-borne releases and tritium. The goal is that the annual effluents will cause calculative annual dose for an individual in the population, arising from the normal operation of a nuclear power plant, which is less than 1% of the limit value of 0.1 mSv.

The Olkiluoto NPP has continued the replacement of cobalt-containing components (containing stellite alloys) in the primary circuit with new ones with low cobalt content. Stellite-containing components represent today approximately 60% of the surface-are of the original design of primary circuit. The reduction in moisture of the primary steam with the equipment upgrades (new steam dryers) during 2005–2007 at the Olkiluoto NPP has contributed the substantial reduction of radiation dose rates at the turbine plant. The risk-informed procedure was deployed to the in-service material inspections in piping and welding for the first time in outages 2012. This has contributed towards reducing the amount of the work carried out in the most radioactive areas, thus reducing the radiation exposure of the employees.

Both the Loviisa NPP and the Olkiluoto NPP have their own ALARA groups where the topics of the ALARA programmes are discussed regularly. At both NPPs ALARA-programmes are described in the radiation protection manuals, which are updated regularly.

The radiation dose statistics of the workers are presented for the Loviisa and Olkiluoto nuclear power plants in Tables 1 and 2 and Figures 15 and 16. The individual radiation doses have remained well under the set annual and five years dose limits. The maximum combined dose of a Finnish worker at the NPPs for a single year during 2013–2015 was 9.2 mSv. For a 5 years period 2011–2015, the maximum dose was 36.6 mSv and was received by a person working at the Loviisa nuclear power plant.

In international comparison (e.g. the ISOE radiation dose database of the NEA, the Nuclear Energy Agency of the OECD countries), the Olkiluoto units 1 and 2 have been among the best boiling water reactors when comparing both the individual and collective radiation doses. The long-term planning of annual maintenance operations has made it possible to keep outage duration short, which usually reduces the amount of work carried out and hence also lower the radiation exposures. Also in comparison with different types of PWRs Loviisa units 1 and 2 have been on an approvable level.

Radioactive effluents

STUK confirms upon the licensee's application the release limits for radioactive materials during the normal operation of a nuclear power plant. Operational Limits and Conditions have more stringent requirements applicable for the radioactive sub-stances of primary coolant (fuel integrity), thus practically preventing more significant releases. The fuel rods at the Olkiluoto and Loviisa NPPs have had very low failure rates. Both nuclear power plants have efficiently implemented measures to reduce the releases of the radioactive substances into the environment.

The radioactive effluents from the plants in 2013–2015 are shown in Tables 3 and 4. Radioactive releases into the environment from the Finnish nuclear power plants have been well below authorised limits (for important nuclides and pathways, of the order of 0.0001% to 0.1% of set values based on the requirements). The noble gas releases from the Olkiluoto NPP have been below minimum detectable activity in 2014 and 2015. Calculated radiation exposures to the individual of the critical group living in the environment of the nuclear power plants are shown in Figure 16.

STUK received reports from the Loviisa NPP (the latest report in 2011) and the Olkiluoto NPP (the latest report in 2010) on the implementation of BAT (Best Available Techniques) for further reduction of the radioactive discharges from the Loviisa and Olkiluoto NPPs. The Loviisa NPP has developed and taken in operation caesium removal technology from liquid releases. The utility reviewed VVER reactor R&D issues and evaluated their own developments underway. They recognized some techniques worth of further research and development.

The Olkiluoto NPP had previously carried out improvements on the water treatment and purification of discharge waters, and no new solutions were presented now. The Olkiluoto NPP had also

Table 2. Annual radiation doses of workers at the Loviisa NPP in 2013–2015.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2013	0,54	8,6	1,14
2014	0,85	9,2	1,47
2015	0,52	7,1	1,12

*) Calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

Table 3. Annual radiation doses of workers at the Olkiluoto NPP in 2013–2015.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2013	0,65	8,1	0,79
2014	0,64	7,7	0,76
2015	0,75	7,9	0,85

*) Calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

an independent assessment, comparing the emissions and operating experience in the Olkiluoto plant units and in equivalent Swedish BWRs. The results indicate that the standard of radiation protection is also in this respect at least on the same level as in the reference plant units surveyed.

STUK concluded that the both utilities apply the BAT principle to abatement of radioactive discharges of their power plants.

Environmental radiation monitoring

STUK has approved the operating programme for environmental radiation monitoring in the surroundings of the Loviisa and Olkiluoto NPPs for 2012–2016. The changes in the programme compared with the previous one were related to, inter alia, the use of reference samples, changes in gardening and agricultural product samples, collecting frequencies of samples, measurements of the water treatment plant sludge and the interpretation of measurement results on carbon-14 nuclides.

Department Environmental Radiation Surveillance and Emergency Preparedness of STUK has acted as an outside contracted laboratory for the licensees. The outside contracted laboratory collects and analyses about 300 samples (air, fallout, sediment, indicator organisms, milk, etc.) per year from the environment of both the Loviisa and

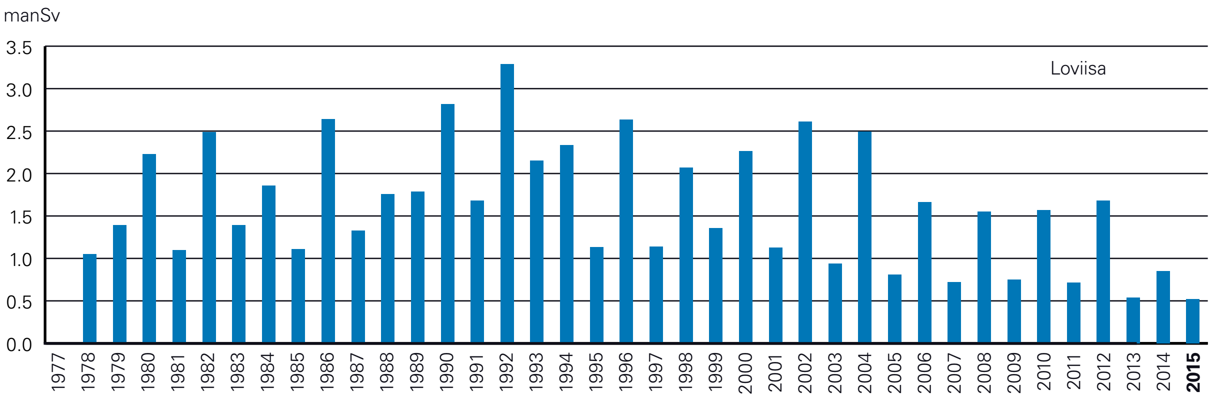


Figure 15. Collective annual occupational doses at the Loviisa nuclear power plant.

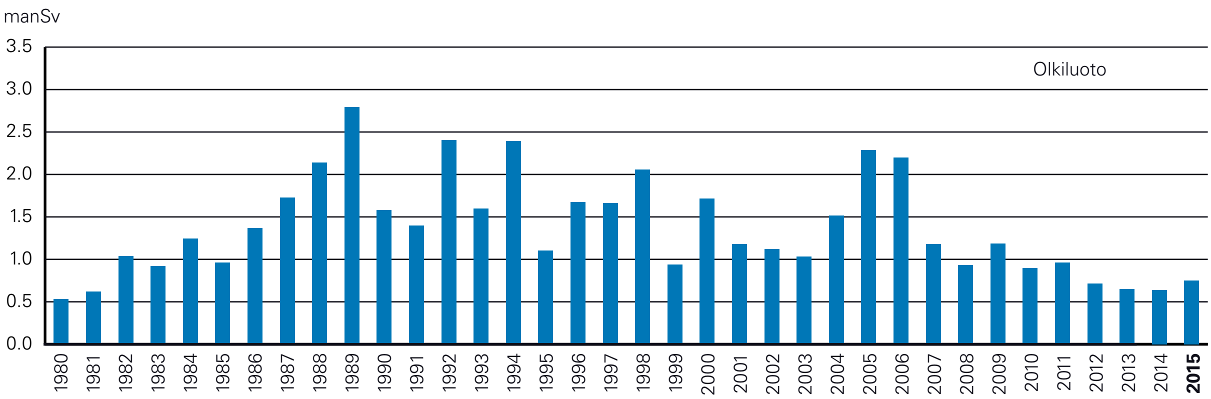


Figure 16. Collective annual occupational doses at the Olkiluoto nuclear power plant.

Table 4. Radioactive effluents from the Loviisa NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2013	6.50E+12 (0,05%)	2.49E+07 (0.01%)	8.35E+08	1.19E+09 (0.1%)
2014	5.83E+12 (0,04%)	4.01E+06 (0.002%)	3.22E+07	1.08E+08 (0.01%)
2015	5.90E+12 (0.04%)	5.07E+06 (0.002%)	3.85E+07	1.04E+08 (0.01%)

Table 5. Radioactive effluents from the Olkiluoto NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2013	2.17E+11 (0.002%)	9.08E+07 (0.09%)	1.99E+07	9.11E+07 (0.03%)
2014	<MDA (<MDA)	2.50E+05 (0.0002%)	7.20E+06	7.74E+07 (0.03%)
2015	<MDA (<MDA)	8.46E+04 (0.0001%)	1.66E+07	1.03E+08 (0.03%)

MDA = minimum detectable activity.

Olkiluoto NPPs. Very small quantities of radioactive substances of local origin were detected in 2010–2012 on some samples from the environment of both nuclear power plants. Concentrations of the radioactive substances were very low, and effects on the public are insignificant.

The IRRS review team recommended that STUK should withdraw from the current practice of conducting the environmental monitoring programmes in the vicinity of the nuclear facilities based on commercial contracts with the licensees. Furthermore, STUK should implement an inde-

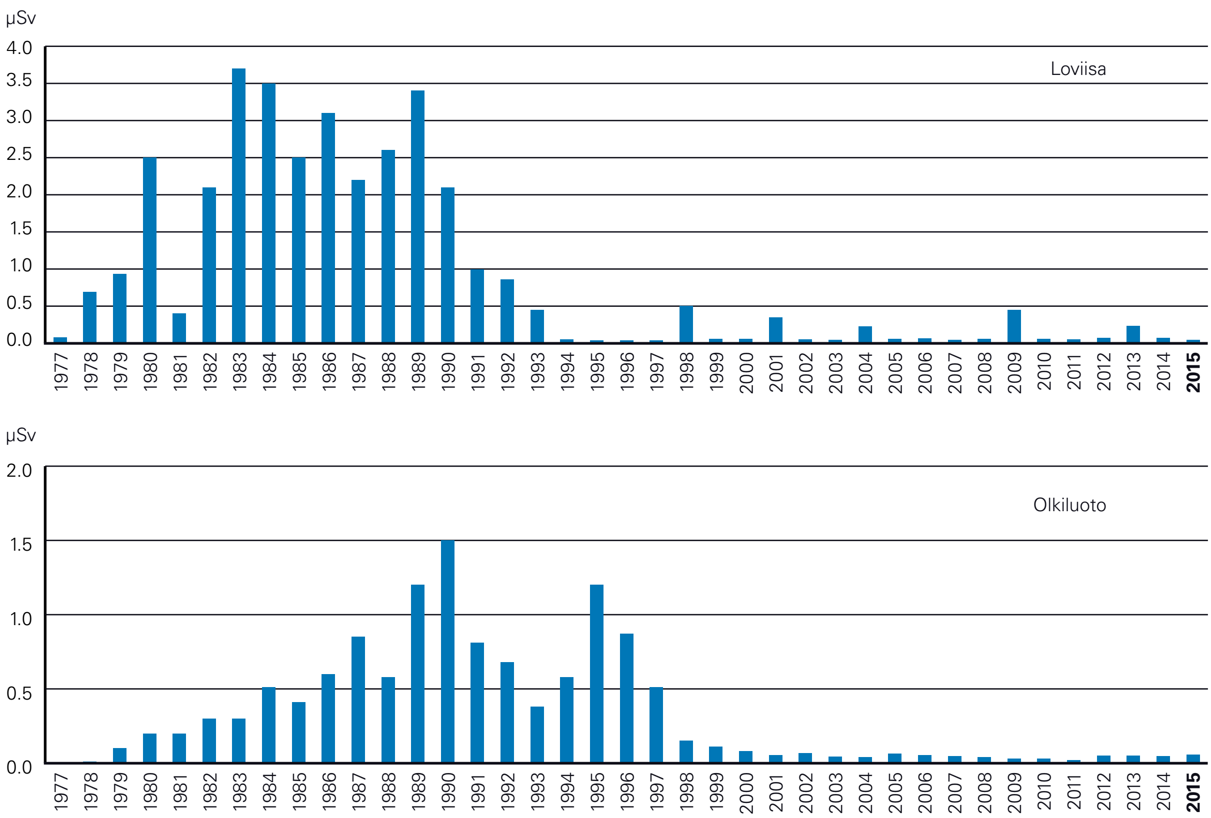


Figure 17. Calculated annual radiation exposures to the members of critical groups in the environment of the Finnish nuclear power plants. Doses have been clearly under the limit 100 µSv.

pendent monitoring programme for the environment, to verify the results of the off-site environmental monitoring programmes required from the licensees. Based on the IRRS recommendation, the Finnish Nuclear Energy Act was amended in 2015 to give STUK legal authority to carry out environmental monitoring as a regulatory activity. The corresponding Guide YVL C.7 "Radiological monitoring of the environment of a nuclear facility" is under preparation and it will be finalized and published in 2016.

Regulatory oversight

On the basis of documents submitted by the licensees, STUK approved in 2016 the use of the dosimetry service of the Loviisa and the Olkiluoto NPPs until 2021. In Olkiluoto the approval covers the agreement between the licensee and the outsourced services provided by the company Doseco Oy, responsible for routine dosimetry at the Olkiluoto NPP. STUK has audited the dose monitoring service at Doseco Oy.

The dosimeters used for measuring the occupational radiation doses of the Loviisa and Olkiluoto plants have underwent STUK's annual tests with acceptable results. These tests comprise irradiating a random sample of dosimeters at STUK's radiation standard laboratory and determination of the doses at the power plant (blind test).

STUK carries out annual radiation protection inspections on-site according to the periodic inspection programme, e.g. covering the resources, expertise and operation of the radiation protection organisation, dosimetry, radiation measurements in the plant, radioactivity measurements of effluents, and monitoring of radiation in the environment. STUK carries out on-site inspections related to radiation protection also during annual maintenance outages. The inspections at the Loviisa and Olkiluoto NPPs have shown e.g. that the plants have introduced technical and IT administration improvements in the field of radiation protection, which made it possible to enhance the control of occupational radiation doses and contamination. Both NPPs have modernized the installed radiation measurements systems.

In conclusion, Finnish regulations and practices are in compliance with Article 15.

Article 16. Emergency preparedness

1. ***Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.***
3. ***Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.***

Emergency preparedness on-site of NPPs

Regulations concerning emergency arrangements at the NPPs are given in the Nuclear Energy Act, the Nuclear Energy Decree and STUK's Regulation on Emergency Arrangements at Nuclear Power Plants (STUK Y/2/2016). Detailed requirements and STUK's oversight procedures are given in the Guide YVL C.5.

The renewed Government Decree on Emergency Response Arrangements at Nuclear Power plants became effective in 2013. Parallel to that the Guide YVL 7.4 was replaced by the Guide YVL C.5 taking also into account the lessons learned from the TEPCO Fukushima Dai-ichi accident.

The Government Decree was replaced by STUK's Regulation (STUK Y/2/2016) at the beginning of 2016 due to the changes in the Nuclear Energy Act. In connection to this latter replacement no significant changes were implemented to the level of requirements.

In the new Regulation, design basis for emergency planning is a simultaneous accident at site's all reactor units. In STUK's decisions made on the basis of the national assessments and European Stress Tests for nuclear power plants, both TVO and Fortum were required to clarify and update their emergency plans and procedures with respect to issues like qualification of the staff in the emergency organisation, management of access control and contamination control in the case when the normal arrangements are out of function and restoring the access routes and connections to the site in case of large-scale damage to the infrastructure. There were some further requirements for licensees regarding site autononomy in case of external hazards in autumn 2015 when Guide YVL C.5 was enforced at the operating NPPs. The work for developing and improving the emergency preparedness arrangements continues.

Fortum and TVO have analysed accident and safety-impairing events at the Loviisa and Olkiluoto NPPs. These analyses are documented in the safety analysis reports of the plants and have been used as the basis for planning the Finnish nuclear power plant emergency response arrangements. Multiunit accident as design basis for emergency planning has prompted licensees to analyse some new accident scenarios.

Emergencies are classified and described briefly in the plant's emergency plan. The notifications and alarms to plant personnel and authorities required by different classes of emergencies, as well as the scope of operations of the emergency response organisation pertaining to the type of emergency, are described in the emergency procedures.

A person responsible for emergency response arrangements has been appointed both for the Loviisa and Olkiluoto nuclear power plants. Due to the updated Nuclear Energy Act the nominated deputies for the persons responsible for emergency response arrangements have been appointed by the licensees and approved by STUK. The emergency response organisation has been described in the emergency plan and procedures, updated with regard to personnel changes once a year. The more limited staffing of the emergency response organisation required for emergency standby state (alert) is defined in the shift supervisor guides for the emergency response.

The facilities of the emergency response organisation at the Loviisa and Olkiluoto nuclear power plants include a system for displaying data directly from the process computer. Several hundred parameters are transmitted also to the STUK's emergency response centre. The automatic data transfer and display system from the Olkiluoto NPP to STUK will be renewed according to the plans during 2016-2017. The new unit Olkiluoto 3 and the unit's training simulator are then added to the data transfer and display system.

Emergency training and exercises are arranged annually for the emergency response organisation of the nuclear power plants. The emergency training includes classroom and group-specific practical training as well as special training, such as first aid, fire and radiation protection training. In addition to severe accidents, emergencies covered by the emergency response exercises also includes conditions classified as alert. The content and scope of the training as well as feedback obtained from the training are assessed in the inspections of the STUK's periodic inspection programme.

STUK verifies the preparedness of the organisations operating nuclear power plants in yearly on-site inspections as well as supervising the licensee's emergency training and exercises. Emergency preparedness at the Loviisa and Olkiluoto power plants meet the regulatory requirements.

At the Loviisa NPP, the objects of the inspection included the emergency response organisation's personnel resources, facilities and equipment, training and alert arrangements, revision of the structure and content of emergency instructions, radiation measurements in the surroundings and meteorological measurements on-site. Emergency exercises and mustering exercises have been conducted annually. In 2014 Loviisa NPP exercised for the first time a two unit's simultaneous accident scenario. An unannounced emergency exercise was organised 2015 starting outside the normal working hours.

At the Olkiluoto NPP, the objects of the inspection included emergency organisation personnel resources, training, exercises, facilities and equipment, alarm arrangements, radiation measurements in the surroundings, meteorological measurements on-site, emergency preparedness of the Olkiluoto unit 3 construction site and the work for revising the emergency preparedness instructions. During the national full command post exercise OLKI-14 actions and decision making of the intermediate phase of the severe accident were exercised for the first time. In 2015 the annual emergency exercise was based on an unlawful action scenario and the exercise was executed unannounced at the same time in both Olkiluoto NPP and Loviisa NPP.

Both the Loviisa and Olkiluoto have networks of monitoring stations providing real time environmental dose rate. Stations are arranged in circles around plant area. Olkiluoto has inner circle close to plant area and outer circle at 5 km distance from the plant. Three additional measurement stations will be installed in the vicinity of Olkiluoto unit 3 before the plant unit is in operation. At the Loviisa NPP, a new monitoring network including 28 stations has been in operational use since summer 2015 after trial run that started in 2013. The design basis of the new measuring stations is at least 3 months autonomic operation in emergency situations with long-term batteries. At the Loviisa NPP, the licensee has renewed the weather monitoring system. The new on-site weather mast and the additional measuring point in the marine environment are now in test operation. The additional measuring point gives more precise data from the sea breeze and the land breeze phenomena which can strongly affect the dispersion of releases.

Off-site preparedness arrangements

In addition to the on-site emergency plans established by the licensees, off-site emergency plans required by the rescue legislation (379/2011) are prepared by regional authorities. The requirements for off-site plans and activities in a radiation emergency are provided in the Decree of the Ministry of Interior (612/2015). STUK is an expert body who supports and provides recommendations to authorities responsible for making decisions and implementing protective actions in case of nuclear or radiological emergency.

STUK publishes VAL Guides for emergency response. Guide VAL 1 (2012) "Protective Measures in Early Phase of a Nuclear or Radiological Emergency" and VAL 2 (2012) "Protective Measures in Intermediate Phase of a Nuclear or Radiological Emergency" provide detailed guidance. In the case of an accident the local authorities are alerted by the operating organisation of the plant.

The Ministry of Interior has published a guide "Nuclear or Radiological Emergencies: Roles and Responsibilities of All Actors" (MI publication 38/2012), which contains the detailed information of the arrangements in the Finnish society in the case of a nuclear or radiological emergency.

STUK has an Emergency Preparedness Manual for its own activities in the case of a nuclear or radiological emergency. STUK has an expert on duty on 24/7 basis. The messages of an exceptional event (alarm) are received from the operating organisations of the facilities, from the automatic radiation monitoring network that covers the whole country (approx. 250 measuring stations, see Figure 18), and from foreign authorities.

The off-site emergency plans include provisions to inform the population in the case of an accident. Written instructions on radiological emergencies, emergency planning and response arrangements have been provided to the population living within the 20 km Emergency Planning Zone. These instructions are regularly updated and distributed.

The regulations and guides are tested in off-site emergency exercises conducted every third year. Full

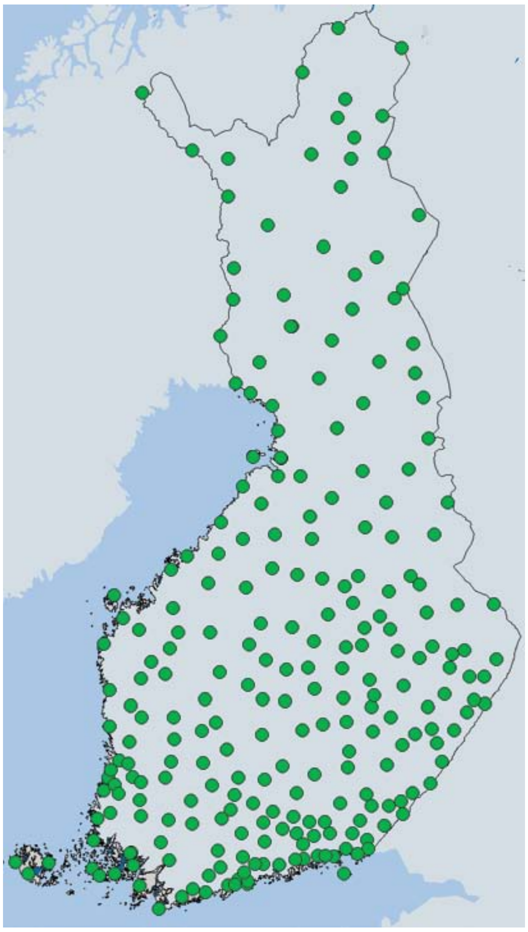


Figure 18. The measuring stations of the radiation monitoring network.

scale off-site emergency and rescue exercise OLKI14 was carried out in 2014 based on the Olkiluoto nuclear power plant accident scenario. Over 70 different organisations participated in this exercise, which concentrated on the second day after a major accident when the release plume had left the area and majority of actions is switching to the planning and starting the decontamination activities.

In April 2016 a full scale off-site emergency and rescue exercise LOVIISA16 was held based on Loviisa nuclear power plant exercise. This exercise was an early-phase exercise with emphasis especially on the initial actions and starting operations outside office hours. The scenario continued for approximately eight hours after the initial event and included release that required protective actions for population to up to 50 km and protection of agricultural production to up to 250 km. Evacuation arrangements were also tested by moving pupils from three schools nearest the plant.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no needs for major changes were identified in off-site emergency preparedness. However, some improvements were identified and implemented. They have improved accessibility to the site in case of extreme natural hazards, ensured that sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services are available and the measures have improved the communication arrangements between emergency centres of NPPs, STUK, and Rescue Service.

The rescue planning is enhanced by the co-operation between the nuclear power plant, regional rescue services, regional police departments and STUK. Permanent coordination groups have been established for both Loviisa and Olkiluoto NPPs in order to ensure coordinated and consistent emergency plans, to improve and develop emergency planning and arrangements and to share lessons from the exercises, regulations and other information. Also extensive training is arranged by these groups. A National Nuclear Power Plant Emergency Preparedness Forum was also proposed after the Fukushima accident for co-operation and combination between permanent groups with participation from Ministry of the Interior and the Ministry of Social Affairs and Health, the regional rescue service authorities, STUK and the NPP licensees. However, after the initial proposals, the group's field of responsibility was found to be mostly overlapping with other existing co-operation and co-ordination bodies. Therefore, it has been decided that creation of new group is not the best way to address the issue. Instead, the membership and responsibilities of existing groups have been adjusted. For example, Ministry of the Interior, medical services and emergency response centre administration are now also members in both of the regional groups.

Information to the neighbouring countries

Finland is a party to the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Vienna 1986). Being a member of the European Union, the Council Decision (87/600/EURATOM) on Community arrangements for the early exchange of information in the event of a radiological emergency applies in Finland, too. In addition, Finland has respective bilateral agreements with Denmark, Germany, Norway, Russia, Sweden and Ukraine. Accordingly, arrangements have been agreed to directly inform the competent authorities of these countries in the case of an accident.

Nordic countries have published two joint documents that detail the cooperation arrangements in case of an radiological emergency. Nordic Manual (updated 2015) describes practical arrangements regarding communication and information exchange to fulfil the stated obligations in bilateral agreements between the Nordic countries. The arrangements in this document include all phases of events, including intermediate and recovery phases. The second document, Nordic Flag Book (published 2014), describes joint guidelines, including operational intervention levels, for protective measures concerning population and functions of society in case of nuclear or radiological emergencies. These guidelines agreed by radiation and nuclear safety authorities in Denmark, Iceland, Finland, Norway and Sweden form a unique document as it includes harmonised and practical criteria for early protective measures as well as recovery actions after contamination. Nordic Manual and Nordic Flag Book ensure that the response to any nuclear or radiological emergency in Nordic countries is harmonised and consistent between the countries.

In addition to the domestic nuclear emergency exercises held annually on each nuclear power plant site, STUK has taken part in international emergency exercises. STUK has also participated as a co-player in emergency exercises arranged by the Swedish and Russian nuclear power plant operators and authorities. Neighbouring countries have been actively invited to take part in the Finnish exercises.

In conclusion, Finnish regulations and practices are in compliance with Article 16.

Article 17. Siting

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

- *i.* ***for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;***
- *ii.* ***for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;***
- *iii.* ***for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation; for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.***

Regulatory approach to siting

Requirements for the siting of a nuclear power plant are provided in the Nuclear Energy Act and the Nuclear Energy Decree. The application for a Decision-in-Principle has to include e.g.:

- a description of settlement and other activities and town planning arrangements at the site and its vicinity
- a description of the suitability of the planned location for its purpose, taking account of the impact of local conditions on safety, security and emergency response arrangements, and the impacts of the nuclear facility on its immediate surroundings
- an assessment report in accordance with the Act on the Environmental Impact Assessment Procedure (468/1994) as well as a description of the design criteria which the applicant will observe in order to avoid environmental damage and to restrict the burden to the environment.

