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Finnish report on nuclear safety

Finnish 8th national report as referred to in Article 5 of the Convention on Nuclear Safety

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Executive summary

Finland signed the Convention on Nuclear Safety on 20 September 1994 and it 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 Eighth Review Meeting in March/April 2020.

There are two operating nuclear power plants 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 (Fortum), and the Olkiluoto plant two BWR units (boiling water reactors), operated by Teollisuuden Voima Oyj (TVO). In addition, a new nuclear power plant unit (PWR) at the Olkiluoto site was granted operating license in March 2019 and is expected to start operation later in 2019. At both sites there are interim storages for spent fuel as well as final disposal facilities for low and intermediate level nuclear wastes. Posiva, a joint company of Fortum and TVO, submitted a construction licence application for the spent nuclear fuel encapsulation plant and disposal facility in the end of 2012. The Government granted the construction licence to Posiva in November 2015.

Finland is currently reviewing a construction licence application for Fennovoima Hanhikivi unit 1 (VVER type design) in Pyhäjoki. Since the review is underway, Hanhikivi unit 1 is discussed in this report mainly with regard to the licensing process,organisatorial matters and siting (see Articles 7, 10, 11 and 17 and Annex 5).

Furthermore, there is a Triga Mark II research reactor, FiR 1 in Espoo operated by VTT Technical Research Centre of Finland Ltd (VTT). The reactor was permanently shut down in the end of June 2015. VTT applied for a license for the decommissioning in June 2017. Radiation and Nuclear Safety Authority (STUK) gave its statement on VTT's application to the Ministry of Economic Affairs and Employment in April 2019. After this the first license application for decommissioning phase in Finland will proceed to the Government for the decision making process.

In this report, the 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 Seventh Review Meeting are as follows: updating of legislative and regulatory framework, granting operating license for Olkiluoto 3, renewing the operating license of Olkiluoto 1&2 nuclear power units in 2018 including Periodic Safety Review (PSR). Furthermore, STUK completed its safety assessment of the operating license for decommissioining for the FiR 1 research reactor. Latest development in the various topics of the Convention on Nuclear Safety is described in the relevant articles.

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 be completed in 2019. 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.

Finland continues to host and to participate in the international peer reviews. The following missions have been performed or are planned for the period of 2017–2022:

- Olkiluoto 1&2 OSART mission. The mission was conducted from 27 February to 16 March 2017
- Loviisa NPP OSART mission. The mission took place in March 2018.
- Pre-Operational OSART mission for Olkiluoto 3. The mission took place in March 2018.
- WANO follow-up review at Loviisa NPP in 2017.
- WANO peer review at Olkiluoto NPP in October 2016 with follow-up in 2018
- IPPAS mission will be performed in 2020.
- ARTEMIS mission has been requested for 2022.
- IRRS mission will be requested for 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, to take into account updates in international requirements, e.g. the Council Directive 2014/87/Euratom amending Directive 2009/71/Euratom, the amendment (2014/52/EU) of Directive 2011/92/EU, and the radiation safety directive (2013/59/Euratom). No deviation from the Convention obligations has been identified in the Finnish regulatory infrastructure including nuclear and radiation safety regulations.
- Due to the aforementioned updates of the legislation, and due the fact that since the renewal of YVL Guides in 2013 nearly all IAEA Safety Requirements have been revised, and updated WENRA reference levels have been published, STUK started to update the YVL Guides anew in 2017. Until now (June 2019) 22 updated YVL Guides out of 47 are already published. Rest of the updated guides will be published later in 2019. The revised guides are applied as such for new nuclear facilities. Separate facility specific implementation decisions are made for the existing facilities and facilities under construction. Regular update and implementation of regulatory guides, particularly with regard to nuclear power plants in operation, are unique measures in the international perspective.
- The licensees have shown good safety performance 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) were reported and no major safety problems have occurred. After reorganising its activities in 2015, TVO experienced a decline in personnel job satisfaction that resulted in increased personnel turnover which challenged TVO's management to retain organisational conditions for a good safety performance. Since then TVO has carried out various development actions to correct the situation and STUK has been able to verify proof of the positive effects of the measures taken by TVO. The licensees' practices are considered to comply with the Convention obligations.
- Safety assessment is a continuous process and living full scope levels 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 2016–2018 in the connection of the operating license renewal. 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 lessons learned.
- The resources of STUK have been increased to meet the needs to oversee the construction of the new nuclear facilities in Finland. VTT supports effectively the regulatory body in the safety assessment work by performing safety analyses and providing safety analysis capabilities and tools. The national research programmes SAFIR and KYT develop and maintain the competencies

in nuclear safety and waste management to enable STUK to take measures in unexpected events at Finnish plants or elsewhere, and to support decision making for the benefits of society and the environment.
- STUK published a new strategy in 2018 covering the period of 2018–2022. The strategy is comprised of nine targets categorizied in three groups and supported by four core values as presented in Figure 1. The implementation of the strategy is underway.

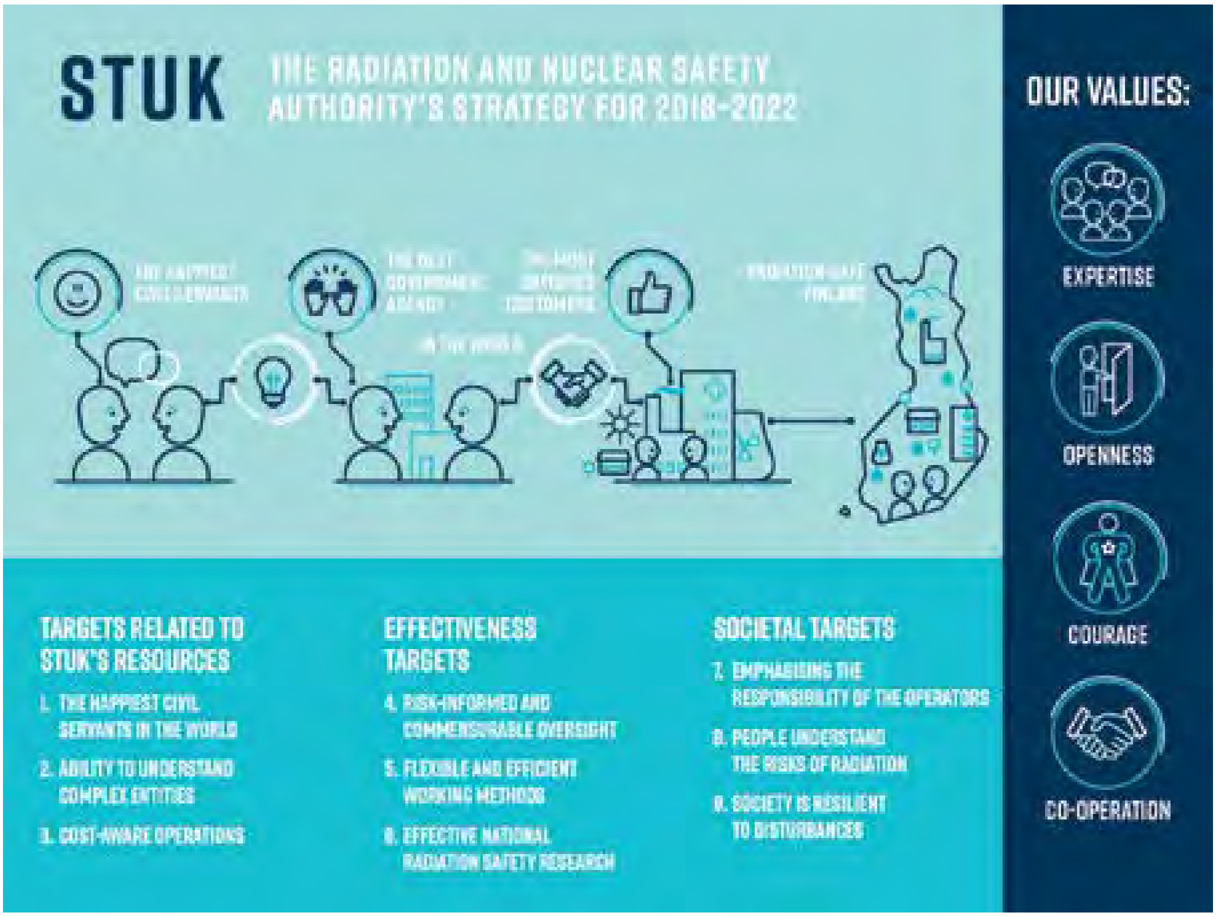


FIGURE 1. STUK's strategy for 2018–2022.

Challenges identified by the Seventh Review Meeting

The Seventh Review Meeting in 2017 identified some challenges and suggestions to improve nuclear safety in Finland. These issues are included and addressed in this report. The issues were as follows:
- To manage simultaneously the oversight of many on-going activities in different life-cycle phases of nuclear facilities. This is a situation that STUK has never dealt with before.
  - Provisions for plant ageing; I&C and other system modernisations carried out at the existing NPPs (incl. safety improvements); ageing management programmes are in place and re-reviewed in PSRs;
  - Commissioning of Olkiluoto unit 3, review of the operating licence application, commissioning tests, and start of operation;
  - Regulatory review of construction license application of Hanhikivi unit 1;
  - Decommissioning of the FiR 1 research reactor.

- To finalise STUK strategic communication plan for raising public awareness and knowledge in risks related to radiation and nuclear utilization.

Concerning the first challenge, the mentioned oversight activities are discussed specially in the context of Articles 14 and 19 and in Appendices 4 and 5. The review of the Olkiluoto 3 operating license application, as well as the review of the FiR decommissioning license application have been completed. On the other hand, the review of the CL application of Hanhikivi-1 has been delayed because some of the required application material has not been yet submitted to STUK. Concerning ageing management, STUK completed the assessment of the periodic safety review of Loviisa NPP in 2017, and of Olkiluoto 1&2 in 2018. The ageing management programmes were evaluated as a part of the assessment. The large I&C modernisation project (ELSA) at the Loviisa NPP was completed in the original timetable in 2018. STUK also participated in the Topical Peer Review under the Nuclear Safety Directive 2014/87/EURATOM, completed in 2017. As the main the oversight tasks are known well in advance, STUK is able to consider them in resource planning and knowledge management and in the use of technical support organisations. STUK's resources and the amount of oversight are discussed in more detail in Article 8.

Interest in nuclear power in Finland is increasing, due to on-going new-build projects and public debate about future prospects of so-called SMRs (Small Modular Reactors). With this in mind, communication and information sharing with media and the general public on nuclear and radiation safety has become an increasingly important success factor for STUK, relevant ministries and utilities. Regulatory processes and decisions have to be clear and understandable by the general public. Risks related to radiation should be communicated realistically. Due to this challenge, STUK has carried out a number of development measures to improve its strategic communications and the use of modern communication tools. In particular, STUK has focused on the communication capacity of its personnel. STUK applies the principle that all STUK's employees have both the right and duty to communicate with public and the media concerning their own area of expertise. For example, STUK's personnel is encouraged to represent STUK in the social media. STUK has also developed key messages to communicate radiation and nuclear risks, and continued to develop its crisis communication capabilities. Furthermore, STUK has defined strategic goals for communication, and measures – not only the outputs but particularly the outcomes – how communication changes opinions, attitudes and change of behaviour.

In addition, in the Seventh Review Meeting, some common major issues were identified based on the Country Group discussions. It was recommended that these issues are taken into account when preparing the national reports. Out of these issues, ageing management and safety culture were chosen to be discussed in the Eighth Review Meeting.

The nine common major issues are listed below with reference to the Articles (in brackets) in which the issues are addressed. Summaries related to ageing management and safety culture are given below, more detailed discussion can be found in Articles 14 (ageing management) and 10 (safety culture).

- Safety culture (Article 10)
- International peer reviews (Annex 6)
- Legal framework and independence of regulatory body (Article 7, Article 8)
- Financial and human resources (Article 8, Article 11)
- Knowledge management (Article 8, Article 11)
- Supply chain (Article 13, Article 14)
- Managing of safety of ageing nuclear facilities and plant life extensions (Article 14)
- Emergency preparedness (Article 16)
- Stakeholder consultation & communication (Article 7, Article 8, Annex 6).

Ageing management

STUK published in 2013 a YVL guide dedicated to ageing management. Up to 2013, the requirements for ageing management were covered by several different guides. In the guide published in 2013, some new requirements were introduced, mainly concerning the scope and content of the ageing management program, annual reporting and management of spare parts for long-lasting accidents. The guide has been updated since then, the latest version was published in February 2019. The implementation of the updated ageing management requirements is underway. The utilities have encountered some challenges in complying with the new requirements. For example, inspections performed after publishing the new guide in 2013 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 became obsolete. Another challenge had to do with knowledge and resources allocated for ensuring appropriate ageing management programme at NPPs. An 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. During recent years significant progress has taken place in the spare part management. Organisational arrangements have been made and a dedicated database (Proactive Obsolescence Management System) has been introduced in both Loviisa and Olkiluoto NPPs. Dedicated groups consisting of necessary disciplines such as maintenance, quality control and procurement have taken charge of spare parts in terms of necessary availability and conditions.

A generic lesson learned is that the closer the nuclear power plants come to the end of their licensed operation, especially due to the low market price of electricity, the more challenging it is for the licensees to initiate modernisations or other major activities to improve the safety of 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. The 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. In order to do that the licensee has to commit to making safety improvements including necessary major modernisations to address the ageing of structures, systems and components (SSC).

An expert group dedicated to ageing management has been established in STUK to oversee how the licensees perform their duties in the ageing management of SSCs. The group, consisting of mechanical, electrical, I&C, civil structure, and human resource experts as well as resident inspectors, plans and coordinates STUK's regulatory duties pertaining to the ageing of nuclear facility systems, equipment and structures. If any shortcomings are found, for example in the condition monitoring or maintenance, the group contacts the licensee for 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.

Finland participated in the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017–18. The overall conclusion was that the ageing management has been satisfactory. However, some challenges and areas for improvement, as well as good practices, were identified and Finland is establishing a national action plan to address the findings. The results of the TPR are discussed under Article 14.

Safety Culture

The STUK Regulation sets a binding requirement for the licensees to maintain a good safety culture where safety is the priority. STUK revised the Guide YVL A.3 setting requirements for leadership and management for safety based on the IAEA GSR Part 2.

STUK carries out safety culture oversight by collecting and analysing observations from resident inspectors, documents, events and from other interactions with the licensee. STUK has implemented a tool for recording the observations. STUK also conducts specific inspections focusing on Leadership and Safety culture. STUK also follows the licensees' safety culture self-assessments (e.g. results, possible changes in the methodology, actions decided based on the results). Furthermore, STUK has utilised VTT to carry out independent safety culture assessments in the licensee organisations. Independent safety culture assessments were done at Olkiluoto 1 and 2 (2016) and Olkiluoto 3 (2017) to support STUK in the Licence Renewal of Olkiluoto 1 and 2 and Operating Licence process of Olkiluoto 3. VTT also carried out an independent safety culture assessment for Fennovoima and its plant supplier and main contractor organisation in 2017.

The utilities employ several different means for maintaining good safety culture. Priority of safety is emphasised in the safety or company policies. In addition to high level policy, the licensees have safety culture programmes, road maps or development plans for implementing the measures for maintaining good safety culture. The licensees monitor the safety culture by regular surveys and in-depth assessments. They also have in their organisations groups or functions independent of the line organisation to oversee and discuss safety and safety culture matters. Corrective action groups or functions exist. Training – including safety culture topics – is given to all newcomers and usually also to contractors. The safety significant contractors are required to familiarise their workforce with safety culture principles which is one of the topics of licensees's audits on contractors and suppliers.

However, some challenges have appeard during the recent years.TVO reorganised its activities in 2015 resulting also in personnel reductions. These changes led to a decline in personnel job satisfaction and working climate. To ensure that these conditions would not affect the safety culture and safe operation, TVO has during the period 2016–2018 carried out various development actions to correct the situation. The effective corrective actions and monitoring their effectiveness were required by STUK. In 2018 and 2019, an improvement in the job satisfaction can be seen in TVO's personnel surveys. Concerning Fennovoima, an independent safety culture assessment in 2017 revealed some deficiencies. The assessment covered also the plant supplier and the main contractor. The conclusion was that the safety culture at Fennovoima was at an acceptable level. However, several areas required improvements. These included e.g. the responsibilities for handling safety related issues, nuclear specific competencies, control of the supply chain and climate for raising concerns.The safety culture assessment also concluded that the safety culture at the plant supplier and at the main contractor need significant further development.

At STUK, safety is emphasised in the Management System. In 2013, all the departments made a self-assessment of their safety culture. The results were used in updating STUK's safety and quality policy. In 2016 a safety culture survey was performed. In 2018 a comprehensive assessment of STUK's safety culture was performed by external experts. The safety culture at STUK was considered to be at a good level and especially safety was considered to be a true value in STUK's organization. Experts also identified several areas for improvement (e.g. learning from events and near misses, risk management, monitoring of safety culture), and these are addressed in a safety culture program which is under preparation. As a part of the preparation, a safety culture event was organised for STUK in April 2019 to discuss safety culture and particularly the risk management and learning from events and experience.

To better understand the ingrained conventions in the Finnish culture and their possible positive and/or negative impacts on safety culture, STUK has continued to explore the sociological factors influencing safety culture in the Finnish nuclear community within the Finnish nuclear research program SAFIR 2018. Furthermore, in March 2019 STUK hosted the OECD NEA and WANO managed Country-Specific Safety Culture Forum in Helsinki where personnel from the Finnish nuclear utilities and STUK discussed the country-specific culture traits and their possible influences on the nuclear safety culture. Report is being prepared by the NEA.

Challenges and good practices identified by Finland

Finland has identified the following challenges:

- Implementation of STUK's strategic objective related to the implementation of more risk-informed and performance-based regulation and oversight, and highlighting licensee's responsibility for safety, including
  - Changes needed to the nuclear energy regulations and regulatory guides, e.g. to be more be goal setting and enabling (also for emerging technologies, e.g. SMRs) and emphasising the licensees' responsibility for safety.
  - Developing the oversight activities to be more risk-informed and performance-based and emphasing licensees' responsibility, e.g. by crediting licensees' own oversight activities.
  - Development of oversight practices and tools to take into account the possibilities offered by digitalisation, and ensuring that the personnel has the necessary related skills.
  - Ensuring resources on the implementation of the strategic objectives as well as on the oversight of many ongoing activities in different life-cycle phases of nuclear facilities.

- Addressing the potential challenge related to the too stringent regulatory requirements preventing licensees to find suppliers to provide systems, structures and components needed for plant modifications and maintenance. Finnish licensees have established a project (KELPO) in which this challenge is partly being resolved by piloting the use of industrial standard components in safety class 3 applications.

- Long-term operation of the NPPs, including retention and renewal of the necessary competence.
  - Ageing management should be proactive and consider also technological obsolescence. Early preparations (design, contracts, qualification, licensing) are advisable. The closer the nuclear power plants come to the end of their licensed operation, especially due to the low market price of electricity, the more challenging it is for the licensees to initiate modernisations or other major activities to improve the safety of the NPPs.
  - Knowledge and resources allocated for ensuring appropriate ageing management programme at NPPs must be maintained.
  - Additional challenge is to conduct relevant research to both educate personnel and to identify possible new ageing mechanisms and to develop new inspection or monitoring technologies for early enough detection of degradation.
  - While new advanced inspection methods may reveal new defects, identification of the associated root or progress of the defecs over time is challenging

- Start of operation of Olkiluoto 3. A transition from a construction phase to operating phase can be a challenge both for the licensee and the regulatory body. The licensee should be ready to take the ownership of the plant, and the regulatory body should shift the focus of the oversight to ensuring safe operation which is different from overseeing a construction project.

A good practice is a practice, policy of program that makes a significant contribution to nuclear safety. It should be tired and proven in the country in question; not widely implemented in other countries but applicable to them. Good performance is otherwise similar, but may not be completely proven yet. Finland considers the following to be a good practice or a good performance:

- **Improving culture for safety:** Finnish nuclear community, including the regulator, has taken various actions to understand and improve culture for safety in their organisations. These include research activities in the Finnish nuclear research program SAFIR 2018 (e.g. the sociological factors influencing safety culture in the Finnish nuclear community), licensees and licence applicant's safety culture programmes complemented by independent safety culture studies conducted by VTT, STUK's studies on its own safety culture programme and development of a safety culture programme for further improvement, and organisation of a Country-Specific Safety Culture Forum in Helsinki where personnel from the Finnish nuclear utilities and STUK discussed the country specific culture traits and their possible influences on the nuclear safety culture. (good practice)

- **Requirement management at STUK:** STUK has developed a systematic approach for regulatory requirement management. The requirement management database contains the requirements presented in the regulations and guides. In the tool, each requirement has attributes (links to higher level legislation, links to licensing phase like construction or operation in which the requirement is relevant etc). Furthermore, the information about the fulfilment of the requirements at the facilities and the possible approved exemptions are recorded in the tool. This enables STUK to have all the time an overall picture of the compliance with the requirements at the NPPs. In updating the regulations and guides, the justification for modifications as well as comments received from the stakeholders are recorded in the tool. Between updates, recognised needs for modifications are also entered into the tool. (good practice)
- **Interpretation and implementation of the Vienna Declaration in the Finnish Regulations:** The Finnish Nuclear Energy Decree stipulates that the radioactive releases resulting 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. This safety goal is similar to the first principle of the Vienna Declaration. In addition, the Decree states that in order to limit the long-term effects, the limit for atmospheric releases of Cs-137 is 100 TBq. 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. STUK has included in the regulatory guides more detailed and more concrete interpretations for those safety goals of the Vienna Declaration. Guide YVL C.3 explains what is meant by "large-scale protective measures". Analyses must be provided to demonstrate that any release of radioactive substances in a severe accident shall not warrant the evacuation of the population beyond the protective zone (appr. 5 km) or the need for people beyond the emergency planning zone (appr. 20 km) to seek shelter indoors. Guide YVL A.7 states that a nuclear power plant unit shall be designed in a way that:
  - the mean value of the frequency of a release of radioactive substances from the plant during an accident involving a Cs-137 release into the atmosphere in excess of 100 TBq is less than $5 \cdot 10^{-7}$/year;
  - the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency. (good practice)
- **Radiation measurement team from volunteers:** A large scale nuclear or radiological emergency like a severe accident at a nuclear power plant, an explosion of a nuclear weapon or an explosion of so called dirty bomb could threat the function of the society. STUK, The National Defense Training Association of Finland and National Emergency Supply Agency launched in 2017 a project to establish a radiation measurement team from volunteers. The persons are trained and equipped by the three above mentioned organizations. The purpose of the team is to support authorities during a large scale nuclear or radiological emergency. In such situations, STUK's duty is to give recommendations to the domestic authorities. The recommendations are based, among other things, on the performed radiation measurements. The first training course for the volunteers was arranged in spring 2018, followed by another course in autumn of the same year.

The team is to consist of about 40 persons and it is assumed to start radiation measurements during the intermediate phase of radiation or nuclear emergency. (good practice)

- **The national nuclear safety research programme SAFIR:** SAFIR is a comprehensive nuclear safety research programme, where all relevant stakeholders are participating. It is a significant resource investment for a small country to ensure and develop national nuclear safety assessment capabilities and competencies. The results of the research projects in SAFIR are publicly available and can be used freely. All the results are reported in English, which enables using the results also outside Finland. (good performance)
- **Collecting regulatory experience:** STUK has further developed procedures and a dedicated database for collecting, recording and analysing findings of regulatory activities. The aim is to improve STUK's regulatory processes and functions based on the regulatory experience and share our lessons learnt with interested parties. The procedure for managing STUK's regulatory experience has been applied since the beginning of 2019. (good performance)
- **Communication with the public and the media:** STUK applies the principle that all STUK's employees have both the right and duty to participate in communication with the public and the media concerning their areas of expertise. STUK, for example, encourages its personnel to represent themselves as experts and STUK in social media. STUK has focused on communication capacity of its personnel and has published guidelines for the principles and practices of communication. Furthermore, STUK has defined strategic goals for communication, and measures – not only the outputs but particularly the outcomes – how communication changes opinions, attitudes and change of behaviour. (good performance)

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 radioactive releases resulting 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 Cs-137 is 100 TBq. 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. Also, the possibility of a release in the early stages of the accident requiring measures to protect the public shall be extremely small. Finnish regulatory guide YVL C.3 explains in more detail what is meant by "large-scale protective measures". Analyses must be provided to demonstrate that any release of radioactive substances in a severe accident shall not warrant the evacuation of the population beyond the protective zone (appr. 5 km) or the need for people beyond the emergency planning zone (appr. 20 km) to seek shelter indoors. Guide YVL A.7 states that a nuclear power plant unit shall be designed in compliance with the Government Decree principles in a way that:

- the mean value of the frequency of a release of radioactive substances from the plant during an accident involving a Cs-137 release into the atmosphere in excess of 100 TBq is less than $5 \cdot 10^{-7}$/year;
- the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency.

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 Nuclear energy Act states that a periodic safety review (PSR) shall be conducted at least every ten years. In addition, it states that 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 the Finnish NPPs since their commissioning. Especially the approach that STUK issues regulatory guides for new NPPs and regularly updates them, and then makes separate decision on the implementation and needed safety improvements at the operating nuclear facilities and facilities under construction, ensures reasonably practicable safety improvements at the Finnish nuclear facilities. Finnish regulations require also that licensees maintain an up-to-date and comprehensive plant-specific probabilistic risk assessment (PRA) and that they use the PRA to enhance nuclear facility safety, to identify and prioritise plant modification needs and to compare the safety significance of alternative solutions. 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 and guides 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 the international guidance (e.g. the IAEA safety standards and the WENRA safety reference levels) and the lessons learnt from the Fukushima Dai-ichi accident. Due to updates in the IAEA Safety Requirements and in the WENRA Reference Levels since then, STUK started to update the YVL Guides anew in 2017. The updated guides will be published in 2019.

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. The IRRS mission (the IAEA's Integrated Regulatory Review Team) was carried out in October 2012 and the follow-up mission in 2015. No urgent need exists 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 Eighth Review Meeting in March/April 2020.

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. 6, 19 January 2018, was used as a guideline for the context of the report. Furthermore, the guidance prepared by the 8th Review Meeting President and sent to the National Contacts by letter dated on December 13, 2018, 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.

This Eighth 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 Seventh 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.

There are two operating nuclear power plants 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 (Fortum), and the Olkiluoto plant of two BWR units operated by Teollisuuden Voima Oyj (TVO). A third unit at the Olkiluoto site, Olkiluoto 3 (pressurized water reactor with nominal thermal power 4300 MW), received operating license in March 2019 and is planned to start operation later in the year. At both sites there are fresh and spent fuel storage facilities, and facilities for storage and treatment of low and intermediate level nuclear wastes. Other existing nuclear installations in Finland are the disposal facilities 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.

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 final 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 disposal facility 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 completed during 2016. Posiva was granted a construction licence for the spent nuclear fuel facility 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 was planning to complement its documentation during the years 2015–2017 according to a licensing plan. However, submitting the licensing documentation has been further delayed and in April 2019 the licensing documentation sumitted to STUK was still incomplete (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 Environmental Impact Assessment (EIA) procedure for decommissioning was conducted in 2013–2015. The reactor was permanently shut down in the end of June 2015. VTT applied operating license for the decommissioning phase in June 2017. At that time, decommissioning was not considered as a separate licensing step in the Finnish legislation, but decommissioning phase was to be carried out under an operating license. In beginning of 2018, decommissioning licence was added in the legislation as a new licencing phase for nuclear facilities. STUK gave its statement about VTT's application to the Ministry of Economic Affairs and Employment in April 2019. After this the first license application for decommissioning phase in Finland will proceed to the Government for the decision making process. 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.

FIGURE 2. FiR 1 research reactor.

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 licensee (Fortum Power and Heat Oy) holds the operating licences of the units, which are valid until the end of 2027 (Loviisa 1) and 2030 (Loviisa 2). The licence renewal of the plant took place in 2005–2007. The Loviisa plant reached its original design lifetime 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 Economic Affairs and Employment with its statement on the safety of the plant. The Finnish Government granted the new operating licences as mentioned above in July 2007. 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 was completed in February 2017. Based on the assessment, STUK considered that the Loviisa NPP meets the set safety requirements for operational nuclear power plants. The second periodic safety review process has started in the end of 2018 and will be finalised before 2023. The licencee's project also includes the evaluation of the possibility to continue operation beyond the current operating licence, but no decision on the lifetime extension has been made yet. Further information about periodic safety reviews at the Loviisa NPP is presented in Annex 2.

