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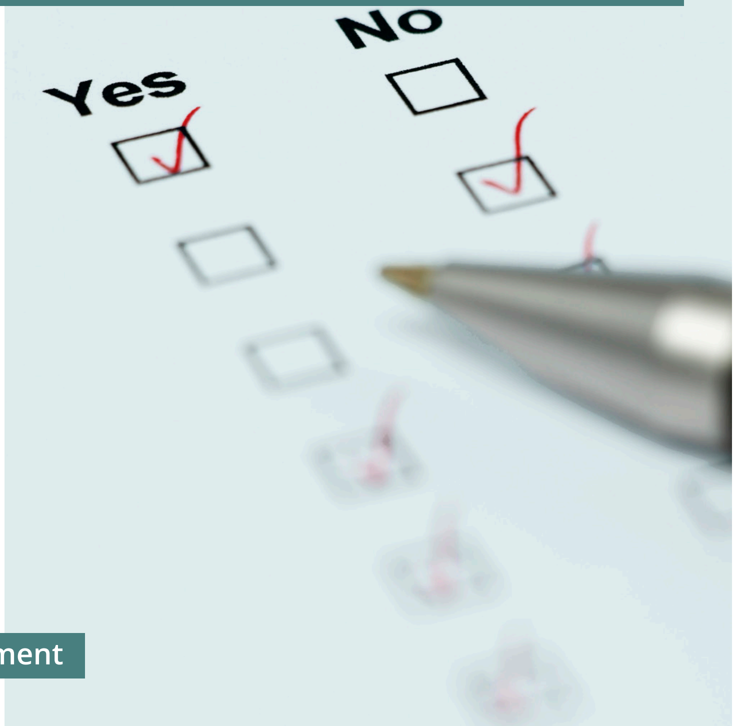
NPP Loviisa 1&2

Life-time extension

Environmental Impact Assessment



Federal Ministry
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Climate Action, Environment,
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pulswerk
Das Beratungsunternehmen des
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Expert Statement

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Oda Becker
Gabriele Mraz

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Project Manager Franz Meister

Authors Oda Becker, technical-scientific consultant (content project management, chapters 4, 5, 6, 7)
Gabriele Mraz, pulswerk GmbH (project coordinator, chapters 1, 2, 7), Philipp Hietler

Translations and English editing Patricia Lorenz

Layout/Type setting Doris Weismayr

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SUMMARY

The nuclear power plant Loviisa consists of two units, Loviisa 1 and 2. The NPP is owned by Fortum Power and Heat Oy. The current operating licence issued by the Finnish government is valid until the end of 2027 and 2030, respectively.

Fortum is now evaluating the extension of the operation time of Loviisa by approximately another 20 years once the current license will have expired. Another option would be the start of decommissioning of the plant.

For the purpose of this evaluation an Environmental Impact Assessment (EIA) is being conducted in accordance with the Espoo-Convention and the EU EIA Directive.

In 2020, the EIA Scoping has been conducted. It was completed with the Ministry of Economic Affairs and Employment (MAEA) issuing its Statement on 23 Nov 2020. (MAEA 2020) The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) commissioned the Environment Agency Austria to provide an expert statement for the scoping phase (UMWELTBUNDESAMT 2020), and again the expert statement at hand for assessing the EIA Report that has been submitted in Oct 2021.

In the expert statement for the scoping phase, requirements for the EIA Report were formulated. In the expert statement at hand, the submitted EIA Report is being assessed and checked against the requirements from the scoping phase.

Austria participates in the EIA procedure to minimise or even eliminate possible significant adverse impacts on Austria resulting from the project.

Procedure and alternatives

It is welcomed that Finland undertakes an EIA for the planned lifetime extension of Loviisa 1&2.

Two main options have been assessed – a 20-years lifetime extension followed by decommissioning (VE1) or the start of decommissioning right after the current licenses will have expired (VE0).

The provided information did not clarify when the decision for or against the life-time extension will be taken, and if 20 years will be final decision and the limit for life-time extension.

It would be welcomed if the presentations and the documentation of the international hearing which was held on 7 Oct 2021 in Finnish and Swedish language will also be made available in English.

Spent fuel and radioactive waste

The decommissioning of the NPP will generate low and intermediate level radioactive waste for which no capacities are available now. These additional capacities will have to be provided for both possible options, VE1 and VE0.