More detailed requirements on the Environmental Impact Assessment (EIA) are provided in the Decree on Environmental Impact Assessment Procedure (713/2006). The Finnish EIA legislation complies with the EU Directive 2001/42/EU on the EIA procedure.

In the design of a nuclear power plant, site-related external events have to be taken into account. According to Section 8 of the STUK Regulation (STUK Y/1/2016) the impact of local conditions on safety and on the implementation of the security and emergency arrangements shall be considered when selecting the site of a nuclear power plant. The site shall be such that the impediments and threats posed by the plant to its vicinity remain extremely small and heat removal from the plant to the environment can be reliably implemented. Furthermore, STUK issued in 2013 the Guide YVL A.2, which describes generally all requirements concerning the site and surroundings of a nuclear power plant, gives requirements on safety factors affecting site selection and covers regulatory control. Requirements on seismic design are set forth in the Guide YVL B.7. Deterministic analyses are made to assess the impact of various natural phenomena and other external events. The probabilistic risk assessment required for the safety review of construction and operating Licence applications provides information on probabilities of releases of radioactivity caused by external events. The limits for radiation doses of the public and for radioactive releases in normal operation, anticipated operational occurrences and accidents (postulated accidents, design extension conditions and severe accidents) are given in the Nuclear Energy Decree. Design extension conditions include among other things accidents caused by a rare external event and which the facility is required to withstand without severe fuel failure.

The general principle in the siting of nuclear power plants is to locate the facilities in a sparsely populated area and remote from large population centres. In the vicinity of the plant, no industrial or other activities are allowed that could pose an external threat to the plant. Site characterisation is performed based on geological, seismic, hydrological and meteorological factors as well as on transport routes and risks, industrial activities, agriculture, nature and population. Extreme meteorological conditions and consequences (e.g. frazil ice formation) have to be taken into consideration in the site evaluation and plant design.

In connection with the decisions for construction of the Loviisa and Olkiluoto NPPs in the 1970s, siting requirements related to population density and land use planning were quite easily and practically achievable in a sparsely populated country like Finland. The precautionary action zones have only a few tens of permanent inhabitants. Similar attention was not given to the recreational houses and the transient summertime population in the coastal area (mainland and islands) where the conditions might be demanding for efficient emergency preparedness and rescue action. The number of recreational houses on the seaside within 5 km radius of the existing plants is about 400–500. The precautionary action zone of the proposed Fennovoima's Hanhikivi NPP has a few hundreds of permanent inhabitants and the number of recreational houses within 20 km radius is a few hundreds.

Finland is a party to the Convention on Environmental Impact Assessment in a Transboundary Context, done in Espoo in 1991. The Convention is applied for Finnish nuclear facility projects by providing a full participation to all countries which announce the willingness to participate in the environmental impact assessment procedure in question. In Finland, the EIA is conducted at an early stage of a NPP project, prior to the selection of the plant design, based on the power range of the plant and on general information on the available designs. The EIA is required to be carried out before the Decision-in-Principle is taken, and the outcome of the EIA procedure is part of the material needed for the application of the Decision-in-Principle. The EIA procedure of the new NPP unit option for the proposed Hanhikivi NPP was completed in 2014. Further information about the EIA process of Hanhikivi NPP is presented in Annex 5.

The new Guide YVL A.2 includes a description of all relevant legal processes, including those based on non-nuclear legislation. Efficient co-operation between the utility and responsible authorities is emphasised, e.g., for:

- maintaining the land use planning in the plant environment during the plant operational life time in line with the safety goal of avoiding dense population in the vicinity
- taking necessary actions to guarantee efficient road connections to the plant area also in case of a severe accident and extreme weather conditions.

Quality, competence and comprehensiveness of the site survey and site confirmation are required and the results shall be assessed by STUK in different licensing stages. The basic goals for population safety has not been changed in the revised guide.

The EIA and other site-related studies are conducted by the licence applicant or licensee depending on the context. The safety related reports are reviewed by STUK. The Ministry of Employment and the Economy arranges the national public hearings and the Ministry of the Environment arranges the international hearings.

The bilateral agreements mentioned under Article 16 include provisions to exchange information on the design and operation of nuclear facilities. In the European Union a specific statement is also prepared for each new nuclear power plant unit in a member state before authorisation of the operation (Euratom Treaty, Article 37). This is based on a General Data report submitted by the member state and on its examination in a plenary meeting of Group of Experts. For Olkiluoto unit 3 this process was conducted in 2010. Based on the legislation on land use planning, statements from neighbouring countries must be requested for the land use plans of a nuclear power plant. Sweden, Denmark, Norway, Germany, Poland, Lithuania, Latvia and Estonia were informed of initiating the regional planning process for Fennovoima's two candidate sites (Hanhikivi in Pyhäjoki and Karsikko in Simo) in Northern Finland and the opportunity to participate.

The detailed requirements on the determination of site-specific design bases for external events are presented in more detail in the new Guide YVL B.7.

Re-evaluation of site related factors

The operating licence for a nuclear facility is granted for a fixed term. Periodic safety review (PSR) shall be conducted either in connection with the licence renewal or as a separate review with intervals of about ten years at most. The site related factors are reviewed and, where necessary, updating is initiated in connection with the PSRs. Updating is also done between PSRs if it is called for by operating experience or research results. Plant modifications shall be implemented on the basis of the updated information on site-related factors if deemed appropriate according to the principle enacted in Article 7a of the Nuclear Energy Act.

The capacity of the NPP units to withstand external hazards is evaluated in deterministic safety analyses and in probabilistic risk assessments (PRA). The PRAs of the Finnish units cover natural and man-made external hazards such as high seawater level, high wind including tornadoes, lightning, high- and low air temperature, high seawater temperature, frazil ice formation in cooling water intakes, algae and other organic material in seawater, and their combinations as well as oil spills from oil tanker ship accidents and earthquakes. During the past twenty-five years the results of external events PRAs have initiated several safety improvements in the plants.

Research on the site related natural hazards is conducted continuously in the Finnish National Nuclear Safety Research Program SAFIR (http://safir2018.vtt.fi/links.htm). STUK has a major role in steering the research and the results support STUK in the review of the reports submitted by the licensees. The research covers seismic hazard and extreme meteorological phenomena and seawater level variations, including the effects of climate variability and change.

The current operating licence of the Loviisa units was granted by the Government in 2007 for the unit Loviisa 1 until 2027 and for the unit Loviisa 2 until 2030. The licensee was required to conduct PSRs and submit the reports to STUK in 2015 and in 2023. The first of them was submitted to STUK in 2015 according to the schedule.

For the Olkiluoto units 1 and 2 the operating licence was granted in 1997 until the end of 2018 and a PSR was submitted to STUK in 2008. The next operating licence renewal application and PSR is under preparation and will be submitted to STUK at the end of 2016.

For the periodic safety review of the Loviisa NPP in 2014–2016 and the Olkiluoto units 1 and 2 in 2007–2009, comprehensive re-assessments of safety, including the environmental safety of the nuclear facility and the effects of external events on the safety of the facility, were conducted by the licensees and reviewed by STUK. The assessments covered meteorology, hydrology, geology, seismology, population and use of land and sea areas. Re-evaluation of the seismic hazard studies for the Loviisa and Olkiluoto sites is currently ongoing.

During the operation of a nuclear facility, the Final Safety Analysis Report (FSAR), including its site-specific parts, has to be periodically reviewed and updated as needed. A detailed re-evaluation of the site related factors was also carried out in 2007–2009 for the Olkiluoto and Loviisa sites in connection with the Environmental Impact Assessment and Decision-in-Principle procedures for the proposed new NPP units Olkiluoto 4 and Loviisa 3. Olkiluoto site related factors will be re-evaluated also in connection with the operating licence procedure for the Olkiluoto unit 3.

In addition to the normal PSRs, an extraordinary review of site related issues was carried out after the TEPCO Fukushima Dai-ichi accident in connection with the so called European stress tests. National studies were initiated immediately after the accident and the EU stress tests were started in June 2011. The stress tests did not reveal any new site-related external hazards or vulnerabilities of the plants to external events. No need for immediate action was recognized, but some additional studies of external hazards and feasibility studies for plant modifications to improve robustness against external events were found justified.

The following examples of safety improvements and additional analyses of external events at the Loviisa NPP can be mentioned: enhanced protection against high seawater level, independent cooling units replacing the service water system in case of blockage of seawater intake have been installed, and detailed structural analysis of spent fuel pools to demonstrate integrity of the pools in the case of an earthquake with consequential boiling in the pools.

At the Olkiluoto NPP, system modifications to ensure the operation of the auxiliary feed water system in case of the loss of the ultimate heat sink (seawater systems) have been implemented at the unit 1 and will be implemented to unit 2 later. Structural analysis to demonstrate the integrity of the spent fuel pools in the case of an earthquake followed by pool boiling have been completed. Seismic walk-downs of the fire extinguishing water system have been carried out and some improvements have been implemented. The emergency diesel generators will be replaced within the next few years. The new emergency diesel generators will be provided with alternative air and seawater cooling, while the existing diesels have only seawater cooling. In addition, engineering is underway on systems to ensure residual heat removal in the case of total loss of AC power and/or loss of the ultimate heat sink due to external or internal events. The effects of extreme seawater levels on the accessibility of the site has been studied as well.

In conclusion, Finnish regulations and practices are in compliance with Article 17.

Article 18. Design and construction

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;***

ii. ***the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;***

iii. ***the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.***

Implementation of defence in depth

Regulatory requirements regarding nuclear power plant design and construction

According to STUK Regulation (STUK Y/1/2016), several levels of protection have to be provided in the design of a nuclear power plant. The design of the nuclear facility and the technology used is assessed by STUK when reviewing the applications for a Decision-in-Principle, Construction Licence and Operating Licence. Design is reassessed against the advancement of science and technology, when the Operating Licence is renewed and in the periodic safety reviews.

In the design, construction and operation, proven or otherwise carefully examined high quality technology shall be employed to reduce the probability of operational transients and accidents and to mitigate their consequences. A nuclear power plant shall encompass systems by means of which operational transients and accidents can be quickly and reliably detected and the aggravation of any event prevented. Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. The design of a nuclear power plant shall be such that accidents leading to extensive releases of radioactive materials must be highly unlikely.

Dispersion of radioactive materials from the fuel of the nuclear reactor to the environment shall be prevented by means of successive physical barriers which are the fuel and its cladding, the cooling circuit of the nuclear reactor and the containment building. Provisions for ensuring the integrity of the fuel, primary circuit and containment are included.

In ensuring safety functions, inherent safety features attainable by design shall be primarily utilised. If inherent safety features cannot be made use of, priority shall be given to systems and components which do not require an external power supply or which, as a consequence of a loss of power supply, will settle in a state preferable from the safety point of view (passive and fail-safe functions).

In order to minimize the frequency of accidents and mitigate the consequences thereof, a nuclear power plant shall be provided with systems for shutting down the reactor and maintaining it in a subcritical state, for removing decay heat generated in the reactor, and for retaining radioactive materials within the plant. Design of such systems shall apply redundancy, separation and diversity principles that ensure implementation of a safety function even in the event of malfunctions. The safety functions necessary for transferring the plant to, and maintaining a controlled state must be ensured, even if any individual system component needed to fulfil the safety function (including the necessary supporting or auxiliary functions) is inoperable and if any other component needed for the function is simultaneously inoperable due to the necessity for its repair or maintenance. Common-cause failures shall only have minor impacts on plant safety. A nuclear power plant shall have reliable off-site and on-site electrical power supply systems. The execution of safety functions shall be possible by using either of the two electrical power supply systems. Due to the TEPCO Fukushima Dai-ichi accident, the Finnish requirements have been supplemented by requiring that the plants must have equipment and procedures to ensure that decay heat from nuclear fuel in the reactor and in spent fuel pools can be removed for a period of three days independent of external electricity and external water supplies in situations which are caused by rare external events or by a malfunction in the plant's internal electricity distribution system.

The plant shall also be provided with systems, structures and components for controlling and monitoring severe accidents. These shall be independent of the systems designed for normal operational conditions anticipated operational occurrences and postulated accidents. Systems necessary for ensuring the integrity of the containment building in a severe accident shall be safety-classified, qualified for the environmental conditions and capable of performing their safety functions, even in the case of a single failure of an active component.

Special attention shall be paid to the avoidance, detection and correction of any human errors during design, construction, operation and maintenance. The possibility of human errors shall be taken into account in the design of the nuclear power plant and in the planning of its operation and maintenance, so that human errors and deviations from normal plant operations due to human errors do not endanger plant safety. The impacts of human error shall be reduced by using various safety design methods, including defence-in-depth, redundancy, diversity and separation.

Limits of radiation exposure and releases of radioactive substances addressing also severe accidents are given in the Nuclear Energy Act 1988/161, section 22b. The requirements for severe accidents are that the release of radioactive substances arising from a severe accident shall not necessitate large scale protective measures for the public nor any long-term restrictions on the use of extensive areas of land and water. In order to restrict long-term effects the limit for the atmospheric release of cesium-137 is 100 terabecquerel (TBq). The possibility of exceeding the set limit shall be extremely small. The possibility of a release requiring measures to protect the public in the early stages of the accident shall be extremely small.

The Finnish requirements for nuclear power plant design, siting and construction are inline with the goals 1 and 3 of the Vienna Declaration on Nuclear Safety. Detailed requirements are given in Guides YVL B.1, YVL B.2, YVL B.3, YVL B.4, YVL B.5, YVL B.6 and YVL B.7. Concerning goal 2 of the Vienna Declaration on Nuclear Safety and the implementation of safety improvements (referred to in the second principle of the Vienna Declaration) at the operating NPP, Finnish regulations state that a periodic safety review (PSR) shall be conducted at least every ten years. In addition, the Nuclear Energy Act states that the safety shall be maintained as high as practically possible. For further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology. Hence, the implementation of safety improvements has been a continuing process at both Finnish NPPs since their commissioning. Goals of the Vienna Declaration on Nuclear Safety are addressed in the regulations and also implemented in Finland.

An assessment of the design of the facility and related technologies is made by STUK for the first time when assessing the application for a

Decision-in-Principle. Later on, the evaluation is continued when the construction licence application is reviewed. Finally, the detailed evaluation of systems, structures and components is carried out through their design approval process. The design of Loviisa plant units was reassessed by STUK in 2015–2016 and Olkiluoto plant units in 2008–2009 in the periodic safety review process. Design of the Olkiluoto unit 3 has been assessed for the construction licence (2005) and during the construction phase. It will be reassessed when reviewing the plant's operating licence application. Design of the Hanhikivi unit 1 will be assessed during ongoing construction licence phase.

Application of defence in depth concept at the Finnish NPPs

The condition of the multiple barriers containing releases of radioactive substances has remained good both at the Loviisa and Olkiluoto NPPs. During the time period 2012-2015, no significant faults or signs of wear or ageing were detected in the integrity of equipment and structures critical to plant safety in Loviisa NPP. During annual outage 2015 at Olkiluoto 2, cracks were observed in a welded joint between a reactor core spray system nozzle and a safe-end (descripted in more detail below).

In connection with the Loviisa plant's licence renewal, Fortum prepared a plan on actions aimed at further enhancing the safety of the plant units in the future. The most important ongoing plant modification project related to the Defence-in-Depth concept at the Loviisa plant is the upgrade of the I&C systems of the plant units.

Fortum and TVO have also reviewed all of the analyses of transient and accident situations at the Loviisa and Olkiluoto nuclear power plants in connection with the operating licence renewal and periodic safety review. Deterministic safety assessment is described in more detail under Article 14.

Severe accidents were not taken into account in the original design of the operating Finnish nuclear power plants. However, since the commissioning of the plants, major improvements have been implemented to prevent and mitigate the consequences of severe accidents. Mitigation systems of the Loviisa and Olkiluoto NPPs are described in detail in Annexes 2 and 3.

For the Olkiluoto unit 3, application of the Defence-in-Depth principle was presented in the Preliminary Safety Analysis Report (PSAR). The design follows the principles laid down in the Finnish regulations. Compared with the existing reactors, the possibilities for mitigation of the consequences of the severe accidents were taken into account already in the design phase. This was achieved by implementing features to ensure containment integrity. Design provisions included e.g. dedicated depressurisation of primary system to prevent high pressure core melt, core catcher for corium spreading and cooling, hydrogen recombination, and containment heat removal. In addition, aircraft crash protection design requirements for both a military aircraft and a large passenger aircraft have been taken into account.

Defence in depth concept in Loviisa NPP

Several plant modifications improving safety have been carried out at the Loviisa NPP during the last ten years. Plates preventing vortices were installed in the intake pipes of the Loviisa plant emergency makeup water tanks during the 2009 annual outage. The objective of the modification is to obstruct air suction into the reactor emergency injection system pumps when the tank water level drops. The Loviisa plant improved suction strainers of the low pressure emergency cooling system and the containment spraying system by means of installing higher density mesh elements in them. The modification serves to ensure fuel cooling in accident conditions by means of preventing materials coming loose from, for example, heat insulation material from being carried to the reactor core via the emergency cooling system. According to analyses, blockages in the core caused by large amounts of fibres could lead to overheating of the reactor core. The modifications were carried out at the Loviisa unit 2 in 2010 and at the Loviisa unit 1 in 2011.

A project for the Loviisa NPP I&C renewal, ELSA, was launched in June 2014. The ELSA project will modernise a large part of the I&C system of the plant, switching it to a software based platform. The plan is to install the first stage of the renewal in 2016. A watertight ceiling will be constructed to protect the control rooms of Loviisa NPP from any leaks at the feedwater tank level above control room level. Modernisation of the reactor coolant system pressure control has been carried out at Loviisa 1 in 2012 and Loviisa 2 in 2014.

The modification aimed at improving the usability and reliability of the pressure control system. The modification included replacing of the pressurizer spray valves and relief valve. Each of the Loviisa NPP secondary circuit main steam lines has two safety valves (with staggered set pressures). These have been qualified for steam flow only. The safety valves with the lower set pressure (six valves) were replaced at Loviisa 2 in 2014. The new valves are qualified for steam, water and a mixture of the two. The plan is to implement a similar modification at Loviisa 1 in 2016.

Based on the safety analyses, it was considered necessary to make modifications in the operation of the Loviisa emergency water tanks of the low pressure emergency cooling system (accumulators). The modification serves to ensure that heat transfer from the reactor can be reliably provided by preventing the nitrogen in the water tank from getting into the reactor. In order to ensure the tightness of the primary circuit, the sealing grooves of two inner sealing groove zones of the Loviisa units 1 and 2 reactor pressure vessel flange face were repaired. The tightness of the reactor pressure vessel and its lid is based on double seal grooves in which a nickel sealing wire is inserted. The first defects which required local repair were detected in these sealing grooves in periodic inspections at the Loviisa unit 2 in 2005. Similar defects were also detected in subsequent inspections at the Loviisa unit 1. The repairs were done during the annual outage 2010 at the unit 1 and during the annual outage 2012 at the unit 2.

Due to the TEPCO Fukushima Dai-ichi accident, safety improvements have been initiated at the Loviisa NPP. Improvements implemented, under planning and implementation for the Loviisa plant include among other things:

- Installation of independent air-cooled cooling units for decay heat removal from the reactor core and from the spent fuel pools. The cooling units provide an alternative ultimate heat sink in case of loss of sea water cooling. The units have been taken into use in 2014–2015.
- Flood protection. The utility has estimated the effects of high sea level to the plant behavior. The utility has submitted to STUK a detailed plan of improved flood protection in 2015. The plan is based on strengthening of flood protection of the buildings most important to safety. The plan will be implemented by 2018 (protection against high seawater level during annual maintenance shutdown already partly implemented).
- Installation of diverse water supply to the spent fuel pools. STUK has approved the design plans. The plant modifications will be completed by 2017.
- The licensee has conducted an evaluation of the availability of cooling water and emergency diesel fuel in case of accidents at both units. The volumes on site have been considered adequate. Furthermore, the diesel fuel distribution capabilities (connections between different fuel tanks) have been improved.

Plant modifications, including Fukushima related modifications at the Loviisa NPP are described in more detail in Annex 2.

Defence in depth concept in Olkiluoto NPP

Several plant modifications improving safety have also been carried out at the Olkiluoto NPP units 1 and 2 during the last ten years. The main steam line isolation valves inside the containment were replaced at the Olkiluoto units 1 and 2 during annual maintenances in 2010 and 2011. The function of the valves is to isolate the reactor pressure vessel and prevent the loss of reactor coolant and releases of radioactive substances outside the containment. The valves also function as a backup for the isolation valves outside the containment. One reason for the valve replacement was the tendency of the old valves to close as the steam flow increases. In a situation where one valve closes, the steam flow through the other valves increases and this can make them close, too.

TVO has replaced in 2010 all rubber collar pipe penetrations below elevation +10 in the rooms containing emergency cooling system pumps with type-approved fire and pressure penetrations. All in all, the modification involved over 60 penetrations. STUK had earlier made a remark about the condition of the penetrations. TVO examined all the similar original penetrations at the plant by means of testing and assessing their compliance with fire, ventilation and water-tightness requirements, and analysed the risks to plant safety. Based on the risk analysis results, the share of the impact of the conditions of the penetrations was about 3% of the total annual core damage frequency based on the PRA model.

TVO has made a decision to replace all current emergency diesel generators (EDGs) of the Olkiluoto units 1 and 2 with their auxiliary systems to correspond to the changed need for emergency power, taking also into account any increases in the need for power due to possible future plant modifications as well as the lessons learnt from the Fukushima accident in relation to securing the power supply. The low voltage switchgears were replaced at both units in 2010–2016.

In 2014, STUK approved TVO's conceptual design plans on replacing the reactor coolant pumps and the frequency converters needed when controlling and supplying power to the pumps. The pumps are planned to be replaced because of their ageing. In connection with the replacement, a flywheel will be added to the reactor coolant pump shaft to ensure sufficient cooling of the nuclear fuel in case of a trip if electrical power is unavailable. The plan is to commission the first new reactor coolant pump at Olkiluoto 1 during the 2016 annual outage, all of the six pumps at Olkiluoto 2 during the 2017 annual outage and the remaining five pumps of Olkiluoto 1 in 2018.

An emergency control room has been commissioned at Olkiluoto 2 in 2015 and at Olkiluoto 1 in 2016.

Safety improvements due to the TEPCO Fukushima Dai-ichi accident implemented or under planning and implementation at the Olkiluoto units 1 and 2 include among other things:

- Assessing possibilities for ensuring cooling of the reactor core in case of total loss of AC supplies and systems. The arrangement will consist of high and low pressure systems. The high pressure system is based on a steam driven turbine. The low pressure system pumps coolant into the core from the fire fighting system. STUK has approved the design plans. The systems will be implemented in 2017-2018.
- Ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water cooling systems. The modification has been implemented at Olkiluoto 1 in 2014. Abnormal vibration and pressure oscillations have been observed during the testing of one subsystem and the reasons are under investigation. The modification will be implemented at Olkiluoto 2 when the vibration and oscillation issues have been resolved.
- Diverse cooling water supply to the spent fuel pools have been completed in 2015. To improve monitoring of the water temperature and level in the spent fuel pools is in progress and will be completed in 2016.
- The utility has acquired new mobile equipment (aggregates, pumps).
- The utility has evaluated the availability of cooling water and emergency diesel fuel in case of accidents at multiple reactor units and other nuclear facilities at the same site.

Fukushima related modifications, as well as other latest ongoing improvements at the Olkiluoto NPP are described in more detail in Annex 3.

Integrity of nuclear fuel

At Olkiluoto unit 1, the first indication of a fuel leakage was observed due to an increased activity of exhaust gases in February 2016. The detected release of neptunium in the reactor water shortly after the release of gaseous fission products indicated a larger leakage. By the end of March 2016, the concentrations of noble gases and iodine were observed to continuously increase. However, the total concentrations were not exceeding the limits set by the Technical Specifications. TVO performed a flux tilting in the beginning of April and three leaking assemblies were detected. TVO decided to perform an additional outage to remove the leaking assemblies from the reactor. After sipping of the core the three leaking assemblies were identified and visually inspected. The observations seem to indicate a Pellet Cladding Interaction (PCI) type of failure mode. Shortly after the additional maintenance outage a new indication of leaking fuel was observed. In May 2016 during the planned annual outage the core was sipped and three additional leaking assemblies were identified, removed and visually inspected during the outage. The root cause analysis continues with the fuel vendor.

Integrity of other barriers

The Loviisa unit 1 primary and secondary circuits were subjected to pressure tests in 2012. The pressure tests are performed every eight years. In the tests, the structural strength and leak tightness of the circuits are tested using a pressure 1.3 times the design pressure, i.e. 178 bar abs for the primary circuit and 73 bar abs for the secondary circuit. Results of the tests were accepted by STUK.

The steel liner of the Loviisa NPP containment is subjected to a leak tightness test at four-year intervals using the design pressure of 1.7 bar abs. The test has been carried out in 2014 at the Loviisa unit 2 and in 2012 at the Loviisa unit 1. Results of the tests have fulfilled the acceptance criteria. The reactor containment at the Olkiluoto NPP is subjected to a leak tightness test three times during a 12-year period. In addition, leak tightness tests have been made systematically to containment isolation valves, personnel airlocks and containment penetrations during the annual outages. The results show that the leak tightness of the containment building has remained acceptable at the both Olkiluoto reactor units. The overall leak tightness of the Olkiluoto unit 2 reactor containment was tested during the annual outage of 2013 and that of the Olkiluoto unit 1 containment during the outage of 2016. Results of the test have fulfilled the acceptance criteria. Olkiluoto unit 3 containment pressure test was conducted in 2014 with acceptable results.

During the period 2013-2015, no significant failures were observed at the Loviisa plant in the safety functions or in the systems, structures and components executing them. No significant faults or signs of wear have been detected during in the integrity of equipment or structures critical to plant safety.

At the Olkiluoto NPP, cracks of various sizes were found on the inside surface of main feedwater runpipe at the both units during the annual outage in 2014. All cracks were in the base material. The cracks were at a mixing point of pipelines from the feedwater system and the shutdown cooling system. They occurred due to thermal fatigue, which was induced by the mixing of the cold feed water (20 °C) and the about 250 °C warmer shut down cooling line water. STUK made a decision in 2014 that required amendment of the operating method and replacement of the cracked pipe sections during the next annual outages. These pipeline mixing points were replaced in 2015-2016. In addition, IRS report 8439 ”Thermal fatigue cracks in feed water piping Tee” was prepared.

At Olkiluoto 2, a crack in one of the welded joints of the reactor feedwater system has been monitored by means of ultrasound and eddy current examinations during in-service inspections since the indication was detected in 2003. The crack is located in a weld in between the reactor pressure vessel nozzle butt weld and its joint (safe-end) on the inside of the nozzle. The crack may be a manufacturing fault that was originally left undetected and whose actual depth could not be determined until the new inspection techniques were employed. On the other hand, the crack may also be a fault caused by stress corrosion that has grown over time and may continue to grow. In an inspection by TVO during the 2013 annual outage, the depth of the internal crack was determined as 23 mm. The acceptable crack depth in terms of operation is max. 25 mm. The inspection was done using phased array ultrasonic testing from the outside of the nozzle. During the 2013 annual outage, STUK approved a strength analysis submitted by TVO and a procedure where the crack would be monitored for the next three years. Based on inspections done during the 2014 and 2015 annual outage, the crack has not grown. The inspections were done using two techniques from the inside of the nozzle and one using technique from the outside. TVO installed a leak detection system that is based on temperature in the area during the 2014 annual outage. TVO has already made preparations for repairing the crack. The repair plan states that the crack will be removed by machining a groove that covers the entire circumference of the nozzle in the cracked area and then welding the groove shut.