As a result of consistent plant improvements, the safety level of the plant has been increased as shown by the results of the probabilistic risk assessment (see Article 14). The latest large improvements – the renewal of the plant I&C safety systems and the renewal of the secondary circuit safety functions – were completed at the outages in 2018.

Due to the TEPCO Fukushima Dai-ichi accident, safety improvements have been implemented at the Loviisa NPP. The most important improvements for the Loviisa 1 and 2 are:

- Flood protection. The licensee has estimated the effects of high sea water level on the plant safety. The licensee 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. Physical modifications have already been implemented and final updates for procedures will be finalized by the summer 2019.

FIGURE 3. Loviisa nuclear power plant units 1 and 2. Source: Fortum.

- Installation of diverse water supply to the spent fuel pools. STUK has approved the design plans. The plant modifications will be completed during 2019 outages.
- 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.
- Ensuring 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 modifications related to the TEPCO Fukushima Dai-ichi accident, as well as other latest ongoing improvements at the Loviisa NPP are described in more detail in Article 18 and in Annex 2.These also include the most significant plant modifications and modernisation projects carried out at the Loviisa nuclear power plant during the plant lifetime, as well as STUK's safety reviews. During recent years, only minor operational events have taken place and no major safety issues have occurred (see also Article 19).

Plant lifetime management includes adequate 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 the Loviisa plant units is the risk of reactor pressure vessel brittle fracture. Several modifications to reduce this risk have been implemented, but some further improvements are to be introduced in 2019 at both units. During the latest operating licence renewal process Fortum submitted a comprehensive analysis based on which the brittle fracture risk can be managed until the end of the 50 years plant lifetime.

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 NPP in November 1990, in March 2007 with the follow-up review in July 2008 and the last one in March 2018. The WANO peer reviews have been carried out at the Loviisa NPP at the beginning of 2001, in March 2010 with a follow-up review in 2012, and in March 2015 including also the WANO corporate review in January 2016 and the WANO follow-up review in 2017. The latest WANO peer review was in March 2019.

TABLE 1. Operational data of Loviisa NPP in 2016–2018.

Year	Net production LO1/LO2 [GWh]	Load factor LO1/LO2 [%]	Duration of refueling and maintenance outage LO1/LO2 [days]	Collective radiation dose LO1/LO2 [manSv]
2016	3863/4069	88,6/93.5	38/20	0.522/0.321
2017	4087/4072	93/92.9	21.4/17,6	0.237/0.276
2018	4229/3771	90.9/85.9	26.5/46.7	0.267/0.973

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 units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the previous 2160 MW licensed in 1983. The original power level of both units was 2000 MW, thus the current power level is 125% of the original one. The Operating Licences of the units are valid until the end of 2038.

The latest periodic safety review (PSR) of the Olkiluoto units 1 and 2 was carried out in 2016–2018 in connection of the licence renewal of the operation of the plant. Based on the application, STUK carried out a comprehensive review of the safety of the Olkiluoto plant. The review was completed in May 2018 when STUK provided the Ministry of Economic Affairs and Employment with its statement on the safety of the plant. The Finnish Government granted in September 2018 an operating licence for units 1 and 2 until the end of 2038. One periodic safety review has to be carried out by the licensee as a licence condition (by the end of 2028). The operating licence renewal of Olkiluoto NPP units 1 and 2 is described in more detail in Annex 3.

The most important safety improvements due to the TEPCO Fukushima Dai-ichi accident under planning and implemented at Olkiluoto 1 and 2 are:

- Assessing possibilities to ensure cooling of the reactor core in case of total loss of AC supplies and systems. The resulting arrangement will consist of high and low pressure systems. The high pressure system is based on a steam driven turbine, and the low pressure system pumps coolant into the core from the fire fighting system. The modifications were implemented in 2016–2018.
- Ensuring operation of the auxiliary feed water system pumps independently of the sea water cooling systems. The modification has been implemented at Olkiluoto 1 in 2014. During the testing of one subsystem abnormal vibration and pressure oscillations were observed, and therefore the modification in Olkiluoto 2 was delayed. The vibration issue at Olkiluoto 1 has been solved and the modification will be implemented at Olkiluoto 2 in 2019.
- The diverse cooling water supply to the spent fuel pools in the reactor building have been completed in 2015. To support monitoring of the water level in the spent fuel pools a measurement system was implemented in 2017.The utility has acquired new mobile equipment (aggregates, pumps) to inject water into the pools.
- The availability of cooling water and emergency diesel generator fuel in case of accidents at multiple reactor units and other nuclear facilities at the same site has been evaluated as adequate.

FIGURE 4. Olkiluoto nuclear power plant units 1 and 2. Source: TVO.

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

In addition to the regulatory oversight and safety assessment, there have been independent safety reviews conducted by international organisations. The IAEA OSART missions has been conducted at Olkiluoto in 1986 and 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 and in 2016. The WANO review 2016 also included the WANO corporate review.

TABLE 2. Operational data of Olkiluoto NPP in 2016–2018.

Year	Net production OL1/OL2 [GWh]	Load factor OL1/OL2 [%]	Duration of refueling and maintenance outage OL1/OL2 [days]	Collective radiation dose OL1/OL2 [manSv]
2016	7048/7301	91.4/94.6	21/10	0.64/0.24
2017	7158/6256	93.1/81.3	10/64	0.22/0.73
2018	6755/7334	87.8/94.3	41/14	0.84/0.26

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 is on-going. TVO submitted the operating licence application in April 2016 to the Ministry of Economic Affairs and Employment. Operating licence is needed prior to loading nuclear fuel into the reactor core. STUK gave its statement and safety assessment in February 2019 and the Finnish Government issued the Operating Licence in March 2019. However, operating license alone does not allow starting fuel loading to the reactor. Some preparations for operation were still ongoing art the time the operating license was granted (e.g. some pre-operational tests, implementation of security arrangments, V&v of operating procedures) and before fuel loading STUK will verify that all preparations for safe operation have been complete. IAEA carried out pre-OSART already in March 2018, as at that time the fuel loading was expected to happen during spring 2018. 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.

FIGURE 5. Olkiluoto NPP unit 3. Source: TVO.

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 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, commissioning, operation and decommissioning 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 legislation aimed to increase the independence of STUK and to extend its authorities. The Nuclear Energy Act was amended in 2015. The Government, when making a decision in principle, and the licensing authority as giving a license, were obligated to take into account STUK's proposals given in the preliminary safety assessment and safety proposals given by STUK in its license application statement. Regulations were added expanding STUK's mandate in radiation monitoring in the immediate vicinity of nuclear facilities and giving STUK a mandate to issue binding

STUK Regulations concerning the areas of previous Government Decrees; the safety of nuclear power plants, safety of the disposal of nuclear waste as well as emergency and security arrangements of nuclear facilities, and a new area concerning mining and milling operations aimed to produce uranium or thorium. STUK issued the regulations on 1st January 2016. Updates were published and came into force on 15th December 2018.

- STUK Regulation on the Safety of Nuclear Power Plants (STUK Y/1/2018)
- STUK Regulation on Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2018)
- 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/4/2018)
- STUK Regulation on the Safety of Mining and Milling Operations aimed at Producing Uranium or Thorium (STUK Y/5/2016).

STUK Regulations and their explanatory memorandums are published in Finnish and Swedish which are official. English translations are also published but their status is unofficial.

The Nuclear Energy Act was amended in 2017 for implementation of the Council Directive 2014/87/Euratom amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations. The amendment of the Nuclear Energy Act entered into force on 1st January 2018 and supplemented also the former implementation (2013) of the Nuclear Waste Directive (2011/70/Euratom) due to the additional questions by the Commission. The most significant changes caused by the directives concerned transparency of activities, licensee's obligation to provide information and responsibility for subcontractors, involvement of the population in decision-making concerning the nuclear facility licensing and international peer reviews. At the same time, the provisions of the act regarding pressure equipment were updated due to the new Pressure Equipment Act (1144/2016) that entered into force on 1st January 2017. In addition, national legislation was deemed to require disambiguation on matters related to the decommissioning of nuclear facilities and nuclear waste management, which is why further specifications were entered in the act regarding these matters, and the decommissioning licence was added as a new licencing phase for nuclear facilities, and changes were made regarding waste management.

The Nuclear Energy Act amendment proposals concerning security arrangements in the use of nuclear energy were started in conjunction with the preparation for the amendment that entered into force in the beginning of 2018, but were separated from the Nuclear Energy Act amendment bill based on the feedback received during the circulation for comments. Preparation of the bill was continued by the Ministry of Economic Affairs and Employment, STUK, the Ministry of the Interior and the Ministry of Justice separately, and the government bill for amending the act was sent for comments on 15 November 2018 and statements were requested by mid-January 2019. The amendment proposal concerns e.g. authorities of security personnel and the temporal dimension of the use of security personnel, specially the point of time when security organisation have to be established in new plant projects. Provisions on health examinations for security and control room personnel and the right to report of the doctor or other medical professional in relation to the health examinations are proposed to be added to the act as completely new items. New items also include rules of jurisdiction concerning defence against drones and unmanned aerial vehicles at nuclear power plant sites. This amendment of the Act will possibly enter into force by the end of 2019.

The amendments to the Nuclear Energy Act due to the amendment (2014/52/EU) of Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment came into force on 1st May 2017. The new requirements in the Act concerned the Environmental Impact Assessment (EIA) responsibilities of the license applicant, informing about a pending application and measures that the licence shall include for preventing or reducing significant detrimental environmental impacts.

The Nuclear Energy Decree (161/1988) was amended in 2017 and the amendment entered into force on 1st January 2018. Due to the amendments made to the Nuclear Energy Act provisions further specifying the licencing procedure regarding decommissioning of nuclear facilities and oversight by STUK were added to the decree. Provisions regarding the minimum contents of the national nuclear waste management programme were also added to the decree. Due to the new Environmental Impact Assessment Act (252/2017) the references to the EIA procedure were updated. Furthermore, provisions regarding the phases of and documents related to the procedure were amended for compliance with the new act. Some minor technical corrections and specifications were also made to the Nuclear Energy Decree.

Implementation of STUK's new strategy includes developing the regulations and guides to support the strategy. STUK has started the evaluation of needed modifications. In the same context, STUK evaluates if there are any needs to modify the present licensing model presented in the Nuclear Energy Act and Nucelar Energy Decree (Decision in Principle – Construction License – Operating License – Decommissioning License), for example considering the applicability of the present models to SMRs.

On 15 December 2018, the new Radiation Act (859/2018), the Government Decree on ionising radiation (1034/2018), the Decree of the Ministry of Social Affairs and Health on ionising radiation (1044/2018) and the Decree of the Ministry of Social Affairs and Health on limiting public exposure to non-ionising radiation (1045/2018) entered into force. The new radiation legislation implemented the EU radiation safety directive (BSS, 2013/59/Euratom). The requirements of the BSS directive concerning the use of nuclear energy were implemented through the amendment to the Nuclear Energy Act (862/2018), which entered into force on 15 December 2018 as an annexed act to the Radiation Act. The new Section 2a on the application of the Radiation Act to the use of nuclear energy was added to the Nuclear Energy Act. New sections on the exemption of radioactive waste from regulatory control, clearance levels and dilution prohibition of nuclear waste were also added to the act.

When the radiation legislation was reformed, not only contents but also statutory levels were checked to ensure that they are in line with the requirements of the Constitution. In practice, this means that requirements that were previously included in radiation safety guides (ST Guides) and decisions issued by the Radiation and Nuclear Safety Authority are now presented as binding provisions in acts, decrees and STUK Regulations issued by virtue of the Radiation Act.

The first regulations issued by virtue of the Radiation Act by the end of December 2018 concerned work-related radiation exposure, radiation safety deviations, security arrangements for radiation sources, and ionising radiation measurements relating to work-related exposure, public exposure and medical exposure. The regulations on radiation safety deviations and security arrangements for radiation sources are not applied to the use of nuclear energy referred to in the Nuclear Energy Act (990/1987).

By virtue of the Radiation Act and the Nuclear Energy Act, STUK also issued on 15 December 2018 a new common regulation on the exemption values for radioactive substances and the clearance levels of radioactive materials. However, the clearance values are not applied to the use of nuclear energy.

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 requirements. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety level in accordance with the Nuclear Energy Act and STUK Regulations, 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 to propose plans for improvement and schedules for achieving compliance. After having heard those concerns, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear facilities, or to those under construction. STUK can approve exemptions from new requirements if it is not technically or economically reasonable to implement respective modifications and if the safety justification is considered adequate. This is a case by case decision. For example Finnish operating NPPs are granted excemptions from the requirements concerning protection against large airplane crashes.

In compliance with the national strategy and with expectations of IAEA the 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 utilising nuclear energy, e.g. OECD/NEA, MDEP (Multinational Design Evaluation Programme), VVER Forum, and EU Clearinghouse. The Finnish policy is to participate actively in the international discussions 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 regularly re-evaluated for updating. If there is not any immediate need for corrections or updates of YVL guides (e.g. EU directives, new international requirements or update of pertinent national legislation) there are criteria in STUK's management system guidance for the review and updating of the regulations. The preparation process of the regulatory guides includes internal and external commenting of STUK and the stakeholders and hearings of relevant advisory committees. The public participation is made possible through the website of STUK where the drafts for external commenting are 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.

A Safety management of a nuclear facility	**B Plant and system design**	**C Radiation safety of a nuclear facility and environment**	**D Nuclear materials and waste**	**E Structures and equipment 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 Leadership and management for safety 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 Information security management of a nuclear facility	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.1 Structural radiation safety at a nuclear facility C.2 Radiation protection and exposure monitoring of nuclear facility workers C.3 Limitation and monitoring of radioactive releases from a nuclear facility C.4 Assessment of radiation doses to the public in the vicinity 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.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 thorium in the mining and milling industry D.7 Release barriers of spent nuclear fuel disposal facility	E.1 Authorised inspection body and the licensee's in-house inspection organisation E.2 Procurement and operation of nuclear fuel and control rods E.3 Pressure vessels and piping 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 E.13 Ventilation and air conditioning equipment of a nuclear facility
Collected definitions of YVL Guides: same data is shown both as the collection and within the guides.				

FIGURE 6. The structure of regulatory guides (YVL Guides).

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 on-site 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 took place during 2016. These were left to wait for publication due to the needed changes in the legislation and upper level regulations. Unofficial English translations of YVL Guides were also published. Justification memorandums were published in connection of each guide in Finnish.

Systematic training on application of new YVL Guides were 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.

The guidance has since 2013 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.

Using numbered requirements enables systematic requirement management. STUK uses a commercially available software (Polarion). In the tool, each requirement has attributes (links to higher level legislation, in which phase of a life cycle of the facility the requirement is relevant etc). The attributes enable performing different searches. Furthermore, the information about the fulfilment of the requirements at the facilities and the possible approved exemptions are recorded in the tool.

With regard to operating nuclear facilities and those under construction, the Guides shall be enforced through a separate decision to be taken by STUK. After publishing the new YVL guides at the end of 2013 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 (Olkiluoto 3) 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's target was to create a common view on application of requirements in new YVL Guides for existing nuclear facilities and store the information in the requirement management system to be utilised in STUK's oversight activities in future. STUK made requirement by requirement assessment in the requirement management tool and based on this work an overall assessment of the safety of the nuclear power plant and planned safety improvements.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 started the evaluation work for Olkiluoto unit 3 in 2016 together with the review of the operating licence application. The implementation decisions were finalised and sent to the licensee in 2017 and the YVL Guides published at the end of 2013 entered into force for Olkiluoto 3 as the operating license was granted on 7th March 2019.

STUK made in 2017 policy decisions regarding the application of the YVL Guides to Posiva's spent fuel encapsulating and disposal facilities during their construction phase and during the future licensing phases.

The YVL Guide implementation decisions covered 45 YVL Guides and the around 6400 requirements included in them. STUK assessed guide-specific reports by the licensees, focusing on the processing of non-conformances and measures proposed by the licensees. According to STUK's evaluation, the revised guides did 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 were in line with the updated requirements). Several plant modifications had also been implemented during last decades or were under implementation based on previously updated regulatory requirements, PRA results and periodic safety review (PSR) results. Operating NPPs had nevertheless, during the next few years, to expand the scope of their accident analyses, to improve measures related to the facilities' ageing management and to develop facility documentation that advances the traceability of modification plans. More than 60 people participated in the preparation of STUK's implementation decisions, using 6 man-years.

After the renewal of YVL Guides in 2013 nearly all IAEA Safety Requirements documents were revised. Just because of TEPCO Fukushima Dai-ichi accident IAEA had 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 had 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 were committed to improve and harmonize their national regulatory systems by implementing the new Safety Reference Levels until the end of 2017.

The updated international requirements were 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) were reviewed and assessed their impact on the Finnish nuclear energy regulations; the legislation and STUK's regulations.

The YVL Guide update work began in 2017 using STUK's requirement management system. Extend of the revision of each YVL Guide was assessed and decided (minor or major changes). In most of the YVL Guides only minor changes were needed. In 2017 a total of 13 and in 2018 24 YVL Guides were sent for comments and statements. The five remaining YVL Guides under update and two totally new YVL Guides (YVL D.6, YVL E.13) will be sent for comments in 2019. Changes in YVL guides were mainly clarifications, updates to references to regulations and minor changes to requirements. Also the feedback from licensees received in the implementation of YVL Guides published in 2013 was taken into account in the update. Special objective in this YVL Guide update was to reduce licensee's and regulators administrative burden where possible. STUK processed together 5000 comments and proposals for changes, 60 per cent of which were approved for implementation in this revision round. Both in 2017 and in 2018 more than 100 persons at STUK participated in the updating of STUK regulations and YVL Guides using approximately 10 person-years within these 2 years. Updated YVL Guides and their explanatory memorandums are published on web (Stuklex and Finlex) in Finnish and English by the end of 2019. Until now (June 2019) 22 YVL Guides are already published.

System of licensing

The licensing process is defined in the Finnish legislation. The construction, operation and decommissioning of a nuclear facility is not allowed without a licence. The licensing process is lead by the Ministry of Economic Affairs and Employment and licenses are granted by the Government. The conditions for granting a licence are prescribed in the Nuclear Energy Act Chapter 5 (Sections 16-27). For a nuclear power plant, nuclear waste disposal facility, or another significant nuclear facility the process consists of four steps (see Figure 7):

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

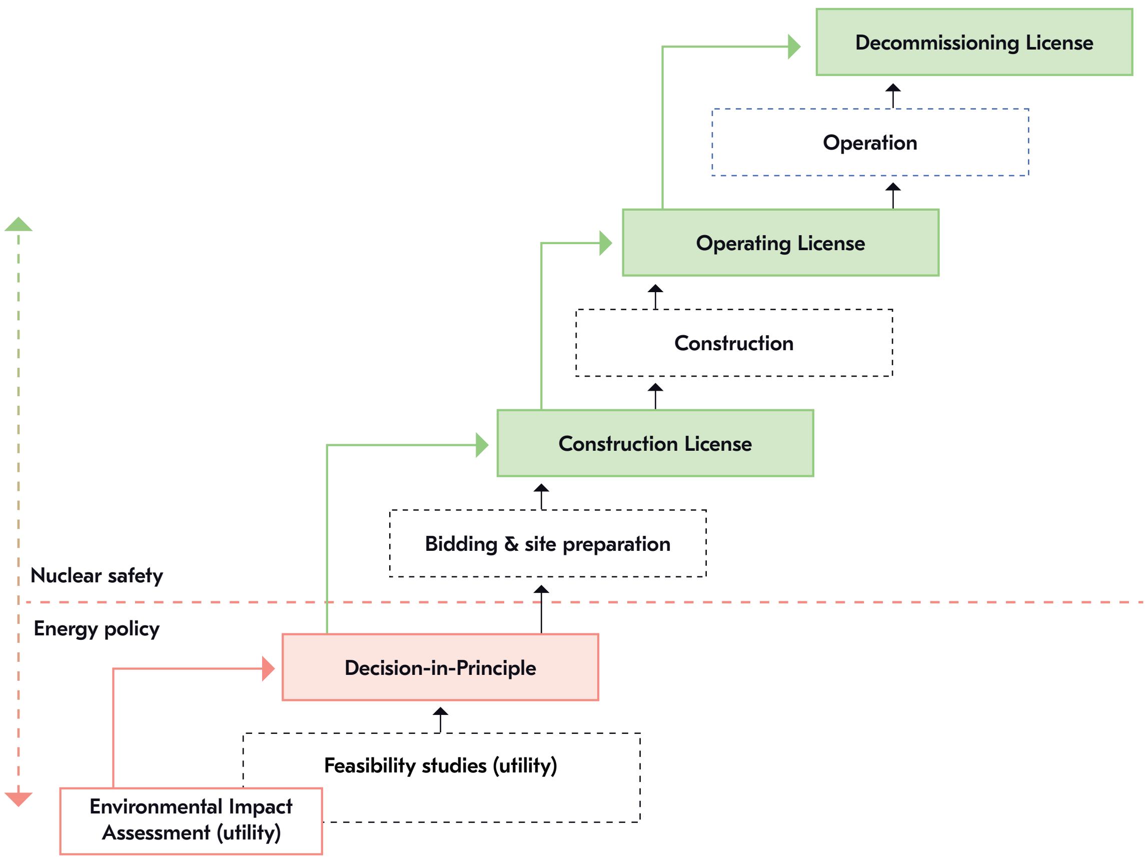


FIGURE 7. Four steps of licensing of nuclear facilities.

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 (DiP) by the Government and a subsequent ratification of the DiP by the Parliament are required. DiP-process is prescibed in the Nuclear Energy Act Chapter 4 (Sections 11–15). 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. Nuclear Energy Decree has been complemented in 2017 with a requirement that the applicant shall submit as a part of DiP application a reasoned conclusion by the competent authority on the EIA assessment report as a conclusion of successful EIA process. The admendment was introduced as a lesson learned from Fennovoima Hanhikivi 1 DiP and EIA processes. 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 8. 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 Committee on Nuclear Safety and from the Ministry of the Interior concerning the emergency preparedness and physical protection arrangements.

For the construction, operating and decommissioning licence application, the Ministry of Economic Affairs and Employment 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 on emergency preparedness and security arrangements. After receiving all statements for the construction, operating or decommissioning license, the Government will make its decision. In the construction, operating and decomminnioning licence phases the acceptance of the Parliament and the host municipality are no more needed.

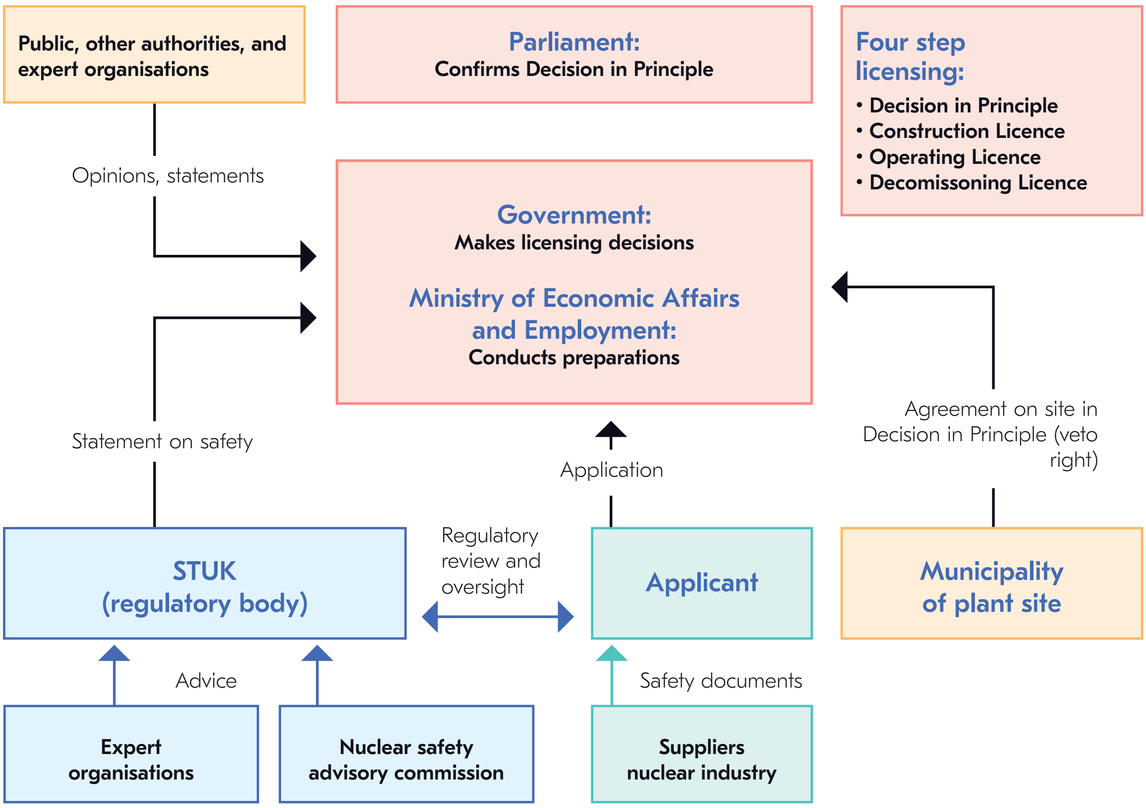


FIGURE 8. Stakeholders in the licensing process.

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 and 2017. Based on these changes the Government has to take into account the proposals included in the STUK's statements when considering the (licensing) 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 (Rosatom 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 Economic Affairs and Employment 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 plant and system-level design data of the plant and systems 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. Decommissioning licensing (Section 20a) was introduced into Nuclear Energy Act during 2017 revision as the need for nuclear facility decommissioning has become actual in Finland with research reactor FiR in Espoo.

System of regulatory oversight 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 (Section 55). 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 a 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, as well as refuelling and 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. Each year STUK defines the inspections within the programme for the next year, including additional inspections as necessary.

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. According to updated internal guide, many of the yearly conducted inspections have been decided to be carried out every two years. The inspections focusing 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. The operating experience is reported to STUK later 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. In 2017, the guidance was supplemented to include inspection program covering the period of construction license application review.

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, 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 Economic Affairs and Employment. The Ministry prepares matters concerning nuclear energy to the Government for decision-making. Among other duties, the Ministry of Economic Affairs and Employment 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 9. 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.

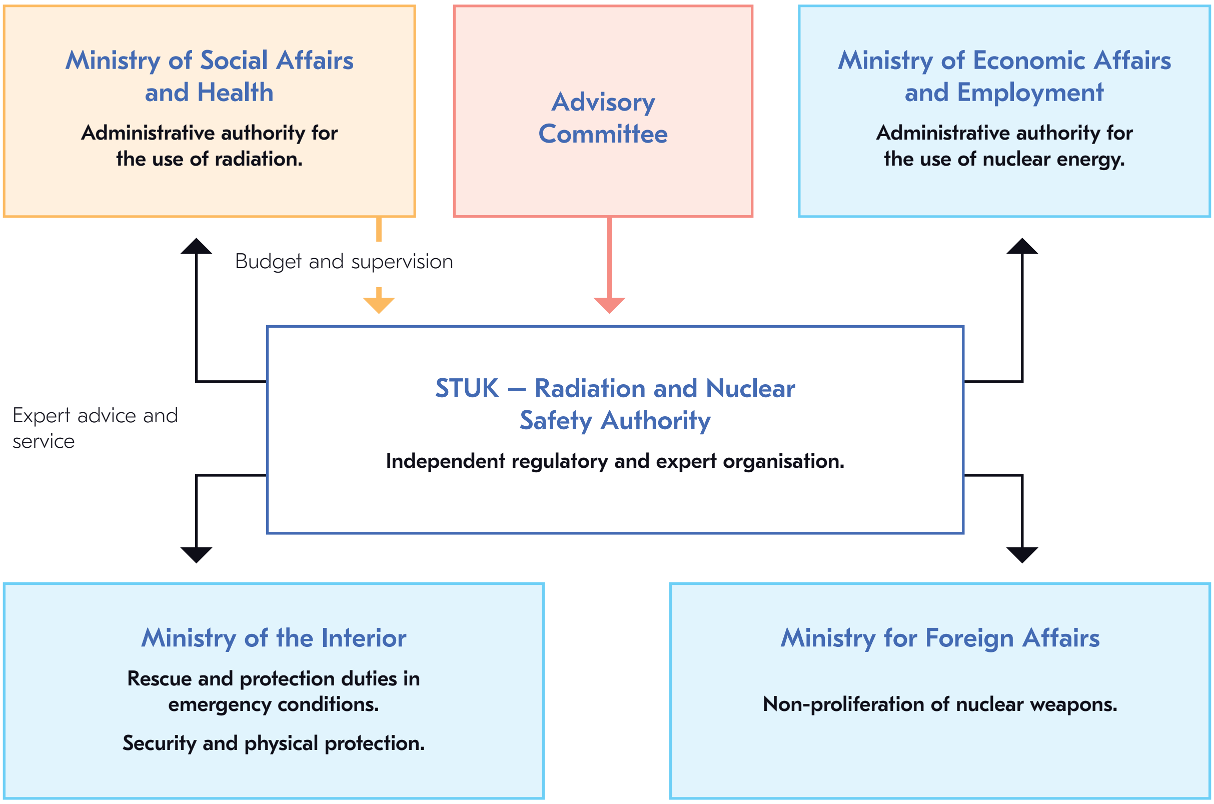


FIGURE 9. Co-operation and interfaces between STUK and Ministries and other organisations.