Additional spent fuel will arise from lifetime extension, the extension of the interim spent fuel storage is envisaged. However, information on timetables and alternative waste management options in case the capacities will not be available in time are lacking.

New results on copper corrosion led to criticism of the KBS-3 method which might be used in the final spent fuel repository. It should be explained how Finland will respond to the corrosion problem in connection with the KBS-3 method.

Long-term operation of the reactor type VVER 440

The reactor units at the Loviisa nuclear power plant were connected to the electrical grid in 1977 (Loviisa 1) and 1980 (Loviisa 2). The Loviisa plant reached its original design lifetime of 30 years in 2007–2010. The Finnish Government granted the new operating licences in July 2007. Thus, the currently envisaged lifetime extension would be the second lifetime extension.

Nuclear power plants undergo two types of time-dependent changes:

- Physical ageing of structures, system and components (SSCs), which results in degradation, i.e. gradual deterioration in their physical characteristics.
- Obsolescence of technologies and design, i.e. the plants becoming out of date in comparison with current knowledge, standards and technology.

To limit ageing-related failures at least to a certain degree, a comprehensive ageing management program (AMP) is necessary. The Finnish nuclear regulator STUK published in 2013 a YVL guide dedicated to ageing management. The guide has been updated since and the most recent version was published in February 2019. The implementation of the updated ageing management requirements is underway. According to STUK, the utilities have encountered some challenges in complying with the new requirements. The EIA Report does not clarify whether the current AMP for Loviisa meets the new requirements.

Finland participated in the Topical Peer Review (TPR) "Ageing Management" under the Council Directive 2009/71/EURATOM establishing a Community framework for the nuclear safety of nuclear installations, amended by 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 were identified and Finland is establishing a national action plan to address the findings. The national action plan and its progress are not presented in the EIA Report.

One ageing management issue at the Loviisa NPP has required significant amount of work and attention from the licensee and STUK over the years. This issue is the irradiation embrittlement of Loviisa reactor pressure vessels (RPVs). However, the very important safety issue of the embrittlement of the RPVs is only presented in a general manner in the EIA Report.

At the request of the government of Finland, an IAEA Operational Safety Review Team (OSART) of international experts visited Loviisa Nuclear Power Plant in March 2018 and in February 2020. The OSART missions revealed deficits in plant maintenance and monitoring; this is relevant for lifetime extension. The findings of the OSART missions as well as the remedial plan are not presented in the EIA Report.

Fortum reported the results of several event analyses and investigations to STUK in 2019 and 2020. Most of the events revealed areas for improvement in procedures and activities. Based on the inspection, STUK urged Fortum to improve the learning from their operating experience.

The development of science and technology continuously produces new knowledge about possible failure modes, properties of materials, and verification, testing and computational methodologies. This leads to technological ageing of the existing safety concepts in nuclear power plants. At the same time, as a result of lessons learned in particular from the major accidents at Three Mile Island, Chernobyl and Fukushima Daiichi, earlier safety concepts are becoming obsolete (conceptual ageing).

The units of the Loviisa NPP are Russian designed Generation II VVER-440 type pressurized water reactors. External hazards such as earthquakes, chemical explosions or aircraft impacts were not taken into account in the original design of these plants. To overcome major shortcomings of the design, both Finnish VVER-440/V-213 reactors are equipped with Western-type containment and control systems.

The old Loviisa NPP is increasingly out of date in comparison with current knowledge, standards and technology. The VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time. The EIA report does not explain whether there are any design changes envisaged for the lifetime extension.

Western European Nuclear Regulator's Association (WENRA) has revised safety reference levels (SRLs) for existing reactors with the aim to integrate the lessons learned from the 2011 Fukushima Dai-ichi accident. A list of 342 SRLs has been published in 2014. According to the SRL F1.1, analysis of Design Extension Conditions (DEC) shall be undertaken with the purpose of further improving the safety of the nuclear power plant. The EIA Report does not include a comparison of the design and measures of the Loviisa NPP with all requirements of SRL F. The WENRA Reference level have been again updated in 2020.

The WENRA "Safety Objectives for New Power Reactors" should be used as a reference for identifying reasonably practicable safety improvements for the Loviisa NPP. The most ambitious WENRA safety objective is to reduce potential radioactive releases to the environment from accidents with core melt. Accidents with core melt which would lead to early or large releases would have to be practically eliminated. Practical elimination of an accident sequence cannot be claimed solely based on compliance with a general cut-off probabilistic value.