When inspecting the internals of the reactor pressure vessel during annual outage 2015 at Olkiluoto 2, cracks were observed in a welded joint between a reactor core spray system nozzle and a safe-end. Fault indications regarding the welded joint of said nozzle were already observed in 2011 and 2013, and the fault indication was classified as an internal failure. During the inspections made in 2015, it was observed that the failure extends to the inner surface of the nozzle, which means that the threshold value laid down in the approval standard has been exceeded. STUK approved a procedure proposed by TVO where the weld will be inspected more often for at least the next three years by means of both a qualified eddy current method and the traditional phased array ultrasonic testing method. STUK also required that TVO must continue to study the causes of the cracks in the reactor pressure vessel nozzles and continue its work on preventing new indications and preventing the old indications from spreading. At the end of 2015, TVO submitted to STUK for approval a plan on related further measures, repair plans and a review on the adequacy of the current nozzle inspection programme. The review applies to all nozzles in the reactor pressure vessels of plant units 1 and 2 that have been manufactured in the same manner.

Inspections carried out in Doel unit 3 in Belgium in July 2012 revealed indications in the reactor pressure vessel (RPV) material, believed to have been created during manufacture due to deficient hydrogen removal heat treatment. In Finland there are no pressure vessels from this manufacturer. However, in March 2013, STUK sent clarification requests to the operating plants at Loviisa and Olkiluoto as well as Olkiluoto unit 3 regarding verification of the integrity of the plant units' pressure vessels, as well as in the case of the pressurised water reactors also the pressurizers and the steam generators. According to a report submitted by TVO, the manufacturing technology of the Olkiluoto unit 1 and Olkiluoto unit 2 reactor pressure vessels is so different than that used in the Belgian reactors that the risk of deficient hydrogen removal heat treatment can, for a justified reason, be considered minor. Furthermore, such faults would have been detected in the non-destructive testing conducted after manufacture. The reactor, steam generators and pressurizer in Olkiluoto unit 3 were manufactured in 2003 and 2004. At that time, the manufacturing requirements for hydrogen content were clearly stricter than those used when the reactors of the Belgian plant units were manufactured in the 1970s. The same applies to the requirements on non-destructive testing. STUK deemed this report acceptable. According to a report by Fortum, manufacturing methods that limit the hydrogen content were used also in the manufacture of Loviisa unit 1 and Loviisa unit 2, and the non-destructive testing method has been assessed as accurate enough to detect any hydrogen flaking indications. However, there were some defects in the manufacturing documentation, which is why STUK demanded that the licensee try to obtain supplementary data and assess the integrity of the reactor's supporting structures and pipe nozzles in more detail to detect any hydrogen flaking indications. Fortum proposed additional RPV base metal UT-inspections from the core area. Such a verification inspection was performed at Loviisa unit 2 during the 2014 annual outage. Nothing to report was observed during the inspection. The pressure vessel of Loviisa unit 1 will undergo a similar inspection during the 2016 annual outage.

Incorporation of proven technologies

According to STUK Regulation (STUK Y/1/2016), the nuclear plant is equipped with systems that function automatically and reliably to prevent severe fuel damage in postulated accidents and in design extension conditions. In addition, it is stated in many YVL Guides that proven or otherwise carefully examined high-quality technology shall be employed in the design, construction and operation of a nuclear power plant.

Practical implementation of the new safety requirements and procedures to ensure adequate reliability of software based instrumentation and control systems in the modernisation projects of the operating power plants and in the design of the new nuclear power plant can be considered as one of the major challenges for the next years. This includes also the issues related to the highly integrated control rooms.

At the Loviisa NPP, I&C systems are currently being renewed. The project began in 2002 with basic conceptual design; implementation begun in 2004 with construction of new buildings to accommodate the new systems. The first phase was implemented at the Loviisa unit 1 in 2008 and at the unit 2 in 2009, including the upgrade of I&C of reactor preventive and control rod position measurement and control functions, part of reactor in-core monitoring system and I&C of some non-safety auxiliary systems. A continuation project "ELSA" for the Loviisa NPP I&C renewal, was launched in June 2014. The ELSA project will modernise a large part of the I&C system of the plant, switching it to a software based platform. The plan is to install the first stage of the renewal in units 1 and 2 during the 2016 annual maintenance outage.

At the Olkiluoto units 1 and 2, changes in I&C systems are made gradually. Software based instrumentation and control technology has already been implemented in the modernised systems. The safety systems, with the exception of new protective relays of electrical systems and neutron flux measurement system, are still of conventional technology.

STUK has reviewed the licensing documents related to the I&C modernisation project of the Loviisa units 1 and 2 and the construction project of the Olkiluoto unit 3. The licensing path covers different layers of the design from architectural design of I&C (including Defence-in-Depth, separation and diversity assessments) to system level design and down to I&C platform and equipment suitability and licensing. During the licensing, STUK is reviewing that proven and qualified solutions are used.

The critical part of the licensing is how to demonstrate that the prevention of failure propagation and independency of different defence-in-depth levels are adequate. Proofing that platforms and equipment fulfil requirements can also be laborious work and must be carefully planned if the equipment has not been originally designed for safety critical use. Cyber security threats must also be considered.

Design for reliable, stable and manageable operation

STUK Regulation Y/1/2016 requires that a nuclear power plant's control room shall contain equipment which provide information about the plant's operational state and any deviations from normal operation as well as systems which monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents. Furthermore, it requires that a nuclear power plant shall contain automatic systems that maintain the plant in a controlled state during transients and accidents long enough to provide the operators sufficient time to consider and implement the correct actions. Special attention shall be paid to the avoidance, detection and repair of human errors. The possibility of human errors shall be taken into account both in the design of the nuclear power plant and in the planning of its operation so that the plant withstands well errors and deviations from planned operational actions.

In conclusion, Finnish regulations and practices are in compliance with Article 18.

Article 19. Operation

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;***

ii. ***operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;***

iii. ***operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;***

iv. ***procedures are established for responding to anticipated operational occurrences and to accidents;***

v. ***necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;***

vi. ***incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;***

vii. ***programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;***

viii. ***the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.***

Initial authorisation

According to Section 19 of STUK Regulation (STUK Y/1/2016), in connection with the commissioning of a nuclear power plant, the licensee shall ensure that the systems, structures and components and the plant as a whole operate as designed. At the commissioning stage, the licensee shall ensure that an expedient organisation is in place for the future operation, alongside a sufficient number of qualified personnel and instructions suitable for the purpose.

Requirements for the commissioning programme are set forth in the Guide YVL A.5. According to the Guide YVL A.5, the purpose of the commissioning programme is to give evidence that the plant has been constructed and will function according to the design requirements. Through the programme possible deficiencies in design and construction can also be observed. The Operating Licence is needed before fuel loading into the reactor. Authorisation for fuel loading is given by STUK after its specific inspection where readiness of the power plant and operating organisation is checked. Furthermore, according to the Nuclear Energy Decree, the various steps of the commissioning, i.e., criticality, low power operation and power ascension, are subject to the approval of STUK.

The commissioning programme is described in the Preliminary and Final Safety Analysis Reports. The participation of the operating staff in the commissioning programme is a requirement of the Guide YVL A.4. The commissioning programme is to be submitted to STUK for approval. The detailed commissioning test programmes and test reports of safety-classified systems are submitted separately to STUK for approval. STUK witnesses commissioning tests and assesses the test results before giving stepwise permits to proceed in the commissioning.

Olkiluoto unit 3 commissioning

Commissioning of the Olkiluoto unit 3 is ongoing. On the turbine island, system commissioning tests are completed as far as possible without steam and other connections to nuclear island. Commissioning for I&C and electrical system is ongoing, and commissioning for process systems has been started during the spring 2016. Commissioning is divided into four actual commissioning phases followed by a-30-day demonstration run before provisional take-over of the plant. The first commissioning phase consists of component and system testing. This is followed by overall system tests – cold and hot functional tests – before core loading. For fuel loading, Operating licence and STUK´s authorisation are required. Hot functional tests with core in sub-critical state and first criticality can then follow. After first criticality, the commissioning proceeds with power tests at various power levels up to rated power. During power tests, transient tests are performed. The transient tests will cover at least reactor trip, turbine trip, loss of off-site power, house load operation, trip of one main circulation pump or main feedwater pump, as well as other minor operational transients.

All commissioning documentation is part of Commissioning Manual which includes also organisational procedures. Vendor has prepared an Overall Commissioning Programme as well as system level commissioning documentation and TVO and STUK have approved some of these documents. Preparations for plant level commissioning are still underway, e.g. preparation of detailed commissioning programs for the later phases of commissioning. STUK oversees the commissioning of safety classified systems and related result documentation is provided for STUK´s review.

Before commissioning activities of a system can be started, the system goes through a commissioning inspection. This step certifies that components and system are properly installed and all activities preceding commissioning have been completed. This is also part of the pressure equipment requirements.

As the STUK Regulation (STUK Y/1/2016) states, one aim of the commissioning is to ensure that an expedient organisation is in place for the future operation. TVO's personnel (e.g. future operators and maintenance personnel) are participating in the commissioning activities in order to gain familiarity with the plant. The documentation for operation, like operating and testing procedures, is validated during the commissioning tests. The Operational Limits and Conditions are being prepared, and trained to TVO's personnel. TVO is also preparing itself for the future operation of the plant by planning refuelling outages, data systems, waste management, radiation protection and other issues related to the plant operation.

As part of the construction inspection programme inspections, STUK oversees TVO´s actions for ensuring that the plant is commissioned appropriately.

Operational Limits and Conditions

Nuclear Energy Decree requires that the applicant for an Operating Licence must provide STUK with the Operational Limits and Conditions (OLCs). The OLCs shall at least define limits for the process parameters that affect the safety of the facility in various operating states, provide regulations on operating restrictions that result from component failures, and set forth requirements for the testing of components important to safety. Technical and administrative requirements and restrictions for ensuring the safe operation of a nuclear power plant shall be set forth in the plant's OLCs. Guide YVL A.6 requires that the minimum staff availability in all operational states and the limits for the releases of radioactive substances are also defined in the document.

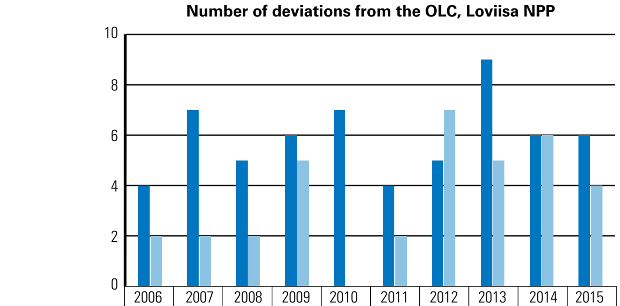
The OLCs have been established for each nuclear power plant unit and are updated based on operational experiences, tests, analyses and plant modifications. The OLCs are subject to the approval of STUK prior to the commissioning of a facility. Strict observance of the OLCs is verified by STUK's continuous oversight, reporting requirements and through a periodic inspection programme. The OLCs, operating procedures and other plant documentation need to be updated as part of plant modification process.

Fortum has established the OLCs for the Loviisa units 1 and 2, and STUK has reviewed and accepted them. The OLCs are continuously updated, and all the changes need to be approved by STUK. The limitations and conditions of the reactor and plant operation, the requirements for periodic tests and the essential administrative instructions are presented in the OLCs.

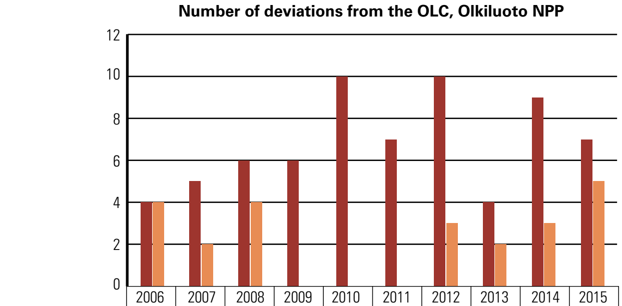
Fortum has renewed the OLCs for Loviisa units 1 and 2 in 2015 and the pertinent documentation of OLCs was sent to STUK in December 2015 for review. The intention of the renewal was to make some smaller changes and to get FSAR references up to date. Some requirements were also clarified.

The OLCs for the Olkiluoto units 1 and 2 determine the limits of process parameters that affect the plant safety, for different operating modes, set the provisions for operating limits caused by component inoperability and set forth the requirements for the tests that are conducted regularly for components important to safety. Furthermore, the OLCs include the bases for the set provisions. TVO has an ongoing development project to update the OLC for the Olkiluoto units 1 and 2. The goal of the development project is to clarify limits and conditions and expand bases and justifications. The project originally started in 2008 and STUK received first updated OLC chapters in 2012. Project is planned to be completed by the end of 2016. Furthermore, minor changes to the OLC has been made regularly based on plant modifications and organizational changes.

The OLCs for the Olkiluoto unit 3 is part of the operating licence application and STUK's review for OLCs is ongoing. STUK received a preliminary version of the OLCs for information in 2015. STUK reviewed the general principles of the OLCs, but not yet the details. The OLCs for the Olkiluoto unit 3 define safety limits for the plant, limiting conditions and surveillance requirements for plant



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Exemptions	4	7	5	6	7	4	5	9	6	6
Deviations	2	2	2	5	0	2	7	5	6	4



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Exemptions	4	5	6	6	10	7	10	4	9	7
Deviations	4	2	4	0	0	0	3	2	3	5

Figure 19. Number of exemptions and deviations from the Operational Limits and Conditions in the Loviisa and Olkiluoto NPPs.

systems, as well as administrative controls. The OLCs also include bases and justification for the conditions.

Figure 19 presents the number of exemptions and deviations from the Operational Limits and Conditions. The main reason for the large number of exemptions at the Loviisa NPP in years 2002-2003 was the project to renew the radiation monitors that required exemptions in all operational states. Based on the results of the last 10 years, the Loviisa NPP applied for STUK's approval for exemptions from the OLCs on the average six times per year. Hence, the number of applications in 2013–2015 (total 21) was a little higher than the average. During the period 2013–2015, most of exemption applications concerned plant modifications and testing of equipment or overdue repairs of component failures. In 2013–2015, there were fifteen events at the Loviisa plant in which the Operational Limits and Conditions were deviated. The figure 19 trend is showing a noticeable increase in deviations. Deviations have occurred three times per year on average during past ten years (2006–2015).

Based on the results of the last 10 years, the Olkiluoto nuclear power plant applied for STUK's approval for exemptions from the OLCs on the average seven times per year. Hence, the number of applications in 2013–2015 (total 20) is close to the average. Most of the applications were related to plant modifications. For example renewal of the radiation measurement system and enlargement of the spent fuel storage required several exemptions from the OLCs. In 2013–2015, there were ten events at the Olkiluoto plant in which the Operational Limits and Conditions were deviated. The number of events is close to the yearly average of the last 10 years (3 events per year). Many of these events were linked to human errors and improper procedures such as separation of auxiliary feed water subsystem without work permit and failure of monthly iodine measurement due to miss of flow in the measurement channel. In all of these events the safety meaning was considered low because there was enough defence-in-depth safety layers available to handle the event.

Procedures for operation, maintenance, inspection and testing

STUK Regulation (STUK Y/1/2016) Section 20, requires that the control and supervision of a nuclear power plant shall utilise written procedures that correspond to the current structure and state of the plant. Written orders and related procedures shall be provided for the maintenance, testing and repair of components. Section 23 requires that the plant shall have a condition monitoring and maintenance programme for ensuring the integrity and reliable operation of systems, structures and components. More detailed requirements are presented in the Guides YVL A.1, YVL A.4 and YVL A.6. The procedures for operation, maintenance, inspection and testing have been established for both Finnish nuclear power plants. The procedures shall be approved by the licensee itself, and most of them are required to be submitted to STUK for information. STUK verifies by means of inspections and continuous oversight performed by resident inspectors that approved procedures are followed in the operation of the facility.

Loviisa NPP

A structured system of procedures exists at the Loviisa plant. The procedures cover work processes and functions important to safety and availability. The system of procedures is a part of the quality system of the plant. Strict requirements have been set in the Quality Assurance Manual for the coverage, responsibilities, updating and observance of the procedures. According to the Manual the evaluation of the system of procedures is included in the annual review of the applicability and effectiveness of the management system. Procedures are maintained, evaluated and developed systematically and in a controlled way. The most important procedure types are:

- Administrative procedures including Organisational Manual and Administrative Rules,
- Operating procedures and testing procedures,
- Procedures for emergency and transient situations,
- Fuel handling procedures,
- Radiation protection procedures, and
- Maintenance procedures.

Loviisa plant has upgraded computer systems used in managing documentation and permit-to-work system. By means of a work order system it is ensured that the plant operators are aware of the state and configuration of the unit. Fortum has developed, and develops further, its work order system based on accumulated operating experiences. In addition to the work order system the operators in the main control room of the units follow failures, repairs and preventive maintenance of the components referred to in the Operating Limits and Conditions. A shift supervisor gives a permit to start a specific work when he has evaluated the work plans specified in the work order system, taking into account the operability requirements of the systems and components set in the Operational Limits and Conditions.

The maintenance activities of the Loviisa units 1 and 2 cover preventive, predictive and repairing maintenance as well as implementation of modification works, spare part maintenance and activities during outages. The scheduling of the modification planning for the next maintenance outage is fixed in order to get enough time for preparations. Minor modifications are concentrated to every second annual maintenance outage and major works are carried out every fourth year. This is accomplished by starting from a long term investment planning which converts into a long term modification plan.

The functioning of the systems and components is ensured with regular tests. The systems and components to be tested and the time periods of the tests are presented in the Operational Limits and Conditions. At least the respective periodic tests are required after the modification and repairing works and maintenance activities requiring dismounting. The performance test programme to be carried out after an essential modification is required to be approved by STUK in advance. In addition, inspections regarding to the functioning and condition of components are carried out when necessary based on operating experiences from other plants and on the advancement of technical knowledge. Other operating organisations of VVER-type reactors have been essential sources of operating experiences in this respect.

STUK oversees monitoring and maintenance activities as well as repair and modification works with regular inspections and continuous oversight performed by resident inspectors. Goal of the inspections is to ensure that the utility has adequate resources, such as a competent staff, instructions, a spare part and material storage as well as tools for the sufficiently effective implementation of the monitoring and maintenance activities. Special subjects are the condition monitoring programmes for the carbon steel piping and their results. Special attention has also been paid to the reliable activities of subcontractors as well as to the technical competence of external human resources. Both the utility and STUK oversee companies that perform inspection activities and the technical competence of organisations that carry out various duties.

Olkiluoto NPP

The measures that are followed in the operation and maintenance of the Olkiluoto units 1 and 2 are based on written procedures. The administrative and technical procedures needed in the operation of the Olkiluoto units 1 and 2 have been gathered into the Operating Manual. The Operating Manual contains also necessary transient and emergency procedures for unusual conditions. The most important procedures have been reviewed by STUK. Updating and comprehensiveness of the procedures are among the inspection issues included in the STUK's periodical inspection programme. TVO updates the procedures when necessary and checks systematically that the procedures are up-to-date in four-year-intervals.

The Work Request System ensures that the operators of the plant are aware of the plant state. TVO has developed its Work Request System and will continue to do so, on the basis of operational experience. In the main control room of the plant units, the operators follow, in addition to the Work Request System, the failures, repairs and preventive maintenance of the components specified in the Operational Limits and Conditions. The Shift Supervisor grants the permission to begin a single work after inspecting the work plans and taking into account the operability requirements for the systems and components set forth in the Operational Limits and Conditions.

The maintenance activities of the Olkiluoto units 1 and 2 cover preventive and corrective maintenance as well as the design and execution of modifications, spare part service, outage actions and the related quality control. The Maintenance

Department plans and implements the annual maintenance outages together with the Operation Department and Technical Support Department. Special attention has been paid to the reliable work of the subcontractors and to the technical competence of the external work force. The technical expertise of testing laboratories and contractors is controlled both by the power company and STUK.

The systems and the components that will be tested as well as the test dates are presented in the Operational Limits and Conditions. Periodical testing that corresponds at least to the aforementioned is required after maintenance measures that require modifications, repairing or disassembling. STUK's approval is required in advance for a functional test programme that is conducted after a significant modification. Inspections that concern the operability and condition of components are also conducted, if necessary, on the basis of operational experience received from elsewhere and development of technical knowledge. The most significant sources of operational experience, in this sense, have been the Swedish BWR plants.

STUK oversees the condition monitoring and maintenance as well as the modification and repair work by regularly repeated inspections. The inspections aim to ensure that the power company has adequate resources such as a competent personnel, instructions, a spare part and material storage as well as the tools for adequately efficient implementation of condition monitoring and maintenance actions. Special items are the condition monitoring programmes of the carbon steel pipelines and their results.

Procedures for responding to operational occurrences and accidents

STUK Regulation (STUK Y/1/2016) Section 20 gives basic requirements for operating and emergency procedures.

At both Finnish nuclear power plants, procedures for anticipated operational occurrences and accidents are in use. To the extent found necessary, the procedures have been verified during operator training at the plant simulators. At both nuclear power plants there are also advanced safety panels for monitoring critical safety functions. STUK has independently evaluated the appropriateness and comprehensiveness of the procedures for anticipated operational occurrences and accidents.

TVO has an ongoing development project to update event-oriented operating procedures for events within the scope of the design. These transient operating procedures will be updated by adding a symptom based chart in the beginning of each procedure. The chart guides operator to choose the right procedure for the ongoing situation. The development work started in 2012 and is scheduled to be completed by the end of 2016. To cope with emergency conditions beyond design, including severe accidents, a set of symptom-based emergency operating procedures (EOPs) is available. The focus of the severe accident EOPs is on ensuring the containment integrity. The symptom oriented accident management procedures (included in EOPs) apply to shutdown states, as well, although prevention of core damage is essential especially in situations with open containment. As a lesson learnt from the TEPCO Fukushima Daiichi accident, the licensee has improved EOPs to support heat removal from spent fuel pools by pool boiling and supplying make-up water to the pools. Also possibility to shutdown the plant from an emergency control room is added to EOPs.

At the Loviisa NPP, immediate Severe Accident Management (SAM) measures are carried out within the EOPs. After carrying out immediate actions successfully, the operators concentrate on monitoring the SAM safety functions with SAM procedures. The SAM procedures focus on monitoring the leak tightness of the containment barrier, and on the long-term issues. As a lesson learnt from the TEPCO Fukushima Dai-ichi accident, the licensee will improve EOPs and SAM procedures to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. EOPs were developed in 2012 for shutdown states covering the immediate recovery of SAM systems.

Engineering and technical support

STUK Regulation (STUK Y/1/2016) Section 25 requires that the organisation shall have access to professional expertise and technical knowledge required for the safe operation of the plant, the maintenance of equipment important to safety, and the management of accidents. The requirements in the Guide YVL A.4 also cover technical support. Competence of the engineering and technical support is supervised by the licensee. In addition, STUK carries out inspections and audits by which also the competence of the support staff is evaluated.

Teollisuuden Voima Oyj has longstanding expertise in nuclear operations. TVO uses external expertise regularly in various design and modification activities when needed. Fortum has under corporate structure own unit for technical support that provides support to the Loviisa NPP among other projects. There are also on-site experts at the Loviisa NPP for various engineering and technical support functions.

Reporting of incidents significant to safety

Guide YVL A.10 provides in detail the reporting requirements on incidents. The Guide provides a number of examples of operational disturbances and events, which have to be reported to STUK. It also defines requirements for the contents of the reports and the administrative procedures for reporting, including time limits for submitting of various reports. STUK publishes information concerning significant events (INES ≥ 1) as press releases. Information from other events is published on STUK´s website. STUK describes the events also in yearly reports on nuclear safety that are also available to the general public through internet.

Loviisa NPP submitted to STUK on an average 19 operational event reports per year (in 2013–2015) and Olkiluoto NPP on an average 18 operational event reports per year (in 2013–2015).

Figures 20 and 21 present the total number of reported events and INES classified (≥ 1) events at the Finnish nuclear power plants.

INES-classified events

At the Loviisa NPP, seven events in 2013, five events in 2014 and five events in 2015 were classified on the International Nuclear Event Scale (INES). Three of these events were rated at level 1, others being of level 0:

- Faulty connections in Loviisa 1 I&C system at Loviisa unit 1 in 2013
- Ice condenser system was not properly returned in operation at Loviisa 2 in 2013
- Relay faults in emergency diesel generators at Loviisa power plant in 2013

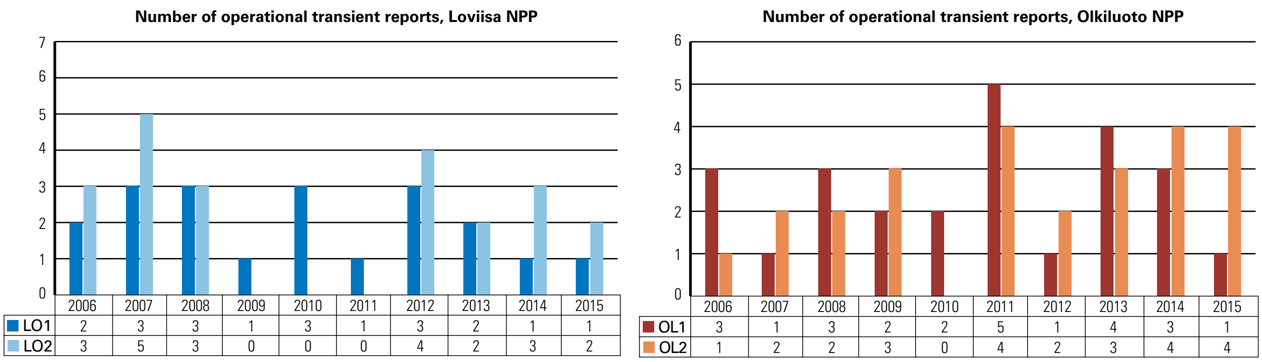


Figure 20. Annual total number of event reports (operational transient reports) submitted by Loviisa and Olkiluoto nuclear power plants.

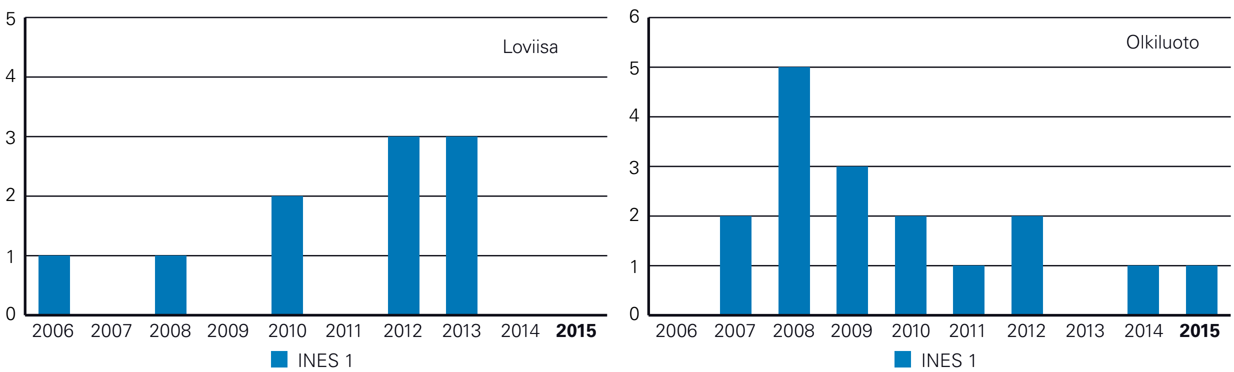


Figure 21. Annual total number of events at INES Level 1 and above at the Finnish nuclear power plants.