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 Committee on Nuclear Safety was established in 1988 by a Decree. This Committee gives advice to STUK on important safety issues and regulations. The Committee also gives its statements on licence applications. The Committee has now two international committees, one for reactor safety (RSC) and one for nuclear waste safety and decommissioning (NWSC). In addition, an Advisory Committee on Radiation Safety has been established. The committee gives statements on important radiation safety issues and regulations. The members of the Advisory Committee on Nuclear Safety and the Advisory Committee on Radiation Safety are nominated by the Government.

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 communicating with 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. STUK also uses social media platforms for two-way public communication. 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. The next IRRS mission is planned for 2022.

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.

The recommendation left open in 2015 follow up mission deals with the STUK's position in the Government which has been discussed further in Finland, however, without any changes in STUK's position. One of the suggestions left open is related to STUK's management system. According to the IRRS team in 2012, STUK should consider further improving its management system. After the follow up, STUK planned all the needed corrective actions and implementened them. At the end of 2018 STUK's management made a decision that an in depth evaluation of STUK's management system will be performed and after the evaluation a development plan for a management system with more integrated approach will be prepared and implemented.

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.

Recommendation on clarifying the legislation related to decommissioning of nuclear installations and closure of a disposal facility is partly addressed. Decommissioning license was introduced to the Finnish legislative framework in the beginning of 2018. Future work needs still to be carried out for clarifying the licensing of closure of disposal facilities.

To establish a sound base for radiation protection research, the co-operation with Finnish universities and international research platforms has been reinforced. Research funding opportunities have been exploited and STUK is in an active role in shaping research agendas of many of these platforms to ensure that national aspects of research funding are taken into account at European level. STUK has also set up an internal research funding mechanism. The income from expert services is partly reserved for research projects and researchers can apply funding for their projects biannually.

IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009 and the follow-up in 2012. The next IPPAS mission has been invited and will be carried out in 2020.

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 10.

STUK receives about 32% 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 2018, the costs of the regulatory oversight of nuclear safety were 17,8 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.

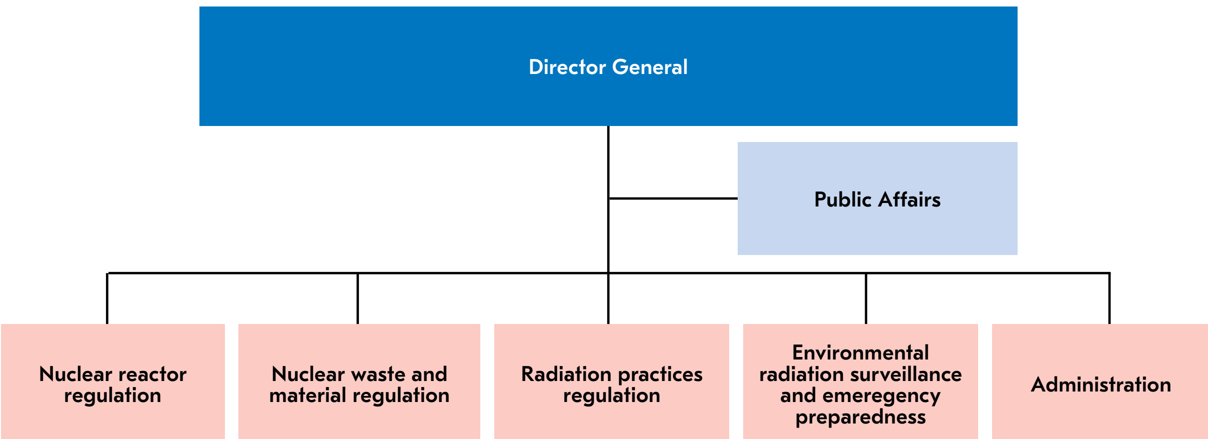


FIGURE 10. Organisation of STUK. The total number of staff at the end of 2017 was 326 and at the end of 2018 it was 333.

At the end of 2017, number of staff in the department of Nuclear Reactor Regulation was 126. 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 and for provision for retirements. STUK is also prepared for the safety review of the new NPP construction project (Hanhikivi unit 1). The number of personnel in the department of Nuclear Reactor Regulation over the period of 2009–2018 is shown in Figure 11. 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 12. Annual volume of the oversight of the Olkiluoto unit 3 construction was about 19 person-years in 2018. Starting from year 2003, inspection organisations have been performing construction inspections in lower safety classes.

The number of staff at the department of Nuclear Waste and Material Regulation, taking care of oversight of safeguards and nuclear waste management, was 27 at the end of 2018.

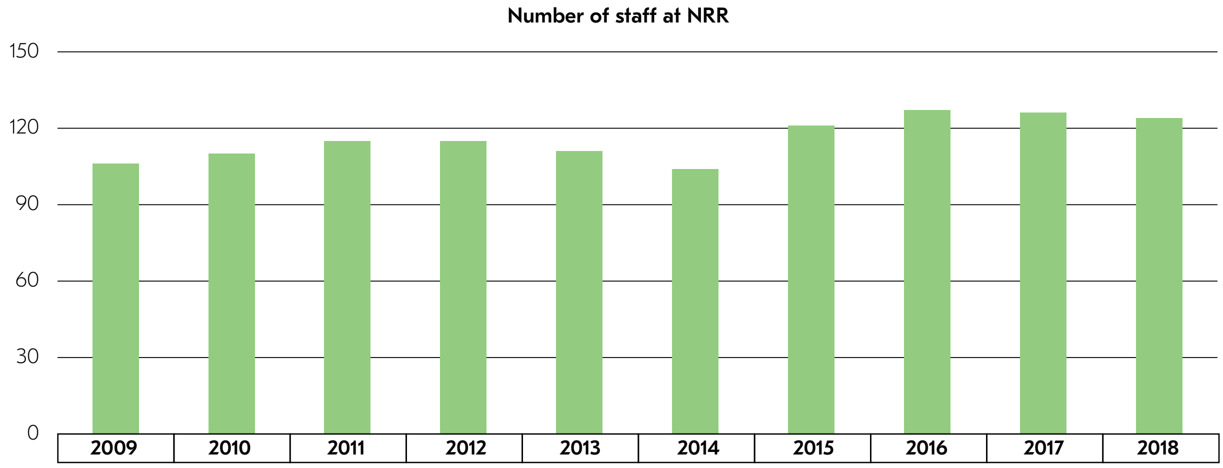


FIGURE 11. Number of staff in the department of Nuclear Reactor Regulation.

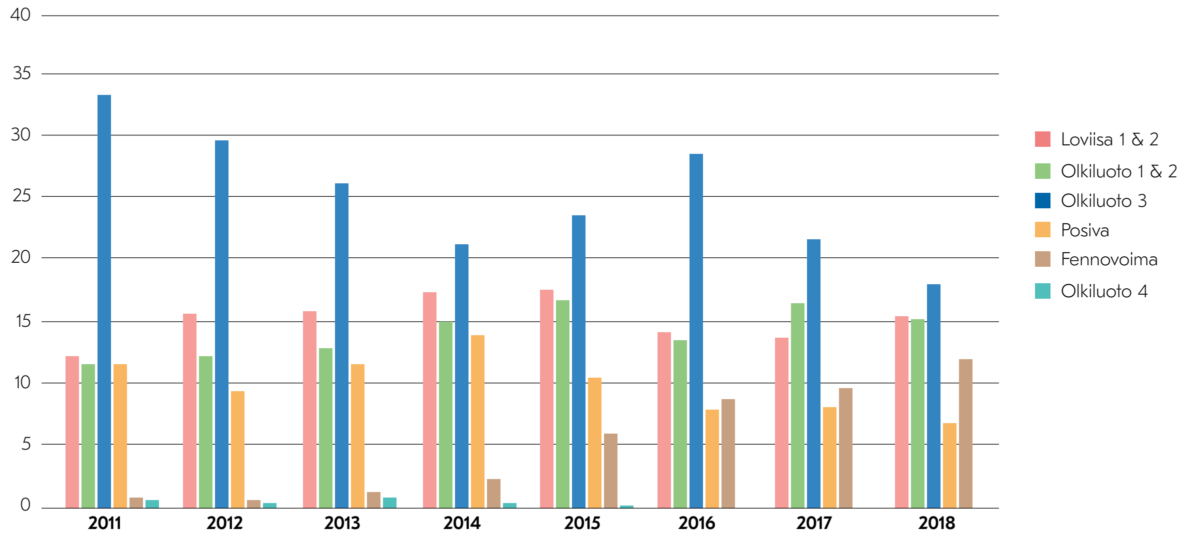


FIGURE 12. Man-power used for the regulatory oversight in full time equivalents.

Ensuring competence

The management of STUK highlights the need for competent workforce. STUK has adopted a systematic approach to competence management and e.g. nuclear and radiation safety and regulatory competencies are also emphasised in STUK's strategy. One of the strategic targets is to enhance STUK's ability to understand complex entities. Implementation of the strategy is reflected into the annual training programmes, on-the-job-training and new competence-driven workforce planning and recruitments.

The national nuclear safety and waste management research programmes have an important role in the competence building of the nuclear energy industry in Finland. These research programmes ensure the availability of the latest research results, the high-level expertise and the development of tools for e.g. regulatory oversight. Furthermore,ensuring the online 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 research programmes.

Most of the STUK's professional staff conducting safety assessments and inspections have 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 and competence development programmes and e.g. to support the new recruitments. The STUK's training programme includes internal courses as well as courses organised by external organisations. The personal development plans include various methods of competence development based on personal needs and targeted outcomes. On an average 5% of the annual working hours are used to enhance the competencies.

An introduction training programme is prepared for all new recruited inspectors at STUK. In addition to administrative issues, the programme includes familiarisation with legislation, regulatory guidance and regulatory oversight practices. Furthermore, the programme includes general technical training. The introduction training programme is tailored to each new inspector and its implementation is followed by the supervisor of the newcomer. 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). During the past few years the national training courses on nuclear safety and on nuclear waste management have been harmonized and combined as one joint training course.

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 2014 was 90 million € (estimate of the Ministry of Economic Affairs and Employment). 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 a temporary increase of the payments collected to the nuclear safety research fund was introduced. The purpose of the temporary increase of the research funding is to renew the ageing infrastructure for the nuclear safety related research. The increased funding is collected in between the years 2016 and 2025. At the first stage the additional funding has been allocated for the hot cells at VTT Centre of Nuclear Safety (CNS) and at the second stage it will be allocated for the thermohydraulic laboratory at Lappeenranta University of Technology. The investment for the VTT CNS hot cells capacity has been 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 (2015–2018) enhanced multidisciplinary co-operation within the research programme. Research areas were 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) were 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 since year 2016 has been about 9 million € for nuclear safety research. Out of this 4 million € is used to research projects and the rest is for the enhancement of the infrastructure. The research projects have also additional funding from other sources. The total volume of the programme in 2016 to 2018 has been between about 7 million € each year. An international evaluation of the programme was performed at the beginning of the year 2018. The scientific level and performance of the programme was found very good.

The new period for the national publicly funded nuclear safety research programme SAFIR2022 was planned and initiated in 2018. The research issues of the new programme continue the main areas of previous SAFIR2018 research programme. However, new research issues concerning the changes in the operating environment are integrated into the programme such as use of 3D-printing for components important to safety, small modular reactors, machine learning etc.

The objective of KYT (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. KYT2018 was 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 0.13% of their respective assessed liability. The current level of annual funding is 1.9 million €.

Similar to SAFIR, the new period for the Finnish Research Programme on Nuclear Waste Management, KYT2022, was planned and initiated in year 2018. The programme continues the traditions of previous periods with the main research areas of:

- safety research in spent nuclear fuel management
- near-surface disposal
- low and intermediate nuclear waste management
- decomissioning
- new and alternative technologies in nuclear waste management and
- social science studies related to nuclear waste management.

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 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 Economic Affairs and Employment for the part of financial liability which is not yet covered by the Fund. At the end of 2018, the fund contained 2657 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 Economic Affairs and Employment 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 priority of safety is emphasised in the Nuclear Energy Act and in the STUK Regulation (STUK Y/1/2018) Section 25. The STUK regulation sets a binding requirement for the licensees to maintain a good safety culture where safety shall be a priority. It 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. 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. The licensees have to ensure that these requirements are applied in all organisations that participate in safety significant activities.

According to the Nuclear Energy Act, a responsible manager has to be appointed for the construction, operation and decommissioning of a nuclear power plant. The appointment is subject to approval by STUK. The responsible manager 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 has revised the STUK's Guide YVL A.3 that sets requirements for management systems. The new guide YVL A.3, published in March 2019, is based on IAEA GSR Part 2 and it includes detailed requirements for promoting good safety culture. The revised guide also describes what the good safety culture includes, e.g. that safety is the overriding priority in decision making and that safety is considered comprehensively. The YVL A.3 requires that the management must demonstrate 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 licensee has to also establish a process to measure, assess and improve its safety culture.

STUK has revised also the Guide YVL A.5 concerning nuclear facility construction, commissioning and modifications. The safety culture requirements from the previous version has been moved to the Guide YVL A.3 to clarify and ease the usability of the guide documents. Still during construction and modification projects 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 according to Guide YVL A.3.

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 has continued to explore the sociological factors influencing safety culture in the Finnish nuclear community within the Finnish nuclear research program SAFIR 2018 (the ORSAC and ORSAP project). Furthermore, in March 2019 STUK hosted the OECD NEA and WANO managed Country-Specific Safety Culture Forum in Helsinki, were personnel from the Finnish nuclear utilities and STUK discussed the country specific culture traits and their possible influences on the nuclear safety culture. A report is being prepared by the NEA.

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. Fortum has a 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 an internal Nuclear Safety Oversight function that supports the senior management in maintaining an overview on, and responding to the high level safety issues. In addition, the Loviisa NPP has an independent nuclear safety committee with external expert members.

The licensee follows a safety culture programme and a roadmap with which it coordinates some of its safety culture development activities. However, a guiding principle at Fortum is that safety is integrated into all activities and the safety culture development activities are mainly practical improvements that the line organisations carry out by themselves. Loviisa power plant has a Corrective Action Programme group which collects and trends various types of observations concerning the safety performance of the organisation. Based on the findings a statement concerning the level of safety culture and corresponding development needs are summarised annually. Loviisa power plant monitors the safety culture also with a personnel survey and analyses whether operational events point to any safety culture related issues. The nuclear safety oversight group carries out in-depth assessements of management system approximately once in every three years. Safety culture induction training is given to all newcomers and regular refresher trainings are arranged.

Safety significant contractors are required to familiarize their workforce in safety culture principles and this expectation is communicated to the contractors e.g. in supplier audits. Practical behavioural expectations are covered in the induction training. In some of the major modification projects the supplier safety culture is analysed more comprehensively. The supplier personnel is, for example, invited to respond to Fortum safety culture survey.

The safety culture self-assessments carried out by the licensee have not identified any major issues in the key areas of a safety culture. Based on the safety culture assessments Fortum has paid attention e.g. to communication of the management expectations. Also STUK has in its oversight emphasised that Fortum's leadership shall improve the prioritisation and follow up of development actions to ensure their effectiveness. There have been recurring operating events in some activities. Fortum has also improved the reporting of low level safety observations.

Olkiluoto NPP

TVO, the licensee operating the Olkiluoto NPP's 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 has a safety committee which is independent from the line organisation and which reviews TVO's major safety relevant decisions and topical issues.

TVO reorganised its activities in 2015. After the reorganization and staff reduction TVO had a decline in personnel job satisfaction and working climate that resulted in increased personnel turnover in the company. STUK intensified its oversight to ensure that TVO takes such actions that these conditions would not affect the safety culture and safe operations. TVO has carried out various development actions to correct the working climate situation during the period 2016–2018. The effective corrective actions and monitoring their effectiveness was a requirement by STUK. During the last years TVO's safety culture improvement activities have been incorporated into a larger corporate-wide development programme which strives towards improved job satisfaction, leadership and safety culture at TVO. TVO has paid attention to, for example, clarity of decision making and personnel resources. Leaders, from senior management downwards have participated in a leadership development programme. Organisational structures and processes were modified in 2017 to resolve issues caused by the previous major reorganisation and to respond to the needs of the forthcoming Olkiluoto 3 operational phase. In 2018 TVO's safety culture survey showed improvements in areas such as management commitment to safety. TVO has started to use Operational Decision Making practices more systematically and communicates the reasons for decisions to the entire organisation. Senior managers practice new ways of interacting with their subordinates. Clear improvement of the job satisfaction and working climate was seen based on a broad personnel survey conducted in 2018. TVO has recruited around 250 new employees in 2016–2018 and safety relevant positions in maintenance and engineering are fulfilled. Personnel turnover rate is currently normal. Some organisational changes are still conducted in 2019 to clarify responsibilities.

TVO carries out regular safety culture surveys (biannually) and more in-depth safety culture self-assessments (in three or four year intervals) to monitor the level of safety culture and to identify needs for improvement. TVO has a Corrective Action Program (CAP) group that works independently from line organisation. It is led by the director of the nuclear safety department and it consists of specialists from quality management, nuclear safety, risk management, human resources 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 carried out safety culture monitoring and continual development also at the construction site of Olkiluoto unit 3. TVO has a specific plan for monitoring and developing the safety culture during the commissioning stage. Safety culture of OL3 activities is assessed through a questionnaire (twice a year), interviews and analysis of all other safety observations. TVO has identified a need to improve the permit to work procedures, roles and responsibilities at the main control room and overall coordination of the commissioning schedules and activities.

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 licensee's own personnel, as appropriate. Introductory nuclear and radiation safety training is a prerequisite for all persons working at the site. Based on the lessons learned from recent plant modifications and outage performance TVO has developed the site access training. 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.

Fennovoima

Fennovoima has a safety culture program that describes the elements needed to establish, monitor and to facilitate a good safety culture in the nuclear power plant construction project. Fennovoima requires its key partners to develop a safety culture programme and to appoint a safety culture coordinator for the Hanhikivi 1 project. Fennovoima organizes regular safety culture related workshops with the supplier and sub-suppliers to enhance their knowledge and commitment to shared practices and Finnish requirements concerning safety culture and leadership. Fennovoima conducts specific safety culture focused audits in the supply chain and monitors the performance of the key partners based on other observations.

Fennovoima has nominated a Responsible Director for the construction phase. A nuclear safety committee, that is independent from the line organization, reviews and provides recommendations on nuclear safety related questions.

In 2017, an independent safety culture assessments was carried out at Fennovoima. The assessment covered also the plant supplier RAOS Project Oy and main contractor Titan 2. The conclusion was, that at Fennovoima, the safety culture was at an acceptable level. However, several areas have required improvements. These include e.g. the responsibilities for handling safety related issues, nuclear specific competencies, control of the supply chain and climate for raising concerns. The safety culture assessment also concluded that the safety culture at the plant supplier and at the main contractor need significant further development.

In 2018, several investigations and analyses on the operations of Fennovoima were performed by STUK and Fennovoima itself. These exhibited development needs in the operations and organisational structure of Fennovoima. Fennovoima has started an extensive development program concerning the whole organization and all operations to address the challenges met in the project.

Regulatory oversight

STUK has continued to regularly inspect the management systems of both licensees (Fortum and TVO) and the license applicant Fennovoima to ensure that they fulfill the requirements of the legislations and the Guide YVL A.3. Based on the inspections, there is still need for development actions to fulfil the requirements concerning both the process based management system, project management and supply chain management.

STUK carries out safety culture oversight by collecting and analysing observations from resident inspectors, documents, events, and from other interactions with the licensee. STUK also conducts specific inspections focusing on Leadership and Safety culture. STUK also reviews the licensees' safety culture self-assessments. Furthermore, STUK has utilised VTT to carry out independent safety culture assessments at the licensee organisations. Independent safety culture assessments were done at Olkiluoto 1 and 2 (2016) and Olkiluoto 3 (2017) to support STUK in the processes Licence Renewal of Olkiluoto 1 and 2 and Operating Licence of Olkiluoto 3. In 2017 VTT also conducted an independent safety culture assessment of the key organizations of the Hanhikivi 1 nuclear power plant project. STUK's has conducted inspections and participated into the supply chain audits to assess the readiness of Fennovoima and the supply chain for the construction phase.

During 2016–2018 specific Leadership and Safety culture inspections have dealt with topics such as management of organisational changes, management expectations, leadership awareness of the safety culture issues in their organisations, the rationale and effectiveness of safety culture improvement actions and (operational) decision making practices. 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.

In order to improve the safety culture oversight process STUK has developed a tool (HAKE) 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 and based on experience and a development project the improved version is implemented 2019. STUK has also developed the process to create an overall picture of the licensee's overall safety including HOF topics utilising a database to maintain this overall picture. The HAKE 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 to improve the processes.

STUK co-operates with VTT on safety culture related research. The researchers have carried out research e.g. concerning safety culture and governance of large projects in the nuclear domain.

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. STUK's Safety and Quality Policy was revised in 2018 to conform STUK's new strategy and to include STUK's data security policy. 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. In 2015 the IRRS follow-up team considered the suggestion to be closed as STUK had enhanced its activities aimed at developing, assessing and improving its safety culture. In 2018 a throughout assessment of STUK's safety culture was performed by outside consultants. As a whole the safety culture at STUK was considered to be at a good level and especially safety was considered to be a true value in STUK's organization. Recommendations to strengthen certain areas at STUK included assessment and management of risks related to the function of the organization, follow-up of STUK's own safety culture as well as utilizing lessons to be learned from incidents.

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 Economic Affairs and Employment). 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, When TVO started to renew all emergency diesel generators the overall investment was 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 2018, the fund contained 2657 million euros.

The national education system for the university level studies (MSc, PhD) in nuclear sciences (and similar) is based on the training programs of the Lappeenranta University of Technology, Aalto University and University of Helsinki. These universities have a strong tradition of providing education programs with the nuclear (and other relevant topic area in engineering and sciences) specific content. In general, the funding of these programs rely on two main sources: about a half of the funding is from the basic national funding driven by the Ministry of Education and Culture. The rest of the funding is acquired from various competitive sources of funds such (as European Commission, Academy of Finland etc.) by each of the universities.

Regulatory requirements regarding human resources

The licensee has the prime responsibility for ensuring that its 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), STUK Regulation STUK Y/1/2018 and Guide YVL A.4. The Nuclear Energy Act Section 7 k was modified in 2017 in order to demand appointing a responsible manager also for the decommissioning phase of a nuclear facility. According to Section 25 of STUK Regulation STUK Y/1/2018, the licensee shall have a sufficient number of competent personnel suitable for the related tasks for ensuring the safety of the nuclear facility. Significant functions with respect to safety within nuclear power plants must be designated, and the competences of the persons working in such positions must also be verified. The operation of the organisation shall be evaluated and continuously developed and the risks associated with the organisation's operation are to be evaluated regularly. The safety impacts of significant organisational changes are to be evaluated in advance.

Guide YVL A.4 sets requirements for training, competence management and for qualifications of personnel working in functions that are important for plant safety. In this Guide there are specific requirements for positions, defined in the Nuclear Energy Act, i.e. responsible manager and persons responsible for nuclear safeguards, emergency arrangements and security arrangements and nuclear facility operators (Appendices A–E). The guide also has specific requirements on management and leadership competencies. The YVL A.4 is under revision during 2018–2019 and it will include the requirements to respond to the revised Nuclear Energy Act (2017) and Radiation Act (2018).

Measures taken by licence holders

Loviisa NPP

Human resource planning at the Lovisa NPP is subject to annual management review and updating. The succession plan for the most critical positions is updated yearly. Lovisa 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 Lovisa NPP are constantly developing. The training unit's main responsibility is to develop the human resource management procedures and organize the general training. The training unit personnel support the line managers with their expertise, but the responsibility for developing the specialist competence lies on the line organisation. Fortum has a procedure for setting up individual development plans for all newcomers and for persons changing positions. Lovisa NPP is currently developing the systematic competence management procedures and tools to be able to ensure also the long-term resource needs. Qualification needs for different positions are based on evaluations performed by line managers. Lovisa NPP has during 2016-2018 conducted one major and a few minor organisational changes. Organisational changes are evaluated from safety point of view prior to change and the evaluation report is sent to STUK for review. The safety-significant organisational changes are also evaluated after implementation. Loviisa NPP has during this period also improved the contractor training for personnel taking part in the outages.

Olkiluoto NPP

TVO has updated the personnel plan regularly according to the phases of Olkiluoto NPP unit 3 construction. In 2015 TVO made a big organizational change including the change of the business model, completely rearranging the organisation structure and also reducing the number of staff. Due to this organizational change TVO also faced challenges concerning working atmosphere, and retention of personnel and competence. TVO made also some smaller organizational changes and had extensive recruitments in 2017 and 2018. This resulted in need for development and strengthening of the induction training arrangments and procedures. Furthermore TVO developed a "rolling" resource planning procedure and a strategic compentence management model. TVO also has an ongoing development program for developing people management and leadership to ensure a good working atmosphere. Due to these TVO's challenges STUK intensified the oversight of resource management and leadership.

TVO has a training program and procedures taking into account the commissioning of the Olkiluoto 3 and the training has been intensified as the commissioning is coming closer. All operators for Olkiluoto 3 have been licensed during 2018.

TVO's new strategic competence and resource management procedure is supported by IT and is similar to the IAEA systematic approach to training (SAT) approach.

TVO has further developed the mandatory outage training for contractors to so that it also can be made by a web application, and introduced a mandatory "mock up-tent session" at the site before the person gets the works pass.

Fennovoima, Hanhikivi project

Fennovoima has developed its process and procedures for ensuring competence. For example, it has in use a tool or evaluating the available and needed competences and has continued developing systematic approach to training. The resource needs at the different phases of the project are compiled in an integrated staffing plan. The development work is still ongoing.

Fennovoima has continued to increase the size of its organization. The amount of personnel increased from 270 in 2016 to more than 310 at the end of 2018.

Fennovoima is planning to move its offices to the site, Pyhäjoki, in the near future. This may be a challenge for preserving competence, if all the personnel do not want to move to Pyhäjoki from the capital area. STUK has requested Fennovoima to order an independent assessment of the move, as it can be comparable to major change of organization.

Development should be continued especially concerning the processes to ensure resources and competencies of the most significant suppliers, and the processes to identify the tasks and positions important to safety, and the related competences needed.

Regulatory oversight

Personnel and human resources related issues are included in STUK's periodic and construction inspection programmes at the nuclear power plants. The construction inspection program covers also the construction license review phase of Fennovoima. The inspection "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. During the years 2016–2018 STUK has paid attention to organisational changes and their management, strategic competence and resource management procedures, induction training for new recruitees and for those changing position, and competences of responsible persons according to the Finnish Nuclear Act paragraphs 7i and 7k that STUK approves (e.g. the responsible manager and her/his deputies). STUK has participated 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 also have made follow-up visits to training events conducted by licence holders. STUK has also used TSO for independent evaluations of human resource and competence management of TVO NPP:s due to the commissioning phase of OL3 and the integration of the project organisation to TVO organization.

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 construction of the Olkiluoto unit 3 and the new reactor project of Hanhikivi unit 1.

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.

The committee report indicated the importance of the continuous development of the nuclear competence on national and organizational levels. Furthermore, the report indicated that the need for nuclear experts with a higher university degree (in engineering or natural sciences) would increase by 38 percent by the year 2025. The general age structure of the Finnish nuclear workforce was also a matter of concern as the demographics indicated a two-peak curve where the industry had many senior experts and young professionals but lacked professionals with 10–20 years of experience. The report also indicated some need for minor adjustments in the education system to ensure the availability of adequate number of potential suitable newcomers to the industry.