Even if the probability of an accident sequence is very low, any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented.

The principle for continuous improvement is laid down in Section 7a of the Finish Nuclear Energy Act (990/1987): *"The safety of nuclear energy use shall be maintained at as high a level as practically possible."* However, when deciding how a new or revised regulatory guide is applied for a specific operating nuclear facility, STUK can approve an exemption when it considers a safety improvement not reasonably practicable. Improvements considered not reasonably practicable at the Finnish operating NPPs include e.g. protection measures against large civil aircraft crashes.

Accident analyses

The EIA Report includes a description of a fictional severe reactor accident. The assessment is based on the assumption that a quantity of radioactive substances (100 TBq of nuclide Cs-137) corresponding to the limit value of a severe accident in accordance with section 22b of the Nuclear Energy Decree 161/1988 is released into the environment.

According to the regulation, a nuclear power plant unit shall be designed in a way that the mean value of the frequency of a Cs-137 release during an accident into the atmosphere in excess of 100 TBq is less than $5 \cdot 10^{-7}$/year. In the latest update of the probabilistic risk assessment Level 2 for Loviisa NPP in 2018, it was estimated that the total frequency of a large release (LRF) to the environment is about $7.8 \cdot 10^{-6}$ per reactor year.

The accident analyses in the EIA Report should use a possible source term for a severe accident derived from the calculation of the current PSA 2. Even though the probability of severe accidents with a large release for existing plants is estimated to be very small, the damage caused by these accidents is very large. In this context it is important to emphasize that the calculated frequency of large releases of the Loviisa NPP is above the limits set in STUK's regulatory guide.

Maintaining containment integrity under severe accident conditions is an important issue for accident management. The Loviisa NPP severe accident management (SAM) strategy strongly relies on retaining corium inside the pressure vessel (in-vessel retention (IVR). However, there are some safety issues that could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) Continuous efforts have been made to reduce frequencies of bypass sequences and this work will continue in the future as well. However, until now large releases of radioactive substances are possible. The EIA Report does not explain how these safety issues of the IVR concept are solved.

The Fukushima Dai-ichi accident highlighted inter alia the importance of the Defense-in-Depth principle and the continued need to ensure that the design basis adequately addresses external hazards.

When the Loviisa NPP units were built no regulatory requirements on **seismic design** existed and earthquake loads were not considered separately in the design. According to STUK, the reassessment of the seismic hazard and seismic risk has turned out to be challenging for the Loviisa plant. Recent hazard updates for Loviisa show increased values of ground accelerations especially for long return periods. At the Loviisa NPP, the SAM systems are not designed to withstand earthquakes, therefore there is no confirmation on the sufficient operability of these systems after an earthquake. According to the EIA Report the improvement measures are still ongoing.

The Loviisa NPP is located on the coast of the Gulf of Finland, approximately 90 km east of Helsinki. In the past decades the threat posed by **flooding** has increased for many nuclear power plant sites. In consequence of the TEPCO Fukushima Dai-ichi accident, safety improvements have been implemented at the Loviisa NPP. To ensure the long-term decay heat removal in case of loss of seawater, an alternative ultimate heat sink has been implemented. The modification consists of two air-cooled cooling units per plant unit powered by an air-cooled diesel-generator. To ensure adequate design basis for the improved flood protection, Loviisa NPP contracted updating of the seawater level extreme value distribution by the Finnish Meteorological Institute. According to the new results the expected seawater levels at low frequencies of occurrence are higher than previously estimated.

According to the Intergovernmental Panel on Climate Change (IPCC), the type, frequency and intensity of **extreme weather events** are expected to change as Earth's climate changes.

In the context of accident analyses, several questions remain open, making it impossible to assess in a comprehensible way if Austria is potentially affected.

Accidents with involvement of third parties

Nuclear power plants are vulnerable to a broad spectrum of possible attacks. Terrorist attacks or acts of sabotage on Loviisa may have significant impacts. However, in the EIA program malicious acts of third parties against Loviisa NPP and their possible effects are not discussed. In comparable EIA procedures such events were addressed to some extent.