These incidents are described in more detail in Annex 2.

At the Olkiluoto NPP, four events in 2013, three events in 2014 and six events in 2015 were classified on the International Nuclear and Radiological Event Scale (INES). Two of these events were rated at level 1, others being of level 0:

- Replacing carbon grounding brushes of the generator during power operation at Olkiluoto unit 1 in 2014
- Open penetrations in containment during work on recirculation pumps at Olkiluoto 1 and Olkiluoto 2 in 2013–2015.

These incidents are described in more detail in Annex 3.

Operational experience feedback

According to the Section 21 of the STUK Regulation (STUK Y/1/2016), nuclear power plant operational experience feedback (OEF) shall be collected and safety research results monitored, and both assessed for the purpose of enhancing safety. Safety-significant operational events shall be investigated for the purpose of identifying the root causes as well as defining and implementing the corrective measures. Improvements in technical safety, resulting from safety research, shall be taken into account to the extent justified on the basis of the principles laid down in Section 7 a of the Nuclear Energy Act.

STUK requires that all incidents at nuclear facilities and activities are analysed and reported to STUK according to the reporting criteria and the reports are assessed by STUK. Based on the analysis, corrective actions are planned and implemented by the operators. Regulatory requirements are given in STUK's Regulatory Guide YVL A.10. The guide provides detailed requirements and administrative procedures for the systematic evaluation of operating experiences, and for the planning and implementation of corrective actions. Operational events at other nuclear power plants and foreign operational occurrences have to be systematically assessed as well, from their applicability and their significance for the nuclear facilities in Finland.

The licensees have developed the required procedures for analysing operating experiences and root causes for events. The licensees are using WANO and IRS reports as basic material to be screened for external OEF and they have OEF groups for screening, analysing of OE entry into processing and following the corrective actions. The licensees have also their internal audit programme and OEF is one topic in these programmes.

STUK verifies by means of inspections and by reviewing licensee´s event reports that the activities of the licensees as regards incident evaluation are effective. In STUK's periodic inspection programme there is inspection focusing to OEF, namely 'Operational experience feedback'. When necessary, a special investigation team is appointed by STUK to evaluate a certain incident or group of incidents. The evaluation of foreign operational occurrences and incidents is based on the reports of the IRS Reporting System (IAEA/NEA) and on the reports of other national regulatory bodies.

Following targets for development have been recognised during 2013–2015: training in the methods of investigation (personnel of licensees and authority) and evaluation of the effectiveness of the preventive and corrective actions.

For review and assessment of OE information abroad STUK has an internal OEF Group for international events with a coordinator and technical experts (18) covering all expertise areas of Nuclear Reactor Regulation and Nuclear Waste and Materials Regulation departments. The group meets monthly and based on the expert assessment in STUK's own IRS database the group members make together an judgement whether there is a need for regulatory or licensee measures on the basis of lessons learned assigning the IRS report into categories with respect to actions to be taken (categories 1 to 3), or not needed (category 0). In the case that an expert to whom the report is assigned for review cannot immediately say if an event requires actions at Finnish plants the report is classified into category 1 (particular issues need clarification) and clarifications of the applicability are initiated with the plant contact persons. After clarifications the event is reclassified. Classification into category 2 (Lessons learned need to be taken into account in certain activities) means that concrete actions are not required but the report contains information which should be considered in inspections by STUK. If actions are required at the Finnish nuclear power plants in operation or under construction the report is classified into category 3 (Actions required). Examples of such events are unexpected failures of components being installed also into the systems or equipment of Finnish plants, or events revealing deficiencies in procedures of the plants. Category 4 (Good practise in Finland) means that actions to prevent an event have already taken or an occurrence of such an event has taken into account in the original design of the plant, or there are special procedures and regulatory requirements in place (YVL guides) preventing a similar event.

Figure 22 shows the distribution of IRS reports into different categories in STUK's review and assessment from 2013 to 2015. Altogether 337 IRS-reports were assessed during that period and most of them (82 %), 276 reports, fell into category 0 requiring no further actions. 11 % (38 IRS reports) of reviewed reports were classified into category 2 and applicability of lessons learned were checked in the inspections of STUK's periodic inspection programme or evaluated in some other inspections. In the case of 4 reported events review resulted specific actions at the Finnish nuclear power plants:

- IRS 8211: "Broken control rod shaft extenders", Sweden
- IRS 8242: "Use of incorrect microfuses on instrumentation and control module assemblies in German NPPs"
- IRS 8315: "EDG failed to start after undetected loss of two phases on 400 kV incoming offsite supply", Sweden
- IRS 8243: "Potential draining of the spent fuel storage pool due to the absence of a siphon breaker on its cooling circuit line", France.

In the 13 events it was realised that similar kind of events were already well prevented by technical

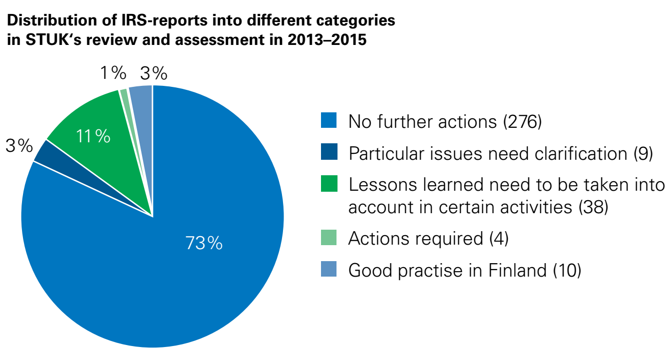


Figure 22. Distribution of IRS-reports into different categories in STUK's review and assessment in 2003–2015.

or administrative arrangements, and thus we have good practices in use.

Reports for the IRS System on safety-significant occurrences at the Finnish nuclear power plants are written by STUK. STUK has delivered six (6) new IRS-reports during 2013-2015.

STUK oversees the utilisation of international OE by licensees.

STUK has also participated in co-operation between international organisations such as the IAEA, the OECD/NEA and the EU (Clearinghouse), which exchange information on safety issues and operating events. In the OECD/NEA/CNRA working groups for e.g. WGOE (Operating Experience) and WGRNR (Regulation of New Reactors) improves nuclear safety by sharing experience and lessons learnt from nuclear installations. Other forums that STUK uses to obtain information are WENRA, MDEP workgroups, the VVER Forum as well as some bilateral agreements. A special exchange of information between Rostechnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants is also ongoing activity. The similar information exchange is arranged also to Sweden (SSM) and France (ASN).

At the Loviisa NPP, VVER reactor operating experience is collected, screened and evaluated by a dedicated operating experience feedback group composed of engineers from the plant operation organisation and from Technical Support. The main information to be handled comes from WANO (Moscow Centre) which links all the VVER reactor operators. Additional information and reports are received from the IAEA, OECD/NEA, NRC (U.S. Nuclear Regulatory Commission) and FROG (Framatome owners group). The activities of the operating experience feedback group are not limited only to VVER reactors. The plant managers of VVER-440 reactors have periodic meetings. The plant operation problems, modernisation, back-fitting, plant life management and safety questions are handled and experiences are exchanged in these meetings and in further individual contacts.

TVO has also an operating experience feedback group. This onsite group gives recommendations to the line organisation that makes decisions on eventual corrective actions. The industry operating experience from similar reactor types is followed by several means. The main sources of information are NordERF (cooperation between Nordic NPPs) with connection to KSU (Swedish nuclear training centre) and WANO. Information is also coming directly from several sources (IAEA and OECD/NEA, IRS), Loviisa power plant (e.g. operating experience meetings and reports), vendors (Westinghouse Atom, Alstom Power Sweden AB), component manufacturers, BWROG (BWR Owners Group) and BWR Forum (FANP).

IRS reports are also received directly by the licensees via WBIRS and evaluated by them. Almost all plant modifications, as improvements in systems, structures, and components, which have emerged from foreign experience originate from plants that are of the same type as the Finnish plants.

Management of spent fuel and radioactive waste on the site

Management of the operational low and intermediate level nuclear wastes and the disposal of these wastes takes place at the NPP sites. Disposal facilities for low and intermediate level waste are in operation at Loviisa and Olkiluoto sites. Since the disposal facilities are operated by the nuclear power plant operators, the technical feasibility and economic motivation to minimise the generation of radioactive waste are evident.

The requirement for radioactive waste minimisation is included in the Guide YVL D.4. It calls for a limitation of waste volumes in particular from repair and maintenance works, and segregation of waste on the basis of activity. Clearance of waste from regulatory control, prescribed in the Nuclear Energy Decree and in the Guide YVL D.4, aims at limiting the volumes of waste to be stored and disposed of. Same guide includes also more specific requirements for the conditioning and interim storage of waste and it requires that besides the short-term radiation protection objectives, also the long-term properties of waste packages with respect to disposal shall be taken into account in the conditioning and storage of waste. The Guide YVL B.4 provides for prevention of fuel failures, which also contributes to the limitation of activity accumulation in waste from reactor water cleanup systems.

The Guide YVL D.5 calls for a waste type description, to be approved by STUK, for each category of waste to be disposed of. In the description of waste type, the most important characteristics of waste with respect to the safety of disposal are defined. The Guide includes also specific requirements for planning, design and operation of the disposal facility and demonstration of compliance with safety requirements.

Low and intermediate level waste

The policy to minimise the waste production at the Loviisa and Olkiluoto NPPs has included the high quality requirements for the fuel, careful planning of the maintenance work and decontamination. The segregation and monitoring of the operational waste have been effective, enabling the clearance from the regulatory control of waste below the clearance levels. Some large metal components from both Loviisa and Olkiluoto NPPs have been transported for treatment to Studsvik facility in Sweden. The purified metal has been recycled in Sweden. Parts of components containing activation products or external contamination have been separated and transported back to Finland for disposal.

At the Loviisa NPP, the design, construction and commissioning activities of the liquid waste solidification plant has continued. The plant is designed for conditioning and disposal of liquid low and intermediate level waste. The commissioning continued in 2014-2015 with the system and plant tests. The commissioning program included also e.g. the operating personnel training and updating the plant design documentation and procedures. The system and plant tests were finalized and the results of the tests approved by STUK in 2015. Loviisa NPP sent the application for the solidification plant operating phase to STUK in 2015. STUK performed the regulatory commissioning inspections and review of the application at the same year. STUK's approval for starting the solidification plant operation was issued in the beginning of 2016.

At the Loviisa NPP site, the repository for the low and intermediate level waste is located at the depth of 110 meters in granite bedrock. It consists of three tunnels for solid low level waste and a cavern for solidified intermediate level waste. The commissioning of the third tunnel, built during 2010-2012, will be done in 2016, after the commissioning inspection made by STUK. Loviisa NPP delivered STUK the periodic safety review of the repository at the end of 2013. STUK reviewed the document and approved it. STUK follows the development projects presented in the periodic safety review of Loviisa NPP repository.

The repository for the low and intermediate level waste at the Olkiluoto NPP site consists of two silos at the depth of 60 to 95 meters in tonalite bedrock, one for solid low level waste and the other for bituminised intermediate level waste.

The original plan presented in the construction licence application for unit Olkiluoto 3 was to dispose all the low and intermediate level waste in the existing repository in Olkiluoto. However, the waste packages of the conditioned intermediate level waste have different dimensions compared to the waste packages from operating units in Olkiluoto. Therefore TVO will in the operating licence application propose that the conditioned intermediate level waste is first stored on-site in the existing waste storage facility, and later disposed of in the extension of the repository. The solid low level waste from Olkiluoto unit 3 can be disposed of in the existing repository.

At the end of 2015, 6390 cubic meters of low and intermediate level operating waste has accumulated at the Olkiluoto NPP and 3571 cubic meters at the Loviisa NPP. About 95 % of Olkiluoto waste and 55 % of Loviisa solid waste has been disposed of in the on-site repositories. Low and intermediate level waste not yet disposed of is stored inside the plants.

Decommissioning

The Guide YVL D.4 requires that provision for a nuclear power plant's decommissioning shall be made already during the plant's design phase. One criterion when deciding the plant's materials and structural solutions shall be that volumes of decommissioned waste are to be minimized. The Guide YVL C.1 requires selection of such construction materials that limit the degree of activation and spread of contamination and makes decontamination of surfaces feasible.

According to the Nuclear Energy Decree the licence applications must include the plans for decommissioning. The utilities are obliged to keep the decommissioning plans up-to-date and submit them to the Ministry of Employment ant the Economy every six years. Review of the decommissioning plan is coordinated by MEE because national waste management fund is administrated by MEE. STUK participates in the review by giving its statement to MEE. Last review for Loviisa NPP decommissioning plan was made in 2012-2013 and for Olkiluoto NPP decommissioning plan in 2014. Next update of the existing decommissioning plans for Loviisa NPP will be in 2018.

The assumption in the decommissioning plan of the Loviisa NPP is that both units will be shut down after 50 years operation in 2027 and 2030. The dismantling starts immediately and lasts approximately 11 years. Olkiluoto units 1 and 2 are planned to be shut down after 60 years operation in 2038 and 2040. The decommissioning strategy for units 1 and 2 is deferred and dismantling starts after 30 years of safe storage period. The main reason for delayed dismantling is the radiation protection of the personnel. Olkiluoto unit 3 is planned to shut down after 60 years operation in 2070's. The decommissioning strategy for the unit 3 is immediate dismantling. Dismantling of all units is expected to be done in one campaign.

According to STUK's opinion expressed to the Ministry of Employment and the Economy, the decommissioning plans at this phase of the NPP operation are reasonably comprehensive and detailed. The decommissioning can be carried out as planned, and the plans are sufficient to be used in the cost estimations.

Spent fuel

Spent fuel from the Loviisa NPP was transported back to Russia until 1996. Amendment of the Nuclear Energy Act issued in 1994 requires that spent fuel generated in Finland has to be treated, stored and disposed of in Finland. Accordingly, spent fuel shipments to Russia were terminated, and the necessary extension of the wet type spent fuel storage facility was commissioned in 2001. The installation of the high density racks into the storage facility started in 2007 and continues until Posiva starts transferring spent fuel to Olkiluodo for final disposal. The capacity of the storage facility will be adequate for the total amount of the spent fuel 1100 tU allowed in the operating licence issued in 2007. This amount covers all spent nuclear fuel that is estimated to be produced in Loviisa NPP until the decommissioning of the reactors.

After the stress tests due to the TEPCO

Fukushima Dai-ichi accident some safety improvements were identified for the Loviisa NPP spent fuel interim storages. The improvements concerned the availability of external cooling water and connections to feed the cooling water from external sources. The water level and temperature monitoring of the fuel pools were planned to be modified to function in all conditions. Also exhaust routes for the vapour were considered to be modified. Fortum has proceeded to the design phase of these planned modifications. Implementations of the modifications are planned to be completed by the end of 2018.

At the Olkiluoto NPP, the wet type spent fuel interim storage facility was commissioned in 1987. The original capacity of 1200 tU was extended to 1800 tU in 2015. TVO completed the enlargement of the Olkiluoto interim storage in summer 2015. The extension included three new pools and it was designed and implemented according the updated safety requirements (Government Decree 717/2013 in force at the time of the review). Extension has been included in Olkiluoto NPP units 1 and 2 operating licence and has been handled as plant modification. STUK gave approval to take enlargement in operation in summer 2015.

After the stress tests some safety improvements for the Olkiluoto NPP spent fuel interim storage were identified. The possibility to feed the cooling water from external source and to monitor spent fuel pool water level and temperature in all cases were the most important safety features to be implemented. These safety features were included and implemented in the spent fuel storage enlargement. The connection for feeding the cooling water from external source was already included in the design of enlargement of the Olkiluoto spent fuel interim storage before Fukushima accident.

At the end of 2015, the spent fuel accumulation at the Olkiluoto NPP was 1432 tons of uranium and at the Loviisa NPP 606 tons of uranium.

Fennovoima submitted the construction licence application in 2015. Fennovoima plans to store spent fuel in the interim storage which will be either pool type wet storage or dry storage. The amount of spent fuel is estimated to be between 1200–1800 tU.

In the construction license application documents Fennovoima provided STUK the licensing plan of the spent fuel interim storage. Fennovoima will make the decision for the storage solution (wet or dry) at the latest in October 2016 and the detailed documentation of the license application will be submitted to STUK by May 2017.

The power companies Fortum and TVO established in 1995 the joint company Posiva to take care of spent nuclear fuel disposal. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in about 2023. The Decision-in-Principle on the spent fuel disposal facility in deep crystalline bedrock was made by the Government in 2000 and ratified by the Parliament in 2001. It covers the disposal of the spent fuel from the Olkiluoto units 1 and 2 and Loviisa units 1 and 2. A separate Decision-in-Principles for the disposal of the spent fuel from the Olkiluoto unit 3 was made in 2002. The spent fuel disposal facility will be constructed in the vicinity of Olkiluoto NPP site. To confirm the suitability of the site, construction of the underground rock characterization facility ONKALO was started in 2004. The excavation of ONKALO was almost completed during 2015, but some extensions will be excavated during 2016.

Posiva submitted a construction licence application for an encapsulation plant and disposal facility for spent nuclear fuel to the Ministry of Employment and Economy in the end of 2012. The detailed technical documentation of the application was reviewed by STUK during 2013-2014 and based on the review STUK gave a statement and safety assessment for the Ministry of Employment and Economy in February 2015. The construction licence was granted for Posiva by the Government in November 2015. The construction licence includes both the encapsulation plant and the underground disposal facility. Licence conditions require that Posiva shall start facility construction in two years time. The capacity of the disposal facility is restricted in the construction licence to 6500 tU which covers the spent nuclear fuel from the NPP units in operation (Olkiluoto 1 & 2, Loviisa 1 & 2) and under construction (Olkiluoto 3).

Fennovoima presented in its Decision-in-Principle application similar general principles as Posiva for the spent nuclear fuel disposal. The positive Decision-in-Principle for a new reactor unit ratified by the Parliament in 2010 included a requirement for Fennovoima either to negotiate a contract with the other Finnish NPP operators under waste management obligation on spent nuclear fuel management co-operation, or to start an environmental impact assessment process for another disposal site for the spent nuclear fuel from Hanhikivi unit 1. Based on the Decision-in-Principle, Fennovoima had six years to fulfill this requirement, until end of June 2016. Fennovoima submitted in June 2016 Environmental Impact Assessment (EIA) programme to the Ministry of Employment and the Economy. According to the programme Fennovoima will start assessment for spent nuclear fuel encapsulation and disposal facility in two alternative municipalities Eurajoki and Pyhäjoki. In Eurajoki municipality, where also Olkiluoto site is situated, Fennovoima plans for site investigation covers in first stage the whole municipality area. In Pyhäjoki municipality, where Hanhiki site is also located, the investigation area is in Sydänneva south from planned NPP site. Fennovoima has proposed that EIA process is finalized in year 2040 after they will apply for Decision-in-Principle. Fennovoima has planned to start spent fuel disposal earliest in 2090's.

Safety regulation for spent fuel handling, storage and disposal is included in the STUK Regulation on the safety of disposal of nuclear waste (STUK Y/4/2016) and STUK Guides YVL D.3 and D.5.

A detailed description of spent fuel and radioactive waste management and related regulation is included in the 4th Finnish National Report as referred to in Article 32 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (STUK-B 180, October 2014).

In conclusion, Finnish regulations and practices are in compliance with Article 19.

ANNEX 1 List of main regulations

Legislation (as of 1st July 2016)

1. Nuclear Energy Act (990/1987)
2. Nuclear Energy Decree (161/1988)
3. Act on Third Party Liability (484/1972)
4. Decree on Third Party Liability (486/1972)
5. Radiation Act (592/1991)
6. Radiation Decree (1512/1991)
7. Act on the Finnish Centre for Radiation and Nuclear Safety (1069/1983)
8. Decree on the Finnish Centre for Radiation and Nuclear Safety (618/1997)
9. Decree on Advisory Committee on Nuclear Safety (164/1988).

STUK Regulations

- STUK Regulation on the Safety of Nuclear Power Plants (STUK Y/1/2016)
- STUK Regulation on Emergency Response Arrangements at Nuclear Power Plants (STUK Y/2/2016)
- STUK Regulation on the Security in the Use of Nuclear Energy (STUK Y/3/2016)
- STUK Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2016)
- STUK Regulation on the Safety of Mining and Milling Operations aimed at Producing Uranium or Thorium (STUK Y/5/2016)

The Regulations are available on the Internet at http://www.finlex.fi/fi/viranomaiset/normi/555001/ (in English).

Regulatory Guides on nuclear safety (YVL Guides)

Group A: Safety management of a nuclear facility

Guide YVL A.1 Regulatory oversight of safety in the use of nuclear energy, 22.11.2013

Guide YVL A.2 Site for a nuclear facility, 15.11.2013

Guide YVL A.3 Management system for a nuclear facility, 2.6.2014

Guide YVL A.4 Organisation and personnel of a nuclear facility, 2.6.2014

Guide YVL A.5 Construction and commissioning of a nuclear facility, 2.6.2014

Guide YVL A.6 Conduct of operations at a nuclear power plant, 5.6.2014

Guide YVL A.7 Probabilistic risk assessment and risk management of a nuclear power plant, 15.11.2013

Guide YVL A.8 Ageing management of a nuclear facility, 20.5.2014

Guide YVL A.9 Regular reporting on the operation of a nuclear facility, 15.8.2014

Guide YVL A.10 Operating experience feedback of a nuclear facility, 15.11.2013

Guide YVL A.11 Security of a nuclear facility, 15.11.2013

Guide YVL A.12 Information security management of a nuclear facility, 22.11.2013

Group B: Plant and system design

Guide YVL B.1 Safety design of a nuclear power plant, 15.11.2013

Guide YVL B.2 Classification of systems, structures and components of a nuclear facility, 15.11.2013

Guide YVL B.3 Deterministic safety analyses for a nuclear power plant, 15.11.2013

Guide YVL B.4 Nuclear fuel and reactor, 15.11.2013

Guide YVL B.5 Reactor coolant circuit of a nuclear power plant, 15.11.2013

Guide YVL B.6 Containment of a nuclear power plant, 15.11.2013

Guide YVL B.7 Provisions for internal and external hazards at a nuclear facility, 15.11.2013

Guide YVL B.8 Fire protection at a nuclear facility, 15.11.2013

Group C: Radiation safety of a nuclear facility and environment

Guide YVL C.1 Structural radiation safety at a nuclear facility, 15.11.2013

Guide YVL C.2 Radiation protection and exposure monitoring of nuclear facility workers, 20.5.2014

Guide YVL C.3 Limitation and monitoring of radioactive releases from a nuclear facility, 15.11.2013

Guide YVL C.4 Assessment of radiation doses to the public in the vicinity of a nuclear facility, 17.3.2015

Guide YVL C.5 Emergency arrangements of a nuclear power plant, 15.11.2013

Guide YVL C.6 Radiation monitoring at a nuclear facility, 15.11.2013

Guide YVL C.7 Radiological monitoring of the environment of a nuclear facility,(underdrafting)

Group D: Nuclear materials and waste

Guide YVL D.1 Regulatory control of nuclear safeguards, 15.11.2013

Guide YVL D.2 Transport of nuclear materials and nuclear waste, 15.11.2013

Guide YVL D.3 Handling and storage of nuclear fuel, 15.11.2013

Guide YVL D.4 Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility, 15.11.2013

Guide YVL D.5 Disposal of nuclear waste, 15.11.2013

Guide YVL D.6 Production of uranium and thorium in mining and milling activities (underdrafting)

Guide YVL D.7 Barriers and rock engineering of nuclear waste disposal facility (underdrafting)

Group E: Structures and equipment of a nuclear facility

Guide YVL E.1 Authorised inspection body and the licensees in-house inspection organisation, 15.11.2013

Guide YVL E.2 Procurement and operation of nuclear fuel, 15.11.2013

Guide YVL E.3 Pressure vessels and piping of a nuclear facility, 15.11.2013

Guide YVL E.4 Strength analyses of nuclear power plant pressure equipment, 15.11.2013

Guide YVL E.5 In-service inspection of nuclear facility pressure equipment with non-destructive testing methods, 20.5.2014

Guide YVL E.6 Buildings and structures of a nuclear facility, 15.11.2013

Guide YVL E.7 Electrical and I&C equipment of a nuclear facility, 15.11.2013

Guide YVL E.8 Valves of a nuclear facility, 15.11.2013

Guide YVL E.9 Pumps of a nuclear facility, 15.11.2013

Guide YVL E.10 Emergency power supplies of a nuclear facility, 15.8.2014

Guide YVL E.11 Hoisting and transfer equipment of a nuclear facility, 15.11.2013

Guide YVL E.12 Testing organisations for mechanical components and structures of a nuclear facility, 20.5.2014

The guides are available on the Internet at http://www.stuk.fi/web/en/regulations/stuk-s-regulatory-guides/regulatory-guides-on-nuclear-safety-yvl- (in English)

ANNEX 2 Loviisa NPP units 1 and 2 under operation

The Loviisa plant comprises of two PWR units (pressurised water reactors, of VVER type), operated by Fortum Power and Heat Oy (Fortum). The plant units were connected to the electrical grid in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original 1375 MW). The increase of the power level was licensed in 1998. The Operating Licences of the units are valid until the end of 2027 (unit 1) and 2030 (unit 2). According to the conditions of the licences, two periodic safety reviews are required to be carried out by the licensee (by the end of the year 2015 and 2023). The assessment of the first periodic safety review has completed during the year 2016.

Most significant plant modifications at the Loviisa NPP during the plant lifetime

Several plant changes have been carried out during Loviisa NPP plant lifetime. The most important projects since the plant commissioning have been modifications made for protection against fires, modifications based on the development of the PRA models, severe accident management programme, reactor power uprating, and construction of training simulator, interim storage for spent fuel and repository for reactor operational waste.

Among the earliest modifications in 1982, a hydrogen removal system was installed in the containment building in order to eliminate the risk of explosion during an accident when hydrogen is released from the core. The system consisted of 60 glow plugs that can ignite a controlled hydrogen burn.

In 1993, strainer area in the floor sumps of the emergency cooling system and the containment spray system was significantly enlarged by new design, and the sump systems were improved so as to provide more reliable pumping of the water accumulated in the two sumps during a loss of coolant accident (when the emergency make-up water tank is empty) back into the reactor and to the spray nozzles. The sumps were equipped with several hundreds of strainer units, a nitrogen flush system to blow any insulation debris off the strainers, and control instrumentation. The amount of debris the strainer system can cope with increased ten-fold.

In connection with the PRISE project in 1994–1995 (protection from primary to secondary leaks), the plant protection system was modified to provide automatic isolation of the damaged steam generator at high water level (the steam and feed water lines are closed), and to stop the respective reactor coolant pump. The aim was to protect the steam line from water hammer. Also new measuring equipment, based on the detection of nitrogen-16 isotope, was installed in the steam lines in order to ensure the detection of any leaks from the primary circuit.

Protection against fires at the Loviisa NPP

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the layout design of the Loviisa plant. Therefore, fire compartments were not implemented so that the plant safety functions could be maintained during all fire situations considered possible. For this reason the significance of an active fire fighting (fire alarm and extinguishing systems as well as operative fire fighting) is important along with structural fire protection arrangements.