One of the recommendations by the committee in 2012 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 called for a separate joint project among research organisations and other stakeholders in the Finnish nuclear sector. At the end of January 2013 the Ministry of Economic Affairs and Employment set up a working group to prepare a national research and development strategy for the Finnish nuclear energy sector. The working group was chaired by a representative of the Ministry of Economic Affairs and Employment. 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 were published at the end of April 2014. The report "Nuclear Energy Research strategy" emphasizes the importance of the research in the competence building. The working group recommended 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 Economic Affairs and Employment 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 Economic Affairs and Employment 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.

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 reached the goals it was given at the time. During the programme 21 new doctors were graduated. YTERA came to an end in 2015 and similar, active, jointly coordinated and funded programmes do not exist at the moment. New doctors are graduated through national research programs.

The main organisations in the nuclear energy sector in Finland develop and organize 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 Economic Affairs and Employment, main TSOs in the area of nuclear waste management). The first course commenced in September 2003. In 2017 the original training course was updated by including the modules of (previously separate) nuclear waste management course as part of the curriculum. So far, over 1000 newcomers and junior experts have participated in these courses. The content and the structure of the course has been enhanced according to the feedback received from the participants – and also by reflecting the development and changes of the nuclear sector (nationally and globally).

The update of the national level competence review was conducted in 2017 in order to reflect the current changes in the operating environment. The national competence review update was carried out by VTT and the final report was published in 2018. The summarized results of the review indicate that the overall age structure of the Finnish nuclear sector has improved from the year 2010. The 'two-peak' shape of the nuclear sector's age structure has become more evenly balanced profile. Between 2010 and 2017 the number of nuclear experts has grown in line with the initial plans (exceeding by 2%). However, due to the changes in the operating environment (e.g. Olkiluoto 4 project was terminated), the estimated number of new experts needed during the following years has been decreased when compared to the estimates of 2011 (2020: by –16% and 2025: by –14%). Yet, by the year 2030 the demand for personnel is expected to return to moderate growth.

The report of the national competence review update indicates that the adequate competence resources for the Finnish nuclear sector will available also in the near future. However, Finnish nuclear sector needs to continue to pay attention in educating, training and introducing new experts to certain competence areas of the nuclear sector.

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

In the Finnish regulation management of human factors is recognized in the Nuclear Enegy Act which further refers to the STUK Regulation (Y/1/2018) for consideration of human factors. STUK regulation section 6 "Management of human factors relating to safety" was renewed in the update of the whole regulation in 2018. The main modification to section 6 was that as the previous version was very focused on human errors now this perspective has been widened to cover also support for good performance i.e. take into account both the capabilities and the limitations of human performance. In the present format section 6 requires that human factors relating to safety shall be managed with systematic procedures throughout the entire life cycle of the nuclear facility. Human factors shall be taken into account in the design of the nuclear facility and in the planning of its operations, maintenance and decommissioning in a manner that supports the high-quality implementation of the work and ensures that human activities do not endanger plant safety. It is further required that attention shall be paid to the avoidance, detection and correction of human errors and the limiting of their effects.

According to section 16 of the STUK regulation (Y/1/2018) A nuclear facility shall contain equipment that provides information on the operational state of the facility and any deviations from normal operation. A 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 consequences. These automatic systems shall be capable of maintaining the nuclear power plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions. In order to control the nuclear power plant and enable operator actions, the nuclear power plant shall have a control room, in which the majority of the user interfaces required for the monitoring and control of the nuclear power plant are located. The scope of monitoring and control duties performed outside the control room shall be designed according to their feasibility. 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 the nuclear reactor and for removing decay heat from the nuclear fuel in the reactor and the spent nuclear fuel stored.

The STUK regulations are detailed in the YVL guides in which the main requirements concerning human factors are presented in guides YVL A.3, A6, and B.1. Guide YVL A.3 "Management system for a nuclear facility" requires e.g. that systematic methods shall be incorporated in the management system in order to identify and manage human and organisational factors affecting safety. And further that human and organisational factors shall be handled together with technical matters, and that the personnel's individual competence shall be developed as regards the identification and management of human factors and potential errors. YVL A.6 requires that the emergency and abnormal operating procedures of a nuclear power plant shall enable the operator to quickly identify the relevant procedure for responding to the plant state at hand. Entry and exit conditions shall be defined in the operating procedures for enabling operators to select the appropriate operating procedure, navigate the different operating procedures, and proceed from operating procedures to severe accident management guidelines when necessary. It is further required that the procedures and guidelines shall be systematically validated and verified. Validation shall also address the role of human factors in the procedures. Guide YVL B.1 "Safety design of a nuclear power plant" requires e.g. that the design of manual control, testing, inspections and maintenance of systems and components important to safety shall be based on a task and reliability analysis. And that the results of this analysis shall be used as a basis for designing the systems so as to ensure sound preconditions for reliable operation, for avoiding errors to the extent possible, and for the prompt detection of possible errors. In addition YVL B.1 requires that with new projects and extensive modifications to the control room, design and implementation shall be governed by a Human Factors Engineering (HFE) concept.

Measures taken by licence holders

Loviisa nuclear power plant

Fortum evaluates human reliability aspects and their effect on nuclear safety as part of the probabilistic risk assessment (PRA). PRA is further described under Article 14.

In 2018 Loviisa power plant finished the automation renewal project (ELSA), which had implications also on the main control room of the plant. From human factors perspective the ELSA project was governed with a human factors engineering (HFE) program with which the control room upgrade was guided and monitored. The V&V (verification and validation) process of ELSA HFE program was conducted by an independent consultant providing human engineering discrepancies (HED) to be resolved by the design organization at several points in the project. In addition, human engineering consistencies (HEC) were sought for. HFE program of the ELSA renewal ended in an integrated control room system validation (ISV) which took place in the spring of 2018. The conclusion of the ISV was that the renewed control room is safe to take into use but there were also issues to be followed in the forthcoming simulator trainings of the operating crews.

Simultaneously, Loviisa power plant continued the implementation of the human performance program the concrete result of which is the implementation of the so called human performance tools (HuP-tools). The HuP-tools in use at the Loviisa power plant are: pre-job-briefing, de-briefing, peer checking and clear communication. The main objective of Loviisa power plant in this phase of the implementation of the tools has been to encourage teams and other orgnisational units to specify the relevant HuP-tools from the perspective of their own work and its relevant risks. This work is on-going.

In the analysis and reporting of operational events Loviisa nuclear power plant has a procedure of always considering whether human (and/or organizational) factors are involved in the reported event. All personnel of the plant are involved in creating observations, some of which will lead to investigations. Majority of the observations are made by personnel during the annual outages. In the yearly analysis of operational events for 2016, 2017 and 2018, human factors was the most prevalent primary cause of events. The most prevalent performance shaping factor in 2016, 2017 and 2018 was work practices. In 2018 also work planning and procedures were as prevalent as work practices. Loviisa power plant identifies corrective actions and lessons learnt based on operational events and follows their implementation. The licensee is currently developing its procedures to monitor the effectiveness corrective actions.

One aspect of management of human factors relating to nuclear safety in the power plant is conducted via proceduralisation of the human activities which are most relevant for safety. These actions include both operations and maintenance related human activities although proceduralisation is not limited to aforementioned functions. The power plant monitors the extent to which procedures are adhered by e.g. management follow-up and self reporting of the personnel. In addition, all the procedures are reviewed and updated on a regular basis. Procedure non-adherence also comes up in the outcomes of event investigations.

Olkiluoto nuclear power plant

TVO evaluates human reliability aspects and their effect on nuclear safety as part of the probabilistic risk assessment (PRA). PRA is further described under Article 14.

The licensee has a human performance program (HU-program) under which all personnel groups of the plant have had the possibility to part take a human performance training. One of the essential contents of the training is the introduction of the human performance tools (HU-tools) which are in use at the Olkiluoto power plants. These tools are: Pre-job briefing, pair working, peer-checking, ensured communication, and post-job-briefing. All personnel of TVO have the possibility to take part in a training involving use of HU-tools.

TVO plans and implements modifications which have effect on the main control room according to the same principles which are used in any modification project. In addition, there is a special organisatorial group named Control room development group which deals with the modifications which have effect either on the main control room or on the work of the operators in some other way. The control room development group is lead by the head of the operational unit and consists of experts from i&c, electrical engineering, training, control rooms, simulators, nuclear safety, and modification design. The group meets at minimum once a year and its objective is to evaluate the modifications and give guidance and recommendations concerning the HFE activities necessary in the modifications.

OL3 NPP unit is currently in commissioning and the HFE program concentrating on the interface between human and automation is in its final phases. In total OL3 HFE program has been a full HFE program starting from analyses of operating experiences and concentrating heavily on different HFE V&V activities towards the end of the project. The Integrated System Validation (ISV) was conducted by a design independent consultant in the spring of 2019. TVO will continue monitoring the human performance in OL3 plant utilizing the processes of training, operating experience and modifications.

TVO takes human factors into account systematically when it investigates operational incidents and events. Human factors are one of the prevalent causes of the events. Most human errors are slip-type errors or they are related to inadequate competence or induction training. TVO has implemented corrective actions related to ensuring competence and it will evaluate the effectiveness of the corrective actions in the near future.

TVO conducts oversight of human factors e.g. procedure adherence as part of the line organisation's day-to-day leadership activity. In addition, comprehensive work permit system and related procedures prevents occurrence of human errors in e.g. maintenance work.

TVO has many practices for monitoring and assessing their procedures. These include, for example, management reviews, internal audits, non-conformance reports and root causes analyses. An extensive self-assessment of safety culture has been conducted every three years since 2004, and the latest one was completed in early 2017. In addition to this, attitudes are monitored via a questionnaire which can be answered by any TVO staff member. The state of organizational aspects is monitored by TVO's safety culture group and the CAP (Corrective Action Program) group.

Regulatory oversight

In 2017 and 2018 STUK has utilised an independent TSO (VTT Technical Research Centre of Finland) to conduct a study on the management of human factors in both Olkiluoto and Loviisa NPPs respectively. The study at Olkiluoto operating units was conducted mainly in 2017. In conducting the study the TSO also created an approach to study and assess the practices of managing human and organisatorial factors. This approach aims at assessing the availability, sufficiency, quality, and effectives of HOF practices. The results of the Olkiluoto study showed that TVO as a company has personnel which are devoted to maintaining high level of safety but simultaneously there are practical issues such as high workload and negative work climate which may show as issues to be tackled with proper human factors and other management practices. The results of the study in Loviisa NPP showed that plant personnel and top management view human factors development work as an operative measure the aim of which is to improve e.g. work conditions and leadership in general. In addition, Loviisa NPP has developed metrics to monitor status of human factors program. Most important development areas at Loviisa NPP are on-going development of the HuP-program and developing measues to include HFE in plant modifications.

At the Loviisa NPP STUK has conducted oversight of the ELSA project from a HFE perspective, as well. The HFE validation plans have been reviewed and approved and the events of ISV were all observed by STUK.

Significant efforts of STUK's human factors oversight have been dedicated to the design and commissioning of Olkiluoto 3, where STUK has paid special attention to the planning and conducting of the HFE program. As oversight of the HFE program STUK has observed significant amount of V&V activities of control room systems and operating manuals. At Olkiluoto 3 STUK has also conducted oversight of the training and learning of the operating personnel and supervised the oral examinations of all the control room operators.

In addition, STUK reviews the status of the nuclear power plants human factors management practices via several other information sources. For example, all STUK personnel involved in the oversight of nuclear power plants are encouraged to report observations concerning human and organizational factors at the plants in the observation data base of STUK. In addition, STUK reviews the operating experience reports of from the point of view of human and organizational factors. Further, significant plant updates and modifications are reviewed from human factors perspective. In 2019 STUK will release an update of the YVL guides which mandates the licensees to utilize a HFE program when modifying systems which are important to safety. According to the forthcoming regulation the HFE program shall be graded according to the significance that the modification has on the work conducted by humans in the plant.

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/1/2018), organisations participating in the design, construction, operation and decommissioning of a nuclear facility shall employ a management system for ensuring safety and the management of quality. The objective of such a management system shall be to ensure that safety is prioritized without exception, and that quality management requirements correspond to the safety significance of the activity and function. The management system shall be systematically assessed and further developed. 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 regarding quality and safety management. Guide YVL A.3 refers to the ISO 9000:2015 definition of quality management according to which quality management consists of quality planning, quality control, quality assurance and quality improvement. Guide YVL A.3 adheres to IAEA Safety Requirements GSR Part 2 Leadership and management for safety. Requirements for quality management of system design are established in the Guide YVL B.1. Further requirements related to specific technical areas are presented in the corresponding technical guides. STUK also has a dedicated YVL guide concerning nuclear facility construction and modifications, i.e., Guide YVL A.5. In this guide, there are requirements on construction and modification phases in addition to requirements concerning for example project and risk management. The management systems of the licensees and applicants are subject to high level 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. STUK has during the period 2016–2018 revised the YVL requirements concerning management systems and quality management taking into account experiences, feedback and development of quality standards (e.g. ISO 19443).

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 structure and content of the Fortum Power & Heat Management System for Loviisa NPP is presented in the *"Quality Assurance Manual"*. 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 assessments. The management system of the plant is compatible with the ISO 14001 and OHSAS 18001 standards. The quality management system for the Loviisa NPP complies with the requirements of the Guide YVL A.3.

During the years 2016–2018 Fortum has developed the process based management system by describing the main processes and process indicators. The responsibilities for developing the management system are clearly defined and Fortum has revised the procedures for reviewing the management system and the procedures and documents are evaluated periodically. Defined quality and safety assurance related meetings are held on regular bases. The integrated Management System ensures that nuclear safety significance is recognised and considered when making decisions and determining procedures.

The functions and responsibilities of Fortum Power & Heat organisations and personnel are described in detail in the Administrative Rules, in the Organisational Manual and in the manuals and instructions of individual organisational units. Self-assessments, internal audits, management reviews and feedback from peer-reviews are methods used regularly to gain information for development needs. Loviisa NPP keeps up a supplier auditing program and aims at ensuring the supply chain quality assurance by auditing suppliers and manufacturers and continuously evaluating the supplier experiences according to their procurement procedures.

Olkiluoto nuclear power plant

TVO's management system documentation consists of a general section and functional section. The general section presents, TVO's vision, mission and values, company policies, organisation and areas of responsibility, general operational principles, quality assurance principles for functional processes, and general descriptions of resources. The functional section comprises more detailed descriptions of the functional processes, manuals and instructions. TVO's management System complies to the requirements of the Guide YVL A.3 and ISO 9001:2015.

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.

TVO is actively developing the management system due to the commissioning of OL3 and the growing organisation. For the Olkiluoto unit 3 construction phase, STUK has approved "The Quality Plan for Olkiluoto 3 Project". The Olkiluoto 3 project quality plan is valid until the end of the project before the transfer of the plant by the plant supplier. After that Olkiluoto 3 unit's management system shall be implemented completely to Olkiluoto 1 and 2 unit's management system.

The TVO integrated Management System ensures that nuclear safety significance is recognised and considered when making decisions and determining procedures. TVO has recently developed, for example, its decision-making procedures, communication of the justifications for the decisions, reporting of safety observations as well as the manner the supervisors collect information and interact with the personnel. These measures also affect the operational processes and personnel groups related to the Olkiluoto 3 nuclear power plant unit.

TVO aims at ensuring the supply chain quality management using a document specifying the requirements set for the quality management systems of the subcontractors and by auditing suppliers and manufacturers.

Fennovoima, Hanhikivi project

Fennovoima has worked on developing its operations and management system during the recent years. Developing licensee competences and capabilities has been challenging in part due to a limited resource pool of experienced nuclear professionals. Management of safety issues and project management in general has suffered from fragmentation. High level issues have remained unsolved and without clear visible leadership. The developed of the management system has not focused sufficiently in correcting these high level issues whereas lower level process development has been performed.

Due to the project challenges Fennovoima has started an extensive development program concerning the whole organization and all operations to improve the situation The development programme perceives the operation as four entities: safe plant design, readiness for construction, implementation quality and readiness for operation. The development of certain key organisations is considerably incomplete. The procedures of the plant supplier and main contractor and their practical application are still in significant need of development. The plant supplier has faced similar challenges as Fennovoima concerning competence and management of safety and project issues.

Regulatory oversight

STUK has followed up the implementation of the Guide YVL A.3 requirements in the management systems of the licensees by means of the periodic inspection programme. The yearly inspection of the STUK's periodic inspection programme for operating NPPs Loviisa 1&2 and Olkiluoto 1&2, "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 "Leadership and Safety Culture" inspection (see Article 10) also contains items concerning management systems. During 2016–2018 the management system inspections in Olkiluoto 1&2 and Loviisa 1&2 have especially dealt with the process management and indicators, project management, 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.

STUK has participated as an observer in the licensee's and vendor's quality audits at the subcontractors. STUK has also increased visits on site with discussions, interviews and observations on safety management topics to follow up the development actions of the licensee also by other means than inspections.

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. STUK's inspections have been focused on the ongoing integration of Olkiluoto unit 3 to TVO's operations.

Concerning Fennovoima's Hanhikivi project, STUK has performed regularly quality management and quality assurance related inspections. The inspections has covered not only Fennovoima's processes and performance, but also those of the main suppliers. STUK has also participated as an observer in several quality audits performed by Fennovoima.

Management system of the regulatory body

STUK's management system documents include safety and quality policy, description of the management system, organisation and management, roles and responsibilities, personnel policy as well as description of processes and procedures. The results of management reviews, internal audits, self-assessments and international evaluations are used as lessons learned and inputs for the continuous improvement of the management system at STUK. STUK's regulation of nuclear facilities has recently developed its internal procedure and a supporting tool further to improve regulatory processes and functions based on regulatory experience gathered from various sources. These have been applied since the beginning of 2019 and the experiences seem promising. In the future, the established procedure will developed be further e.g. including practices for sharing the lessons learnt with interested parties.

At the end of 2018 STUK's management made a decision that an in depth evaluation of STUK's management system will be performed and after the evaluation a development plan for a management system with more integrated approach will be prepared and implemented.

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 for other documents considered necessary for safety demonstration.

Design of the facility is described in the Preliminary (PSAR) and Final (FSAR) Safety Analysis Reports. 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.

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 renewal of operating license of the Olkiluoto plant was carried out in 2016–2018 (see Article 6).

According to the STUK Regulation 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 and requirements for failure tolerance analyses are presented in YVL B.1. Acceptance criteria for the deterministic analyses are presented in Guides related to reactor and nuclear fuel, primary circuit pressure boundary and containment (YVL B.4, YVL B.5 and YVL B.6). Requirements for probabilistic risk assessments are given in the Guide YVL A.7. Acceptance criteria for limitation of radioactive releases and public exposure in the environment of a nuclear power plant or other nuclear facility are given in the Nuclear Energy Decree 1988/161.

Deterministic safety assessment

As mentioned above, detailed requirements concerning transient and accident analyses, including sensitivity or uncertainty analyses, are presented in the Guide YVL B.3. Requirements for the analyses and their acceptance critera are graded according to the frequency of the event; The event categories are shown in the Table 3 with related criteria for limitation of readioactive releases and public exposure.

Accident and transient analyses of the operating nuclear power plants, as well as the analysis methods, have been updated and developed throughout the operation of the plants.

TABLE 3. Event categories and related acceptance criteria.

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

Fortum has revised almost all of the safety analyses in connection with the I&C renewal, periodic safety review and renewed YVL guides. Fortum supplemented the deterministic safety analyses by analyses by analyse of design extension conditions. Deterministic assessment of extreme external events has been updated to correspond to renewed requirements and was submitted to STUK in early 2019.

TVO revised the accident and transient analyses in conjunction with the application for the renewal of its operating licence which was granted in 2018. In addition to revising previous accident and transient analyses to take into account plant modifications and development of analysis methods since the previous periodic safety review (in 2007–2009), the analyses for design extension conditions without core melt were added to the scope due to the revised YVL Guides.

The analyses of Olkiluoto unit 3 were presented to STUK in connection with the application for the construction licence. These analyses have been updated during construction and commissioning phase to correspond the as-built plant. The analyses have been reviewed as a part of the Olkiluoto unit 3 operating licence application, and the operating license was granted in early 2019.

Fennovoima has submitted some of the deterministic analyses for construction license application of Hanhikivi 1 plant. Full scope of the analyses is expected to be delivered.

To support in the review of deterministic safety analyses of Finnish NPPs, STUK contracts technical support organizations, e.g. VTT Technical Research Centre of Finland, to carry out independent analyses to verify the results given by the utilities and to conduct sensitivity analyses.

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 design information presented in PSAR. Generic reliability data for components can be used if data from similar plant designs are not available. PRA for operating licence application is based on essentially final design information (FSAR) and vendor or plant design specific component reliability data, where available, and more detailed modelling of systems.

According to the STUK Regulation (STUK Y/1/2018), 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.

In addition, it is also required that the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency.

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:

- Use of PRA in OL3 operating licence application review process (full scope updated PRA and commissioning risk assessment)
- Development of security PRA methodology - vital area identification
  - Analysis of brute force sabotages (explosion) already required and applied PSA application
  - Protection strategy assessment against insider threat: tool under development
- Intermediate Spent fuel storage PRAs
- Spent fuel encapsulation plant PRA
- Use of PRA in practical elimination of early or large releases

- More systematic use of PRA to support regulatory decision making
    - Development project ongoing at STUK to explore methods and tools for risk informed decisions making (RIDM).

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 (FinPSA) developed at STUK has been continued by 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 Loviisa NPP

Fortum provided STUK with Level 1 internal events 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 2008 is shown in Figure 13. 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 2018 the calculated estimate for the total frequency of reactor core damage was about $1.2 \cdot 10^{-5}$ per reactor year for unit 1 and $1.4 \cdot 10^{-5}$ 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 14. There are no major differences between unit 1 and unit 2 risk profiles.

The most significant initiating events at full power (power operation, PO) are fires in the control building 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.

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 2018, it was estimated that the total frequency of a large release to the environment is about 7.8·10–6 per reactor year. The estimate includes all initiating event groups, except for seismic events. The following modifications have 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.

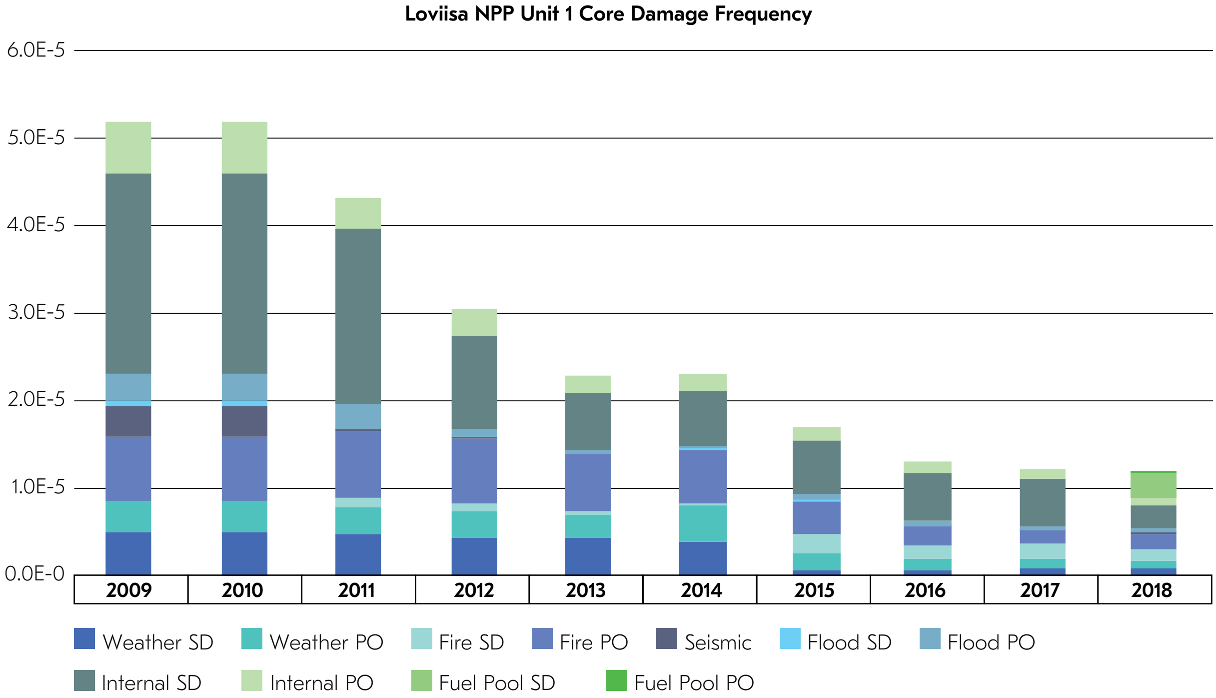


FIGURE 13. Development of the estimate of annual core damage frequency of the Loviisa NPP unit 1 in 2009–2018.

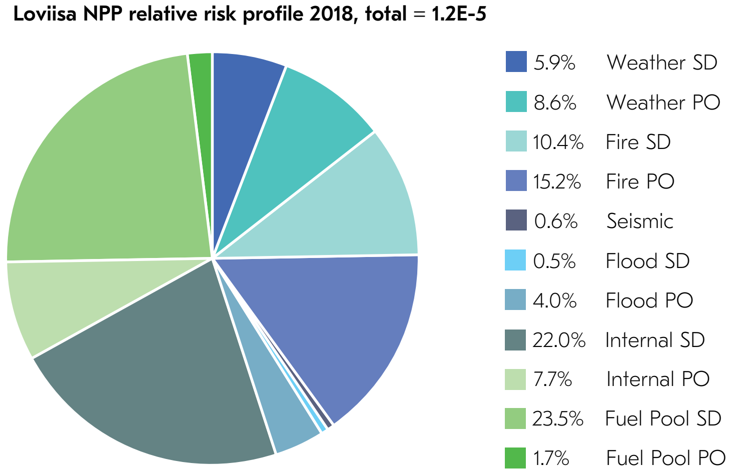


FIGURE 14. Relative contribution of different initiating event types to the annual core damage frequency in 2018 for Loviisa NPP unit 1. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

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). In the Risk-Informed In-Service Inspection programme for piping, the number of inspections was increased but the focus shifted from higher 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 have decreased 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 internal events 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 2008 is shown in Figure 15. Plant modifications have been carried out continuously at the Olkiluoto plant, including backfitting with severe accident management systems and power uprate and modernisation 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 2018 the overall core damage frequency was approximately $6.4 \cdot 10^{-6}$ per reactor year for Unit 1 and $1.1 \cdot 10^{-5}$ 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 were 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 will be implemented at unit 2 in 2019–2020. The relative contributions to annual core damage frequency from different groups of initiating events are shown in Figure 15.

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. Risk decrease in 2016 is due to the new recirculation line modification in auxiliary feedwater system which removed the dependency from sea water cooling.

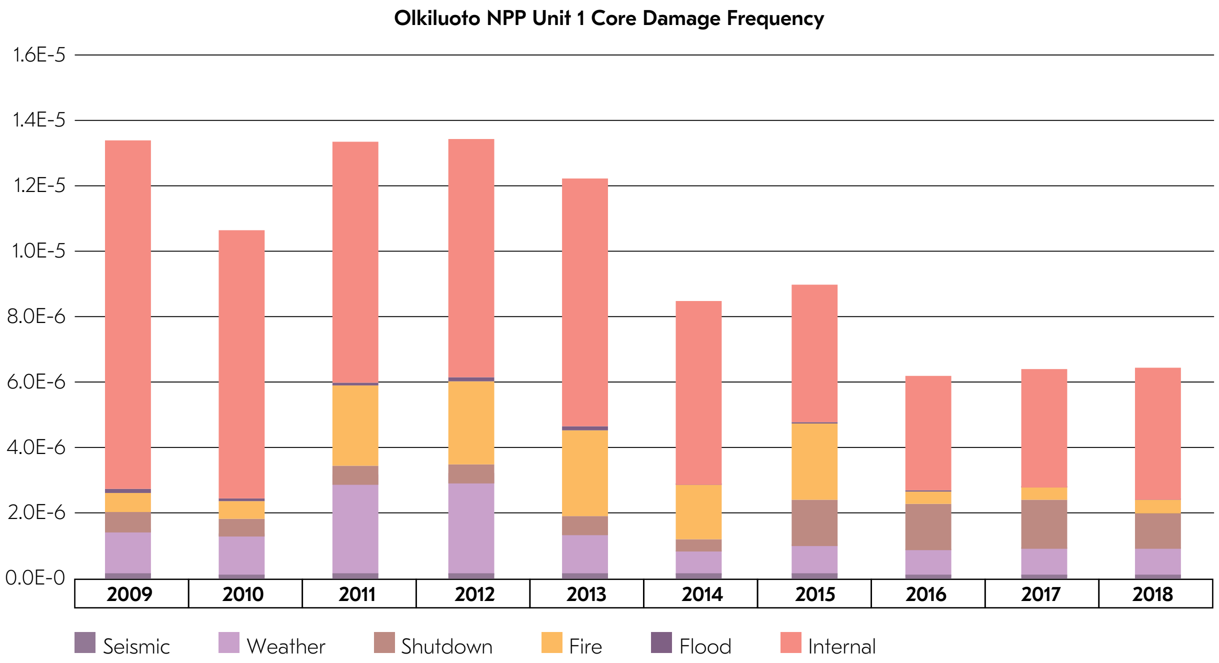


FIGURE 15. Development of the estimate of annual core damage frequency for Olkiluoto unit 1 in 2009–2018.

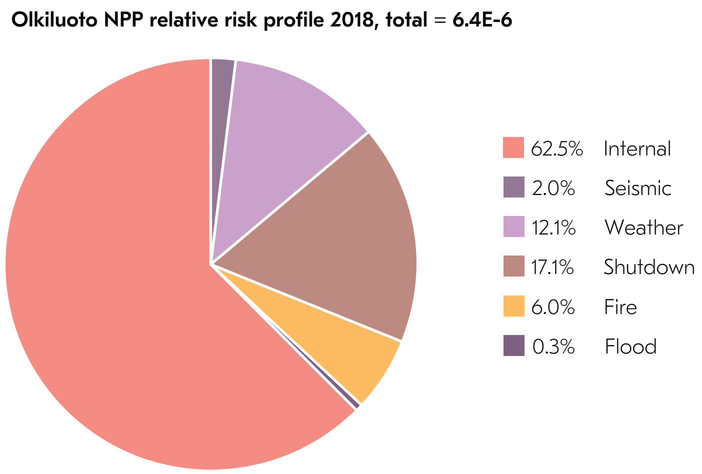


FIGURE 16. Relative contribution of different initiating event types to the annual core damage frequency in 2018 for Olkiluoto unit 1. The most significant internal initiating events at full power are the loss of off-site power and loss of feedwater. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

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 $2.1 \cdot 10^{-6}$ per reactor year, which is approximately one third of the core damage frequency at OL 1. 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.

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 and an update in October 2016. The modelling was improved in several areas taking into account the detailed design information. Main improvements were related to the modelling of internal fires and the extension of the PRA to cover seismic events. PRA review was finalised in the beginning of 2018.

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, Olkiluoto unit 3 fulfils with a wide margin the probabilistic safety goals. The total core damage frequency estimate is approximately $3.0 \cdot 10^{-6}$ 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 Pre- and In-Service Inspection programme, optimisation of testing intervals, optimisation of Operational Limits and Conditions (allowable outage times), and planning of plant commissioning tests.

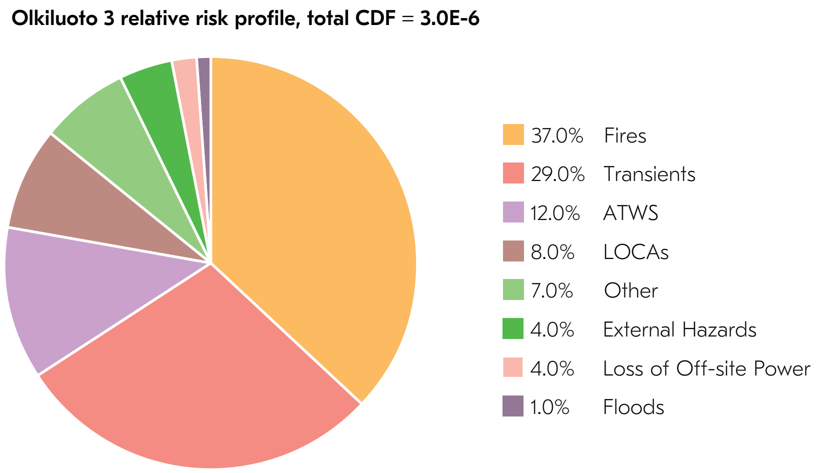


FIGURE 17. Relative contribution of different initiating event types to the annual core damage frequency in 2016 for Olkiluoto unit 3. Note: "Floods" includes only internal flooding from process systems.

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 Economic Affairs and Employment 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 Economic Affairs and Employment 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/1/2018) 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 maintaining and verification of the operability of a nuclear power plant are

- periodic testing according to the Operational Limits and Conditions
- preventive and predictive maintenance programmes
- in-service inspection programmes for pressure retaining components
- time limited analyses and qualifications
- 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 2016–2018. 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 licensee shall have available an FINAS accredited qualification body for inspection system qualification management, planning, implementation, control and assessment as well as the issuing of qualification certificates. Pursuant to Section 60 a of the Nuclear Energy Act (990/1987), the licensee shall have the accredited qualification body approved by STUK.

The qualification body and its activities shall meet the minimum requirements for a type 1 independent third party organisation presented in ENIQ Recommended Practice 7. In this case it shall also meet, at a minimum, the general independency requirements for a type A inspection organisation presented in standard SFS-EN ISO/IEC 17020. Alternatively, it shall meet the requirements for a personnel certification body presented in standard SFS-EN ISO/IEC 17024.

In Finland, Inspecta Certification has been accredited according to standard SFS-EN ISO/IEC 17024 and approved by STUK. 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. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications.

Most of the qualifications for Loviisa and Olkiluoto 1 and 2 NPPs as well as Olkiluoto 3 preservice inspections have already been performed by the qualification body and approved by STUK. The qualification work for Olkiluoto 3 inservice inspections and Posiva spent fuel canister NDT inspections has begun.

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/1/2018), 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, Guide YVL A.8, sets requirements for ageing management to license applicants and holders, and describes regulator's control measures in this matter. The requirements covers all the phases from early conceptual design to 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. Current operating licences of the Loviisa units 1 and 2 are valid until end of 2027 and 2030, respectively. For both units, deterministic and probabilistic safety analyses will be evaluated in the PSRs (by end 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 C 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 sent 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. Then the documents provided confirmed necessary actions for safe operation of the unit 2 reactor pressure vessel.

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, such as new reactor coolant pumps and emergency diesel generator sets, contributed to recent operating licence renewal up to 2038. 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 licence renewal and periodic safety review (PSR) carried out in 2016–2018. Supporting assessment has been done in several periodical inspections on plant site. The main components were generally found to be in good condition, however, reactor pressure vessel nozzles (safe-end) have been found susceptible to stress corrosion cracking. Two of total 20 nozzles were repaired 2017 by machining and making an overlay welding with a material more resistant to stress corrosion cracking. The licensee plans to apply the same procedure to the nozzles with no indications so far. 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 E.4. 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. Integrity of reactor pressure vessel and internals were evaluated against possible degradation mechanisms such as irradiation/thermal embrittlement fatigue, stress corrosion cracking, general/erosion/flow assisted corrosion, mechanical wear

At the Olkiluoto 1 and 2 units, the primary circuit's periodic pressure test has not been performed after the commissioning of the units. So far periodic pressure tests, as stipulated in the Finnish pressure equipment legislation, have been replaced with tightness tests (1.02 × operating pressure), which is guided by ASME XI for reactor plants planned and inspected in accordance with ASME requirements. At the time of commissioning it was not known that the service life of the units would be longer than the 40 years as presumed in the ASME version effective at that time. From now on, during the extended operation time, periodic pressure tests will be conducted every eight year at the maximum allowable operating pressure (design pressure). The purpose of the pressure test is to confirm that no ageing mechanism (expected or unexpected) has impaired the integrity of the primary circuit after 40 year of operation. The first pressure test is to performed at Olkiluoto unit 2 in 2019.

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, periodic safety reviews (PSRs) and site inspections 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. However, significant progress has taken place in the spare part management. Organizational arrangements have been made and a special software (Proactive Obsolescence Management System) has been introduced. Dedicated groups consisting of necessary disciplines such as maintenance, quality control and procurement have taken charge of spare parts in terms of necessary availability and conditions. 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.

STUK participated in the Topical Peer Review under the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017–2018. The topical peer reviews will be carried out every six years and the topic for the first peer review was ageing management.

Proactive ageing management, consolidation of ageing management data base and elaboration of Time Limited Ageing Analyses were recognised as areas for improvement. Furthermore, ageing management for long construction periods, and realising the importance of ageing management aspects in desing (e.g. inspectability and maintainability) in the new build projects were identified as challenges. A national action plan to address the above mentioned topics is under preparation. The peer review also noted some good practices, like interdisciplinary ageing management working groups established by the licensees, the concept of maintenance categories and STUK's periodic inspection programme.

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 (859/2018), Government Decree on Ionising Radiation 1034/2018), STUK Regulations and YVL Guides, Group C (7 guides). Government Decree stipulates that the effective dose caused to a worker shall not exceed 20 millisieverts (mSv) per year. The constraint 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 detailed implementation requirements are given in the YVL Guides both for NPP workers and release abatement. To meet the requirements stipulated e.g. in the BSS-directive (Basic Safety Standards Directive, 2013/59/Euratom), the radiation protection legislation went through an overall reform during the years 2014–2018. The STUK Regulations were restructured in 2018 to also include regulations given by virtue of the Radiation Act and the accordingly renewed guidance of STUK will be published in 2019. (see Article 7 for more details).

Radiation doses of the NPP workers and the public

The most important tools to reduce radiation doses of 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 2018. 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 the collective dose has decreased at the Loviisa NPP to 0.4 manSv/reactor unit/year. The ALARA programme includes also the goal that no employee at the plant should receive a radiation dose exceeding 13 mSv per year.

During the last ten years, the most important measure to lower the dose rates at the Loviisa NPP has been the minimisation of ^{122}Sb and ^{124}Sb on the primary circuit surfaces. It was discovered that the original seals of the main coolant pumps were the main reason for these activation products in the primary circuit. Since the seals were replaced with antimony-free materials during years 2012–2014, the dose rates near the primary circuit have fallen significantly. In 2019 the Loviisa NPP plans to modify the purification system of the primary circuit to allow primary water purification during outages in the future. This would allow an efficient purification of e.g. ^{110m}Ag, that is a significant contributor to the radiation dose arising from the primary water during outages. 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 optimising the timing of works between annual 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 Loviisa NPP has not set numerical target values for the effluents, but a target value for the calculated annual effective dose to a representative person in the environment has been set to be less than 10% of the constraint of 0.1 mSv.

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 be exceeded (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. The collective dose in this new NPP is expected to be below 0.05 manSv during the first year of operation.

In order to minimize the doses to the population, target values for the main radioactive effluents like noble gases, iodine isotopes, water-borne releases and tritium are included in the ALARA programme. A target value for the calculated annual effective dose to a representative person in the environment has been set to be less than 1% of the constraint of 0.1 mSv.

The Olkiluoto NPP has continued the replacement of cobalt-containing components (especially stellite alloys) in the primary circuit with new ones with low cobalt content. So far, the original amount of stellite in the primary circuit has been reduced by over 40% in Olkiluoto 1 and Olkiluoto 2 units. The reduction of moisture content in the primary steam with the equipment upgrades (new steam dryers) during 2005–2007 at the Olkiluoto NPP has resulted in a substantial reduction of radiation dose rates at the turbine plant. The risk-informed procedure was deployed to the in-service material inspections of piping and welding for the first time during the outages in 2012. This has resulted in 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 a systematic way to address radiation protection issues in different working groups and pre-job meetings. 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 4 and 5 and Figures 18 and 19. The individual radiation doses have remained well under the set annual dose limits. The maximum individual dose of a Finnish worker at the NPPs for a single year during 2016–2018 was 12.5 mSv.

TABLE 4. Annual radiation doses of workers at the Loviisa NPP in 2016–2018.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2016	0.84	9.8	1.61
2017	0.51	6.3	1.22
2018	1.24	12.5	2.04

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

TABLE 5. Annual radiation doses of workers at the Olkiluoto NPP in 2016–2018.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2016	0.88	8.1	0.89
2017	0.95	9.1	0.82
2018	1.1	9.5	0.95

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

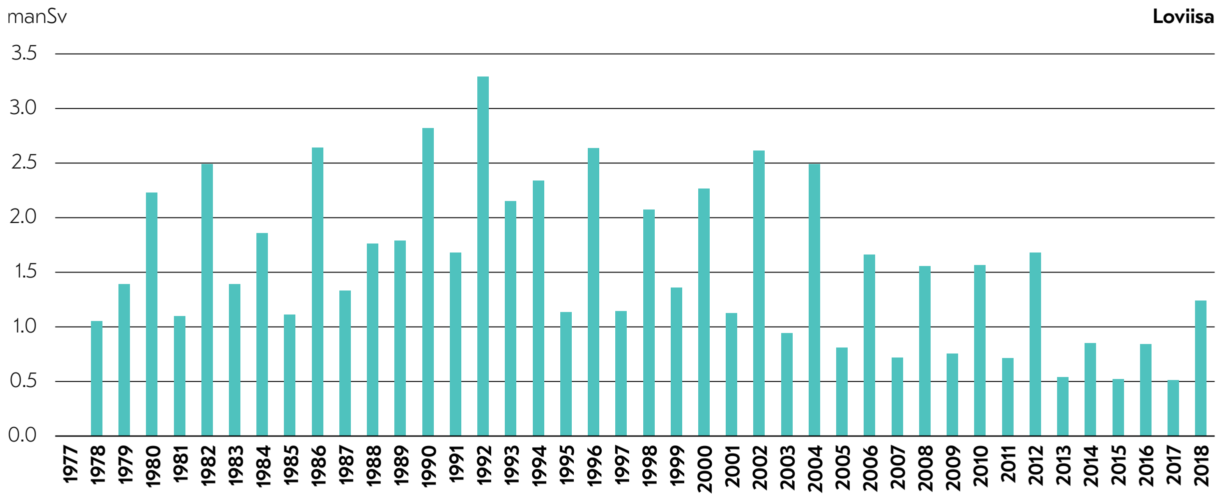


FIGURE 18. Collective annual occupational doses at the Loviisa nuclear power plant.

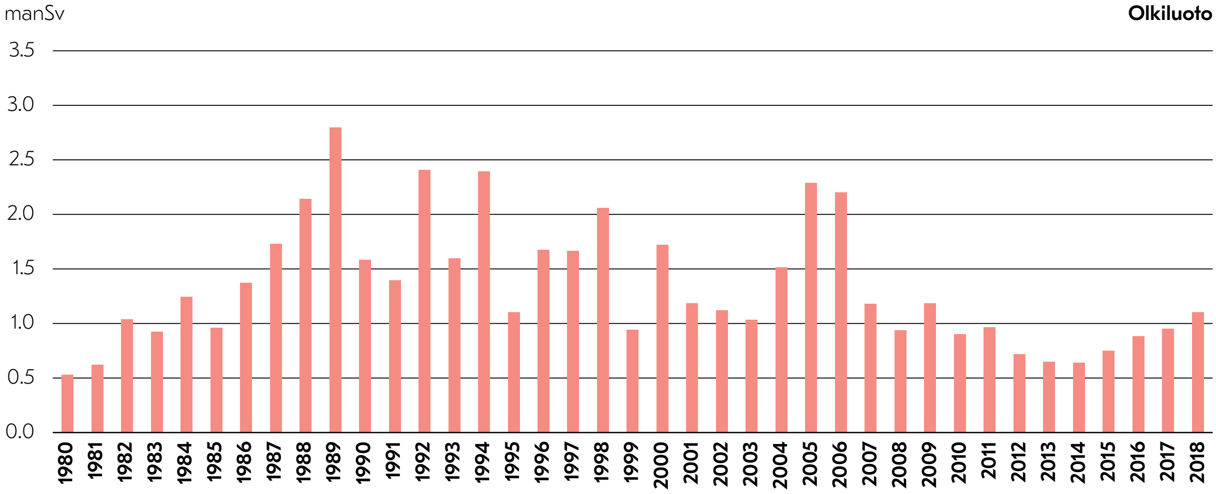


FIGURE 19. Collective annual occupational doses at the Olkiluoto nuclear power plant.

In international comparisons (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 the 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, the units 1 and 2 of the Loviisa NPP have been on an approvable level.

Radioactive effluents

STUK confirms upon the licensee's application the release limits for radioactive effluents during the normal operation of a nuclear power plant. The Operational Limits and Conditions of a NPP have more stringent requirements applicable for the radioactive substances of primary coolant (fuel integrity), thus practically preventing more significant releases. Fuel rods in the Loviisa NPP have had a very low failure rate. The fuel rod failure rate in the Olkiluoto NPP has increased over the last five years, still continuing to be relatively low. 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 2016–2018 are shown in Tables 6 and 7. Radioactive releases into the environment from the Finnish nuclear power plants have been well below authorised limits, as stated in the Tables 6 and 7. The Olkiluoto NPP has had to remove leaking fuel assemblies in unscheduled outages in 2016 and 2017, which is not common in Finland. Due to these fuel failures the levels of iodine and noble gas discharges have risen from the Olkiluoto NPP. Also, the aerosol discharges from the Olkiluoto NPP have risen due to events in the turbine hall causing an undelayed discharge of short lived nuclides into the ventilation stack. Despite of these raised levels of discharges, the levels of the calculated effective doses to the representative person in the environment of the nuclear power plants have still been very small, as can be seen Figure 20.

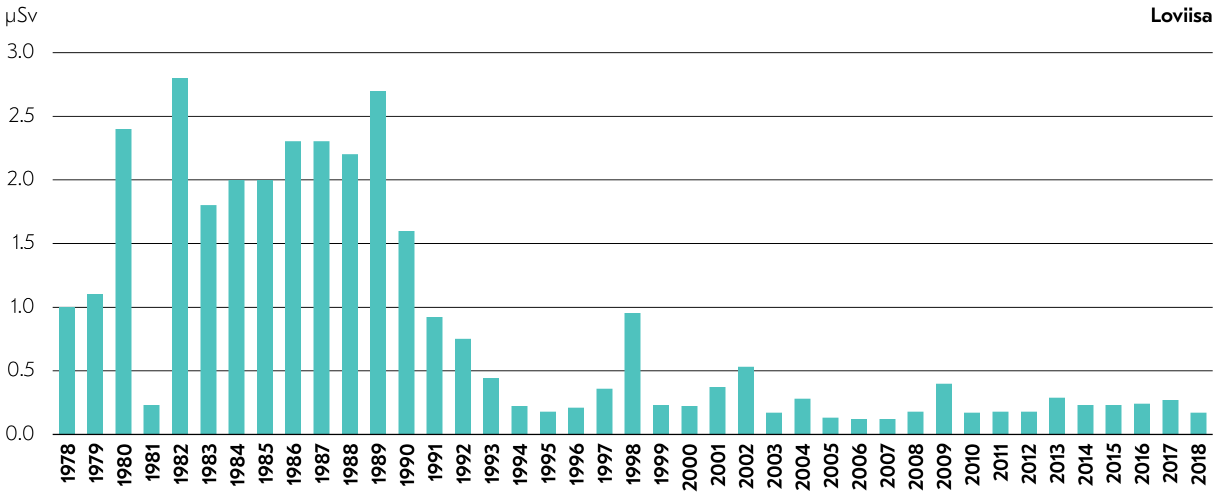
Both Loviisa and Olkiluoto NPPs have evaluated their implementation of BAT (Best Available Techniques) for further reduction of the radioactive discharges. The Loviisa NPP has developed and taken in operation caesium removal technology from liquid releases in the 90's. The utility has reviewed VVER reactor R&D issues and evaluated their own developments underway. They have recognized some techniques worth further research and development.

TABLE 6. Radioactive effluents from the Loviisa NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

	Airborne effluents			
Year	**Noble gases Kr-87 ekv. [Bq]**	**Iodine I-131 ekv. [Bq]**	**Aerosols [Bq]**	**Liquid effluents excluding tritium [Bq]**
2016	5,62E+12 (0.04 %)	1,24E+06 (0.0006 %)	2,90E+07	1,41E+08 (0.02 %)
2017	4,84E+12 (0.03 %)	9,75E+05 (0.0004 %)	4,13E+07	1.64E+09 (0.2 %)
2018	4,66E+12 (0.03 %)	3,61E+06 (0.002 %)	5,38E+07	1.59E+08 (0.02 %)

TABLE 7. Radioactive effluents from the Olkiluoto NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

	Airborne effluents			
Year	**Noble gases Kr-87 ekv. [Bq]**	**Iodine I-131 [Bq]**	**Aerosols [Bq]**	**Liquid effluents excluding tritium [Bq]**
2016	9,69+12 (0.1 %)	1,56E+09 (1,51 %)	2,41E+11	1,54E+08 (0.05 %)
2017	3,43E+12 (0.04 %)	8,71E+08 (0.85 %)	2,55E+10	2,55E+08 (0.09 %)
2018	9,06E+11 (0.01 %)	4,94E+08 (0.48 %)	5,52E+08	1,28E+08 (0.04 %)



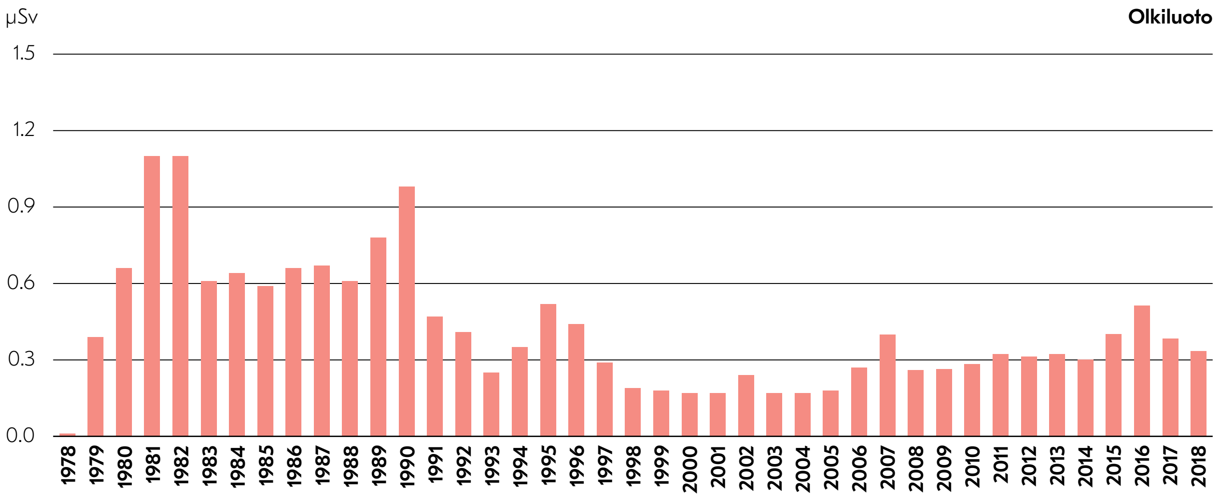


FIGURE 20. Calculated annual effective doses to the representative person in the environment of the Finnish nuclear power plants. The doses have been clearly under the constraint of 0.1 mSv.

The Olkiluoto NPP has previously carried out improvements on the water treatment and purification of discharge waters. An independent assessment has been made, comparing the emissions and operating experience in the Olkiluoto plant units to their sister units. The results indicated that the standard of radiation protection is 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

The IRRS review team recommended in 2012 that STUK should withdraw from the 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 independent 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. Guide YVL C.7 "Radiological monitoring of the environment of a nuclear facility" was published in 2016. The operating programmes for environmental radiation monitoring in the surroundings of the Loviisa and Olkiluoto NPPs for 2018–2022 were approved by STUK in 2018. The Environmental Radiation Surveillance and Emergency Preparedness Department of STUK implements an independent monitoring programme for the environment to verify the results of the off-site environmental monitoring programmes required from the licensees. Even though the new programmes of the licensees are significantly reduced compared to the previous ones, the overall environmental surveillance will not be reduced. In total more than 300 samples are collected and analysed (air, fallout, sediment, indicator organisms, milk, etc.) per year from the environment of both the Loviisa and Olkiluoto NPPs. Very small quantities of radioactive substances of local origin were detected in 2016–2018 in some samples from the environment of both nuclear power plants. Concentrations of the radioactive substances were very low, and the effects on the public are insignificant.

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. The Loviisa NPP personnel carry out the dosimetry service fully by themselves. In the Olkiluoto NPP the approval covers the agreement between the licensee and the outsourced services provided by the company Doseco Oy, that operates the routine dosimetry at the Olkiluoto NPP. STUK has inspected 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 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 have made it possible to enhance the control of occupational radiation doses and contamination.

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, Radiation Act Act, Government Degree on Ionizing Radiation and STUK's Regulation on Emergency Arrangements at Nuclear Power Plants (STUK Y/2/2018). 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 and refreshed (STUK Y/2/2018) in the end of 2018 due to the changes in the Nuclear Energy Act and Radiation Act. In connection to this latter renewal some changes were implemented to the level of requirements. Major changes were related to changes in accepted doses during emergency work and establishing new emergency roles in radiation emergencies.

In the current Regulation, design basis for emergency planning is a simultaneous accident at site's all nuclear installations. 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 autonomy in case of external hazards in autumn 2015 when Guide YVL C.5 was enforced at the operating NPPs. Since March 2019 Guide YVL C.5 was enforced also for OL3 NPP unit. 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 and his deputies have been appointed both for the Loviisa and Olkiluoto nuclear power plants. Due to the updated Nuclear Energy Act the nominated persons responsible for emergency response arrangements and their deputies are approved by STUK. The emergency response organisation has been described in the emergency plan and procedures, updated with regard to personnel changes at least 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 is going through renewal that according to the project schedule will be finished during spring 2019. The new unit Olkiluoto 3 and the unit's training simulator were added to the data transfer and display system in autumn 2017 before OLKI17 emergency exercise.

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. Some of the emergency exercises are organized so that they start unannounced and/or 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 2016 TVO exercised for the first time a multi unit's simultaneous accident scenario pertaining both operating NPP units and used fuel facility. In 2018 the annual emergency exercise OLKI18 was based on an unlawful action scenario that pertained all units including OL3. In OLKI18 exercise OL3 was considered to be operating unit. TVO has organized smaller scale exercises for OL3 organization to train and test the improvements in emergency plan.

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 were installed in the vicinity of Olkiluoto unit 3 in autumn 2017. TVO will renew the measurement network before Posiva's disposal facility receives operating licence in early 2020's. At the Loviisa NPP, a new monitoring network including 28 stations has been in operational use since summer 2015. 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 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 21), and from foreign authorities.

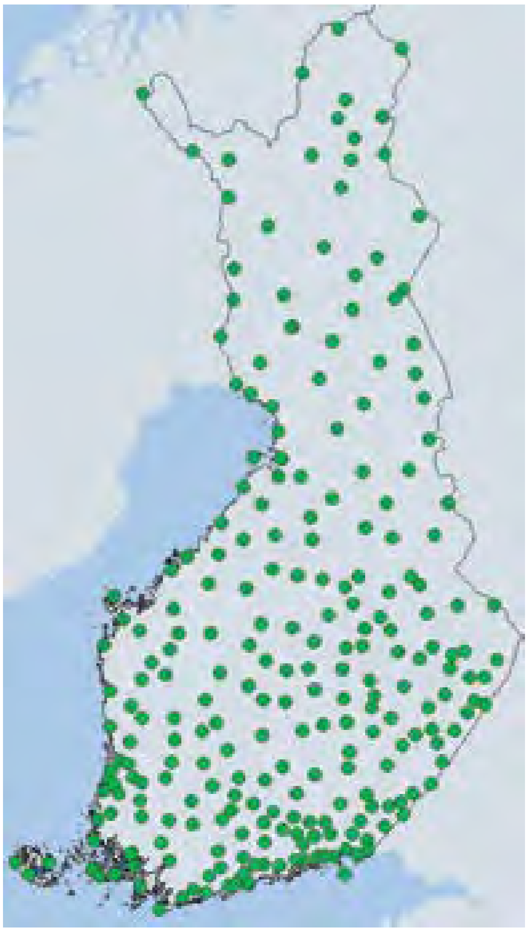


FIGURE 21. The measuring stations of the radiation monitoring network.