Fire safety has been improved with several measures at the Loviisa plant after its commissioning. These measures have been implemented in various fields of fire protection. As a result, the plant safety against the effects of fires has been essentially improved.

For a provision against oil fires in the turbine hall several measures have been taken. Fire insulators of the load-bearing steel structures of the turbine building have been installed. The turbine hall has been equipped with an automatic sprinkler system and the significant parts of the turbines have been protected. Later on, the fire wall of the turbine hall has been built up to protect components important to reactor decay heat removal. Furthermore, the additional emergency feedwater system has been built for the case that all feedwater and emergency feedwater systems would be lost in a turbine hall fire. At the Loviisa NPP the decay heat removal systems are in the turbine hall. Thus, a separate building for additional decay heat removal system outside turbine hall was built in 2005. The new system is needed for cooling the plant to cold shutdown, if normal systems are not operable.

The main transformers have been protected with a sprinkler system which essentially reduces the risk that a fire would spread into the surrounding buildings, especially into the turbine hall. The risk to lose the AC-power (station blackout) during transformer fires has been reduced by protecting the diesel generators against fires. The 110 kV net connection has been physically separated from the 400 kV connection so that the loss of both connections as a result of a transformer fire is improbable. Several improvements against fires have been done in off-site power supply arrangements and in diesel generators. The original fire water pumps are supplied only from the off-site electrical network. Therefore, an additional fire water pump station has been constructed at the plant. It has been equipped with diesel-driven fire water pumps and with a separate fire water tank. Fire water piping and fire extinguishing systems as well as their coverage have been improved. A new addressed fire alarm system was completed in 1999 at Loviisa 1 and in 2001 at Loviisa 2. Several structural improvements for fire safety have been done, or are under design.

The level of the operative fire protection has been improved by establishing a plant fire fighting crew which is permanent, constantly ready to depart and has the proper equipment. As regards fire protection and fire risks also plant instructions have been complemented.

Severe Accident Management implementation at Loviisa NPP

The Loviisa severe accident management programme, which includes plant modifications and severe accident management procedures, was initiated in the end on 1980's in order to meet the requirements of STUK. For Loviisa NPP, the severe accident management approach focuses on ensuring the following top level safety functions:

- depressurisation of the primary circuit
- absence of energetic events, i.e. hydrogen burns and steam explosions
- coolability and retention of molten core in the reactor vessel
- long term containment cooling
- ensuring subcriticality
- ensuring containment isolation.

The developed severe accident management (SAM) strategy lead to a number of hardware changes at the plant as well as to new severe accident guidelines and procedures.

The primary system depressurisation is an interface action between the preventive and mitigation parts of SAM. If the primary feed function is operable, the depressurisation may prevent the core melt (primary system cooling by feed and bleed). At the same time the mitigation actions and measures to protect the containment integrity and mitigate large releases are initiated, in case the core cooling cannot be restored. Manual depressurisation capability has been designed and implemented through motor-operated high capacity relief valves. Depressurisation capacity will be sufficient for bleed & feed operation with high-pressure pumps, and for reducing the primary pressure before the molten corium degrades the reactor vessel strength. Depressurisation is to be initiated from indications of superheated temperatures at core exit thermocouples. The depressurisation valves were installed at the same time with the renewal of the pressuriser safety valves in 1996.

The cornerstone of the SAM strategy for Loviisa is the coolability of corium inside the reactor pressure vessel (RPV) through external cooling of the vessel. Due to in-vessel retention of molten corium all the ex-vessel corium phenomena such as ex-vessel steam explosions, direct containment heating and core-concrete interactions can be excluded.

Some of the design features of the Loviisa plant make it most amenable for using the concept in-vessel retention of corium by external cooling of the RPV as the principle means of arresting the progress of a core melt accident. Such features include the low power density of the core, large water volumes both in the primary and in the secondary side, no penetrations in the lower head of the RPV, and ice condensers which ensure a passively flooded cavity in most severe accident scenarios. On the other hand, if in-vessel retention was not attempted, showing resistance to energetic steam generation and coolability of corium in the reactor cavity could be laborious for Loviisa NPP, because of the narrow, water filled cavity with small floor area and tight venting paths for the steam out of the cavity.

An extensive research programme regarding the thermal aspects was carried out by Fortum. The work included both experimental and analytical studies on heat transfer in a molten pool with volumetric heat generation and on heat transfer and flow behaviour at the RPV outer surface. Based on experiments, the in-vessel retention concept for Loviisa was finalised. STUK approved the conceptual design in December 1995. The modifications were completed in 2002. The most laborious one of them was the modification of the lower neutron and thermal shield such that it can be lowered down in case of an accident to allow free passage of water in contact with the RPV bottom. Also a strainer facility was constructed in the reactor cavity in order to screen out possible impurities from the coolant flow and thereby prevent clogging of the narrow flow paths around the RPV.

Due to in-vessel retention of molten corium, the only real concern regarding potential energetic phenomena is due to hydrogen combustion events. The Loviisa NPP reactors are equipped with ice-condenser containments, which are relatively large in size (comparable to the volume of typical large dry containments) but have a low design pressure of 0.17 MPa. The ultimate failure pressure has been estimated to be well above 0.3 MPa. An intermediate deck divides the containment in the upper (UC) and lower compartments (LC). All the nuclear steam supply system components are located in the lower compartment and, therefore, any release of hydrogen would be directed into the lower compartment. In order to reach the upper compartment, which is significantly larger in volume, the hydrogen and steam have to pass through the ice-condensers.

In the 1990's an extensive research programme was carried out at Fortum to assess the reliability and adequacy of the existing igniters system. The experiments and the related numerical calculations demonstrated that the global convective loop around the containment for ensuring well mixed conditions will be created and maintained reliably provided that the ice-condenser doors will stay open. A new hydrogen management strategy for Loviisa was formulated which concentrates on two functions: ensuring air recirculation flow paths to establish a well-mixed atmosphere (opening of ice condenser doors) and effective recombination and/or controlled ignition of hydrogen. Plant modifications included installation of autocatalytic hydrogen recombiners, modifications in the igniters system (igniters were removed from the upper compartment and the system in the lower compartment was modified and rearranged) and a dedicated system for opening the ice-condenser doors. The modifications were completed in 2003.

The studies on prevention of long term overpressurisation of the containment showed that the concept of filtered venting was not possible at the Loviisa NPP because the capability of the steel liner containment to resist subatmospheric pressures is poor. An external spray system was then designed to remove the heat from the containment in a severe accident when other means of decay heat removal from the containment are not operable. Due to the ice condenser containment, the time delay from the onset of the accident to the start of the external spray system is long (18–36 hours). Thus the required heat removal capacity is also low, only 3 MW (fraction of decay power is still absorbed by thick concrete walls). The system is started manually when the containment pressure reaches the design pressure 0.17 MPa. Autonomous operation of the system independently from plant emergency diesels is ensured with dedicated local diesel generators. The active parts of the system are independent from all other containment decay heat removal systems. The containment external spray system was implemented in 1990 and 1991.

The SAM strategy implementation included also a new, dedicated, limited scope instrumentation and control system for the SAM systems, a dedicated AC-power system and a separate SAM control room which is common to both units and to be used in case the main control room has to be abandoned during a severe accident. These were implemented mainly in year 2000 for Loviisa unit 1 and in 2002 for unit 2.

In addition to the hardware modifications, severe accidents guidance for the operating personnel has been implemented. It consists of SAM procedures for the operators and of a so-called Severe Accident Handbook for the Technical Support Team. The SAM procedures are started after a prolonged uncover of the reactor core indicated by highly superheated core exit temperatures. The procedures are symptom oriented and their main objective is the protection of containment integrity through ensuring the top level severe accident safety functions.

Modernisation and power uprating of Loviisa NPP in 1994–1997

The key aspects in the project for the modernisation and power uprating of the reactor units of the Loviisa NPP were to verify the plant safety, to improve production capacity and to give a good basis for the extension of the plant's lifetime to 50 years, which corresponds to the additional 20 years of operation applied for both units of the Loviisa NPP in 2006.

In the first phase, before starting the project, a feasibility study for uprating of the reactor thermal power was carried out. The main result was in short that no technical or licensing issues could be found which would prevent the raising of the reactor thermal output up to 1500 MW from the original level of 1375 MW. The feasibility study gave also a good picture of the necessary plant modifications. It focused on the following tasks: the optimisation of the power level and definition of the new parameters of the main process, reactor core and fuel studies, including RPV irradiation embrittlement, safety analyses and licensing, the main components and systems, and project planning and risk assessment.

The reactor thermal power uprating from 1375 MW to 1500 MW was planned on the basis of optimising the need for major plant modifications. In the primary side and the sea water cooling system, the mass flow rates were not affected, but the temperature difference has been increased in proportion to the power upgrading. In the turbine side, the live steam and the feedwater flow rate were increased by about 10%; the live steam pressure was not changed.

The reactor fuel loading was considered on the basis of the previous limits set for the maximum fuel linear power and fuel burn-up. The increase in the reactor thermal output was carried out by optimising the power distribution in the core and the power of any single fuel bundle was not increased above the maximum level before power upgrading. In parallel with this work, more advanced options related to the mixing rate of the cooling water in the fuel subchannels and the increasing of fuel enrichment were investigated. The dummy elements installed on the periphery of the core at the Loviisa units 1 and 2 were preserved to minimise irradiation embrittlement of the reactor pressure vessel.

The VVER 440 design margins in the primary side are rather large and the hardware modifications needed there were quite limited. Replacement of the pressuriser safety valves was indicated already during the feasibility study as a necessary measure because of the power upgrading. Most of the other substantial measures in the primary side were carried out on the basis of the continuing effort to maintain and raise the safety level of the plant, and they were not directly included in the power upgrading.

It was necessary to carry out more extensive measures in the turbine plant and to the electrical components. Steam turbines were modified to a higher steam flow rate. Because of these measures, also the efficiency and operation reliability have improved. Certain modifications were carried out in the electrical generators and the main transformers to ensure reliability in continuous operation with the upgraded power output.

The implementation of the modernisation project was carried out in co-operation between Loviisa NPP and the Fortum Group's own nuclear engineering company. In addition, many other organisations such as the Technical Research Centre of Finland (VTT) participated in the work. The last step in the process to uprate the reactor thermal power was the long-term trial run to verify the main process parameters as well as plant operation in both steady state and transient situations. Normal operation and in a limited way also transient behaviour of the plant were studied in the trial tests. Studies were made by means of the plant simulator and the results of transient analyses were used in the planning of the trial test programme. Due to the small number of plant modifications required for the power increase of the Loviisa plant, a simple trial test programme supported by the simulator studies was considered as appropriate and acceptable.

The first trial run at 103% reactor power could be started in January 1997. Test runs continued step by step during the year, and the last transient test at final reactor power 109% was completed successfully in December 1997. Transient tests defined in the test programme were performed with a reactor thermal power of 105% and 109%. The test results corresponded very well with all analyses and calculations. All the acceptance criteria for the tests were fulfilled. Measures to improve the efficiency of the steam turbines continued in the annual maintenance outages until the year 2002.

STUK was closely involved at every stage of the project, from the early planning of the concept to the evaluation of the results from the test runs. STUK examined all the modification plans that might be expected to have an impact on plant safety. Individual permits were granted stage by stage, based on the successful implementation of previous work.

The renewal of the operating licence for the increased reactor power was carried out according to the nuclear safety legislation. First the Ministry of Employment and the Economy (former Ministry of Trade and Industry) gave a permission to make plant modifications and test runs with upgraded reactor power under the existing operating licence and under the control of STUK. Then the assessment of the environmental impact (EIA-procedure) of the project was carried out. STUK approved the Final Safety Analyses Report (FSAR), the safety-related plant modifications, and the test programmes and the results. Finally the Government granted the renewed operating licence in April 1998. The licence was awarded to 1500 MW nominal reactor thermal power until the end of the year 2007.

The revision of emergency operating procedures (2000–2005)

The emergency operating procedures of Loviisa nuclear power plant were revised in the so called HOKE project, launched in 2000. The project encompassed the drawing up of diagnosis procedures for transients and emergencies arising from primary and secondary leaks, procedures for operators and the safety engineer as well as action sheets for onsite measures.

In accordance with the new procedures, nuclear power plant operators follow their own separate procedures and initiate the necessary actions in their fields of responsibility in the event of an emergency or a transient. The shift manager co-ordinates these actions and reviews the main actions and parameters using his own procedures. The safety engineer in parallel with the operators independently oversees safety functions using separate procedures to ensure that plant behaviour is as planned.

The revised procedures consist of guidelines and instructions presented as flow charts. The guidelines define strategy and give grounds for operator actions during emergencies and transients. It serves as a basis for actual control room procedures containing operator procedures. The guidelines are used for training purposes as well.

The validation and verification of the procedures and their background material ascertains authenticity of the procedures i.a. by comparison with the plant and by simulator tests. Verification authenticates i.a. correlation and functioning of the new procedures with other plant procedures. The project included training given to the control room personnel of the Loviisa plant in the use of the new procedures. Due to the revision's significance STUK required that shift supervisors and operators working in the control room have given shift-specific proof of workmanship prior to the introduction into use of the revised procedures.

In December 2005, STUK authorised the introduction into service of the revised emergency operating procedures.

Examples of latest plant modifications at the Loviisa NPP (2012–2016)

Modernisation of the primary system pressure management

Modernisation of the pressuriser system at the Loviisa unit 1 was carried out in 2012. The modification was done because of restrictions to use the emergency spray of the pressuriser in a pressure higher than 12 bars. At the same time, the valves of the pressuriser spray system were replaced and the spray lines coming from the high pressure emergency core cooling system were moved to the low pressure core cooling system. In addition, the capacity of the relief train of the pressuriser was increased. The modification also involved I&C, electrical and piping changes. The same modification was implemented at the Loviisa unit 2 during the 2014 annual maintenance outage.

Construction of new off-site diesel power plant

Construction of a new diesel powered off-site generator plant was carried out in 2011-2012. The power of the plant is 10 MW and it can be used as a peak power plant for electrical grid or as a power supply for the nuclear plants. It is not safety classified, but it can supply power as a last resort to the safety and non-safety classified systems of the nuclear plants. It's also used as a back up diesel for the systems used in the loss of ultimate heat sink as an air-cooled diesel which is located on the highest place of the site.

Steam generator safety valves

Each of the Loviisa NPP steam generators has two secondary side safety valves (with staggered set pressures). These have been qualified for steam flow only. The safety valves with the lower set pressure (six valves) were replaced at Loviisa 2 in 2014. The new valves are qualified for steam, water and a mixture of the two. The plan is to implement a similar modification at Loviisa 1 during the annual outage in 2016.

Steam line radiation monitors

New steam line radiation monitors were installed in 2015 to the Loviisa unit 2. Each of the Loviisa NPP secondary circuit main steam lines has one radiation monitor to detect primary-to-secondary leakages (PRISE). The old system has had no longer technical support and modernisation had to be done to ensure the operation and to guarantee availability of spare parts to the end of the operating licence. Detection of the PRISE will also be improved with the higher accuracy of the new monitors. The plan is to implement the same modification at Loviisa 1 in 2016.

Construction and commissioning of a liquid waste solidification facility

A solidification facility for liquid radioactive waste has been constructed on the Loviisa plant site. The solidification facility processes the evaporation residues generated at the power plant and the radioactive ion exchange resins from the purification filters. The power company initiated the commissioning phase of the solidification facility implementation project during 2006 by carrying out system and plant level tests using inactive substances. Plant level tests continued in 2008 using radioactive evaporation residues and in 2009 with radioactive ion exchange resins. Based on the results of the commissioning tests of the plant some system modifications were designed and implemented during 2011-2012. The commissioning continued in 2013 with operating personnel training activities and updating the plant design documentation and procedures. The concrete containers used in solidification at the end of 2013 were found defect, and thus the trial runs were discontinued to study their cause. STUK deemed the conclusions made based on reports correct. The commissioning continued in 2014-2015 with the system and plant tests. The commissioning program included also e.g. the operating personnel training and updating the plant design documentation and procedures. The system and plant tests were finalized and the results of the tests approved by STUK in 2015. Loviisa NPP sent the application for routine operation to STUK in 2015. STUK performed the regulatory commissioning inspections and review of the application at the same year. STUK's approval for starting the solidification plant routine operation was issued in early 2016.

Examples of latest incidents at the Loviisa NPP (2013–2015)

Faulty connections in Loviisa unit 1 I&C system

During the in-service testing of the I&C system at Loviisa 1 on 10 January 2013, it was noted that two of the boron feed pumps would not have operated properly in the event of an accident. The pumps would not have started automatically if the reactor had cooled down too quickly.

Automatic starting of the pumps had been prevented when the plant unit was shut down for repairs on 25 September 2012. At that time, representatives of the power plant noted that preventing automatic starting of the pumps was not necessary during the repair outage in question. They failed to remove this task from the plant's shutdown instruction, however, which means that automatic starting of the pumps was prevented by bypassing them. Such bypassing is usually recorded in the plant's work management system so that all temporary connections can be reliably removed prior to the subsequent startup of the plant unit. Using forms that are manually filled out is also allowed in some cases. The form filled out in connection with this bypassing incident could not be traced when investigating the event. It is likely that the form was not properly archived in a folder in the control room. Thus, no information about the bypassing was available during the startup of the plant unit and the bypass connection was not removed.

The reactor of a nuclear power plant is shut down with the help of the control rods in the event of an accident. The detected fault would not have prevented the shutting down of the reactor. Boron is supplied to the reactor under specific accident conditions to verify that the reactor has shut down. The detected fault would have prevented automatic starting of the pumps, but they could still have been started manually. Furthermore, the plant has other safety systems that can be used to supply boron to the reactor. Thus, the event did not pose any risk to the plant, people or the environment.

The representatives of the power plant eliminated the fault immediately after its detection. They also inspected other similar connections at both plant units and found no other non-conformances. The power plant has specified its procedures to prevent reoccurrence of the event. In the future, all such entries will be made in a new work management system that has been commissioned in 2015.

There was a similar event at Loviisa 2 in 2008: at that time, I&C system connections had not been restored, either. An extensive and thorough investigation of the event and its underlying causes was conducted. It was observed that the simulation practices have not been properly specified and are not consistent. The power plant implemented corrective measures after the event to prevent its reoccurrence. The underlying causes of the new event are not the same, and thus it cannot be deemed to have been caused by improper corrective measures of the previous event.

On the INES scale, the event 2013 is rated at Level 1 (basic rating, no additional factors).

Ice condenser system was not properly returned in operation

Maintenance outage took place at Loviisa 2 in October 2013. Under hatches of the ice condenser system in containment building were shut with wedges to avoid unnecessary operation. This is normal procedure during the outages. Wedges should be removed before starting up the plant. This was not done.

Deviation was noted two days after the plant start-up. Wedges were removed immediately. Procedures were updated as a corrective action. The event was rated as INES Level 1 (basic rating, no additional factors).

Relay faults in emergency diesel generators at Loviisa power plant

Two of the emergency diesel generators of Loviisa 2 did not operate as planned during testing in December 2013. The generators started operating normally during retesting, however. The underlying cause of both unsuccessful testings was a temporary malfunction of a relay (electromechanical switch). The relays in all diesel generators at the Loviisa power plant were replaced.

Both Loviisa plant units have four diesel generators that start when necessary to supply power to the plant's safety systems. Operability of the diesel generators is verified by testing them every four weeks. The relay malfunction was such that it would have delayed the automatic emergency startup of the diesel generator and, if escalated, could have prevented automatic emergency start-up of the diesel generator when needed. In addition to the diesel generators, the plant includes other electricity supply systems that can be used to maintain the safety functions if normal power supply is lost. The event was rated as INES Level 1 (basic rating INES 0, common cause failures as an additional factor).

Periodic safety reviews at the Loviisa NPP

During the years 1996–1998 the overall safety review of the Loviisa plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Employment and the Economy (former Ministry of Trade and Industry) in March 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The relicensing of the operation of the plant took place in 2005–2007. The operating licence application was addressed to the Government and was handled by the Ministry of Employment and the Economy. Fortum filed the application to the Ministry of Employment and the Economy in November 2006. Legislative and regulative requirements for the application of the operating licence are described in the Nuclear Energy Decree (161/1988) Sections 33, 34, 36 and in the Guide YVL 1.1 (currently in YVL A.1).

The Loviisa plant was reaching its original design age in 2007–2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (PRA).

Based on the application, STUK carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Employment and the Economy with its statement on the safety of the plant. The Finnish Government granted in July 2007 to Fortum new licences for unit 1 until the end of 2027 and for unit 2 until the end of 2030. The length of the operating licences corresponds to the current goal for the plant's lifetime, which is 50 years. Two periodic safety reviews (by the end of the year 2015 and 2023) carried out by the licensee was set as a licence condition according the Nuclear Energy Act (11.12.1987/990) §24.

The first periodic safety review in the current licence period was carried out 2013-2016, where the evaluation of the documents was performed by STUK 2015–2016. Fortum sent to STUK for approval the periodic safety review related documents 2014–2015. These documents include e.g. summary of the most significant changes to the licensing documents, report on fulfilment of the requirements given in Government Regulation and Nuclear Regulatory Guides (YVL), summary of the renewed safety analyses and conclusions drawn from these results, descriptions of safety and management culture and how operating experience feedback and R&D results are utilized to improve safety. Based on the assessment, STUK considered that the Loviisa Nuclear Power Plant meets the set safety requirements for operational nuclear power plants. Key issues in assessment were ageing management, organisational issues and deterministic and probabilistic safety analyses and the status of safety improvements. The implementation of the revised regulatory YVL Guide requirements was carried out during 2015 as a separate project. Hence, there was no need in PSR to go through all the modified regulatory requirements in detail as the decisions of implementation were just referenced in the PSR.

The design basis has been laid down during the 1970s. However, substantial modernisations have been carried out at the Loviisa NPP since its commissioning to improve safety. Risk factors have been systematically identified and eliminated using operating experience, research and development and probabilistic risk analysis. Fortum has also many ongoing projects for enhancing safety and reducing the accident risk. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act. The recent risk reducing modifications are connected to the Fukushima Dai-ichi accident: including improvements to the plant residual heat removal, protections against the flooding and 72 hours operability for safety systems. Others are for example the improvements aiming at reducing the risk arising from heavy load lifting with the structural reliability of the polar crane and developing the procedures relating to lifting. The project was established already after the operating licence renewal in 2007, but it has been delayed. The project is now at the planning phase – commissioning would be just before 2017 outages. At shutdown the most significant initiating events are drop of heavy loads.

As a part of the ageing management the safety of the reactor was assessed in connection with the plant's periodic safety review. Fortum stated during the last operating licence renewal process that the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The primary circuits of both Loviisa plant units are still in good condition. The validity of the operating licence of the reactor pressure vessel of the Loviisa unit 2 was extended in 2010 until the end of 2030, i.e., to the end of the plant unit's current operating licence. Similarly, STUK assessed the renewal of the reactor pressure vessel operating licence for the Loviisa unit 1 in 2012 and the validity of the operating licence of the reactor pressure vessel of the Loviisa unit 1 was extended until the end of the plant unit's current operating licence. STUK has had some concerns about the embrittlement margins of LO2 reactor pressure vessel before the expected end of life in 2030. Related to PSR 2015 assessment Fortum will send at the end 2016 to STUK for information the documents concerning the actions to increase the embrittlement margins of Loviisa unit 2 reactor pressure vessel in the future.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the prerequisites for safe operation of Loviisa NPP have been met.

Planned and ongoing activities to improve safety at the Loviisa NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Loviisa nuclear power plants since its commissioning and there exists no urgent need to upgrade the safety of this plant in the context of the Convention.

For continued safe operation, plant improvement projects are still necessary. The largest ongoing investment is the complete renewal of the plant I&C system. Also some improvement measures will be done based on the lessons learnt from the TEPCO Fukushima Dai-ichi accident.

Safety assessments and improvements based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Based on the results of assessments conducted after the TEPCO Fukushima Dai-ichi accident on 11 March 2011, it is concluded that no such hazards or deficiencies have been found as would require immediate actions at the Loviisa NPP. However, the areas where safety can be further enhanced have been identified and there are plans on how to address these areas. Main changes are aimed at decreasing the dependency on plant's normal electricity supply and distribution systems as well as on the sea water cooled systems for residual heat removal from the reactor, containment and spent fuel pools. There are also ongoing activities to improve protection against external flooding.

Natural hazards

The renewed regulations and YVL Guides published in 2013 include updated requirements on provisions for external hazards, including, e.g., earthquakes, high sea water level, harsh weather conditions and hazards related to transport and industrial activities. For the operating units the fulfilment of the new requirements was evaluated separately and new Guides implemented 2015.

According to the PRA results, the risk caused to the operating units by external events is a relatively small fraction of the total risk. However, there are areas where possibilities for further risk reduction exist, for example improving the protection against high seawater level.

Safety margins were assessed by the licensee and reviewed by STUK. Based on the results, STUK required further clarifications on the following main points:

- seismic resistance of spent fuel pools including situations with water temperature exceeding the design bases;
- seismic resistance of fire fighting systems; and
- plans for improving flooding margin for the Loviisa plant by end of 2013.

Seawater level variations in the Baltic Sea are moderate. Due to geological conditions and the shallow water strong tsunami type phenomena are not considered possible in the Baltic Sea. At the Loviisa NPP, the observed maximum seawater level is +1.77 m above the mean sea level (N60 reference system). The design basis of the Loviisa NPP is about +3 m during power operation and about +2.1 m during refuelling shutdown. Based of extreme value distribution fitting, the annual probability of exceeding the level +3 m is about 4·10-7. The refuelling shutdowns are scheduled for summer and early autumn when the seawater level variations are small. The design basis of the Loviisa NPP is considered sufficient in the short term. Although the estimated annual probability of exceeding the design value is very small, the consequences of flooding of the basement of the Loviisa NPP would be severe, as all cooling systems might be lost. Therefore, to ensure safe operation in the long term, the possibilities for decreasing the risk of seawater flooding had to be examined.

Loviisa NPP has improved in 2012 flood protection during certain annual shutdown states with open hatches in the condenser cooling seawater system; the design water level was increased from +2.1 m to +2.45 m and further increase to +2.95 m is considered.

The licensee was required to submit plans to improve protection against external flooding by the end of 2013. The licensee has been examining site area protection with leeves and protected volume approach and also their combination to improve of the flooding resistance of the Loviisa plant. The work has turned out to be more challenging than originally estimated. The utility has estimated the effects of high sea level to the plant behaviour. The decisions made are based on updated flooding hazard estimates contracted from the Finnish Meteorological Institute. The utility submitted a detailed plan of improved flood protection in 2015. The plan is based on strengthening of flood protection of the buildings most important to safety (the auxiliary emergency feedwater and auxiliary residual heat removal buildings). The plan will be implemented by 2018 (protection during annual maintenance shutdown already partly implemented).

Design issues

At the Loviisa NPP, the systems needed for residual heat removal from the reactor, containment and fuel pools require external power and the ultimate heat sink is the sea. A reliable supply of electrical power to the systems providing for basic safety functions at the Loviisa NPP is ensured by the Defence-in-Depth concept. As a result of multiple and diversified electrical power sources at different levels, the probability of loss of all electrical supply systems is considered very low. However, as a result of the studies made after the TEPCO Fukushima Dai-ichi accident, further changes were implemented. Main changes implemented are decreasing the dependency on plant's normal electricity supply and distribution systems as well as on the sea water cooled systems for residual heat removal from the reactor, containment and spent fuel pools.