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 scale off-site emergency and rescue exercise OLKI17 was carried out in 2017 based on the Olkiluoto nuclear power plant accident scenario. Approximately 50 different organisations participated in this exercise. Exercise scenario concentrated on OL3 NPP unit. According to STUK's Regulation (STUK Y/2/2018) emergency arrangements shall comply with the emergency plan before fuel is loaded into the reactor and an emergency exercise shall take place before loading to demonstrate that the emergency arrangements function properly. OLKI17 scenario was sufficiently broad that all major functions in the emergency plan had to be activated and practiced. Based on OLKI17 exercise evaluation TVO started development project to improve some parts of their emergency plan. While OLKI17 is considered to be the exercise demanded by regulation some arrangements still need to be finished before fuel loading permit to OL3 can be granted by STUK.

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 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. Fennovoima and local authorities from northern Finland have been observing and participating in some of the groups emergency exercises and meetings.

STUK, The National Defense Training Association of Finland and National Emergency Supply Agency launched in 2017 a project to establish a radiation measurement team from volunteers. The purpose of the team is to support authorities during a large scale nuclear or radiological emergency. The persons are trained and equipped by the three above mentioned organizations. In an emergency, STUK's duty is to give recommendations to the domestic authorities. The recommendations are based, among other things, on the performed radiation measurements. The first training course for the volunteers was arranged in spring 2018, followed by a another course in autumn of the same year. The team is to consist of about 40 persons and it is assumed to start radiation measurements during the intermediate phase of radiation or nuclear emergency.

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. 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 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 (252/2017 replacing 468/1994) and the reasoned conclusion of the competent authority 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 (277/2017 replacing 713/2006). The Finnish EIA legislation complies with the EU Directives 2011/92/EU and 2014/52/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/1/2018) 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.

The site-specific external hazards shall be taken into consideration in the design of a nuclear facility as stipulated in section 14 of the Regulation STUK Y/1/2018:

1. The design of a nuclear facility shall take account of external hazards that may endanger safety. Systems, structures, components and access shall be designed, located and protected so that the impacts of external hazards deemed possible on nuclear facility safety remain minor. The operability of systems, structures and components shall be demonstrated in their design basis external environmental conditions.

2. External hazards shall include exceptional weather conditions, seismic events, the effects of accidents that take place in the environment of the facility, and other factors resulting from the environment or human activity. The design shall also consider unlawful and other unauthorised activities compromising nuclear safety and a large commercial aircraft crash.

Furthermore, the Guide YVL A.2 issued by STUK 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 design provisions for seismic events and other external events are set forth in the Guide YVL B.7. Deterministic analyses are made to assess the impact of earthquakes, and other natural and human induced external events. In addition, the probabilistic risk assessment (PRA) provides information on the annual probability of core damage and release of radioactive substances caused by seismic events and other external events. According to the Guide YVL A.7 a preliminary PRA shall be submitted in connection with the Construction Licence application and PRA shall be updated during the life cycle of a nuclear installation, as explained in more detail under Article 14.

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 rare external events .

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. external flooding, 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, with radii of about 5 km, 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 planned 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. The EIA is conducted by the licence applicant or the licensee. The Ministry of Economic Affairs and Employment is the competent authority of the EIA procedure for nuclear installations and arranges the public hearings. The Ministry of the Environment arranges the international hearing according to the Espoo Convention. STUK gives its statement on the parts of EIA relevant to nuclear and radiation safety, nuclear security and safeguards.

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 shall be carried out before the Decision-in-Principle application is submitted, and the EIA report and the reasoned conclusion by the competent authority on the EIA shall be attached to the application for the Decision-in-Principle. The EIA procedure of the new design 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 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 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 requirements on the determination of site-specific design bases for external events are presented in more detail in the 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. The studies on site-related factors are conducted by the licensee and reviewed by STUK in cooperation with relevant expert organizations. 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://safir2022.vtt.fi). 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 in 2015 according to the schedule and STUK has issued its statement on the PSR.

For the Olkiluoto units 1 and 2 a new operating licence was granted in 2018 until the end of 2038 with a requirement of a PSR by the end of 2028.

For the periodic safety review of the Loviisa NPP in 2014–2016 and the renewal of the operating licence of Olkiluoto units 1 and 2 in 2018, 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, human-induced hazards, population and use of land and sea areas. Re-evaluation of the seismic hazard studies for the Loviisa and Olkiluoto sites have been recently updated and submitted to STUK for review.

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 were reviewed 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 operating unit 1 and will be implemented to unit 2 in 2018–2019. 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 replacement of emergency diesel generators is ongoing. The new emergency diesel generators will be provided with alternative air and seawater cooling, while the existing diesels have only seawater cooling. In addition, steam turbine driven auxiliary feed water systems have been installed at the operating units 1 and 2 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/1/2018), 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 primary 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. In addition, there shall be fixed systems for residual heat removal with no material supplements (water, fuel, recharging batteries) for at least 8 hours.

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 Decree 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. The wording in Nuclear Energy Decree Section 22b is very close to the Vienna Declaration. Finnish regulatory guide YVL C.3 explains in more detail what is meant by "large scale protective measures". Analyses must be provided to demonstrate that any release of radioactive substances in a severe accident shall not warrant the evacuation of the population beyond the protective zone (appr. 5 km) or the need for people beyond the emergency planning zone (appr. 20 km) to seek shelter indoors. Guide YVL A.7 states that a nuclear power plant unit shall be designed in compliance with the Government Decree principlesin a way that:

- the mean value of the frequency of a release of radioactive substances from the plant during an accident involving a Cs-137 release into the atmosphere in excess of 100 TBq is less than 5E-7/year;
- the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency.

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 Nuclear Energy Act states 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 design of Olkiluoto units 1 and 2 have been assessed for operation license renewal (2018). Design of the Olkiluoto unit 3 has been assessed for the operation licence (2019). 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.

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.

Other safety improvements have also been implemented during the lifetime of the plants improving the safety functions of the plant and hence defence in depth. Some of the improvements are described below and in the appendixes.

Defence in depth concept in Loviisa NPP

Several plant modifications improving safety have been carried out at the Loviisa NPP during its lifetime. During the last years the the most major modification has been the I&C renewal project, ELSA, which was finalised in 2018. In ELSA project reactor control and limitation system, reactor protection system and automatic reactor protection back up system was modernised using software based I&C platform. Hard wired manual back up system for reactor protection and engineered safety features actuation functions was also added in the project. In connection with the I&C renewal protection of the control rooms from any leaks at the feedwater tank level above control room level has been improved.

Due to the TEPCO Fukushima Dai-ichi accident, improvements implemented and under 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.
- The utility has estimated the effects of high sea level to the plant behavior based on which the flooding protection of the plant is being improved. The flood protection of the buildings most important to safety has been strengthend. In addition, means to cope with extensive loss of electrical systems are being implemented. The implementation of the new means and related instructions will be completed in 2019.
- Installation of diverse water supply to the spent fuel pools. The plant modifications will be completed by 2019.
- Availability of emergency diesel and severe accident diesel fuel on-site was improved by adding filling lines from off-site diesel plant to on-site diesel tanks.

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 lifetime of the plant improving the defence in depth.

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 increasing diversity to the heatsink of EDG cooling (air and sea water). In addition of replacements there will be an extra EDG that can be connected to either unit.

Other safety improvements implemented or under implementation at the Olkiluoto units 1 and 2 include among other things:

- Ensuring cooling of the reactor core in case of total loss of AC supplies and systems. The arrangement consists of high and low pressure systems. The high pressure system is based on a steam driven turbine pump. The low pressure system pumps coolant into the core from the fire fighting system. The systems have been implemented.
- Ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water cooling systems. The modification was implemented at Olkiluoto 1 in 2014. Abnormal vibration and pressure oscillations were observed during the testing of one subsystem. The issue has been solved the modification will be implemented at Olkiluoto 2 in 2019.
- Diverse cooling water supply to the spent fuel pools have been completed in 2015. Additional instrumentation to improve monitoring of the water temperature and level in the spent fuel pools has also been implemented.
- The utility has acquired new mobile equipment (aggregates, pumps).
- The utility has evaluated the availability of makeup 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 units 1&2 are described in more detail in Annex 3.

For the Olkiluoto unit 3, application of the Defence-in-Depth principle was presented in the Preliminary Safety Analysis Report (PSAR) and again in Final Safety Analysis Report (FSAR) when applying operating license. The design follows the principles laid down in the Finnish regulations. Common cause failure of a safety system in connection with an anticipated operational occurrence or class 1 postulated accident has been provided for. The mitigation of the consequences of the severe accidents was included in the plant 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.

Integrity of nuclear fuel

At Olkiluoto unit 1, altogether six fuel rods with cladding failure was detected in 2016, and an additional outage was needed to remove affected fuel. However, the reactor water fission product concentration limits set by the Technical Specifications were not exceeded. Pellet Cladding Interaction (PCI) was confirmed as the failure mechanism in Post-Irradiation Examinations (PIE) performed in 2018 with the fuel vendor. With stricter fuel operating rules similar large cladding failures have been avoided since. Three individual fuel rods with minor gas leakages have been detected at Olkiluoto units 1 and 2 in later reactor operating cycles. These leaks were most probably caused by other mechanisms, such as foreign material fretting.

Integrity of other barriers

The Loviisa unit 2 primary and secondary circuits were subjected to pressure tests in 2018. 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.

STUK requested in 2018 in relation to opearing licence renewal that Olkiluoto 1 and 2 primary circuit will be subjected to periodical pressure tests at every eight years, first with OL2 in 2019 and next with OL1 in 2020. The pressure tests (with pressure of 1,02 times the operation pressure) will replace the periodical leak tightness tests conducted earlier based on ASME XI requirements.

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 2017. Results of the test have fulfilled the acceptance criteria. Olkiluoto unit 3 containment leak tightness test was conducted in the beginning of 2019 with acceptable results.

During the period 2016–2018, no significant failures were observed at the Loviisa plant in the safety functions or in the systems, structures and components executing them. Loviisa 1 reactor pressure vessel primary nozzles were subjected in 2016 to periodic NDT-inspections with a new phased array NDT-inspection technique. In this inspection one indication was detected that required strength analysis to be approved before permission to continue plant operation. STUK required to repeat the inspection in 2017 outage with qualified inspection procedure. Corresponding inspections were requested to carry out also at Loviisa 2. In addition STUK required Fortum to clarify the cracking mechanism to manage the situation. Also provisions to plan repair procedures were requested to clarify. In 2018 NDT-inspections there were no changes found concerning the year 2016 Loviisa 1 nozzle indication.

Thermal fatigue cracks were found at the Olkiluoto units 1 and 2 on the inside surface of main feedwater runpipe during the annual outage in 2014. All cracks were in the base material. The cracks located at a mixing point (T-joint) of pipelines between the feedwater system and the shutdown cooling system. These mixing points were replaced in outages 2015 at OL2 and 2016 at OL1. In addition, IRS report 8439 ”Thermal fatigue cracks in feed water piping Tee” was prepared.

In 2003 an indication in the reactor feedwater system at Olkiluoto 2 was detected and thus subjected to more frequent in-service inspections, as reported earlier. The indication was located in the weld between the reactor pressure vessel nozzle and the safe end of the feedwater piping. Later on, a similar indication was detected in the reactor core spray system. Both indications have been surveyed by non destructive ultrasonic (UT) and eddy-current testing (ET). The indications may have initiated from welding defects with possible growth during operation. The size of the indications promoted STUK to require annual inspections and updated crack propagation calculations to verify safe operation for the following power cycles. In addition to these 2 major indications a additional non-recordable indications were detected in the periodical inspections, indicating ageing of the safe end welding material. This called the licensee TVO to start a major safe end repair campaign at Olkiluoto 1 and 2 units.

The licensee submitted a repair plane for the safe-ends in 2016–2017, with the main objective to eliminate the indications and return back to the original in-service inspection interval. According to the plan, the indications will be removed by local machining and repair welding before final machining.

The repair campaign was launched for Olkiluoto 2 at the outage in 2017, with the aim to do similar repairs at Olkiluoto 1 in 2018. As a result of the tight schedule during the first quarter of 2017 a complete factory acceptance test (FAT) under remote control, including all the different working steps, could not be completely carried out. Partly due to this, the Olkiluoto 2 repair campaign encountered challenges that caused delays and modifications to the plan. There were challenges with the excavation and welding processes, detecting indications during repair as well as with the final machining. This prompted TVO to modify the objective of the original repair plan. As a result, the larger indications in the main feedwater and reactor core spray systems at Olkiluoto 2 were repaired, and all other smaller indications were left out.

After the repair campaign of 2017 TVO concluded not to continue repairing of the smaller non-recordable indications at Olkiluoto 1 in 2018. Obvious risks were foreseen related to the successful execution of such a repair campaign that could jeopardize the objective to return to the original inspection interval. TVO is required to monitor the two repaired safe-ends annually for three years , before returning to the inspection interval as used prior to the repair campaign. In relation to this, TVO has also made a new strategy in 2018 for a back-up repair campaign, which relies on complete replacement of the safe-end instead of repairing it.

The inspections carried out after the hydrogen flake findings at Doel unit 3 in 2012 have been assessed and realized in Finland. Olkiluoto 1, 2 and 3 units were regarded to be free of hydrogen flaking problem. To confirm this with Loviisa 1 and 2 additional UT-inspections for the RPV core areas were carried out in 2014 and 2016 without detection of such indications.

In Olkiluoto 3, pre-operational commissioning included pressure tests of the containment building and the primary circuit, as well as leak tightness test of the containment building. The containment pressure test and leaktightness tests were carried out successfully in January 2014. The leak tightness test was repeated in 2019 and it will be performed regularly during operation. The primary circuit pressure test was performed successfully in 2017.

Incorporation of proven technologies

According to STUK Regulation (STUK Y/1/2018), the nuclear plant shall be equipped with systems that function automatically and reliably to prevent severe fuel damage in postulated accidents and in design extension conditions; manually actuated systems can be used to manage accident situations if it can be justified from a safety perspective.

Practical implementation of 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 plants is a big challenge. This includes also the issues related to the highly integrated control rooms.

At the Loviisa NPP, a big part of I&C systems are now 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 modernised a large part of the I&C system of the plant, switching it to a software based platform. The project were completed in the original timetable during the 2018 annual maintenance outages.

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 projects 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, application software and equipment suitability. 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/1/2018 section 16 requires that a nuclear facility shall contain equipment that provides information on the operational state of the facility and any deviations from normal operation. A 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 consequences. These automatic systems shall be capable of maintaining the nuclear power plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions. In order to control the nuclear power plant and enable operator actions, the nuclear power plant shall have a control room, in which the majority of the user interfaces required for the monitoring and control of the nuclear power plant are located. STUK regulation Y/1/2018 also requires that human factors related safety must be taken into account in the design of the nuclear plant and in the design of its operation and maintenance. In particular in designing control rooms this means that a justified HFE program is required for new builds and control room modifications. For the purposes of the design process and the regulatory control exercised by STUK, the control room and emergency control room are be treated as a functional entity similar to a Safety Class 3 system.

STUK oversees new builds and modifications from the point of view of quality planning and from the point of view of human factors engineering process.

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/1/2018), in connection with the commissioning of a nuclear facility or its modifications, the licensee shall ensure that the systems, structures and components and the nuclear facility as a whole operate as designed. At the commissioning stage, the licensee shall ensure that appropriate procedures are in place for the future operation of the nuclear facility.

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 facility 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 Guide YVL A.5 also requires that the licensee's personnel shall participate in the commissioning testing to familiarize themselves with the facility and its systems. During commissioning, it shall also be ensured that the licensee's organization is adequate to ensure the safe operation of the nuclear facility.

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 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. 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 consisted of component and system testing, which are still partly ongoing. These tests were followed by the plant level overall system tests or the so called cold and hot functional tests without the core which were completed in the years 2017 and 2018, respectively. In the late 2017 and early 2018 the fresh nuclear fuel was also delivered to the site and is currently being stored in the spent fuel pools of the fuel building.

Currently, the preparation phase for the first fuel loading is ongoing at the site. This includes for example the finalization of the remaining system level tests and the necessary re-tests that are due to the modifications implemented at the unit and the other finalization works. Furthermore, the plant operating procedures are still partly under preparation and the validation of the procedures is still incomplete. The preparation phase for the first fuel loading is followed by the fuel loading itself. For the fuel loading, the Operating licence and STUK´s authorisation are required. Hot functional tests with the 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 coolant 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. The licensee has approved an Overall Commissioning Programme as well as system level commissioning documentation prepared by the plant supplier and STUK has approved the documents that are safety relevant. Preparations for plant level commissioning are still underway, e.g. preparation of detailed commissioning programs for the later phases of commissioning such as the power tests. STUK oversees the commissioning of safety classified systems and related result documentation is provided for STUK's review.

As the Guide YVL A.5 requires, one aim of the commissioning is to ensure that a sufficient organisation is in place for the future operation. TVO's personnel (e.g. future operators and maintenance personnel) have participated and are still 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. 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). Furthermore, the STUK Regulation (STUK Y/1/2018) Section 22 states that the OLCs of a nuclear facility shall include the technical and administrative requirements for ensuring the nuclear facility's operation in compliance with the design bases and the assumptions of safety analyses. 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. Guide YVL A.6 sets forth more specific requirements for the OLCs. It requires for example that the minimum staff availability in all operational states and the limits for the releases of radioactive substances shall also be 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. Any amendments to or departures from the OLCs shall be submitted to STUK for approval prior their implementation as per the Guide YVL A.6.

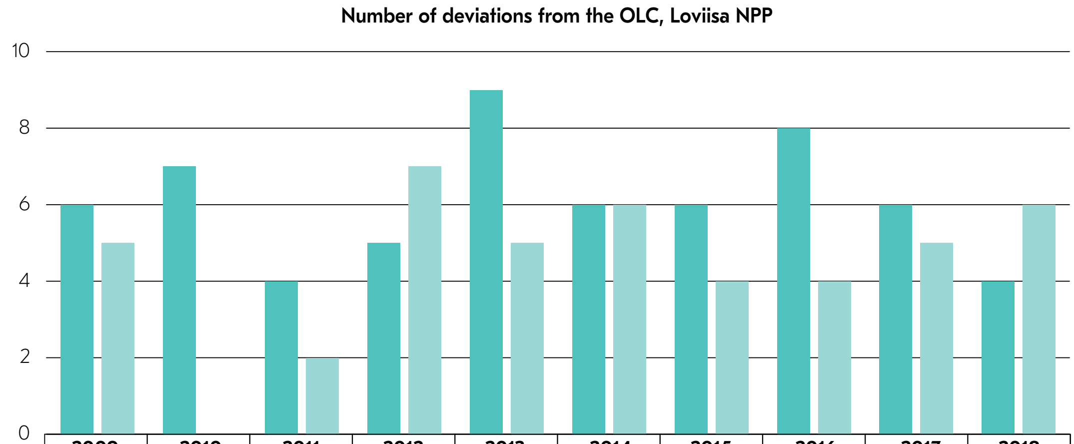
Fortum has established the OLCs for the Loviisa units 1 and 2, and STUK has reviewed and accepted them. The OLCs are continuously updated, and all the changes need to be approved by STUK. The limitations and conditions of the reactor and plant operation, the requirements for periodic tests and the essential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

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 had a development project to update the OLC for the Olkiluoto units 1 and 2. The goal of the development project was 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 was completed in 2017. Furthermore, minor changes to the OLC has been made regularly based on plant modifications and organizational changes.

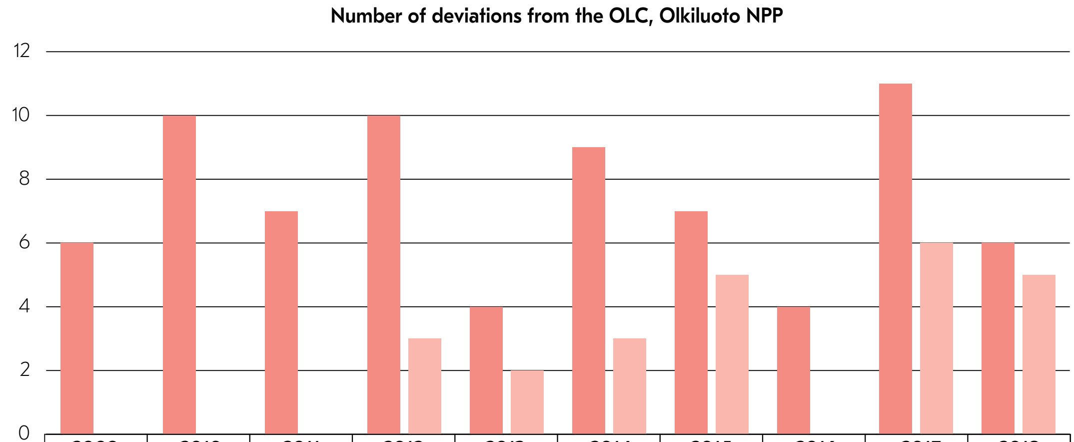
The OLCs for the Olkiluoto unit 3 was reviewed by STUK as a part of the operating licence documentation. STUK approved the OLCs for Olkiluoto 3 with requirements and the OLCs shall be updated according to the STUK requirements and approved by STUK before the first fuel loading.The OLCs for the Olkiluoto unit 3 define the safety limits for the plant, limiting conditions including the completion times and surveillance requirements for plant systems, structures and components, as well as administrative controls. The OLCs also include bases and justification for the conditions. Currently, there is a limited subset of OLCs in force in the fuel building of Olkiluoto 3 where the fresh nuclear fuel is being stored.

Figure 22 presents the number of exemptions and deviations from the Operational Limits and Conditions. 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 2016–2018 (total 18) was same as the average. During the period 2016–2018, most of exemption applications concerned plant modifications and testing of equipment or overdue repairs of component failures. In 2016–2018, there were fifteen events at the Loviisa plant in which the Operational Limits and Conditions were deviated. The figure 22 is showing that the deviations are close to average. Deviations have occurred four times per year on average during past ten years (2009–2018).

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. Most of the applications were related to plant modifications In 2016–2018, 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. 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.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Exemptions	6	7	4	5	9	6	6	8	6	4
Deviations	5	0	2	7	5	6	4	4	5	6



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Exemptions	6	10	7	10	4	9	7	4	11	6
Deviations	0	0	0	3	2	3	5	0	6	5

FIGURE 22. Number of exemptions and deviations from the Operational Limits and Conditions at the Loviisa and Olkiluoto NPPs.

Procedures for operation, maintenance, inspection and testing

STUK Regulation (STUK Y/1/2018) 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 operating nuclear power plants and for Olkiluoto 3 unit these procedures are still partly under preparation. 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.

For Olkiluoto 3 unit the written procedures for the operation and maintenance are partly still under preparation and will be finalized before the first fuel loading. The administrative procedures of Olkiluoto units 1 and 2 are updated to take the unit 3 into account considering also the differences between the boiling and pressurized water reactors. Furthermore, new procedures for unit 3 are prepared where necessary.

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.

At the Olkiluoto 3 unit the plant suppliers work management system is currently being used for reporting the component failures and managing the works at the plant. TVO's own system which is in use at the units 1 and 2 will be commissioned before beginning of the commercial operation of the unit.

The maintenance activities of the Olkiluoto units 1 2 and 3 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 for Olkiluoto units 1 and 2 whereas the unit 3 will utilize the experiences especially from the other EPR units in Taishan and Flamanville.

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/1/2018) Section 20 gives basic requirements for operating and emergency procedures. More specific requirements regarding the procedures including emergency operating procedures and severe accident management guidelines are set forth in the Guide YVL A.6.

At both Finnish operating 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 had a 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 was completed in 2017. 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 Dai-ichi 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. EOP to manage accident conditions affecting multiple units (OL1/OL2/OL3) and spent fuel pools is under preparation.

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, connection of the additional water supply to the spent fuel pools will be carried out in 2019 outage. EOPs were developed in 2012 for shutdown states covering the immediate recovery of SAM systems.

At the Olkiluoto 3 unit the procedures for abnormal and emergency operation including severe accident management guidelines are under preparation. All these procedures will be verified and validated in the training simulator before the first fuel loading. The purpose of the emergency operating procedures is to prevent the core melt. The emergency operating procedures of Olkiluoto 3 unit consist of the event-based procedures and of the symptom-based procedures. In addition, necessary event diagnosis procedures for abnormal and emergency operation are included as well as the safety function monitoring procedures for the safety engineer. The plant level procedures are in the form of the flow charts and in electronic format. In case of losing the electronic procedures, the paper-based procedures also exist in the main control room. STUK has supervised the validation activities of the procedures at the simulator. Based on the validation results, several modifications have to be made to the procedures.

As mentioned above, the severe accident management guidelines or the operating strategies for severe accidents (OSSA) are also being prepared and validated for Olkiluoto 3 unit. The purpose of the OSSA is to ensure the integrity of the containment and to mitigate the consequences of the severe accident.

The assessment conducted for Olkiluoto 3 unit due to the TEPCO Fukushima Dai-ichi accident showed that the external hazards had been taken into accuountin the design sufficiently and there was noneed for immediate actions. However, the following safety improvements among others have been implemented: the possibility to feed the spent fuel storage pool by movable hoses and pumps and the possibility to transfer the fuel from the emergency diesel generator storage tank to the station blackout diesel generator.

Engineering and technical support

STUK Regulation (STUK Y/1/2018) 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.

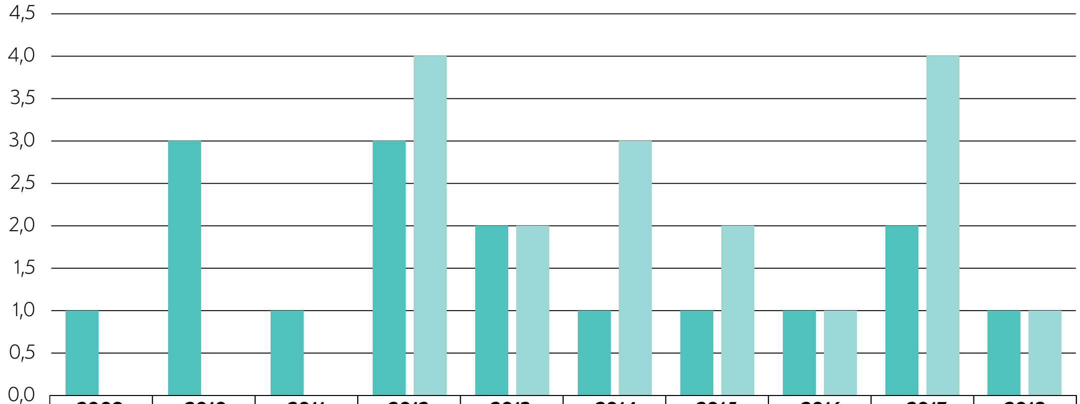
Reporting of incidents significant to safety

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 $\geq$ 1) as press releases. Information from some 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 21 operational event reports per year (in 2016–2018) and Olkiluoto NPP on an average 17 operational event reports per year (in 2016–2018). Average level is similar to previous period 2013–2015 (Loviisa NPP 19, Olkiluoto NPP 18).

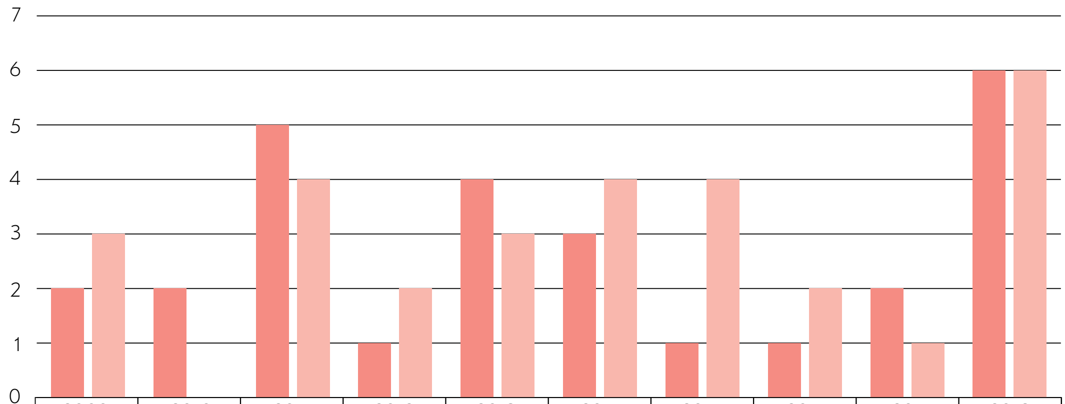
Figures 23 and 24 present the total number of safety-significant events (criteria: Guide YVL A.10 requirements A01–A07) and INES classified ($\geq$ 1) events at the Finnish nuclear power plants.

Number of operational transient reports, Loviisa NPP



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Loviisa 1	1	3	1	3	2	1	1	1	2	1
Loviisa 2	0	0	0	4	2	3	2	1	4	1

Number of operational transient reports, Olkiluoto NPP



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Okiluoto 1	2	2	5	1	4	3	1	1	2	6
Olkiluoto 2	3	0	4	2	3	4	4	2	1	6

FIGURE 23. Annual total number of safety-significant event reports (criteria: Guide YVL A.10 requirements A01–A07) submitted by the Loviisa and Olkiluoto nuclear power plants.

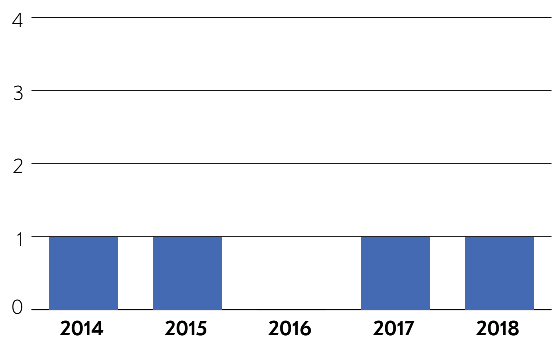


FIGURE 24. Annual total number of events at INES Level 1 at the Finnish nuclear power plants. All events were ≤ INES Level 1 in 2014–2018.

INES-classified events

At the Loviisa NPP, six events in 2016, eight events in 2017 and seven events in 2018 were classified on the International Nuclear Event Scale (INES). One of these events were rated at level 1, others being of level 0:

- A fresh nuclear fuel assembly fell from the fuel transfer machine into the fuel transfer basket, 28.2.2017, INES 1 (IRS 8474)

This incident is described in more detail in Annex 2.

At the Olkiluoto NPP, two events in 2016, six events in 2017 and seven events in 2018 were classified on the International Nuclear and Radiological Event Scale (INES). One of these events were rated at level 1, others being of level 0:

- Reactor scram on high reactor power in natural circulation conditions (SS15), 8.5.2018, INES 1.

These incidents are described in more detail in Annex 3.

Operational experience feedback

According to the Section 21 of the STUK Regulation (STUK Y/1/2018), 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 incidents at nuclear facilities and activities are analysed. 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 screened and 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 2016–2018: interface between OEF organization and line organization (roles and responsibilities) and results of the OEF function (learning from experiences).

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 25 shows the distribution of IRS reports into different categories in STUK's review and assessment from 2016 to 2018. Altogether 499 IRS-reports were assessed during that period and most of them (75%), 373 reports, fell into category 0 requiring no further actions. 16% (81 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 8505 "Unit removed from service for maintenance due to a through-wall crack formation in the base metal of control rod drive tube in cell 05-38", Russia
- IRS 8315 "EDG failed to start after undetected loss of two phases on 400 kV incoming offsite supply", Sweden
- IRS 8435 "Outbreak of fire in a reactor coolant pump", France
- IRS 8493 "Generic deviations in the 1450 MWe units involving primary reactor coolant pump suction adapter screws", France.

In the 13 events it was realised that similar kind of events were already well prevented by technical or administrative arrangements, and thus we have good practices in use.

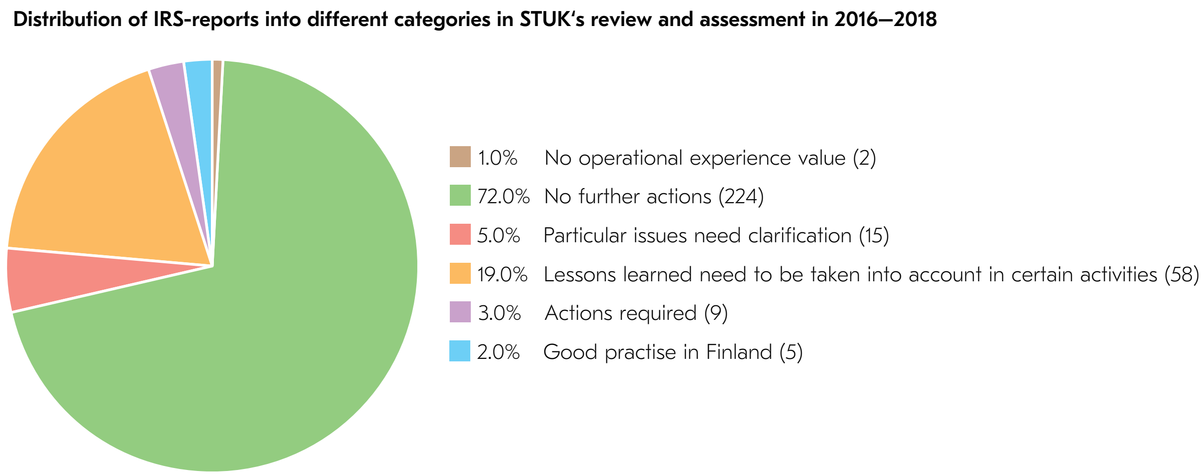


FIGURE 25. Distribution of IRS reports into different categories in STUK's review and assessment in 2016–2018.

Reports for the IRS System on safety-significant occurrences at the Finnish nuclear power plants are written by STUK. STUK has delivered four (4) new IRS-reports during 2016–2018.

- IRS 8756 "Programmable technology in qualified relays results in expiration of qualification", Generic report, reported 4.7.2016. Several occurrences of relays found with programmable technology have been found out, Four separate events that took place in Finland in 2012, 2014 and 2015
- IRS 8677 "Prolonged opening time of main steam safety relief valve at repeated actuation", Loviisa-1, reported 10.10.2017.
- IRS 8747 "Challenges with operation of fuel transfer machine" , Loviisa-2, reported 22.11.2018.
- IRS 8761 "Common cause failure in control rod drives" , Olkiluoto-1, reported 13.12.2018.

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 and there are plans to construct a disposal facility also for the new built NPP site Hankikivi in Pyhäjoki. Since the disposal facilities are operated by the nuclear power plant operators, the technical feasibility and economic motivation to minimize the generation of radioactive waste are evident.

The requirement for radioactive waste minimization 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 Radiation Act, STUK regulation on exemption levels and clearance levels, Nuclear Energy Decree and in the Guide YVL D.4, aims at limiting the volumes of waste to be stored and disposed of. The Guides YVL D.3 and D.4 includes also more specific requirements for the conditioning and interim storage of waste and spent nuclear fuel 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 requirements 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 (LILW)

The policy to minimize 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 Cyclife Sweden facility in Studsvik. 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.

The predisposal management of LILW was developed in Loviisa NPP during the reporting period as the solidification plant was authorized for full operation in 2016. Loviisa NPP has now been able to start the solidification of historical liquid wastes, which had been stored in tanks from the start of NPP's operation in the late 1970s. The aim is to solidify and dispose of all existing liquid waste in the forthcoming years.

At the Loviisa NPP site, the disposal facility 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 hall for solidified intermediate level waste. Two tunnels for low level waste disposal have been in use from the very beginning of the facility. The third tunnel, built during 2010–2013, was licensed for storage of low level solid waste. In 2016 it was licensed to include also interim storage of the solidified intermediate level packages until end of 2018. Since the disposal hall for intermediate level is not commissioned yet, the license of the third tunnel was extended until end of 2021. In the end of 2018 Loviisa NPP delivered STUK the updated post closure safety case of the disposal facility. The updated safety case covers both operational waste and decommissioning waste. STUK will review the safety case during 2019.

The renewal of the operating license for Olkiluoto 1&2 in 2018 included the possibility to use the waste handling equipment and storage rooms for wastes originating from Olkiluoto 1, 2 and 3 site area and other radioactive waste with same activity level originated from other licenses or State. The similar principle was introduced in the operating license application for Olkiluoto 3 for the waste from the Olkiluoto NPP site area. All together the interim storage capacity for low and intermediate level wastes in Olkiluoto NPP site area will be 30000 m^3.

The disposal facility 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 bituminized intermediate level waste. The license conditions of the low and intermediate level waste disposal facility were updated in 2012 and the disposal of low and intermediate level wastes from Olkiluoto 3 in the facility was allowed as well as disposal of non-nuclear radioactive wastes originating, e.g. from research, industry and hospitals. Non-nuclear waste has been stored in a cavern in the LILW disposal facility at Olkiluoto. The disposal of waste started in 2016 and currently the most of the waste accumulated over the years have been disposed of.

At the end of 2018, 6420 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. Rest of the low and intermediate level disposal waste is stored at the NPP site area.

Decommissioning

Revised Nuclear Energy Act and Nuclear Energy Decree were issued in January 2018. In this revision a decommissioning license was added into the Finnish licensing system. The licensee shall apply for the decommissioning license, while the operating license is still valid. The license application for decommissioning shall be submitted to the authorities in time to ensure that they are able to review the application while the operating license is still valid. The requirements for the licensing documentation are presented in the Nuclear Energy Decree (paragraphs 33 a, 34 a and 36 a).

The Nuclear Energy Act sets the basic principles and requirements for the decommissioning. Dismantling of a nuclear facility and other measures taken for the decommissioning of the facility may not be postponed without a due cause. Decommissioning costs shall be included into the total cost estimates of the nuclear waste management of Licensee and will be taken into account in the liability and fund target estimations for the Nuclear Waste Management Fund. More detailed requirements for the decommissioning are presented in the Guide YVL D.4. Decommissioning of the nuclear facility shall be taken into account already in the design phase of a nuclear facility. According to the Nuclear Energy Decree decommissioning plan has to be included in the construction license application documentation. Since the operating license the utilities are obliged to keep the decommissioning plans up-to-date and submit them to the Ministry of Economic Affairs and Employment every six years for review. The final decommissioning plan is required for the decommissioning license application. The decommissioning of a nuclear facility shall be performed in accordance with the safety requirements and with a decommissioning plan approved by STUK. The last review for Olkiluoto NPP decommissioning plan was made in 2014. Loviisa NPP submitted the updated decommissioning plan for review in the end of 2018.

The strategy for the decommissioning in the Loviisa NPP is that both units will be shut down after 50 years operation in 2027 and 2030 and the dismantling of the NPPs starts immediately and lasts approximately 11 years. In Olkiluoto units 1 and 2 are planned to be shut down after 60 years operation in 2038. 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. Unit 3 is planned to shut down after 60 years operation in 2070's. The decommissioning strategy for the unit 3 is immediate dismantling and it is planned to be dismantled after dismantling the units 1 and 2 has been completed.

In 2012 VTT (Technical Research Centre of Finland Ltd) decided to shut down Finland's only research reactor FiR 1 (TRIGA Mark II, 250 kW). By this decision, the research reactor will be the first nuclear reactor to be decommissioned in Finland. The Environmental Impact Assessment procedure for the decommissioning was conducted in 2013–2015. VTT submitted an application to the Government for a decommissioning on June 20, 2017. Formally it was an application for a new operating license as the Finnish legislation didn't define a decommissioning license at that time. In the license application VTT presents two alternative time schedules for the decommissioning. The first option is based on the assumption that the spent fuel can be repatriated into the USA according original returning agreement in 2019. In this case the actual dismantling of radioactive parts of the facility would be ready in 2020 and the site would be released from the regulatory control in 2023. The other schedule is based on assumption that spent fuel needs to be interim stored in Finland before transportation to USA. In this option, the dismantling could not be started until the interim storage concept is licensed separately according the Nuclear Energy Act. In this case the dismantling would be ready at the end of 2025. STUK submitted its statement and safety evaluation report of the application to the Ministry of Economic Affairs and Employment in March 2019.

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 dense racks into the storage facility started in 2007 to increase the capacity and it will be continued until Posiva starts transferring spent fuel to Olkiluoto for disposal. The capacity of the interim storage will be adequate for the total amount of the spent fuel 1100 tU allowed in the operating license 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.

The Loviisa spent fuel storages have been improved since the Fukushima Dai-ichi accident. The main changes were aimed at reducing the dependency on the plant's normal electricity supply and distribution system, as well as on the seawater cooled systems for residual heat removal from the reactor, containment and spent fuel pools. Two air-cooled cooling units were constructed and commissioned in 2014–2015 to ensure long-term decay heat removal in case of the loss of seawater. In order to improve safety in all conditions, the installations of a diverse water supply from external sources to the spent fuel pools and instrumentation of the water level and temperature monitoring of the fuel pools are planned to be carried out during 2019.

At the Olkiluoto NPP, the wet type spent fuel interim storage was commissioned in 1987. In 2009 TVO submitted documentation for STUKs approval on extension of the capacity of the facility. The spent fuel interim storage underwent numerous safety improvements during its capacity extension, which became operational in summer 2015. These included, e.g. protection against large airplane crashes and enabling a cooling water feed from outside the storage facility. After the extension the interim storage serves all three units at Olkiluoto NPP. The original capacity of 1200 tU was extended to 1800 tU. Based on the evaluation in relation to the Fukushima Dai-ichi accident, water level and temperature monitoring functions have been improved for earthquake resistance and for the potential loss of the facility power supply. Instrumentation of the water level and temperature monitors were installed to the spent fuel pools at the beginning of 2019.

At the end of 2018, the spent fuel accumulation at the Olkiluoto NPP was 1864 tons of uranium and at the Loviisa NPP 734 tons of uranium.

Fennovoima submitted the construction licence application in 2015 for the NPP. Fennovoima plans to store spent fuel in an interim storage which will be a pool type wet storage. The amount of spent fuel to be stored is estimated to be around 1400 tU.

In the construction license application documents Fennovoima provided STUK the licensing plan of the spent fuel interim storage. The detailed documentation of the license application was submitted to STUK in two batches in 2017 and 2018.

The power companies Fortum and TVO established in 1995 the joint company Posiva to take care of the spent nuclear fuel disposal. Research, development and planning work for the spent fuel disposal is in progress and the disposal facility is envisaged to be operational in 2024. 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.

Posiva submitted the construction licence application for an encapsulation plant and a disposal facility for spent nuclear fuel to the Ministry of Economic Affairs and Employment in the end of 2012. The construction licence was granted for Posiva by the Government in November 2015. The capacity of the disposal facility is restricted in the construction license to 6500 tU which covers the spent nuclear fuel from the NPP units in operation (Olkiluoto 1 & 2, Loviisa 1 & 2) and in commissioning (Olkiluoto 3).

The Decision in Principle for Posiva disposal facility allowed Posiva to construct an underground rock characterization laboratory ONKALO® to confirm the suitability of the site. It was built during 2004–2016 and it was also planned to be a part of the disposal facility. After the construction license was granted to Posiva, the underground construction activities outside the scope of ONKALO® were started in the end of 2016. In the beginning of 2019 Posiva has proceeded to excavate the beginning part of the central tunnel of the first disposal panel.

The encapsulation facility will be built on the ground level and above the disposal facility. The base for the encapsulation facility is already excavated and the construction work is about to begin in summer 2019. According to Posiva, the operation license application will be provided for the authorities in the end of 2021.

In 2016 Fennovoima submitted Environmental Impact Assessment (EIA) program for disposal of spent nuclear fuel to the Ministry of Economic Affairs and Employment. According to the program Fennovoima will start assessment for spent nuclear fuel encapsulation and disposal facility in two alternative municipalities Eurajoki and Pyhäjoki. Fennovoima has proposed that EIA process is finalized in year 2040 and after that they will apply for Decision-in-Principle. Fennovoima has planned to start spent fuel disposal at earliest in 2090's. At the same time, a co-operation agreement with Posiva Solutions Oy (Posiva's subsidiary that focuses on supplying services) was signed to ensure that the expertise of Posiva is available for Fennovoima's spent nuclear fuel management activities. Co-operation started in 2016.

The 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/4/2018), STUK Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018) and in the Guides YVL D.3 and D.5. STUK published also a new Guide YVL D.7, Release barriers of spent nuclear fuel disposal facility.

A detailed description of spent fuel and radioactive waste management and related regulation is included in the 6th 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 218, October 2017).

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

ANNEX I
List of main regulations

Legislation (as of 31 December 2018)

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 (859/2018)
6. Government Decree on Ionizing Radiation (1034/2018)
7. Decree of the Ministry of Social Affairs and Health on Ionizing Radiation (1044/2018)
8. Act on the Finnish Centre for Radiation and Nuclear Safety (1069/1983)
9. Decree on the Finnish Centre for Radiation and Nuclear Safety (618/1997)
10. Decree on Advisory Committee on Nuclear Safety (105/2016)

STUK Regulations by virtue of Nuclear Energy Act

- STUK Regulation on the Safety of Nuclear Power Plants (STUK Y/1/2018)
- STUK Regulation on Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2018)
- 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/4/2018)
- TUK Regulation on the Safety of Mining and Milling Operations aimed at Producing Uranium or Thorium (STUK Y/5/2016)

STUK Regulations by virtue of Radiation Act and Nuclear Energy Act

- STUK Regulation on Exemption and Clearance Levels (STUK SY/1/2018)
- STUK Regulations by virtue of Radiation Act (applied to the use of nuclear energy)
- STUK Regulation on the Investigation, Assessment and Monitoring of Occupational Exposure (STUK S/1/2018)
- STUK Regulation on the Radiation Measurements (STUK S/6/2018)

The Regulations are available on the Internet at https://www.stuklex.fi/en/maarays (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, 15.2.2019
Guide YVL A.3 Management system for a nuclear facility, 15.3.2019
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, 15.3.2019
Guide YVL A.6 Conduct of operations at a nuclear power plant, 15.6.2019
Guide YVL A.7 Probabilistic risk assessment and risk management of a nuclear power plant, 15.2.2019
Guide YVL A.8 Ageing management of a nuclear facility, 15.2.2019
Guide YVL A.9 Regular reporting on the operation of a nuclear facility, 15.2.2019
Guide YVL A.10 Operating experience feedback of a nuclear facility, 15.2.2019
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, 15.16.2019
Guide YVL B.2 Classification of systems, structures and components of a nuclear facility, 15.16.2019
Guide YVL B.3 Deterministic safety analyses for a nuclear power plant, 15.11.2013
Guide YVL B.4 Nuclear fuel and reactor, 15.3.2019
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, 15.6.2019
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, 15.3.2019
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, 15.3.2019
Guide YVL C.4 Assessment of radiation doses to the public in the vicinity of a nuclear facility, 15.3.2019
Guide YVL C.5 Emergency arrangements of a nuclear power plant, 15.11.2013
Guide YVL C.6 Radiation monitoring at a nuclear facility, 15.13.2019
Guide YVL C.7 Radiological monitoring of the environment of a nuclear facility, 19.12.2016

Group D: Nuclear materials and waste

Guide YVL D.1 Regulatory control of nuclear safeguards, 24.5.2019
Guide YVL D.2 Transport of nuclear materials and nuclear waste, 15.15.2019
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, 13.12.2018
Guide YVL D.6 Production of uranium and thorium, under drafting
Guide YVL D.7 Barriers and rock engineering of nuclear waste disposal facility, 13.2.2018

Group E: Structures and equipment of a nuclear facility

Guide YVL E.1 Authorised inspection body and the licensees in-house inspection organisation, 15.3.2019
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, 15.2.2019
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, 15.13.2019
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, 15.3.2019
Guide YVL E.13 Ventilation and air conditioning equipment of a nuclear facility, under drafting

The guides are available on the Internet at https://www.stuklex.fi/en/yvl-ohje (in English)

ANNEX 2
Loviisa NPP units 1 and 2 in operation

The Loviisa NPP 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 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 and 2030 for Loviisa 1 and 2, respectively. According to the conditions of the licences, two periodic safety reviews were required to be carried out by the licensee (by the end of the years 2015 and 2023). STUK's assessment of the first periodic safety review was completed in February 2017. Based on the assessment, STUK considered that the Loviisa NPP meets the set safety requirements for operational nuclear power plants. The second periodic safety review process has started in the end of 2018 and will be finalised before 2023. The licencee's project also includes the evaluation of the possibility to continue operation beyond the current operating licence, but no decision on the lifetime extension has been made yet.

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 disposal facility for operational radioactive 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 reactor coolant pump in the corresponding loop. 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 lay-out 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, an auxiliary emergency feedwater system has been built for the case that both the feedwater and the 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 the normal systems are not operable.

The main transformers have been protected with a sprinkler system, which essentially reduces the risk of fire spreading into the surrounding buildings, especially into the turbine hall. The risk to lose the AC-power (station black-out) 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 and equipped with diesel-driven fire water pumps and with a separate fire water tank. The 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 also been done.

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 (SAM) programme was initiated in the end on 1980's in order to meet the requirements of STUK. For Loviisa NPP, the SAM strategy was developed and the approach chosen focuses on ensuring the following top level safety functions in case of a severe accident:

- depressurisation of the reactor coolant system (RCS)
- 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.

Introducing the SAM strategy lead to a number of hardware changes at the plant as well as to new severe accident guidelines and procedures.The RCS depressurisation is an action in the interface between the preventive and mitigation measures of the SAM strategy in the Loviisa NPP. If the emergency core coolant injection function is operable, the depressurisation may prevent the core melt (RCS 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. The manual depressurisation capability has been designed and implemented through motor-operated high capacity relief valves. The depressurisation capacity will be sufficient for feed & bleed 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 the core exit detected by dedicated 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 of 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 the licensee. 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 RPV lower head thermal shield such that it can be lowered down in case of an accident to allow a free passage of water in contact with the RPV bottom. Also a strainer structure was constructed in the reactor cavity in order to screen 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 by the licensee 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. Therefore, an external spray system was 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 (a fraction of decay power is still absorbed by thick concrete walls). The system is started manually when the containment pressure reaches the design pressure of 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.

Maintaining the containment integrity ensures that the environemental releases through possible small leakages remain low. To support the containment leaktightness the seals of the large hatches were replaced with the material capable of withstanding the conditions during severe accidents. Furthermore, production of gaseous iodine compounds is evaluated to remain low due to high pH of the sump water. As the ice in the ice-condensers contain large amount of borax, the sump water pH remains well above 7 during severe accident despite of possible cable fires and radiolysis procuding hydrochloric acid and nitric acid, respectively.

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 1 and in 2002 for Loviisa 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.

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. 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.

Transient tests defined in the test programme were performed with a reactor thermal power of 105% and 109%. The last transient test at final reactor power 109% was completed successfully in December 1997. 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 Economic Affairs and Employment (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 (2016–2018)

I&C renewal project at Loviisa NPP

A project for the Loviisa NPP I&C renewal, ELSA, was launched in June 2014. The ELSA project modernise a large part of the I&C system of the plant, switching it to a digital equipment platform. The delivery contract had been made with the Rolls-Royce. The installation of the the first stage of the renewal was in 2016. In its first phase, the control and indication system of preventive safety functions and the I&C status monitoring system were renewed for both plant units. The second phase covering manual back-up and the extension of monitoring system was installed in both units during the 2017 annual outage. The preliminary installations for the third phase were also done at that time. The safety I&C, the element which is most important for the safety of the I&C reform, was installed during the 2018 annual outages in Loviisa unit 1 and 2.

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 were constructed to 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 was 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. And after starting ELSA project installations Fortum has launched many smaller automation projects to cover the final scope of the needed renewal as a part of aging management. One example is the modernization of the automation of the four emergency dieselgenerators (preliminary plan is to renew all Loviisa unit 1 EDG's automation, but not Loviisa unit 2).

The modernisation of secondary circuit safety functions

In connection with the I&C renewal protection of the control rooms from any leaks at the feedwater tank level above control room level were completed at the outages in 2018. It has been long term project where the safety functions are based on the mechanical protections and functional and physical separation of the redundancies.

Installations in previous years/ unit:

- additional emergency supports and jet shields for steam pipelines were installed for main steam lines in 2008
- additional emergency feedwater supply lines were installed for two remaining steam generators (now every steam generator has the suply instead of 4/6) in 2010
- installation of minimum flow lines for residual heat removal pumps in 2008
- modification of the one main feedwater pump (minimum flow, cooling of pump and motor) in 2009 to be available as reserve pump similarly as emergency feedwater pump during plant start-up and shutdown
- fast acting isolation valve of the main steam collector installation (to form two separate groups

when steam collector pressure < 35 bar, three steam generators in each) in 2008. Also the main feed water collector was equipped with two isolation valves using same protection signal to enable the main feed water suply to the three intact steam generators, if the others are lost due to a leak.
- installation of the water-steam qualified main steam safety valves (1/each steam generators) in 2014 and 2016
- wide range water level measurement of the steam generator.

In 2018 the finalization of the project covered:
- renewal of the protective signals (main steam & feedwater separation/isolation and stop of the primary circulation pumps)
- installation of new minimum flow lines for the emergency feedwater pumps and change of the emergency feedwater supply (supply only from the emergency feed water tank)
- better separation of the feed water collector lines
- new bypass pipe lines for the main feed water to be used in the start-up and shutdown.

Examples of latest incidents at the Loviisa NPP (2016–2018)

Fall of a fresh fuel assembly in the fuel transfer pool of Loviisa 2 on 28 February 2017 (IRS-report 8747)

On February 28, 2017, fresh nuclear fuel assembly was accidentally dropped ca. three meters from the fuel transfer machine into the fuel transfer basket in a pit of the Loviisa 2 reactor hall. The incident occurred while fresh fuel assemblies were being transferred under water from the storage pool to the refueling pool. When the fuel transfer machine operators were trying to lay down one of the fresh fuel assemblies on the refueling pool, the assembly inadvertently got stuck on the gripper. The operators noted an indication lighting signaling "no gripping", but they failed to check the reading of the fuel transfer machine scale, which was still indicating attachment of the assembly. When they were picking up the next fuel assembly, they observed that the previous assembly was still stuck on the gripper. The operators decided to transfer the fuel assembly to its original position but when they lowered the assembly towards the fuel transfer basket, it fell off from the gripper.

The incident was reported to the supervisor of the fuel transfer work who contacted a reactor engineer who further contacted the responsible manager who convened a operative decision-making meeting to decide on the procedures. The main control room was also informed about the incident and the operating shift went through specifications for the fuel handling incident. Radiation and Nuclear Safety Authority (STUK) and the head of the division were also informed about the incident. The fuel transfer operation was stopped to determine the corrective procedures and the reasons for the incident. Fortum carried out extensive inspections of the fuel, transfer basket and refueling machine.

A camera inspection showed that the lower end of the fallen fuel assembly was deformed and there were deflections at the supporting structure of the fuel transfer basket's floor structure. There were scratches and burrs on the point of attachment at the upper end of the fuel assembly but according the safety assessment it was still safe to handle.

A burr on the gripper of the fuel transfer machine was evaluated as the direct cause for the incident. Because of the burr the fuel assembly got stuck in the gripper although a main mast was rotated to the release angle and the gripper was open.

The event was rated as an INES category 1 event. The event did not compromise nuclear or radiation safety, but it did reveal obvious deficiencies in the power company's activities and in the condition of the refueling machine.

As this was fresh fuel, there was no radiation hazard, but as similar transfers are also carried out for spent fuel, the event was significant. Similar mistakes had been made in fuel handling at the Loviisa NPP in recent years. Due to the situation, STUK sent a request to Fortum, stating that Fortum can only continue fuel transfers after STUK has assessed the rectifying actions proposed by Fortum as sufficient for preventing similar events.

The inspections and necessary immediate rectifying actions specified by Fortum were acceptably completed, and the personnel were provided with additional training before the operations could continue with STUK's permission on 18 April 2017. In addition, STUK carried out an operational control inspection regarding refuelling activities in the summer for ensuring that the long-term development actions promised by Fortum have progressed and monitored the activities during annual outage.

On the basis of processing and investigating the matter, it is obvious that Fortum has significantly reformed its refuelling methods. The refuelling machine modernisation project has been progressed. The organisational change related to reforming the refuelling activities entered into force from the beginning of 2018. STUK was monitoring the effects of Fortum's organisational change in its inspection in 2018 ensuring through its other oversight activities that the refuelling machine modernisation project advances and the lessons of the event were taken into account in the activities.

Furthermore, STUK carried out its own internal investigation regarding its activities concerning the event in order to develop its activities during the next strategy period. The investigation was completed at the end of 2017 and resulted in recommendations regarding the oversight of transfer and lifting equipment as well as regarding the oversight processes of STUK in general.

Physical and electrical separation of the non-safety classified automation system in March 2018

Loviisa has planned to renew the process computer system in the 2019 outages. In March 2018, STUK was at the site walkdown related to the non-classified process computer renewal and detected that the separation of this automation system was not adequate: the process computer automation cabins included some safety classified and non-classified signals wired from both redundancies without the electrical separation. In case of fire, this could cause malfunctioning of the both non-safety and safety systems.