At the Loviisa NPP, the availability of an alternate heat sink depends on the plant state and feed water availability. If primary circuit can be pressurised (i.e. reactor vessel head is in place), atmosphere can be used as an alternate heat sink as long as there is enough water available for dumping steam into atmosphere from the secondary circuit. There is a separated diesel driven auxiliary emergency feed water system with two pumps which feed water to the steam generators in case of loss of AC power. It is also possible to transfer heat to spent fuel cooling system and hence to intermediate cooling system, giving time for restoring ultimate heat sink.

In addition, the licensee has evaluated measures needed to secure the availability of the auxiliary emergency feedwater system in the case of loss of electrical power, water supply for the diesel driven auxiliary emergency feed water pumps, and electricity supply for instrumentation needed in accidents. The modifications were realised during 2012 and 2013, with the exception of improving the instrumentation by 2016.

The licensee at the Loviisa NPP has completed also the modification to ensure the long-term decay heat removal in case of loss of seawater by implementing an alternative ultimate heat sink. The modification consists of two air-cooled cooling units per plant unit powered by an air-cooled diesel-generator. The other cooling unit would remove decay heat from the reactor and the other one ensures the decay heat removal from the spent fuel pool inside the containment and from the separate spent fuel interim storage pools. The cooling unit is connected to the intermediate cooling circuit, and it backs up the seawater cooled heat exchangers. The cooling units for the reactors are dimensioned to be able to remove the decay heat after 72 h, and until then the heat removal can be carried out by steam dumping into the atmosphere from the steam generator secondary side. The modifications create a possibility to closed-loop operation also in case of loss of ultimate heat sink. The cooling units were installed in 2014–2015. The commissioning of the system was performed during the outages in 2015.

The experiences from the Fukushima Dai-ichi accident were taken into consideration in the renewal of the Finnish Regulatory Guides (YVL Guides). For example there is a new requirement for arrangements that enable the decay heat removal from the reactor out of the containment and arrangements to ensure sufficient cooling of the fuel in spent fuel storages. In spite that there are fixed severe accident management systems installed at Loviisa operating units, STUK required the licensee to investigate needs and possibilities to use mobile power supply and mobile pumps in accidents. Loviisa NPP has studied the possibilities to utilise mobile power supply and mobile pumps to support safety functions.

At the Loviisa NPP, the current AC power supply systems include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators per unit, a diverse diesel power plant and a dedicated connection to a nearby hydropower plant, two SAM diesel generators, and the possibility to supply electricity from the neighbouring NPP unit. No modifications are planned to the current design concerning AC power supply.

At the Loviisa NPP, there is enough diesel fuel in the emergency diesel generator (EDG) tanks for at least 72 h of operation, and with realistic loads in case of an accident, the duration is evaluated to be twice as long. Currently the emergency diesel generators (EDGs) at the Loviisa NPPs use conventional diesel fuel, which is available only in limited scope. An investigation of replacing conventional diesel with widely available biodiesel was performed by the licensee and the diesel engine manufacturer. Based on the investigations biodiesel is allowed to use in exceptional circumstances. In 2012, the licensee of the Loviisa NPP purchased a container to transfer diesel fuel at the site. The purpose of this container was to make fuel transfer between the tanks on-site easier and faster. In addition, to improve the delivery of the fuel and to ensure the 72 h operation, the licensee has built during 2015-2016 a new fuel line from the new air-cooled diesel power plant fuel storage tank to the emergency diesel customers (emergency diesel fuel storage tank, diesel driven auxiliary emergency feed water pumps daily tank) and made a new extra storage tank for SAM diesels.

At the Loviisa NPP, the depletion times of some DC batteries are considered to be rather short. The duration of DC power supply has been considered to be enhanced. Especially the reactor coolant pump seal water system functionality must be ensured. The licensee submitted a plan regarding these improvements to STUK at the end of 2012. There is also an ongoing automation renewal project in which the depletion time of the batteries will be lengthened substantially. It is possible to charge the batteries using the AC power sources. The licensee installed two new separate underground cables from the new diesel power plant to the 6.3 kV diesel busbar in 2012–2013, which will furthermore ensure and enhance battery charging possibilities.

Regarding spent fuel pools, the approach in Finland is to “practically eliminate” the possibility of fuel damage. The licensee have evaluated alternative means of decay heat removal from fuel pools in case of loss of existing systems, and to supply coolant to fuel pools (including potential need for new instrumentation). There has been done further analysis before starting the detailed design work. The more detailed analysis was performed in 2013. STUK has approved in 2015 the design plans concerning the installation of diverse water supply to the spent fuel pools. The plant modifications will be completed by 2017. Furthermore, the licensee will improve Emergency Operating Procedures (EOPs) and SAM Guidelines to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. Licensee has also studied the seismic resistance of the spent fuel storage pools as well as the influence of pool water boiling to the pool structures.

Severe accident management

A comprehensive severe accident management (SAM) strategy has been developed and implemented at Loviisa 1&2 plant units during 1990's after the accidents in TMI and Chernobyl (see above). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary. However, the licensee is expected to consider spent fuel pools in the SAM procedures as well as any implications on them possibly arising from simultaneous multi unit accidents. In addition, there are many actions related to the update of the emergency plans.

At the Loviisa NPP, the design basis for all SAM safety functions is that the actions can be done, when the other supplies have been lost, with dedicated independent SAM electrical systems and dedicated independent SAM I&C from SAM control room or main control room. The SAM strategies and their implementation at the Loviisa NPP follow the requirements set in the Government Decree 733/2008 (in force at the time) and the YVL Guides. The approach and the plant modifications have been approved by STUK. Since the systems for management and mitigation of severe accidents have already been implemented at Loviisa operating units and the corresponding procedures are in place, no further measures for this purpose are foreseen at the moment. However, the soundness and adequacy of the accident management schemes is being constantly assessed against the latest knowledge and experience obtained from different international sources.

Loviisa NPP is investigating possibilities to implement additional injection points for mobile pumps to provide more flexibility to the water supply of the containment external spray. These connections could provide capability to inject enough water for both units with one pump. The different possibilities were analysed in more detail in 2013. Currently, the containment external spraying for heat removal from the containment can be carried out by fire trucks, individually for the both units, in case of failure of the fixed pumps. Investment decision for mobile power supply and mobile pumps will be made jointly with the decision of comprehensive solution for flooding protection by 2018.

At the Loviisa NPP, immediate SAM measures are carried out within the Emergency Operation Procedures (EOP). After carrying out immediate actions successfully, the operators concentrate on monitoring the SAM safety functions with SAM procedures. The SAM procedures focus on monitoring the leak tightness of the containment barrier, and on the long-term issues. At the Loviisa NPP, licensee will improve EOPs and SAM procedures to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. New EOPs for shutdown states, which cover the immediate recovery of SAM systems, have been developed in 2012.

I&C renewal project at Loviisa NPP

A continuation project for the Loviisa NPP I&C renewal, ELSA, was launched in June 2014. The ELSA project will modernise a large part of the I&C system of the plant, switching it to a digital equipment platform. The delivery contract has been made with the Rolls-Royce. The plan is to install the first stage of the renewal in 2016. The second and the third stage of the ELSA project including safety classified parts are intended to be implemented during the annual outages of 2017 and 2018 at the both reactor units.

Preliminary planning of the renewal project started several years ago and in the beginning of 2005 the licensee signed the delivery contract with the consortium of Framatome and Siemens. New buildings at the plant site have been constructed and will accommodate the main equipment of the safety and operational I&C. The first phase of this LARA project included e.g. the renewal of the reactor preventive protection I&C and was implemented in the outage 2008 at Loviisa unit 1 and at Loviisa unit 2 in the outage 2009. The change of the supplier was made before the second phase of the LARA project including the renewal of the reactor protection system.

The scope of the ELSA renewal is not as extensive as it was at the LARA project. The assessment concerning the scope change impacts for safety relevant functions and other modernisation projects was made as a part of the periodic safety review in 2015.

ANNEX 3 Olkiluoto NPP units 1 and 2 under operation

The Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oyj (TVO). The plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The present nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018. According to the conditions of the licences, the licensee carried out a periodic safety review and submitted it to the regulator at the end of 2008.

Most significant plant modifications at the Olkiluoto NPP during the plant lifetime

Several plant changes have been carried out during Olkiluoto NPP plant lifetime. The most important projects since the plant commissioning have been two reactor upratings, severe accident management programme, modifications based on the development of the PRA models, construction of training simulator, interim storage for spent fuel and repository for operational waste, and investigation programme for disposal of spent fuel. The first power uprating project was carried out in 1983–1984. Thermal power was uprated from 2000 MW to 2160 MW (8%). The plant modifications included for example a new relief valve that was installed in the reactor primary system, changes in the reactor protection system, and increase of cooling capacity of some heat exchangers.

Severe Accident Management implementation at the Olkiluoto NPP

Several new research programmes were launched in the beginning of 1980's, whose objective was both to clarify the character and magnitude of loads arising from a severe accident and to find means for controlling the loads on the containment. The main provisions for severe accident management were installed at the Olkiluoto units 1 and 2 during the SAM project which was completed in 1989. The measures implemented were

- containment overpressure protection
- containment filtered venting
- lower drywell flooding from wetwell
- containment penetration shielding in lower drywell
- containment water filling from external source
- containment instrumentation for severe accident control
- Emergency Operating Procedures for severe accidents.

The means for managing severe accidents had to be adjusted to the existing design, and so an optimal implementation of all chosen solutions was not possible. Subsequent development of the accident management procedures and additional minor plant modifications at Olkiluoto plant have taken place during the years after that when new aspects on the issue have emerged.

To secure depressurisation of the reactor primary system in severe accident situations and to prevent a new pressurisation of the reactor, two valves of the relief system were modified. It is now possible to keep the valves open with the help of nitrogen supply or water supply from outside the containment.

One of the most significant deficiencies at the Olkiluoto plant containments, from the standpoint of controlling severe accidents, has been the small size of the containment, which may cause the containment to pressurise due to the hydrogen and steam generation during an accident (common feature for BWRs). Another deficiency is the location of the reactor pressure vessel inside the containment, which is such that the core melt erupting from the pressure vessel may expose the structures and penetrations which ensure the tightness of the containment, to pressure loads and thermal stresses. To eliminate these deficiencies, the containment was e.g. provided with a filtered venting system. Gases that pressurise the containment can be removed through a filter designed for the purpose, if the pressure inside the containment threatens to increase too much. The part of the containment underneath the reactor pressure vessel can be flooded with water in order to protect the containment bottom and penetrations from the thermal effect of core melt. Some penetrations of the containment have been protected from the direct effect of core melt also by structural means. To ensure the cooling of reactor debris, the plant units are also provided with a water filling system, by the means of which the water level inside the containment can be raised all the way to the same level with the upper edge of the reactor core.

The cooling of reactor core melt and the protection of containment penetrations requires that the lower dry well of the containment is flooded at such an early stage of the accident that if the pressure vessel melts through, the erupting core melt falls into a deep water pool. When the core melt falls into the water a so-called steam explosion, which causes a strong and quickly propagating pressure wave in the water pool, may occur. A lot of research has been done on steam explosions. The results show that the core melt discharged through the pressure vessel cools down as it travels through the water pool and cannot create a steam explosion. However, the structures of the lower equipment hatch have been enforced to decrease the risk for loss of containment integrity due to loads caused by limited steam explosions.

Research results have demonstrated that in unfavourable conditions iodine may form organic compounds that are not easily absorbed in the containment or in the filter. Such conditions may occur at the Olkiluoto plant, if the water inside the containment is acidified due to chemicals released during the accident. Organic iodine may also be generated in the primary circuit, if iodine reacts with the hydrocarbons that are released, when the boron carbide contained in the control rods becomes oxidised during the core damage. To improve the possibilities for retaining organic iodine in the filtered venting system, chemicals have been added to the water in the scrubber tank of the system. To minimise the formation of organic iodine, it is also possible to control the pH of the containment water volume by a specific system. The function of the system is based on addition of NaOH to the fire fighting water reservoir which is used for filling of the containment in post-accident conditions. The lower drywell will be flooded from the wetwell prior to the NaOH supply and the lower drywell water pool pH will be kept above 7.

Protection against fires at the Olkiluoto NPP

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the existing Olkiluoto plant. Fire safety has been improved in different areas of the fire protection at the existing Olkiluoto plant after commissioning. Although the loss of external electrical supply has been taken into account in the plant design, both units were provided with e.g. second start-up transformer, based on the experience gained from the fire of the electric supply unit in 1991, to improve the independency of plant's external grid connections. Furthermore, the main transformers, in-house transformers and start-up transformers are protected with a sprinkler extinguishing system, which reduces essentially the risks arising from transformer fires. The use of halon is forbidden in Finland since the year 1999 with the exception of some special items. Due to this the halon extinguishing systems at the existing Olkiluoto plant were replaced with other extinguishing systems by the year 2000. Fire risks have been assessed in a probabilistic risk assessment that concentrates on fire issues. Based on this the fire protection of cables, that are crucial to safety, have been improved by renewing fire detectors and improving fire extinguishing systems in cable tunnels. On the basis of the probabilistic risk assessment these improvements reduce the risks arising from fires considerably.

Modernisation and power uprating of Olkiluoto NPP in 1994–1998

The main goals of the modernisation project at the Olkiluoto NPP were the reviewing of safety features and enhancing safety, when feasible, improving the production related performance, identifying factors limiting the plant lifetime and eliminating them, when feasible, and enhancing the expertise of the own staff and improving productivity. In order to achieve the safety goal, the existing plant design was reviewed and compared by the TVO to the present and foreseeable safety requirements. Compliance with the European Utility Requirements (EUR) was also reviewed. The feasibility of fulfilling new requirements set for the new nuclear power plants was considered case by case. The living PRA model of the plant was utilised in this context.

The most important safety related modifications included in the modernisation programme are listed below:

- Reactor pressure relief system was diversified by installing two additional relief valves.
- ATWS behaviour was improved by modifying some trip signals and making boron injection automatic and more effective.
- Additional severe accident mitigation measures were implemented.
- Earthquake resistance of the plant was checked and related modifications were made.
- Partial scram function was strengthened.
- Generator breaker was replaced with a new one, which is able to break also short circuit current.
- Protection against frazil ice at the seawater intake was improved.
- Protection against snowstorms at the air intake of the emergency diesels was improved.

Modification of the safety features in connection with the modernisation programme as a whole reduced the severe core damage frequency estimate by a factor of three.

The radiation exposure of the population was reduced in accordance with the ALARA principle. Liquid releases were reduced by a factor of ten by improving the liquid waste handling systems. Also occupational doses were reduced. In practice, this meant minimising the cobalt content in the primary circuit. Renewal of steam dryers reduced the occupational doses remarkably, because the moisture of the steam was reduced.

The development of the BWR technology, margins revealed by operational experience, and plant modifications due to other reasons made also power uprating possible. Thermal power was uprated from 2160 MW to 2500 MW (15.7%). The most important changes were made in fuel technology. The operation was changed from with 8×8 bundles to 10×10 bundles. The new bundles have 40 percent lower average linear heat rating than the old ones. Some additional design changes implemented due to the uprating were the increasing of inertia of the main circulation pumps electrically, steam separators replacement, high-pressure turbine and feed water system modifications, decay heat removal system capacity increasement, and generator and main transformers replacements. The low pressure turbines were also replaced and in that way about 30 MW additional production capacity in each unit was achieved.

The modernisation programme of the Olkiluoto plant units 1 and 2 was started in 1994 and completed in 1998. The installations were performed during the refuelling outages of the years 1996–1998. Some later installations were realised during outages in 1999. In spite of large modifications the refuelling outage times were reasonable, between 15 and 20 days. The test programme was quite the same as in the case of a new plant.

Test operations were conducted in stages at different power levels under STUK's supervision and within the frames permitted by STUK. Before uprating the reactor power to a higher power level STUK conducted a safety review concerning the test operation for the power level in question and asked the Nuclear Safety Advisory Committee for a statement concerning the review before granting the test operating licence.

Test operation programmes that included the entire plant units and were drawn up by TVO, were based on the original commissioning programmes that were run through during the start-up phase and that were modified taking into account the test requirements caused by the modernised systems. For the long-term test operation of the plant units the thermal power of both reactor units was uprated step by step from the nominal power of 2160 MW to 2500 MW.

The most significant plant transient tests of the test operation were the load rejection test, turbine trip test and the by-pass test of the high-pressure preheaters. STUK considered it necessary to continue the test operation at the 2500 MW power level for about two months before issuing a statement in favour of continuing the operation of the plant units at the 2500 MW power level.

Licensing steps related to the modernisation programme included an uprated Safety Analysis Report (PSAR, for example) and an uprated Probabilistic Safety Assessment (level 1 PSA), which were reviewed and approved by STUK. Design modifications and test runs were accepted by STUK before implementation. The Final Safety Analysis Report (FSAR) and the related Topical Reports were rewritten. It meant also that almost all transient and accident analyses were redone taking into account the uprated power level and modified plant design. The FSAR and Topical Reports were submitted to STUK at the end of 1996. An operating licence renewal application, covering design modifications and the power uprating, was submitted to the Government at the end of 1996. The licence was granted in 1998. The power uprating was reviewed also according to the Environmental Impact Legislation.

Modernisation and power uprating project contained several safety, ageing and efficiency remedies. Influences of modifications have been positive in most cases. A negative finding has been a slight increase of steam moisture. To improve this the steam dryers in both units were replaced in outages 2005–2007. Another slightly negative finding was increase of condensate clean up temperature, which decreased the life cycle of clean up resins. To avoid this problem the location of condensate clean up system was changed in the process. In this context the first LP-preheaters were replaced and modernised as well.

The modernisation of turbine plant was continued with replacement of steam reheater moisture separators (MSR). They were replaced with modern two stage MSR's. This replacement required modernisation of HP-turbine as well. These replacements were performed in annual outages 2005 and 2006. In the same outages the I&C system of the turbine plant process was be replaced with a modern digital one.

Turbine plant process automation system renewal (2004–2006)

A new computerised turbine plant automation system was installed in the Olkiluoto unit 2 in 2005 annual maintenance outage (equivalent modification was performed at Olkiluoto unit 1 in 2006). One reason to switch from analogue to programmable technology was the obsolescence the old system. In addition, the modifications made in the turbine plant process in 2005, and in 2006, required some additional modifications to the automation system. The new system improves information management and control of the turbine plant as well as facilitates component maintenance. Another system renewal objective has been to increase reliability and reduce by adding redundancy susceptibility to malfunctions.

The new automation system has been implemented by programmable technology. This allows an increased number of process status measurements and versatile information handling possibilities. As regards turbine automation, it facilitates for turbine operators improved information management, process control at operating work stations, trend monitoring and setting of safety limits. Safety limit settings enable turbine operator reaction to even minor process changes. The control desk for the turbine side in the control room was replaced with a safety function control desk and a turbine systems control and monitoring board with operator's work stations. The control room was also fitted with a screen display. In addition, the process computer system capacity had to be upgraded in connection with the control system renewal to handle the large volume of data yielded by the turbine automation. The automation interface was introduced at the Olkiluoto units 1 and 2 training simulator in September 2004, which made possible the training of operating personnel in its use.

Examples of latest plant modifications at the Olkiluoto NPP (2013–2015)

Upgrade of the plant radiation measurement systems

In a radiation measurement equipment upgrade project, practically all stationary radiation measurement equipment were replaced at the Olkiluoto units 1 and 2. The first new devices were installed and operational in 2008. Apart from the existing measurements, some completely new measurements were installed in the project. The purpose of the test operation was to compare the measurement results of the new devices with the measurement results of the old devices. The aim has been to place the new devices in more representative places according to operating experience gained.

Another aim has been to find alarm limit set values that would be optimal in terms of radiation safety and plant process monitoring.

The latest upgrades were improvements of release and activity measuring in case of an accident in the vent stack and room radiation measuring systems. During the 2013 annual outage, two upgraded and one new measuring channel were commissioned in Olkiluoto 2. All of the new monitors used for measuring during an accident were commissioned by the end of 2013.

During the 2014 annual outages, the radionuclide specific activity measuring instruments used in fuel leak detection were replaced at both units. The new measuring instruments are easier to maintain than the old ones: the cooling system used for radionuclide analytics can be modernised so that it is electrically cooled. The project was finalized during year 2015 when the radiation measuring instruments used to monitor releases during normal operation of the plant was upgraded.

Low-voltage switchgear replacement project

TVO has implemented a project for replacing the switchgears of the low-voltage distribution systems (the SIMO project) at the Olkiluoto units 1 and 2. The primary reason for replacing the switchgears was the increase in maintenance costs due to the ageing of original equipment, as well as the need to modernise the switchgear to correspond to the current requirements regarding plant and personnel safety. The replacement mainly concerns the switchgears and associated transformers of electrical systems important to safety. TVO replaced the medium-voltage switchgear (6.6 kV) in 2005 and 2006. The voltages in the low-voltage networks of the units vary from 24 V DC to 660 V AC. The switchgears are used to supply the required electrical power to the I&C systems and components of the units. TVO has continued the work during last years. The project was finalized in 2016 by replacing the last remaining switchgear train during the annual outage of Olkiluoto 1.

Construction of an emergency control room

Pursuant to a STUK Regulation Y/1/2016 (previously Government Decree 733/2008), a nuclear power plant shall have a supplementary control room independent of the main control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing residual heat from the nuclear reactor and spent fuel stored at the plant in a situation where operations in the main control room are not possible.

TVO has constructed emergency control rooms for the Olkiluoto units currently in operation in compliance with the requirements set out in the latest periodic safety review of the Olkiluoto NPP in 2009. The emergency control rooms have been commissioned at Olkiluoto unit 2 in 2015 and at unit 1 in 2016. The emergency control rooms have been redesigned and relocated to provide better coordination and control for plant shutdown and safety function monitoring. Plant units can now be brought to stable state solely by the controls from the emergency control room. Cooling the reactor down to a cold state can be carried out after the shutdown by using emergency control room and some local control posts.

Enlargement of the spent fuel interim storage

TVO completed the enlargement of the spent fuel interim storage (the so-called KPA storage) in summer 2015. In the project three additional pools were built, and the storage structures has also been modified to comply with the current safety requirements (e.g. taking into account the requirement to protect the facility against large civil aircraft crashes). The extension increases the capacity to comply with the spent fuel coming from the Olkiluoto plant units 1, 2 and 3. TVO submitted the documentation regarding extension of the storage to STUK for approval at the end of 2009.

Extension of the interim storage has been included in Olkiluoto NPP units 1 and 2 operating licence and has been treated as plant modification. In 2014, system modifications pertaining to the extension were completed and some systems were commissioned. Two STUK's commissioning inspections regarding the entire facility were carried out and STUK gave approval to take the extension in operation in summer 2015.

After the stress tests some safety improvements for the Olkiluoto NPP spent fuel interim storage were identified. The possibility to feed cooling water from external source and to monitor spent fuel pool water level and temperature in all cases were the most important safety features to be implemented. These safety features were included and implemented in the spent fuel storage extension project. The connection for feeding the cooling water from external source was already included in the design before the TEPCO Fukushima Dai-ichi accident.

Examples of latest incidents at the Olkiluoto NPP (2013–2015)

Replacing carbon grounding brushes of the generator during power operation

After the annual outages of Olkiluoto NPP in May and June of 2014, it was observed that the main generator carbon grounding brushes were being worn through faster than normal. The worn out components of Olkiluoto 2 were replaced in the summer during an extra outage so that occupational safety and radiation protection issues could be taken into account.

The plan was to inspect the grounding brushes of Olkiluoto 1 on 30 September 2014 when the unit was in power operation. It had been observed in connection with an inspection that the carbon brushes could be simultaneously replaced. However, the shift supervisor of the unit (Olkiluoto 1) was not informed of the replacement of the carbon brushes and there was no work permit for the replacement of the brushes. The task took place in a room that has been classified in the Operational Limits and Conditions (OLCs), based on the radiation level, as a room where work may not be performed without a radiation work permit but there was no such permit for the task.

The event did not influence the unit's nuclear security or nuclear safety but it was still classified as a Level 1 event on the International Nuclear Event Scale (INES) due to the fact that the OLCs were not followed and the event indicated defects in the safety culture (basic rating INES 0, safety culture issues as an additional factor).

Open penetrations in containment during work on recirculation pumps

Annual outages at Olkiluoto 1 and Olkiluoto 2 have included maintenance and replacement work on penetrations. Repair and replacements projects of penetrations have been carried out in a systematic manner since 2011. When work has been carried out on penetrations located in the containment, the effect of open penetrations has not been taken into account as concerns potential bottom leaks in the reactor pressure vessel during the annual outage. A bottom leak in the reactor pressure vessel through the penetration of the shaft of a recirculation pump is a highly improbable event.

TVO took actions to prevent the recurrence of this type of event. Before work is started on recirculation pumps, TVO will make sure that the penetrations of the pump level are leak-tight and there is no possibility of a water leak from penetrations and pipe nozzles to the outside of the containment. The event was rated as INES Level 1 (basic rating INES 1, no additional factors).

Periodic safety reviews at the Olkiluoto NPP

During the years 1996–1998 the overall safety review of the Olkiluoto plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Trade and Industry in June 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The latest overall safety review of the Olkiluoto plant took place in 2007–2009 in connection of the periodic safety review. The operating licence for Olkiluoto NPP units 1 and 2, required that a comprehensive periodic safety review (PSR) shall be carried out by the end of 2008. The operating licence also covers the interim storage facilities for spent fuel and medium and low activity operational waste, so these facilities were also included in the PSR. Regulatory Guide YVL 1.1 (currently YVL A.1) specifies the contents of the PSR. For a separate periodic safety review, STUK shall be provided with similar safety-related reports as in applying for the operating licence.

TVO began preparations for the periodic safety review a few years after the existing operating licence was granted. The PSR documentation was submitted to STUK for approval in the end of 2008. STUK made a decision concerning the PSR in

October 2009. In the STUK's decision the licensee's PSR was approved as a comprehensive periodic safety review according to the licence condition. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK.

The issues addressed in the assessment and the related evaluation criteria are set forth in the nuclear energy and radiation safety legislation and in the regulations issued thereunder. Based on the assessment, STUK considered that the Olkiluoto Nuclear Power Plant units 1 and 2 meet the set safety requirements for operational nuclear power plants, the emergency preparedness arrangements are sufficient and the necessary control to prevent the proliferation of nuclear weapons has been appropriately arranged. The physical protection of the Olkiluoto nuclear power plant was not yet completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue based also on the principle of continuous improvement were included in the decision relating to the periodic safety review.

The safety of the Olkiluoto nuclear power plant was assessed in compliance with the Government Decree on the Safety of Nuclear Power Plants (733/2008), which came into force in 2008. The decree notes that existing nuclear power plants need not meet all the requirements set out for new plants. Most of the design bases pertaining to the Olkiluoto 1 and 2 nuclear power plant units were set in the 1970s. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning to improve safety. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act. The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO submitted to STUK action plans for the observed points requiring improvement. STUK included also some additional requirements in the decision relating to the periodic safety review. Systematic assessment and development of the diversity principle was required, including investigation of possibilities for residual heat removal to be independent of seawater. TVO submitted a report regarding the adequacy of the diversification at the plants and an action plan for developing the plants at the end of 2010. STUK approved the report in 2012. Another requirement considered plant modifications to improve safety in situations involving spurious opening of the turbine bypass valves. TVO has submitted required report and STUK has approved TVO's disquisition and action plans to improve the situation.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the safety of the Olkiluoto nuclear power plant units 1 and 2 is sufficient and the licensee utilises the necessary arrangements to continue the safe operation of the plants.