The principles of signal routing to the process computer is originally 70's design. Physical separation rules were not followed in original installation and the supplier of the process computer system was probably not aware about the physical separation need of incoming signals; electrical isolation were installed in computer cabinets in some cases.

STUK immediately required licensee to analyze and report the possible signal error types and effects of the possible fire to the plant. This analysis covered the design and the separation of the 6300 signals, effects of the possible malfunctions to the safe shutdown of the plant in case of fire event and the PRA.

Conclusion of the analysis was that there are no effects to the reactor protection system, plant protection system or severe accident management system and no effects to reach the controlled state, but safe shutdown state might need local and manual operations (at the switch gears). One example of the results of the assessment was that fire and errorneous control signals can result in a limited small LOCA (via pressurizer relief valve, when pressure > 6 bar) but plant can handle the situation by using local and switching station controls. A very conservative calculation of the increase of the risk gave the result of 710–8/a (= 0,6 % of Loviisa 1 annual core damage frequency).

Improvements for the fire protection arrangements concerning the case were done immediately and the operation procedures for safe shutdown were updated during 2018.

Based on the analyses and actions taken STUK approved that there is no need for modifying the signals before 2019 outages. The safety significant modifications can be made in the 2019 outages in connection with the modernization project of the process computer system. Rest of the signals will be repaired separately during 2020 and 2021.

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 Economic Affairs and Employment (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 Economic Affairs and Employment. Fortum filed the application to the Ministry of Economic Affairs and Employment 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 Economic Affairs and Employment 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) Section 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 Decrees and Nuclear Regulatory Guides (YVL Guides), 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 of the Loviisa NPP 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 polar crane project was established already after the operating licence renewal in 2007, but it was delayed. The installation and commission of the new polar crane has been done for Loviisa unit 2 in 2018 before the outages and will be carried out before outages 2019 for Loviisa unit 1. At shutdown the most significant initiating events are drop of heavy loads.

As a part of the ageing management, the safety of the reactor pressure vessel was assessed in the 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. 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 sent 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. The most limiting case concerning the embrittlement margins is an inadvertent start of containment spraying (cooled water) so the main action by Fortum will be to change the water temperature at the start of spraying. The modification of the cooling water temperature has planned to be implemented in 2019 outages for both Loviisa units.

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.

The second periodic safety review process has already started by Fortum in the end of 2018 and will be finalysed before 2023. The licencee's project includes also the possibility to apply for a new operating licence with life time extension but no decisions has been made yet.

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.

The nuclear safety at the Loviisa NPP is maintained and further improved by necessary renewal activities and backfitting measures. The largest ongoing investment is the complete renewal of the plant I&C system. Also some improvement measures based on the lessons learnt from the TEPCO Fukushima Dai-ichi accident will be finalised in 2019.

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 plans were made on how to address these areas. Main changes 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 have also been measures 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 were implemented in 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 +3.0 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 is relatively low and variations are small. The design basis of the Loviisa NPP was 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 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 in stages first from +2.1 m to +2.45 m and further to +2.95 m. The last modications of the hatches were implemented in 2018 outages.

The licensee was required to submit plans to improve protection against external flooding by the end of 2013. The licensee examined 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 turned out to be more challenging than originally estimated. The utility estimated the effects of high sea level to the plant behaviour. The decisions made were 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 was based on strengthening of flood protection of the buildings most important to safety (the auxiliary emergency feedwater and auxiliary residual heat removal buildings. Due the plan, the flood protection of the buildings most important to safety has been strengthend (the auxiliary emergency feedwater and auxiliary residual heat removal buildings). In addition, means to cope with extensive loss of electrical systems are being implemented. The implementation of the new means and related instructions will be completed in 2019.

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.

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. The depletion time of the batteries was 15...30 minutes. In the implementation of the new YVL guidelines the requirement of the two-hour discharge time for all battery sets supplying loads important to safety and the 24-hour discharge time for the battery sets supplying severe accident management systems was set. The batteries important to safety depletion time was lengthened by the licencee in 2014–2018 and the renewal of the SAM batteries is planned to be implemented by the end of 2019.

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 2019. 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 required 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. The update of the emergency plans and SAM procedures will be completed in 2019.

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.

At the Loviisa NPP, immediate SAM actions are carried out within the Emergency Operation Procedures (EOPs). After carrying out immediate actions successfully, the operators concentrate on monitoring the SAM safety functions with the SAM procedures. The SAM procedures focus on monitoring the leaktightness 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.

ANNEX 3
Olkiluoto NPP units I and 2 in 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 2038. 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 2028.

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 disposal facility 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. Hydrogen burns are prevented by inerting the containment atmosphere by nitrogen, which is an original design feature of Olkiluoto 1 and 2.

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 PRA), 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 (2016–2018)

Renewal of main recirculation pumps and their frequency conventers

TVO has implemented a project for replacing the main circulation pumps and their frequency conventers at the Olkiluoto unit 1 and 2. According to TVO the decision on the replacement was made, because the pumps were more than 35 years old and the availability of product support and spare parts from the original equipment manufacturer was significantly reduced.

The new pumps are in the main parts similar to the old pumps. The most important difference is the flywheel mounted on the pump shaft to ensure the safe shutdown of the recirculation pumps in case power supply is lost. This ensures that the pump speed is reduced passively in the event of scram or power loss and the previous electrically connected and separate flywheels will no longer be required to ensure fuel integrity in the context of these transients. The main circulation pumps of the Olkiluoto unit 2 were modernised in 2017. At the Olkiluoto unit 1 one new pump was installed in 2016, and the rest of the pumps in 2018.

High and low pressure auxiliary feed water system

TVO has finalized a project for an independent way of pumping water into the reactor pressure vessel in case of loss of AC power. The arrangement consists of high and low pressure systems. The low pressure system pumps coolant into the core from the fire fighting system. The high pressure system consists of a steam driven turbine pump for which the steam is drawn from the main steam line and supplied through a dedicated line to the pump turbine. The water is 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 the conceptual design plan of the new system in 2015. The project was finalized in 2018 when the high pressure system was installed to both plant units. The plant modification was one of the actions based on the lessons learnt from the Fukushima Daiici accident.

Examples of latest incidents at the Olkiluoto NPP (2016–2018)

Olkiluoto 2 reactor scram in May 2018

On 8 May 2018, Olkiluoto 2 was undergoing power raise after the 2018 annual outage. At power level 98%, a reactor scram occurred due to condition SS15 (high power relative to the main coolant flow) when five of the six main coolant pumps stopped simultaneously. The reason for the main coolant pumps stopping was a transient in the off-site grid. Due to the transient, the protections of the main coolant pump frequency converters stopped the frequency converters (the contactors opened), which caused the main coolant pumps to stop. The grid transient was caused by a deviation in the changeover switching of the Fenno-Skan connection managed by Fingrid.

As a consequence of the tripping of the scram, all control rods went into the reactor in scram mode and the cooling of the condensation pool started. All of the safety functions for scrams functioned as planned.

For the frequency converters, it was a common cause failure in regard to the protection parameter settings. A protection function based on a parameter value that was too low caused five frequency converters to stop during a transient where the protection function in question was not necessary. In the situation, the impact mainly focused on the Olkiluoto 2 unit, where the replacement of main coolant pump frequency converters had been fully completed. As a result of the event, the protection settings where changed, due to which the immunity to interference of the frequency converters of both plant units is better in regard to similar transients.

The event did not affect the plant's nuclear or radiation safety, but due to the common cause failure of the frequency converters, the event has been rated at level 1 of the International Nuclear and Radiological Event Scale (INES).

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 next overall safety review of the Olkiluoto plant took place in 2007–2009 in connection of the periodic safety review. 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.

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. 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 plant was to be further improved during the 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.

The latest periodic safety review was carried out during 2016–2018 in connection of the relicensing of the operation of the plant units.

Operating licence renewal for the Olkiluoto 1 and 2 plant units

STUK delivered its statement on the operating licence application to the Ministry of Economic Affairs and Employment on 31 May 2018. In its statement, STUK supported the application to continue the operation of the operating plant units in Olkiluoto. According to STUK's assessment, the continued operation of the plant units is safe and meets the statutory requirements. STUK also assessed that the nuclear waste management arrangements used by TVO are adequate and appropriate. Therefore, STUK saw no reason not to issue an operating licence for the plant units for 20 years in accordance with TVO's application.

The safety of the Olkiluoto nuclear power plant was assessed in compliance with the STUK regulations brought into force in 2016, in addition to the Nuclear Energy Act. These include STUK's regulations on the safety of a nuclear power plant, the emergency arrangements of a nuclear power plant, security in the use of nuclear energy, and the safety of disposal of nuclear waste. The safety regulation (STUK Y/1/2016) takes into account that operating plants must meet certain requirements set for new plants to the extent that their application is justified with due consideration to the technical solutions of the nuclear power plant unit in question and the principle laid down in Section 7(a) of the Nuclear Energy Act (STUK Y/1/2016, Section 27, Transitional provision). In accordance with the principles set forth in Section 7 a of the Nuclear Energy Act, the safety of nuclear energy use must 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, safety research and advances in science and technology.

Review started at STUK in early 2017, once TVO had submitted to STUK the documents connected to the periodic safety review in accordance with Guide YVL A.1. Key areas of STUK's review included ageing management, revised safety analyses, the organisation and personnel as well as matters related to operation of the plant and its safety culture.

The design basis concerning the structures, systems and components of the Olkiluoto 1 and 2 nuclear power plant units was primarily issued in the 1970s. The goal for the operating period of the plant has been to ensure the continuous improvement of plant safety. TVO has updated the Olkiluoto 1 and 2 plant units to a significant degree and, during the facility's operating history, carried out extensive modifications on the plants' systems, structures and components in order to improve safety. In its statement, STUK emphasised that, in the coming operating licence period, it is important to continue the implementation of the safety-improving measures. Based on the documentation submitted to STUK, TVO is committed to continuing the efforts to improve plant safety also during the coming operating licence period. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act.

Over the course of the current operating licence period, TVO has significantly reduced the risk of core damage and large release at the Olkiluoto 1 and 2 units. However, among the risk reduction opportunities, the share of a common cause failure in the protection I&C system's output relays, which is currently about 8% of the total core damage frequency, remains to be examined. Based on its own periodic safety review, STUK required TVO to investigate in more detail how this risk could be reduced. TVO must analyse the significance of common cause failures in the protection I&C system's output relays from the perspective of the reliability of the safety functions and the core damage frequency and use these analyses to determine the necessary measures to reduce the core damage risk caused by the aforementioned common cause failures.

TVO's application for the continuation of the operating licence in such a way that the original design-basis service life of 40 years will be exceeded by 20 years is largely based on ageing management.

TVO's goal is to keep the systems, structures and components (SSCs) of the Olkiluoto 1 and 2 nuclear power plant units continuously up-to-date and in good condition in terms safety and production capacity. TVO has an ageing management programme which entails the functions, tasks and responsibilities to ensure the operability of the SSCs related to safety for the entire duration of their service life. Early identification of the relevant SSCs and the related ageing phenomena makes possible far-reaching predictions and plans on the requisite fundamental improvements and maintenance tasks. According to STUK's assessment, ageing management at the Olkiluoto 1 and 2 units has been organised in an appropriate manner.

TVO has updated the strength analyses of the primary circuit to correspond to a service life of 60 years. The analyses cover the Safety Class 1 pipes, the reactor pressure vessel and the reactor pressure vessel internals. The strength analyses cover dimensioning against pressure and other mechanical design loads as well as tension and fatigue analyses for critical points. The design loads account for the various operating and accident situations of the primary circuit as well as the effects of the environmental conditions. Based on the analyses, the safety margins remain sufficient for the entire planned 60-year service life of the plant unit.

At the Olkiluoto 1 and 2 units, the primary circuit's periodic pressure test has not been performed since the commissioning of the plant units. By STUK decisions, periodic pressure tests have been replaced with tightness tests (1.02 × operating pressure) conducted at 8-year intervals, which is permitted by the ASME XI standard for reactor plants planned and inspected in accordance with ASME requirements. When the pressure test was originally replaced with a tightness test compliant with ASME XI, it was not known that the service life of the plant units would be longer than the 40 years presumed in the ASME version effective at the time. For this reason, STUK required, based on its own periodic safety review, that the periodic primary circuit tightness test prescribed by the current procedure must be replaced with a periodic pressure test conducted every eight years at the maximum allowable operating pressure. The purpose of the pressure test is to demonstrate through tests that the known or any possible latent ageing mechanisms have not weakened the integrity of the primary circuit once the plant units have reached their original design life span. The first pressure tests on Olkiluoto 2 must be conducted in 2019 and the first tests on Olkiluoto 1 in 2020.

The Finnish Government issued a new operating licence for the plant units on 20 September 2018. TVO has now licence to operate the units until the end of 2038. TVO must carry out a periodic safety review of the plant units and submit it to STUK for approval by the end of 2028.

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 diversification of reactor water level measurements.

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 submitted the plans for tightening the aforementioned seam and carried out the modifications after STUK's approval. The licensee submitted at 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 finalaising 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 enabling 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. TVO has studied the issue and solved the problems at Olkiluoto 1 by for example improving recirculation pipeline support. The modification is planned to be implemented at Olkiluoto 2 in 2019.

In addition, an independent way of pumping water to the reactor pressure vessel in case of loss of AC power has been implemented to the plant units. The arrangement consists of high and low pressure systems. The low pressure system pumps coolant into the core from the fire fighting system. The high pressure system consists of a steam driven turbine pump: the steam is drawn from the main steam line and supplied through a dedicated line to the pump turbine. The water is 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. The project was finalized in 2018 when the high pressure system was installed to both plant units.

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 was a plan to equip the fuel pools with a level measurement system. The implementation has been 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. The licensee has improved procedures 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 the emergency operating procedures. Procedrues to manage accident conditions affecting multiple units (OL1/OL2/OL3) and spent fuel pools is under preparation.

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 2019.

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. Design work is progressing and the current schedule is to install the new devices for test use in annual outages of 2020 and 2021. However, at the same time TVO also studies whether similar safety benefits could be achieved by other methods and will send an application to STUK during 2019.

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 the power supply from any of the current EDGs of the Olkiluoto units 1 or 2 during the installation. 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 autumn 2019. The plan is to have the entire diesel generator replacement project completed by the spring 2023.

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 Economic Affairs and Employment) 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.

Pre-operational testing of the Olkiluoto unit 3 is on-going. Plant level commissioning tests were completed in May 2018, but finalization of remaining system level tests, retests after modifications and preparation for fuel loading are still on-going. Next step will be fuel loading and nuclear commissioning. TVO submitted operating licence application to the Ministry of Economic Affairs and Employment in April 2016. Operating Licence is needed prior to loading nuclear fuel into the reactor core. STUK gave its statement and safety assessment in February 2019 and the Council of State issued the Operating Licence in March 2019. STUK will ascertain that the prescribed safety requirements are met following the issuance of the operating licence for the nuclear facility and before fuel is loaded into the reactor.

FIGURE 26. Commissioning tests of main steam relief trains at Olkiluoto 3. Source: STUK.

Challenges

Olkiluoto 3 was supposed to start commercial operation in 2009. According to present schedule, commercial operation will start in January 2020, ten 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 was the first European Pressurised Reactor (EPR) where construction started. 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 earlier phase of the project, I&C design 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. The main issues where STUK 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 also asked more clarification how possible spurious actuations are taken into account in the design and corresponding safety analyses. STUK received answers to the aforementioned concerns as well as the related analyses and approved the I&C design.

During the pre-operational testing of the Olkiluoto 3 nuclear power plant unit, it emerged that the vibration of the surge line of a pressuriser that is a part of the primary circuit exceeds the set criteria. TVO and the plant supplier have investigated solutions to dampen the vibrations. Alternative solutions exist, and the studies to find out the optimal solution considering safety are ongoing. STUK will review the detailed plans of the solution chosen by TVO, oversee the progress of the work and verify before fuel loading that modifications necessary for safe operation have been implemented and the necessary tests have been performed.

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 19900 applications – about 11800 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.

FIGURE 27. STUK's resident inspector on her way to perform inspection for primary circuit. Source: STUK.

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.

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 and with the line-up of the demineralized water distribution system to the emergency feed water tanks, the water inventory is sufficient for 72 hours. After 72 hours, make-up water will be added from the fire water distribution system with diesel powered pumps. 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
Hanhikivi NPP unit 1 in construction licensing 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 Economic Affairs and Employment.

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 Economic Affairs and Employment 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 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).

FIGURE 28. Hanhikivi site in Pyhäjoki selected for Fennovoima new NPP (FH-1, Feb 2016). Source: Fennovoima.

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 Economic Affairs and Employment 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 disposal facility 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 Economic Affairs and Employment 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. Fennovoima chose the latter option, and submitted the EIA program to the Ministry of Economic Affairs and Employment in June 2016. EIA program will be followed by a long research phase until 2035. The final EIA report will be published around 2040. A separate DiP will be required for the disposal facility.

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 (FH1) 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 had meetings to be prepared for the construction licence safety assessment process. STUK organised seminars in 2010, 2011 and 2013 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 new set of YVL guides was published 1st December 2013 (see Annex 1). Systematic training on application of new YVL Guides were provided by STUK's personnel involved in preparation of guides. Furthermore several training courses on YVL Guides directed for stakeholders, were provided in English. A further update of the guides was started in 2017 and is expected to be comleted by the end of 2019. The updated guides are applied as such to new facilities.

STUK has developed its requirement management (RM) to support its review process.

According to the set dead line in DiP, Fennovoima filed a construction license application (CLA) for Hanhikivi 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. According to licensing auhortity, the Ministry of Economic Affairs and Employment (MEAE), batch-wise submission of licensing documentation is in accordance with Finnish administrative legislation. Fennovoima was planning to complement its documentation during the years 2015–2017 according to the first revision of the 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 robust configuration management in place and self-standing document submittals in logical order. Fennovoima has delivered some CLA submittals during the years 2015–2018, but main parts of the application submittals e.g. Hanhikivi plant specific Preliminary Safety Assessment Report (PSAR) and plant specific Propabilistic Safety Assessment (PRA/PSA) have not been completely submitted for regulatory review and assessment. The plant high level design issues, which were highlighted in STUK Preliminary Safety Assessment of AES-2006 design have not been fully addressed in plant and systems level design. License applicant Fennovoima is working with the plant vendor RAOS Projekt Oy to solve the open plant and system level design issues to be able to submit Hanhikivi specific licensing documentation fulfilling Finnish Safety, Security and Safeguards requirements. For example, the strategy of managing severe reactor accidents is still under discussion.

The geological surveys aiming at determining the exact location of the plant and the design basis of the foundations progressed from planning to implementation. The geological surveys aiming at determining the exact location of the plant and the design basis of the foundations progressed from planning to implementation. Obscurities were found in the geological site investigations and Fennovoima decided to conduct an internal investigation in two stages to analyse how the site geological investigations were managed and conducted, how the geological investigation results were recorded, drilling core samples stored and conclusions drawn as well as documented. Based on the results of both stages of the investigations and regulatory correspondence from STUK, it was deemed necessary to carry out additional site investigations, improve documentation presenting the results of the investigations and define the design basis for the plant foundations. Most of the additional investigations performed at the plant site were completed by the end of 2018.

FIGURE 29. Hanhikivi site in Pyhäjoki under site preparation and additional site surveys during the Autum 2018. Source Fennovoima.

Discussions have continued with the licence applicant and the plant supplier on the approval and selection of materials for mechanical equipment. Based on the most recent meetings, the plant supplier has a clear vision on how the approval process in question should be carried out.

The delivery chain for I&C technology has not yet been defined as regard to design and implementation. The I&C licensing documentation to be submitted for regulatory review by authorities in the construction licence phase has not yet been specified in its entirety.

Fennovoima has continued the radiological baseline study of Hanhikivi site.. Fennovoima has also progressed in the commissioning of weather monitoring systems at the plant site, for example the weather mast was built in 2018.

STUK has started the CLA review of those documents that have been submitted. Until now, STUK has received parts of PSAR and PRA documentation for preliminary information and small part of it has been submitted for regulatory CLA safety assessment and review purposes. Following PSAR chapters have been submitted for preliminary information or for review and assessment: Introduction and General Plant Description, Site characteristics, Design of Structures, Systems, Components and Equipment Conduct of Operations, Commissioning, Analysis of transients and accidents (without SA), Operating Technical Specifications, Management systems and quality management, PRA(reference plant) and Licence Applicant's Own Safety Assessment.

STUK is also conductiong inspections according to the inspection programme on Fennovoima, Plant Vendor ROSATOM, and its main sub-suppliers. STUK have conducted management system inspections to Fennovoima and one to the General Designer JSC Atomproekt, St Petersburg, Russia, during the years 2015–2018 and shall conduct follow-up inspections on Fennovoima and ROSATOM main design organisations during the year 2019 to support its document review and assessment. Vendor and its supply chain need further development in design processes. Major areas of improvement within the

Vendors design orgainastions are design processes such as Requirment Management and Configuration Management supported with robust Change Management. Knowledge and understanding of Finnish regulatory radiation and nuclear safety regulations and safety guide requirements is a key factor and should be supported with engineering competence and tool set.

STUK is publishing three times per annum its overall status report on CLA review and assessment and complementing the public report with executive summaries of inspection findings on STUK's web pages.

Fennovoima did a review of license applicant organisation capabilities and organisation structure during 2018 and informed the regulator body early 2019 that Fennovoima will make necessary changes to meet the requirements of the intelligent customer.

Fennovoima Hanhikivi 1 Construction License application review has been so far a lengthy process as the parties involved with the plant design has not been able to present plant and system level design, which fully complies the Finnish safety regulation requirements. STUK presented Preliminary Safety assessment findings already 2014. License applicant Fennovoima with the Vendor RAOS Project Oy (ROSATOM) and its design organisations are working to agree on needed changes in plant and system level design of AES2006 and preparing the licensing documentation (e.g. PSAR, PRA/PSA) for regulatory review and assessment. Fennovoima is expecting to obtain a Construction License from the Government 2021.

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 Economic Affairs and Employment (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 for construction).

The latest peer reviews in Finland are the following:

- IAEA OSART safety review at Loviisa NPP in March 2018
- 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 took place in 2017.
- IAEA OSART safety review at Olkiluoto NPP in March 2017, and pre-OSART at Olkiluoto 3 in March 2018.
- 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 was 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. The next IPPAS mission will take place during 2020.
- 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. Next IRRS mission is planned for 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 (revised in 2015). 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. Practical guidelines concerning roles and responsibilities as well as communication and cooperation arrangements among authorities have been published in November 2012 and updated in 2016. Emergency exercises are conducted annually between the licensee and STUK. Every third year all authorities are training together at each site involving large number of participating organizations from governmental, regional and local level.

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. Further improvement of arrangements for the coordination of information to the public and media during emergencies is needed to ensure that messages issued by different authorities are consistent.

Finland participates actively in the international co-operation also in the field of emergency preparedness, such as IAEA, OECD/NEA, EU/EC and HERCA. These working groups discuss i.e. cross-border assistance, communication, co-operation and co-ordination of actions during nuclear of radiological emergencies. Under these working groups Finland has actively promoted joint statements and agreements for further strengthening international emergency preparedness and response activities. Nordic countries have published two joint documents for cooperation arrangements: the Nordic Manual (updated 2015) describes practical arrangements during preparedness and response phases, and the Nordic Flag Book (published 2014) which describes joint guidelines and operational intervention levels for protective actions.

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 Economic Affairs and Employment. 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 3 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.

Recommendation on clarifying the legislation related to decommissioning of nuclear installations and closure of a disposal facility is partly addressed. Decommissioning license was introduced to the Finnish legislative framework in the beginning of 2018. Future work needs still to be carried out for clarifying the licensing of closure of disposal facilities.

To establish a sound base for radiation protection research, the co-operation with Finnish universities and international research platforms has been reinforced. Research funding opportunities have been exploited and STUK is in an active role in shaping research agendas of many of these platforms to ensure that national aspects of research funding are taken into account at European level. STUK has also set up an internal research funding mechanism. The income from expert services is partly reserved for research projects and researchers can apply funding for their projects biannually.

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 2016-2018 in context of the operating license renewal.

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 discussion 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.

After the renewal of YVL Guides in 2013, several IAEA Safety Requirements documents have been revised and also WENRA has updated the safety reference levels. Furthermore, the Nuclear Energy Act and Nuclear Energy Decree have been amended, and the radiation legislation has been renewed to implement the updated international requirements (for example 2014/87/Euratom, 2013/59/Euratom and 2014/52/EU). STUK established a project in early 2016 to update STUK's Regulations and the YVL Guides to accommodate the changes in the upper level legislation. The updated regulations were published in December 2018. The update of the YVL Guides is still ongoing, by June 2019, 22 updated YVL Guides were published.

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 Council Directive 2014/87/Euratom amending Directive 2009/71/Euratom, the amendment (2014/52/EU) of Directive 2011/92/EU, and the radiation safety directive (2013/59/Euratom) were implemented in amendments of Nuclear Energy Act in 2017-2018 and in the new Radiation Act that entered into force in December 2018. Due to the changes in the upper level legislation, STUK Regulations were updated and they were published in December 2018. Updating the YVL Guides is ongoing.

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.

Competence building

Strengthen and maintain competence 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 STUK's training programmes, on the job training and new re-cruitments. STUK's strategy highlights the importance of the ability to understand complex entities. This understanding is achieved through systematic development of regulatory competence.

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.

The basic professional training course on nuclear safety is annually organised in cooperation between the main Finnish nuclear energy organisations. The first course commenced in autumn 2003. and the following 6-week basic professional training course will commence in autumn 2019. So far, more than 1000 newcomers and junior experts, of whom about 100 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 – and also by reflecting the development and changes of the nuclear sector. STUK has an active role in development and steering of the training course. Furthermore, a significant number of STUK experts act as lecturers of the training course.

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 and to meet the needs of the organizations in the nuclear section. The original study was completed in March 2012. The update of the competence review was carried on in 2017 to reflect the current changes in the operating environment. The final report of the updated competence review was published in 2018.

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 radiological 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 10^{th} 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

Interest in nuclear power in Finland is increasing, due to ongoing new-build projects and public debate about future prospects of so-called SMRs. With this in mind, 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. Risks related radiation should be communicated realistically. Due to the challenge, STUK has carried out a number of development projects to develop its strategic communications and the use of modern communication tools. In particular, STUK has focused on communication capacity building of the staff, focused on developing key-messages to communicated radiation and nuclear risks, and continued to develop its crisis communication capability.

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. Emergency exercises arranged with stakeholders regularly include a communication element.

STUK pays special attention to using internet and social media to inform public and interested stakeholders about nuclear and radiation safety. In example, we communicate about risks related to radiation and use of nuclear energy, safety requirements, roles and responsibilities of STUK, 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 English.

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 done 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 2025. At the first stage the additional funding was allocated for the new hot cells at VTT Center of Nuclear Safety (CNS) and at the second stage it will be allocted for the thermohydraulic laboratory at Lappeenranta University of Technology. The investment for the VTT CNS hot cells laboratory was 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 (2015-2018) enhanced multidisciplinary co-operation within the research programme. Research areas were 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) were 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 since year 2016 has been about 9 million € for nuclear safety research. Out of this 4 million € is used to research projects and the rest is for the enhancement of the infrastructure. The research projects have also additional funding from other sources. The total volume of the programme in 2016 to 2018 has been between about 7 million € each year. An international evaluation of the programme was performed at the beginning of the year 2018. The scientific level and performance of the programme was found very good.

The new period for the national publicly funded nuclear safety research programme SAFIR2022 was planned and initiated in year 2018. The research issues of the new programme continue the main areas of previous SAFIR2018 research programme. However, new research issues concerning the changes in the operating environment are integrated into the programme such as use of 3D-printing for components important to safety, small modular reactors, machine learning etc.

The objective of KYT (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. KYT2018 (2015–2018) was 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 0.13 % of their respective assessed liability. The current level of annual funding is 1.9 million €.

Similar to SAFIR, the new period for the Finnish Research Programme on Nuclear Waste Management, KYT2022, was planned and initiated in year 2018. The programme continues the traditions of previous periods with the main research areas of:

- safety research in spent nuclear fuel management
- near-surface disposal
- low and intermediate nuclear waste management
- decomissioning
- new and alternative technologies in nuclear waste management and
- social science studies related to nuclear waste management

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. Other important research organizations are 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.