The next periodic safety review will be carried out during 2016–2018 when the Olkiluoto NPP applies for a renewal of operating licence.

Planned and ongoing activities to improve safety at the Olkiluoto NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Olkiluoto nuclear power plant units 1 and 2 since their commissioning and there exists no urgent need to upgrade the safety of these plant units in the context of the Convention.

There are several ongoing and planned safety upgrading measures at the Olkiluoto nuclear power plant. For example renewal of the diesel generators and reactor coolant pumps and their frequency converters. Furthermore, systems for ensuring cooling of the reactor core in case of total loss of AC supplies as well as diversification of reactor water level measurements are under design.

Safety assessments and improvements based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Natural hazards

Safety margins were assessed by the licensee and reviewed by STUK. Based on the results, STUK required further clarifications on the following main points:

- seismic resistance of spent fuel pools including situations with water temperature exceeding the design bases; and
- seismic resistance of fire fighting systems.

The licensee of the Olkiluoto NPP was also requested to carry out a more detailed assessment on the effects of exceptionally high seawater level on the cooling systems of the spent fuel interim storage and their electric power supply. Cooling system pumps are situated at the +0.5 m level. The spent fuel interim storage is designed as watertight up to the seawater level +1.2 m. At higher seawater levels some seepage of water through the soil to the drainage system is anticipated. According to the licensee, the seepage would be stable and slow and the water could be removed with submersible pumps. Fast flooding of the interim storage would be possible through the doors if the seawater level exceeds +3.5 m and through the seam between the seawater pumping station and seawater pipe culvert at the level +2.5 m. The licensee has submitted plans for tightening the aforementioned seam and submitted by the end of 2012 plans for further improving the protection of the interim storage against flooding, including increase of the capacity of the submersible pumps.

TVO has carried out seismic walkdowns for the fire extinguishing water systems of Olkiluoto. In 2014, TVO improved seismic resistance of the fire water systems by reinforcing pipe supports and the supports of electrical cubicles and relay cabinets in the relay rooms.

Design issues

At the Olkiluoto units 1 and 2, sea water is the primary ultimate heat sink and an alternative heat sink exists only partially. Both units can evaporate residual heat from the reactor core to atmosphere by conducting the steam produced inside the reactor pressure vessel to the condensation pool through the safety relief valves, by letting the condensation pool to boil, and by venting the steam from the containment to atmosphere through the filtered venting system. However, the systems required to pump water into the reactor pressure vessel are either dependent on the sea water based component cooling systems or on the condensation pool water, which means that the complete loss of sea water as the ultimate heat sink will eventually prevent the supply of water to the reactor pressure vessel.

Licensee is planning plant modifications on the current residual heat removal chain to decrease the dependence on the sea water cooling. A modification in the auxiliary feed water system is planned to enable cooling of the components by demineralised water in addition to sea water based cooling chain. By this modification system can remain operational for a significant period of time even during the loss of the primary ultimate heat sink (sea water). The new recirculation line modification was implemented at Olkiluoto 1 in 2014. Abnormal vibration and pressure oscillations have been observed during the testing of one subsystem. This did not influence operation of the pump, however, and the fault would not have prevented the supply of water to the reactor in case of need. Studies to eliminate this problem are ongoing. The modification will not be implemented at Olkiluoto 2 until the observations at unit 1 are resolved.

In addition, an independent way of pumping water to the reactor pressure vessel is under design by the licensee in case of loss of AC power. The arrangement will consist of high and low pressure systems. The low pressure system pumps coolant into the core from the fire fighting system. The high pressure system will consist of a steam driven turbine pump: the steam will be drawn from the main steam line and supplied through a dedicated line to the pump turbine. The water will be supplied to the reactor by the system via one auxiliary feedwater line. The exhaust from the turbine is routed to the wet-well suppression pool. Such a high pressure system is necessary because, based on studies conducted by TVO, it is apparent that the a low pressure system with supply via the fire water system alone would not be enough to guarantee integrity of the reactor core in case of a total loss of power. The high pressure system will offer more time to guarantee adequate pressure decrease for starting the low pressure system. STUK approved a conceptual design plan of the new system in 2015. More detailed system design is currently ongoing and the implementation is planned to be made in 2017-2018.

At the Olkiluoto units 1 and 2, the current AC power supply systems include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators per unit, a gas turbine, a dedicated connection to a nearby hydropower plant, and the possibility to supply electricity from the neighbouring NPP unit. The licensee has decided to renew all the eight emergency diesel generators. Renewal of the diesel generators is descripted in more detail below.

At the Olkiluoto units 1 and 2, the depletion times of DC batteries are well above 10 h, in some cases tens of hours. It is possible to charge the batteries using the AC power sources. DC batteries supplying the severe accident monitoring systems can also be recharged by mobile generators for instance, during long-lasting accidents.

At the Olkiluoto units 1 and 2, the licensee has evaluated that water injection into the pool and boiling of the pool water could be used as an alternative means to remove decay heat from the pools inside the reactor building. To support monitoring of the water level in the reactor building spent fuel pools, there is a plan to equip the fuel pools with a level measurement system. The implementation is planned to be made in 2016. The fixed pipelines from the fire water system dry risers to the fuel pools at both units has been installed in 2014-2015.

At the Olkiluoto units 1 and 2, the licensee started the investigation of needs and targets for mobile power supply in autumn 2011. Investigation includes also renewal of the present mobile SAM diesel generators. Today there are four new mobile aggregates and two old mobile aggregates. Enhancing charging of batteries has also been found feasible to improve the availability of DC power. The licensee has investigated the possibilities for fixed connection points for recharging of all safety important batteries and other important consumers (e.g. weather tower) using transportable power generators, and the decision to install fixed connection points has been made.

Severe accident management

A comprehensive severe accident management (SAM) strategy has been developed and implemented at the Olkiluoto units 1 and 2 during 1980's and 1990's after the accidents in TMI and Chernobyl (see above). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary. However, the licensee is expected to consider also spent fuel pools in the SAM procedures as well as any implications on them possibly arising from simultaneous multi unit accidents. In addition, there are many actions related to the update of the emergency plans.

Hydrogen leakages out of the containment during severe accidents has been analysed for all Olkiluoto NPP units, and the results show that design leakages do not cause a threat to the containment integrity. For spent fuel pools, the approach in Finland is to "practically eliminate" the possibility of fuel damage. The possibility of top venting of reactor hall has been studied at the Olkiluoto units 1 and 2 for the steam release in case of spent fuel pool boiling. Hydrogen possibly formed in the spent fuel pools or leaked from the containment could be exhausted through this route as well. Minor plant modifications are required, which will be implemented in near future.

Diversification of reactor water level measurements

The reactor water level measurement system consists of four parallel subsystems, two of which are sufficient for implementing the protection function (from high and low level). The subsystems are based on differential pressure measurement. TVO has studied possibilities to supplement the currently used low level measurement system with another system based on a different measuring principle. TVO's plans to implement the modification have been delayed. The current plan is to install the new devices for test use in annual outages of 2017 and 2018.

Renewal of the diesel generators

TVO has initiated a project for replacing all current emergency diesel generators and their auxiliary systems at the Olkiluoto units 1 and 2. There are four emergency diesel generators in use at both operating reactor units in Olkiluoto. The replacement project is implemented taking also into account any increases in the need for power due to possible future plant modifications as well as the lessons learnt from the TEPCO Fukushima Dai-ichi accident in relation to securing the power supply. The nuclear safety requirements dictate that a power margin of at least 10% is available in all load conditions. Furthermore, both main components of the EDGs (the diesel engine and the generator) are old models, whose development and manufacture has been discontinued, and the availability of spare parts and the supplier's technical support are declining. STUK approved the conceptual design plan on the replacement of the diesel generators in early 2013.

The purpose of the emergency diesel generators and their associated auxiliary systems is to supply electrical power to the 660 V emergency power system in case of loss of supply from the 6.6 kV main bar. Both plants have four subsystems, and each subsystem has its own standby diesel generator. Replacement of the diesel generators will also mean that the main switchgear in the 660 V emergency power network has to be replaced; this has already been done as part of the replacement of low-voltage switchgear as a modification project separate from the replacement of the EDGs.

The intention is to implement the EDG replacement project during the normal operation of the plant units as far as possible. According to the plan, the new EDGs will be installed and commissioned during power operation so that one new EDG is installed to both plant units during one power operation cycle. For this purpose, a ninth EDG unit has to be constructed to replace any one of the current EDGs of the Olkiluoto units 1 or 2. In the future, the ninth EDG can be connected to replace an EDG undergoing periodic maintenance at the Olkiluoto units 1 or 2, or it can replace a failed EDG. A new building will be constructed for the ninth EDG, while the replacement EDGs will be installed at the same premises where the current units are located.

The renewal plan includes several safety improvements. First of all, the new EDGs would be equipped with two diverse component cooling systems. The primary EDG cooling would be provided by the sea water based cooling system, similar to present EDGs units. An alternative, automatically activated air based cooling system would be added to cope with situations involving the loss of availability of sea water. This would provide extra protection against external hazards, internal hazards such as fires, as well as component failures.

During last years TVO has continued the preparation of the replacement of the emergency diesel generators at Olkiluoto 1 and Olkiluoto 2. At present, TVO has started construction of the building for the ninth emergency diesel generator that will be shared by the units. According to the current estimated schedule, this emergency diesel generator, which will be used during the replacement project instead of the diesel generator that is currently being replaced at the units, will be installed and commissioned in the spring 2018. The plan is to have the entire diesel generator replacement project completed by the spring 2022.

Replacement of reactor coolant pumps and their frequency converters

In 2014, STUK approved TVO's conceptual design plans on replacing the reactor coolant pumps and the frequency converters needed when controlling and supplying power to the pumps. The pumps are replaced because of their ageing. In connection with the replacement, a flywheel will be added to the reactor coolant pump shaft to ensure sufficient cooling of the nuclear fuel in case of a trip during which the electrical power is unavailable. The pump is currently shut down by means of electric control. The first new reactor coolant pump has been commissioned at Olkiluoto 1 during the 2016 annual outage. The plan is to replace all of the six pumps at Olkiluoto 2 during the 2017 annual outage and the remaining five pumps of Olkiluoto 1 in 2018.

ANNEX 4 Olkiluoto NPP unit 3 under construction

Licensing steps

Decision-in-Principle procedure was carried out during the period November 2000 – May 2002 when Teollisuuden Voima Oyj (TVO) applied a Decision-in-Principle for the fifth NPP unit in Finland and the Government approved it and the Parliament confirmed the approval. Construction licence application for the Olkiluoto unit 3 was submitted by TVO to the Ministry of Trade and Industry (predecessor of the Ministry of Employment and the Economy) in January 2004. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens. The technical requirements for Olkiluoto unit 3 were specified by using the European Utility Requirements (EUR) document as a reference. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent. STUK gave its statement and safety assessment in January 2005 based on the review of the licensing documentation and the Government issued the Construction Licence in February 2005.

Construction of the Olkiluoto unit 3 still continues. In the turbine island, commissioning tests of the systems have been completed as far as possible without connection to reactor island. The turbine island is under preservation. In the nuclear island, the finishing of installation is going on and the commissioning tests have been started. Next major licensing step is the operating licence. TVO submitted operating licence application to the Ministry of Employment and the Economy in April 2016. Operating Licence is needed prior to loading nuclear fuel into the reactor core. IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP before core loading.

Challenges

Olkiluoto 3 was supposed to start commercial operation in 2009. According to present schedule, commercial operation will start in the end of 2018, nine years after the original target. At the moment, the licensee and the vendor have agreed on the time schedule, and detailed time schedules for the remaining work have been drafted.

There are certain factors that have affected greatly the project progress. Olkiluoto unit 3 is the

Figure 23. Olkiluoto NPP unit 3 in construction phase in autumn 2015. Source: TVO.

first European Pressurised Reactor (EPR) being constructed. Construction of the unit started after a long break in nuclear power plant construction in Europe, which had resulted in loss of experienced and qualified engineering and manufacturing resources. Lack of knowledge on Finnish regulatory framework and safety requirements, insufficient completion of the design prior to construction, some difficulties with advanced manufacturing and construction technologies and lacks in safety culture in the earlier phase of construction works at site have been challenging aspects in the project and caused delays. On the other hand parties have succeeded to find deviations induced during the project and the end products have finally fulfilled quality, performance and safety requirements.

During the project, I&C design has lagged behind process system design and for a long time it set the timeline of the project. Using of integrated, software based I&C platforms sets new requirements for designing, safety analyses as well as for implementation and testing of the systems. Configuration and requirement management and verification & validation actions have more essential role during these phases than earlier when analog systems were used. The main issues where STUK has asked more clarification concern defining and management of interfaces of different I&C systems so that failure of one system can't disturb other systems. STUK has also asked more clarification how possible spurious actuations are taken into account in the design and corresponding safety analyses. STUK has received answers to the aforementioned concerns as well as the related analyses and has been able to approve the I&C design. The individual I&C systems were tested in testbay in Erlangen. As the tests indicated no major deficiencies in the design, STUK allowed the shipment of the systems to Olkiluoto site. Installation and testing of the I&C on site is currently ongoing.

Regulatory oversight

During the construction, STUK oversees the project comprehensively. The licensee's performance is evaluated via Construction Inspection Program. The purpose of the program is to verify that the performance and organisation of the licensee ensure high quality construction and implementation in accordance with the approved designs while complying with the regulations and STUK's decisions. Under Construction Inspection Program STUK has performed around 15 inspections every year. Some of the inspections have been unannounced inspections.

In addition to Construction Inspection Programme, STUK has strong on-site presence by the resident inspectors at the construction site. There are four resident inspectors dedicated for Olkiluoto unit 3 project. This provides STUK constant flow of information and oversight capabilities and gives additional information on licensee's activities. STUK has therefore also very quick ability to response with short notice to any immediate safety concern or incident. Findings made by resident inspectors are also important inputs for the construction inspection programme inspections.

The construction of a nuclear facility shall not begin before the Government has granted the Construction Licence. After that, prior to start manufacturing, installation or commissioning of the system, structure or component, STUK's approvals for the detailed design or plans are needed. STUK also approves manufacturers of nuclear pressure equipment for their duties and inspection organisations and testing organisations for duties pertaining to the control of pressure equipment at nuclear facilities. During the Olkiluoto unit 3 project, STUK has reviewed more than 16500 applications – about 10500 of them are submitted to STUK for approval.

STUK also inspects the compliance of the design and manufacturing of mechanical components and structures. Inspections are performed during and after the manufacturing in manufacturers' premises and at the site after installation and during commissioning. In lower safety classes these inspections are conducted by Inspection Organisations.

Based on the findings made during the technical inspections, inspections under construction inspection programme, document reviews and other visits during construction, STUK prepares annually a comprehensive safety evaluation how safety aspects are fulfilled and taken into account during the construction. The experience has shown that STUK's practice to oversee the project in all level of activities has been effective way to find possible weak points and deviations in early phase of the project. Translations of annual report can be found from the STUK's website.

Safety assessments based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Following the accident at the TEPCO Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessment of Olkiluoto unit 3 was initiated. The topics included the preparedness against loss of electric power supply, loss of ultimate heat sink and extreme natural phenomena. As being a unit under construction, any immediate actions were not necessary, but STUK required the licensee to carry out additional assessment and present an action plan for safety improvements. Assessment was conducted and reported by the licensee to STUK on 15 December 2011. STUK reviewed the assessment and made decision on 19 July 2012 on the suggested safety improvements and additional analyses.

External conditions in Finland are moderate. No destructive earthquakes or tsunami waves have been observed. Storms are not comparable to tropical cyclones and strong tornadoes are quite rare. Olkiluoto unit 3 fulfils the current regulatory requirements concerning external events. The design basis of Olkiluoto unit 3 for external events has been selected conservatively in the design phase. The design basis covers earthquakes, internal and external flooding, extreme weather and other natural hazards (like snowstorms, frazil ice formation and impurities in the seawater) as well as human induced hazards. The design values correspond to return periods of up to 100.000 years and much longer for events with "cliff edge" type consequences. As the estimated conditions corresponding to such long return periods involve large uncertainties, considerable physical margins to the largest values observed in the neighbourhood of the site have also been ensured.

Figure 24. STUK's resident inspector performing construction inspection for primary circuit piping.

The ultimate heat sink of the Olkiluoto unit 3 is the sea. In case of the total loss of the availability of sea water for cooling, the residual heat from the reactor core would be released to the atmosphere via the steam generators. The water inventory of the emergency feed water tanks is sufficient for 24 hours. After 24 hours, make-up water will be added from the fire water distribution system with diesel powered pumps. In addition to the fire water distribution system, other water sources exist; mobile pump with hoses can be used for water transfer from the demineralized water tanks to the emergency feedwater tanks. Also the nearby Korvensuo reservoir can be used as water source.

During refuelling outage the containment filtered venting could be used to release the steam out from the containment in case of loss of sea water cooling. Filtered venting system is not an original safety feature of EPR concept but it was required by STUK in an early phase of the conceptual design of Olkiluoto unit 3 to ensure the pressure management of the containment during severe accidents.

In the fuel building, the spent fuel pools can be cooled by evaporation. Make-up water is added from the fire water distribution system. In order to ensure water supply to the spent fuel pools independent of the fixed OL3 systems, mobile pump with hoses can also be used to add water to the pools. In the fuel building there are pipe fittings where the hoses can be connected or water can be injected directly to fuel pools with hoses. Water source is either demineralized water tanks or Korvensuo reservoir.

The current AC power supply systems of the Olkiluoto unit 3 include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators (EDGs), two station black out (SBO) diesel generators, a gas turbine and the possibility to supply electricity from the neighbouring NPP units via 400 kV switchyard. To ensure long autonomy of SBO diesels possibility to move fuel from EDG storage tanks to SBO diesels has been added. In addition, the licensee further evaluated the robustness of EDG building doors against flooding and the results indicate that there is no threat to loss of EDGs due to flooding (doors leak tight up to over 10 m of water).

For uninterrupted power supplies, there are separate and diversified 2 h and 12 h battery backed power supply systems. The first set of batteries supplies all electrical equipment which require uninterruptible power in the nuclear island and the second set of batteries supplies loads which are important in case of a severe accident. The licensee evaluates that there is no need for upgrading the battery capacity.

Severe accidents have been considered in the original design of the Olkiluoto unit 3. STUK has reviewed the overall SAM strategy and the approach has been accepted. No changes to this approach are expected based on current knowledge from the TEPCO Fukushima Dai-ichi accident.

ANNEX 5 New NPP units and construction licence application for Hanhikivi NPP unit 1 in planning phase

Environmental Impact Assessment of new nuclear power plants and candidate sites

In 2007, initiatives for building additional nuclear power plant units in Finland were announced. Environmental Impact Assessment (EIA) was carried out according to EIA legislation for the possible Olkiluoto 4 and Loviisa 3 units in 2007–2009. The Competent Authority for EIA procedure for NPP's in Finland is the Ministry of Employment and the Economy.

A new nuclear power company, Fennovoima Oy, was founded in 2007. The company started a preliminary site survey process, mainly on the coast of the Gulf of Bothnia (the northern gulf of the Baltic Sea) and on the eastern Gulf of Finland (the eastern gulf of the Baltic Sea), the northernmost candidate site being 20–30 km from the borderline of Sweden. Fennovoima prepared an EIA programme and subsequently an EIA report for three (originally four) alternative new candidate sites in 2007–2009.

The EIA process did not reveal any major nuclear or radiation safety issues as regards the proposed new NPP sites or new units on the existing sites. EIA is a legal process to cope comprehensively with the environmental issues depending on the specific site (e.g. sea environment and eutrophication, special natural species and phenomena, biodiversity, Natura natural reserve assessment, fisheries, salmon migration, combined heat and power production) and to increase the opportunity for citizens and other stakeholders to receive information, become involved in the planning and express their statements and opinions on the project.

Comments were requested from altogether nine countries near the Baltic See by the Finnish Environmental Ministry on the basis of so called Espoo convention. Several comments from e.g. Estonia, Sweden and Germany were given and considered by the Finnish authorities. Additionally, the Austrian Government as a party of the Espoo convention sent their statement on each EIA and requested for consultation in Finland. Thus, subsequent meetings were arranged in 2008–2009 at the Finnish Ministry of the Environment where a Finnish delegation of experts from the utility concerned, STUK and the Ministry of Employment and the Economy gave detailed explanations to the questions provided.

Separate applications for the Decision-in-Principle for new NPP units were submitted to the Government in 2008 and 2009 by TVO, Fortum and Fennovoima. The relevant site-related factors potentially affecting the safety of a the planned

Figure 25. Hanhikivi site in Pyhäjoki selected for Fennovoima new NPP (Hanhikivi 1). Source: Fennovoima.

new NPP units and the related nuclear facilities during their projected lifetime were evaluated for the existing Loviisa and Olkiluoto sites and for the alternative new sites at Pyhäjoki, Simo and Ruotsinpyhtää proposed by Fennovoima. In late 2009, Fennovoima removed the Ruotsinpyhtää site from its application for the Decision-in-Principle. The evaluations were reviewed by STUK and other expert organisations in their respective fields. In addition to the Finnish regulations, IAEA Safety Requirements and Safety Guides and WENRA requirements were considered in the review.

Specific issues regarding the new sites are the size of precautionary action zone (5–6 km radius in Finland), the limitation of maximum population within it which may be affected in a severe accident situation and the possibility to evacuate the population. According to the Finnish regulations, an early evacuation before an expected release shall be possible within a time of four hours from the evacuation decision. The population in 2010 in the vicinity of the Finnish candidate sites is internationally compared relatively small (maximum of 3000 inhabitants up to 6 km from the site at Simo).

According to STUK's preliminary safety assessments, no site related factors were found at any of the sites which would prevent building the proposed new NPP units and the related other nuclear facilities according to the safety requirements. More detailed evaluation of the site related factors will be conducted and site characterisation is accepted in connection with the Construction Licence process.

Fennovoima completed site selection process in October 2011 by selecting Hanhikivi site in Pyhäjoki. The company stated that the main technical arguments for site selection were bedrock intactness, lower seismicity, shorter cooling water tunnels and population density.

Decisions-in-Principle and safety assessments of new nuclear power plant units

Three new nuclear power plant units have been under consideration in Finland (see more details of the licensing process under Articles 7 and 17). TVO submitted application for a Decision-in-Principle (DiP) to the Ministry of Employment and the Economy in 2008, Fennovoima and Fortum in 2009. In addition, two DiP applications by Posiva Oy have been handled for the expansion of the planned capacity of spent fuel repository for Olkiluoto 4 and Loviisa 3 units. The applications for NPP units were accompanied by documents of a total of seven alternative plant designs.

In the Decision-in-Principle (DiP) the Government judges whether the proposed use of nuclear energy is in line with the overall good of society. STUK gave the Ministry of Employment and the Economy preliminary safety assessments of all Decision-in-Principle applications in 2009. STUK's preliminary safety assessments consisted of an assessment of the safety of the plant alternatives and the sites as well as of an assessment of the organisations, expertise and the quality management of the applicant. The assessments also covered the physical protection and emergency preparedness arrangements, nuclear fuel and nuclear waste management, nuclear liability and non-proliferation. STUK stated in its preliminary safety assessment whether any factors have arisen indicating a lack of sufficient prerequisites for constructing a nuclear facility as prescribed in the Nuclear Energy Act. Safety assessment was based on the Government Decrees issued under the Nuclear Energy Act. Furthermore, STUK took a stand on the possibility of fulfilling other requirements laid down in legislation and YVL Guides as regards the issues to be reviewed by STUK. The aim of the preliminary safety assessment was to find any "show stoppers" in sites, organisations or plant design alternatives. Seven different plant design alternatives were assessed during the preliminary safety assessment period: ABWR (Toshiba-Westinghouse), AES-2006 (Atomstroyexport), APWR (Mitsubishi Heavy Industry), APR-1400 (Korean Hydro and Nuclear Power), ESBWR (GE Hitachi), EPR (AREVA) and KERENA (AREVA).

Most of the plant alternatives reviewed in the STUK's preliminary safety assessments did not meet Finnish safety requirements as such. The nature and the extent of the required modifications vary between the plant alternatives. Some plant alternatives would only require fairly minor modifications; some would require more extensive structural modifications. The required technical solutions were still open for some alternatives.

All DiP applications were handled simultaneously and in May 2010 the Government granted two Decisions-in-Principle, one to Teollisuuden Voima Oyj (TVO) and another to Fennovoima Oy.

TVO's DiP was granted according to the application to build Olkiluoto unit 4 (OL4), single reactor with maximum output of 4600 MWth. In the Fennovoima's case Government granted DiP only for a single reactor with maximum reactor power of 4900 MWth, although Fennovoima applied to build one or two reactors with maximum reactor power of 4300–6800 MWth.

The Government also granted a Decision-in-Principle for Olkiluoto unit 4 spent fuel disposal, applied by the spent fuel management company Posiva Oy. For Fennovoima's spent fuel disposal, the Government gave two options. By mid 2016, Fennovoima shall present a co-operation agreement of spent fuel disposal with TVO and Fortum (the owners of Posiva) or start its own EIA process for the spent fuel disposal. Regardless of the option chosen a separate DiP will later be required for disposing of the spent fuel from Fennovoima's planned reactor unit. For this DiP process also the corresponding EIA report needs to be updated or prepared for a possible new site.

At the same time the Government rejected Fortum's DiP application to construct a new reactor to Loviisa site (Loviisa unit 3), as well as the DiP application for expanding the capacity of the spent fuel disposal facility to include also the spent fuel from the Loviisa unit 3 was rejected.

According to the Nuclear Energy Act, the granted DiP's were sent without delay to the Parliament for confirmation. The Parliament may reverse the Decision-in-Principle as such or may decide that it remains in force as such. After the hearings in the all main permanent committees, the Parliament ratified both granted NPP applications on the 1st of July 2010. Both the Decisions-in-Principle for new reactors state that the construction licence shall be applied within five years from the Parliaments confirmation (by the end of June 2015).

Due the delay of Olkiluoto 3 project utility TVO applied a five years extension of time to the granted Olkiluoto 4 DiP. TVO filed in May 2014 an application for complementary DiP to the Government. Also utility Fennovoima had to apply a complementary DiP from the Government, because they chose ROSATOM AES-2006 plant design, which was not presented for preliminary safety review scope of Fennovoima 2010 DiP. Fennovoima sent the application for complementary DiP to the Government in March 2014. STUK prepared its statements promptly after summer 2014. The Government did decisions on both applications in September 2014. Governments Decision-in-Principle was positive for Fennovoima Hanhikivi 1 project and negative for extension of the validity time of the DiP applied by TVO for Olkiluoto 4. Hence, the Olkiluoto 4 project ended in June 2015 since TVO did not submit an application for construction licence.

Fennovoima Hanhikivi unit 1 construction licence phase

According to the Nuclear Energy Act, the applicant may ask advice or send plans for STUK's review before the applications are filed to the Government. With this mandate, the utilities and STUK have had meetings to be prepared for the construction licence safety assessment process. STUK has organised seminars with licence applicants on construction licence application requirements in relation to the plant design processes and shared the lessons learned from the Olkiluoto unit 3 construction project. Process system and plant engineering (layout) design maturity in PSAR phase is dominating factor for successful construction licence application review.

The main challenge for construction licence application review was to conclude the renewal process of the legislation and the regulatory guides – new YVL guides. STUK started internal development project for its requirement management (RM) to support the review process.

According to the set dead line in DiP, Fennovoima filed a construction license application (CLA) for Hanhikivi unit 1 NPP on 30 June 2015 to the Government and submitted according to the Nuclear Energy Decree first batch of safety, security and safeguards documentation to STUK for regulatory review and assessment. It was noted that Fennovoima was not able to submit a complete licensing documentation to the regulatory review and assessment at the same time. Fennovoima will complement its documentation during the years 2015–2017 according to a licensing plan. The Government has asked STUK to give its statement and safety assessment during the year 2017, if possible. One of the main challenges in batch-wise CLA submittals and regulatory review is to have rigid configuration management in place and self-standing document submittals in logical order.

STUK has started the CLA review and also the inspection programme on Fennovoima, Plant Vendor ROSATOM, and its main sub-suppliers. STUK conducted five management system inspections to Fennovoima and one to the General Designer JSC Atomproekt, St Petersburg, Russia, during the year 2015 and shall conduct about 12 inspections on Fennovoima and ROSATOM main design organisations during the year 2016 to support its document review and assessment. STUK is publishing its inspection findings in periodical reports available on STUK's web pages.

ANNEX 6 Implementation of the IAEA Action Plan on Nuclear Safety

The transparency and international co-operation are one of the corner stones in the Finnish nuclear safety policy. Finland has signed the international conventions and treaties aiming on safe and peaceful use of nuclear energy. After the TEPCO Fukushima Dai-ichi accident, Finland signed among 130 other countries in the General Conference in September 2011 the IAEA Action Plan. The twelve main actions included in the IAEA Action Plan and the related Finnish measures are discussed in this Annex. All Fukushima-related decisions by STUK, the national reports and action plans have been published on STUK's website.

Safety assessments in the light of the accident at TEPCO's Fukushima Daiichi NPP

Undertake assessment of the safety vulnerabilities of nuclear power plants in the light of lessons learned to date from the accident

Following the accident at the TEPCO Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessments in Finland were initiated after STUK received a letter from the Ministry of Employment and the Economy (MEE) on 15 March 2011. The Ministry asked STUK to carry out a study on how the Finnish NPPs have prepared against loss of electric power supply and extreme natural phenomena in order to ensure nuclear safety. STUK asked the licensees to carry out assessments and submitted the study report to MEE on 16 May 2011. Although immediate actions were not considered necessary, STUK required the licensees to carry out additional assessments and present action plans for safety improvements. Assessments were conducted and reported by the Finnish licensees to STUK on 15 December 2011. STUK has reviewed the results of national assessments, and made licensee specific decisions on 19 July 2012 on the suggested safety improvements and additional analyses.

Finland also participated in the EU Stress Tests and submitted the national report to European Commission by the end of 2011. An EU level peer review on the report was completed by April 2012. The recommendations of the EU peer review have been taken into account in the regulatory decisions and were considered in the development of national regulations. In addition, Finland participated in the second Extraordinary Meeting of the Convention of Nuclear Safety (CNS) in August 2012 and prepared a report introducing national actions in Finland initiated as a result of the TEPCO Fukushima Dai-ichi accident. STUK has prepared a National Action Plan in the framework of EU stress tests addressing the measures initiated on a national level and at the nuclear power plants as a result of the TEPCO Fukushima Dai-ichi accident. The National Action Plan takes into account the national safety assessments and related regulatory decisions as well as the recommendations from the EU stress tests and Extraordinary CNS. All STUK's related decisions, the national report to European Commission, the report to the Extraordinary CNS, and the National Action Plan have been published on STUK's website.

Based on the results of assessments conducted in Finland to date, it is concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. Areas where safety can be further enhanced have been identified and there are plans on how to address these areas. The experiences from the TEPCO Fukushima Dai-ichi accident are incorporated into the legislation and revised Finnish Regulatory Guides (YVL Guides).

IAEA peer reviews

Strengthen IAEA peer reviews in order to maximize the benefits to Member States

Finland regularly hosts international peer reviews and also offers its experts for the review in other countries. Finland also supports activities to improve peer review services and has already participated in the development of IAEA's peer review services (e.g. IRRS (Integrated Regulatory Review Service) and the OSART (Operational Safety Review Team) missions.

The latest peer reviews in Finland are the following:

- IAEA OSART safety review at Loviisa NPP in March 2007, with a follow-up review in July 2008
- WANO peer review at Loviisa NPP in March 2010 with a follow-up in April 2012, and in March 2015. The WANO review 2015 included also the WANO corporate review in January 2016. The WANO Follow up review will be in 2017.
- WANO peer reviews at Olkiluoto NPP in 2006, with a follow-up in August 2009, in 2012 with a follow-up in May 2014. The next WANO review will be carried out in October 2016.
- IAEA's International Physical Protection Advisory Service (IPPAS) mission in Finland in 2009, with a follow-up mission in April 2012
- A Peer Review of STUK's waste management related activities in 2009 (all EU member states were invited and representatives from 11 countries participated in the peer review)
- In 2011 STUK hosted a peer review of the emergency preparedness with the OECD NEA countries
- Finland had IRRT (International Regulatory Review Team) mission in 2001 and the follow-up mission in 2003. IRRS mission was carried out to the regulatory body in October 2012 and the follow-up mission in 2015.
- The Government of Finland has requested the IAEA to carry out four OSART missions in Finland between 2017-2022:
  - Olkiluoto 1&2 OSART mission will be conducted from 27 February till 16 March 2017
  - Loviisa NPP OSART mission would take place in March 2018
  - Pre-Operational OSART mission for Olkiluoto 3 before the first fuel loading (according to current schedule in April 2018)
  - Pre-Operational OSART mission for Fennovoima (Hanhikivi 1) would take place in 2022.

Finland continues the hosting and participation in the international peer reviews and will report the findings of these peer reviews as well as progress of the action plans in the national Convention on Nuclear Safety (CNS) report.

Emergency preparedness and response

Strengthen emergency preparedness and response

The Finnish concept of off-site nuclear emergency response has been developed since 1976, when the first public authorities' off-site emergency plan was prepared. The development has been a continuous process since then. The requirements for off-site plans and activities in a radiation emergency are provided for in the Decree of the Ministry of the Interior issued in 2011. Off-site emergency plans are prepared by regional rescue authorities. Legislation and plans define clearly the roles and responsibilities of stakeholders having a role in an emergency. Emergency exercises are conducted annually between the licensee and STUK. Every third year all authorities are training together at each site.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no needs for major changes were identified in off-site emergency preparedness. However, some improvements were identified and implemented those requiring improved accessibility to the site in case of extreme natural hazards, ensured that sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services and improved the communication arrangements between emergency centres of NPPs, STUK, and Rescue Service.

The rescue planning is enhanced by the co-operation between the nuclear power plant, regional rescue services, regional police departments and STUK. Permanent coordination groups have been established for both Loviisa and Olkiluoto NPPs in order to ensure coordinated and consistent emergency plans, to improve and develop emergency planning and arrangements and to share lessons from the exercises, regulations and other information. Also extensive training is arranged by these groups.

A National Nuclear Power Plant Emergency Preparedness Forum was also proposed in after the Fukushima accident for co-operation and combination between permanent groups with participation from Ministry of the Interior and the Ministry of Social Affairs and Health, the regional rescue service authorities, STUK and the NPP licensees. However, after the initial proposals, the group's field of responsibility was found to be mostly overlapping with other existing co-operation and co-ordination bodies. Therefore, it has been decided that creation of a new group is not the best way to address the issue. Instead, the membership and responsibilities of existing groups have been adjusted. For example, Ministry of the Interior is now also member in both of the regional groups.

In addition, a transportable, insulated and heated container for personnel protective equipment and radiation measuring instrument has been purchased in 2015 to quickly provide a certain amount of equipment in such a case when the normal storages in the NPP are unavailable e.g. due to the external hazards or fallout. The container can be transported by a truck and it can be connected to the electricity grid or to the movable power engine. The use of the container has been trained together with the NPP staff, police, rescue services and STUK.

Further improvement of arrangements for the coordination of information to the public and media during emergencies is needed to ensure that the messages issued by different authorities are consistent. Guidelines for co-operation among authorities have been written in a guidebook published in November 2012 and updated in 2015.

Nordic countries have published two joint documents that detail the cooperation arrangements. Nordic Manual (updated 2015) describes practical arrangements regarding communication and information exchange to fulfil the stated obligations in bilateral agreements between the Nordic countries. The arrangements in this document include all phases of events, including intermediate and recovery phases. The second document, Nordic Flag Book (published 2014), describes joint guidelines, including operational intervention levels, for protective measures concerning population and functions of the society in case of nuclear or radiological emergencies. These guidelines agreed by radiation and nuclear safety authorities in Denmark, Iceland, Finland, Norway and Sweden form a unique document as it includes practical criteria for early protective measures as well as recovery actions after contamination. Nordic Manual and Nordic Flag Book ensure that the response to any nuclear or radiological emergency in Nordic countries is consistent between the countries.

Finland participates actively in the international co-operation also in the field of emergency preparedness, such as IAEA, OECD/NEA and EU/EC (WENRA and HERCA). These working groups discuss i.a. mutual assistance and communication, co-operation and co-ordination of actions during nuclear of radiological emergencies. STUK has also hosted in 2009 a peer review organised by OECD/NEA on guides concerning protective measures in early and intermediate phases of a nuclear or radiological emergency.

National regulatory bodies

Strengthen the effectiveness of national regulatory bodies

According to the Finnish Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Employment and the Economy. It prepares for example licensing decisions for the Government. According to the Radiation Act, the overall authority in the field of the use of radiation and other radiation practices is the Ministry of Social affairs and Health. According to Section 6 of the Radiation Act and Section 55 of the Nuclear Energy Act, STUK is responsible for the regulatory control of the safety of the use of radiation and nuclear energy. The rights and responsibilities of STUK are provided in the Radiation and Nuclear Energy Acts.

The regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. No Ministry can take for its decision-making a matter that has been defined by law to be on the responsibility of STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

STUK carried out a self-assessment concerning i.a. the effectiveness of the regulatory body for the latest IRRS mission conducted in Finland in October 2012. STUK identified many topics to be further improved during the self-assessment and some additional recommendations and suggestions were also given during the mission. The IRRS mission team found that STUK is a competent and highly credible regulator and is open and transparent. It also concluded that STUK is very active in promoting experience sharing both nationally and internationally. Areas for further improvement to enhance overall performance of the regulatory system, included for example the following:

- although STUK operates in practice as an independent regulatory body, the Government should strengthen the legislative framework by establishing the regulator as a body separate in law from other arms of government
- the Government should seek to modify the Nuclear Energy Act so that the law clearly and unambiguously stipulates STUK's legal authorities in the authorization process for safety. In particular, the changes should ensure that STUK has the legal authority to both specify any licence conditions necessary for safety and specify all regulations necessary for safety
- Finnish legislative framework should be further developed to cover authorization for the decommissioning of nuclear facilities and the final closure of nuclear waste repositories
- STUK can further enhance the effectiveness of its inspection activities by enhancing the focus of inspection on the most safety-significant areas and developing a formal qualification programme for inspectors.

Based on the recommendations and suggestions an Action Plan has been prepared by STUK.

The IRRS follow-up mission was conducted in 2015. The purpose of the IRRS follow-up was to review the measures undertaken following the recommendations and suggestions of the 2012 IRRS mission. The scope of the follow-up mission was same as in 2012 i.e. nuclear facilities (except the research reactor FiR-1), radiation sources and transport. As the result of the follow-up mission the review team concluded that the recommendations and suggestions from the 2012 IRRS missions have been taken into account systematically by a comprehensive action plan. Significant progress has been made in most areas and many improvements have been implemented in accordance with the action plan. The IRRS team determined that 7 out of 8 recommendations and 19 of 21 suggestions made by the 2012 IRRS mission had been effectively addressed and therefore could be considered closed. Two new recommendations were raised to amend the legislation to clarify that decommissioning of an installation and closure of a disposal facility require a licence amendment; and to address the arrangements for research in radiation safety. STUK has updated its action plan and taken actions to complete it.

Operating organizations

Strengthen the effectiveness of operating organizations with respect to nuclear safety

The responsibility for the safety rests with the licensee as prescribed in the Finnish Radiation and Nuclear Energy Acts. Accordingly, it is the licensee's obligation to assure safe use of radiation and nuclear energy. Furthermore, it shall be the licensee's obligation to assure such physical protection and emergency planning and other arrangements, necessary to ensure limitation of nuclear damage, which do not rest with the authorities.

It is the responsibility of the regulatory body to verify that the licensees fulfill the regulations. This verification is carried out through continuous oversight, safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasises the licensee's commitment to the strong safety culture. The obvious elements of licensee's actions to meet these responsibilities are strict adherence of regulations, prompt, timely and open actions towards the regulator in unusual situations, active role in developing the safety based on improvements of technology and science as well as effective exploitation of experience feedback.

Several peer reviews have been carried out at the both Finnish NPPs during the last ten years (see above the section concerning IAEA peer reviews). The licensees have annually sent several peers to foreign peer reviews.

According to the Finnish regulatory guides, the licensees shall carry out a periodic safety review (PSR) at least every ten years. The Finnish PSR process and scope are in line with the IAEA guidance (SSG-25). PSR is seen as a very important tool for promoting the continuous safety improvement approach. The last periodic safety reviews were finalised in Loviisa in 2016 and in Olkiluoto in 2009. STUK regularly updates the regulatory requirements based on the operational experience feedback, research and technical development. The procedure to apply new or revised regulatory guides to existing nuclear facilities is such that after having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction.

IAEA safety standards

Review and strengthen IAEA Safety Standards and improve their implementation

The most important references considered in rulemaking at STUK are the IAEA safety standards, especially the Requirements-documents, and WENRA (Western European Nuclear Regulators' Association) Safety Reference Levels and Safety Objectives for new reactors. Finnish policy is to participate actively in the international work on developing safety standards and adopt or adapt the new safety requirements into national regulations. The newly developed regulations are highly in line with the most recent development of the IAEA safety requirements. Lessons learned from the Forsmark event in 2006 and the TEPCO Fukushima Dai-ichi accident in 2011 are incorporated into the STUK Regulations and the new set of YVL Guides published in 2013. STUK will update its Regulations and YVL Guides in 2017 taking into account e.g. updated IAEA Requirements documents.

International legal framework

Improve the effectiveness of the international legal framework

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. Finland has implemented the obligations of the Convention and also the objectives of the Convention are complied with. Finland has regularly reported and participated in the review meetings. Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in the use of a research reactor. Finland has participated in the working group on effectiveness and transparency of the Convention on Nuclear Safety and is supporting the initiatives to improve the CNS process.

The financial provisions to cover the possible damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of the Paris and Brussels Conventions in 2004, Finland has decided to enact unlimited licensee's liability by law (the Finnish Nuclear Liability Act). This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1500 million) has been exhausted. The revised law will also have some other modifications, such as extending the claiming period up to 30 years for victims of nuclear accidents. The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by government decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force.

As the ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect. In Finland, the finishing off the international ratification process of the convention amendments without any undue delay is considered to be extremely important.

Finland is a Member State of the European Union. In 2011 some amendments were done in the Nuclear Energy Act due to the Nuclear Safety Directive (Council Directive 2009/71/Euratom). In 2013, the Nuclear Energy Act and the Radiation Act were under an amendment process to implement the Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

The updated international requirements are reviewed and assessed by STUK to clarify the need for further modifications of STUK's regulations (STUK Regulations and YVL Guides). In this connection also the new requirements of Council Directive (2014/87/Euratom) amending Nuclear Safety Directive (2009/71/Euratom) and BSS directive (Basic Safety Standards Directive, 2013/59/Euratom) are reviewed and assessed their impact on the Finnish nuclear energy regulations; the laws and STUK's regulations.

Member states planning to embark on a nuclear power programme

Facilitate the development of the infrastructure necessary for Member States embarking on a nuclear power programme

Providing support to embarking countries is considered important in Finland. Finland is a member of the IAEA Regulatory Co-operation Forum and has participated on the Integrated Nuclear Infrastructure Reviews (INIR) missions organized by the IAEA. In addition, Finland participates in EU/EC INIS activities by providing experts and training to embarking countries as well as tutoring to experts from embarking countries. Finland has also organised and continues to organise training courses on the experience on regulatory oversight on new construction and project management, regulatory framework in Finland, and experts from embarking countries have participated. Experts from Finland have also lectured in individual IAEA training courses focused on embarking countries.

Capacity building

Strengthen and maintain capacity building

The competence of the licensees as well as the vendor and main subcontractors is one of the key review areas in the licensing processes for the use of radiation and nuclear energy and during the lifetime of the facilities. The requirements on the resources needed to be available for the licensee during normal operation as well as during emergencies are given in the regulatory guides.

The management of STUK highlights the need for competent workforce. STUK has adopted a competence management system and nuclear safety and regulatory competencies are also emphasised in STUK's strategy. Implementation of the strategy is reflected into the annual training programmes, on the job training and new re-cruitments.

The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organisations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and for the second ensuring the on-line transfer of the research results to the organisations participating to the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

There is a basic professional training course on nuclear safety organised together with the Finnish organisations in the field. The first course commenced in September 2003 and the 14th 6-week basic professional training course will commence in autumn 2016. At the moment, about 800 newcomers and junior experts, of whom about 80 have been from STUK, have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants.

Due to planned expansion of the use of nuclear energy in Finland, a comprehensive study has been conducted in Finland to explore the need of experts and education of experts in Finland to meet the needs from the organizations in the field. The study was completed in March 2012. The update of the competence review is planned to be carried on in 2017 to reflect the current changes in the operating environment.

Protection of people and the environment from ionizing radiation

Ensure the on-going protection of people and the environment from ionizing radiation following a nuclear emergency

During nuclear or radiological incidents and emergencies STUK is responsible for safety assessment of radiation situation and recommendations and advice for protective measures as defined in the Rescue Act. STUK provides recommendations of protective measures to authorities on local, provincial and governmental level. Furthermore, STUK provides advice to private sector for trade and commerce.

STUK has prepared so called VAL Guides, which contain the intervention strategy in Finland. VAL Guides contain protective measures and intervention levels in early and intermediate phases of a nuclear or radiological emergency, for various types of emergencies (such as fallout from nuclear detonation, severe accident in a NPP, malicious acts, contamination due to radioactive substances etc.). VAL Guides contain reference levels of exposure during the first year and factors, other than radiation, affecting choice of protective measures and protective measures to be considered during nuclear or radio-logical emergencies and transition to recovery. VAL Guides contain criteria when protective measures are needed and when those can be lifted or modified. Criteria are given for each countermeasure as a projected dose and as an operational intervention level. They also include triggers such as plant condition, or emergency action levels such as duration of a protective measure. VAL Guides include principles for reducing exposure of various parts of society (e.g. actions concerning population, exercising own profession in a contaminated area, decontamination, handling of waste containing radioactive substances etc.). VAL Guides are to be put into force by the Ministry of the Interior.

In Finland, there is an automatic external dose rate monitoring network consisting of about 250 stations throughout the country. Results are available in real time (every 10th minute). In addition, a network has 22 stations with spectrometers situated around the Finnish NPPs and in Helsinki. Nuclear power plants have trained monitoring teams capable of making dose rate and air concentration measurements. STUK has trained monitoring teams for dose rate monitoring, mobile spectrometers and a laboratory vehicle which has state of the art monitoring equipment for gamma (HPGe), alpha and air sampler. Results can be obtained in 30 second interval.

There is also a network of environment and foodstuffs laboratories which have the capability to measure gamma radioactivity levels in the food and environmental samples. STUK coordinates operation and provides technical support if needed. In addition, STUK has delivered regional hospitals monitoring equipment for monitoring iodine in thyroid. This measuring capability is meant for screening the public for contamination of iodine.

In addition to actual emergency rescue planning, roles and responsibilities of authorities for longer-term actions following a nuclear accident have been defined. Longer-term actions include e.g. decontamination of environment, management of waste containing radioactive substances, radiation monitoring and surveys, health control of the population, measures concerning agricultural and other production and measures to ensure uncontaminated food and feeding stuffs.

Communication and information dissemination

Enhance transparency and effectiveness of communication and improve dissemination of information

The Decree on the Finnish Centre for Radiation and Nuclear Safety (618/1997) defines STUK's tasks. One of the tasks is to inform about radiation and nuclear safety matters and participate on training activities in the area. STUK utilises many means to communicate with the public and interested stakeholders, such as meetings, seminars, and training courses. All these are tailored and targeted to different stakeholders and stakeholder groups.

STUK pays special attention to using internet to inform public and interested stakeholders about nuclear and radiation safety in general, risks related to radiation and use of nuclear energy, safety requirements, roles and responsibilities of STUK, STUK's organization, current activities and operating experience, significant regulatory decisions taken, events and publications and safety research. STUK web pages can be found (www.stuk.fi) in Finnish, Swedish and in English. STUK has also made itself available in social media (Facebook and twitter).

What comes to radiation emergencies and hazards, according to the Rescue Act and the Decree of the Ministry of the Interior concerning informing public during nuclear or radiological emergencies, the authority in charge is responsible for informing public on protective measures and other activities to be carried out. Authorities at governmental, provincial, and municipal level provide information on their own activities and give instructions regarding their own sphere of responsibility. In case of a nuclear power plant accident there are many organisations providing information. Thus special attention needs to be paid to coordination of timing and contents of information.

Further improvement of arrangements for the coordination of information to the public and media during emergencies is needed to ensure that the messages issued by different authorities are consistent. Guidelines for co-operation among authorities have been written in a guidebook published by the Ministry of Interior in November 2012, which contains the detailed information of the arrangements in the Finnish society in the case of a nuclear or radiological emergency. Even more general principles and guidance of coordination or public communication during emergencies are given in the guidance by prime ministers office.

In an accident situation the principal information route of warnings to the public is FM radio, TV and internet. The first outdoor warning to the public close the NPP is given by general warning signal via sirens or loudspeakers. By arrangement with broadcasting companies, urgent RDS-notifications can be transmitted promptly over the FM-radio and TV. There is a specific law for warning messages via radio and TV.

Finland has bilateral agreements with Sweden, Norway, Russia, Ukraine, Denmark and Germany on early notification of nuclear or radiological emergencies and exchange of information on nuclear facilities. In addition, STUK has bilateral arrangements with several foreign regulatory bodies, which cover generally the exchange of information on safety regulations, operational experiences, waste management etc. Such an arrangement have been made with NRC (USA), ASN (France), FANR (United Arab Emirates), NSSC and KINS (Republic of Korea), TAEK (Turkey), ENSI (Switzerland), SUJB (Czech Republic), Rostechnadzor (Russian Federation), CNSC (Canada), AERB (India), ONR (Great Britain), HAEA (Hungary), NNR (South Africa), NRA (Japan) and SSM (Sweden).

Research and development

Effectively utilize research and development

The Nuclear Energy Act was amended in 2003 to ensure funding for a long term nuclear safety and nuclear waste management research in Finland. Money is collected annually from the licence holders to a special fund. Regarding nuclear safety research the amount of money is proportional to the actual thermal power of the licensed power plants or the thermal power presented in the Decision-in-Principle. For the nuclear waste research, the annual funding payments are proportional to the current fund holdings for the future waste management activities. In 2016 the Nuclear Energy Act was amended and the temporary increase of the money collected to the nuclear safety research fund was introduced. The purpose of temporary increase of the research funding is to renew the ageing infrastructure for the nuclear energy related research. The increased funding is collected in between the years 2016 and 2015. At the first stage the additional funding is allocated for the new hot cell at VTT Center of Nuclear Safety (CNS) and at the second stage for the thermohydraulic laboratory at Lappeenranta University of Technology. The estimated investment for the VTT CNS hot cell laboratory is about 18 million euros.

The research projects are selected so that they support and develop the competences in nuclear safety and to create preparedness for the regulator to be able to respond on emerging and urgent safety issues. These national safety research programmes are called SAFIR and KYT. The structure for SAFIR2018 was renewed to enhance multidisciplinary co-operation within the research programme. Research areas are 1) Plant Safety and Systems Engineering, 2) Reactor Safety and 3) Structural Safety and Material. The key topics of the recent nuclear safety research programme (SAFIR2018) are automation, organisation and human factors, severe accidents and risk analysis, fuel and reactor physics, thermal hydraulics, structural integrity and development of research infrastructure. The amount of money collected from the licensees in year 2016 was about 9 million € for nuclear safety research. 4 million € is used to research projects and the rest is for the enhancement of the infrastructure. The decision by TVO to terminate the Olkiluoto unit 4 project in 2015 decreased the funding by 24 % for the SAFIR2018 research projects. The research projects have also additional funding from other sources. The total volume of the programme in 2016 was 6.4 million €. The results of the research programme are public. More information on the planning, steering and the research reports of the SAFIR and KYT programmes are available on the public websites (http://safir2018.vtt.fi/ and http://kyt2014.vtt.fi/).

In 2011, research needs originating from the TEPCO Fukushima Dai-ichi accident were studied, and an appendix addressing the topics for further research (e.g. spent fuel pool accidents) was added to the research programme. The SAFIR2014 research programme already included research projects on extreme weather phenomena, extreme seawater level variations and seismic issues. As a result of the TEPCO Fukushima Dai-ichi accident, a reassessment was made how the accident should be taken into account, and the research projects were somewhat redirected. The research programme was supplemented with research topics related to natural hazards and multiple failure events, the adequacy and scope of nuclear power plant design basis, mitigating the impact of accidents (e.g. high concentration of boron in the reactor circuit, hydrogen formation and transport, range of fission products released in core melt), and the overall life cycle of nuclear fuel including spent fuel pools. Some additional resources have also been allocated to the research of external events. The topics related to the TEPCO Fukushima Dai-ichi accident continue in the ongoing SAFIR2018 research programme. As an example of the newly started issues is the resilience of the accident management and systemic approach to the safety culture.

The objective of KYT2018 (Finnish Research Programme on Nuclear Waste Management) is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods. Likewise the previous programme also KYT2018 is divided into three main categories:

- new and alternative technologies in nuclear waste management
- safety research in nuclear waste management and
- social science studies related to nuclear waste management.

The main emphasis in the research programme will continue to be devoted to safety related research. The funding of the research programme is provided mainly by the State Nuclear Waste Management Fund (VYR) into which those responsible for nuclear waste management pay annually 0.08 % of their respective assessed liability. The current level of annual funding is 1.8 million €.

In Finland, the Technical Research Centre of Finland Ltd (VTT) is the largest research organisation in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy, half of them full-time. The total volume of the nuclear energy research in the year 2012 was about 75 million € (estimate of the Ministry of Employment and the Economy). This figure includes research related to use of nuclear energy made in all the stakeholder organisations. Two thirds of the research is focused on the disposal of spent fuel, mostly funded by the company Posiva Oy. The largest individual organizations are VTT, GTK (Geological Survey of Finland), LUT (Lappeenranta University of Technology) and Aalto University (former Helsinki University of Technology, HUT).

Finland also participates in international research activities, such as OECD/NEA/CSNI working groups, consortium which builds the Jules Horowitz research reactor (JHR) in France, Scandinavian NKS research programme, EU programmes, and bilateral co-operation with several countries. The Finnish technical support organisations are active parties of TSO organisations co-operation such as ETSON in Europe and IAEA TSO Forum.