The terror threat to nuclear power plants has received considerable public attention in the last twenty years. This attention has – for obvious reasons – focused on the hazard of the deliberate crash of a large airliner.

The reactor buildings of the Loviisa NPP are not designed against an airplane crash and according to STUK, improvements are not "practically reasonable". In connection with the lifetime extension for the Loviisa NPP a potential terrorist attack on the spent fuel pools should be evaluated in the EIA Report, but there is no information provided in the EIA Report.

Trans-boundary impacts

A severe accident with releases reaching Austrian territory can lead to significant impacts on Austria. In the EIA Report an accident was calculated with a source term of 100 TBq Cs-137, dispersion calculations were made to cover a distance of up to 1,000 km. This might underestimate impacts on Austria. Firstly, it is not proven that the occurrence of a higher source term can be excluded; and secondly, a calculation distance of 1,000 km is insufficient to assess impacts on Austria.

ZUSAMMENFASSUNG

Das Kernkraftwerk Loviisa verfügt über zwei Reaktorblöcke, Loviisa 1 und 2. Das Kraftwerk steht im Eigentum des Unternehmens Fortum Power and Heat Oy. Die geltenden Betriebsgenehmigungen, die von der finnischen Regierung erteilt wurden, sind jeweils bis Ende 2027 bzw. 2030 gültig.

Fortum erwägt nun die Verlängerung der Lebensdauer des KKW Loviisa um circa weitere 20 Jahre nach Ablauf der geltenden Genehmigung. Die Alternative dazu wäre der Beginn der Dekommissionierung des Kernkraftwerks.

Dafür wird ein Umweltverträglichkeitsverfahren gemäß der Espoo-Konvention und der EU-UVP-Richtlinie durchgeführt.

Im Jahre 2020 wurde das UVP-Scoping durchgeführt. Es wurde vom finnischen Ministerium für Wirtschaftliche Angelegenheiten und Arbeit (MAEA) mit der Stellungnahme vom 23. November 2020 abgeschlossen (MAEA 2020). Das Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) beauftragte das Umweltbundesamt mit der Erstellung einer Fachstellungnahme für die Scoping-Phase (UMWELTBUNDESAMT 2020) wie auch mit der vorliegenden Fachstellungnahme zur Bewertung des UVP-Berichts, der im Oktober 2021 übermittelt worden war.

In der Fachstellungnahme für die Scoping-Phase wurden die Anforderungen an den UVP-Bericht formuliert. In der vorliegenden Fachstellungnahme wurde der UVP-Bericht bewertet und den Anforderungen aus der Scoping-Phase gegenübergestellt.

Österreich beteiligt sich an diesem UVP-Verfahren, um mögliche signifikante nachteilige Auswirkungen des Projekts auf Österreich zu minimieren oder zu beseitigen.

Verfahren und Alternativen

Es ist zu begrüßen, dass Finnland für die geplante Lebensdauerverlängerung von Loviisa 1&2 eine Umweltverträglichkeitsprüfung (UVP) durchführt.

Es wurden zwei prinzipielle Optionen untersucht – eine Lebensdauerverlängerung von 20 Jahren mit anschließender Dekommissionierung (VE1) oder ein Dekommissionierungsbeginn sofort nach Ablauf der aktuell geltenden Genehmigungen (VE0).

Die Frage, wann die endgültige Entscheidung für oder gegen die 20-jährige Laufzeitverlängerung getroffen und ob es sich dann um das Limit für die Lebensdauerverlängerung handeln wird, lässt sich aus den übermittelten Dokumenten nicht ersehen.

Es wäre wünschenswert die Präsentationen und die Dokumentation der internationalen Anhörung vom 7. Oktober 2021 nicht nur auf Finnisch und Schwedisch, sondern auch auf Englisch zur Verfügung zu stellen.

Abgebrannte Brennelemente und radioaktiver Abfall

Bei der Dekommissionierung des KKW werden schwach- und mittelaktive Abfälle (LILW) anfallen, für die noch keine Lagerkapazitäten verfügbar sind. Diese zusätzlichen Kapazitäten werden für beide in Betracht kommende Optionen – VE1 und VE0 – geschaffen werden müssen.

Zusätzlicher abgebrannter Brennstoff wird durch die Lebensdauerverlängerung anfallen, eine Ausweitung der Zwischenlagerung ist vorgesehen. Allerdings sind Angaben zu den Zeitplänen und alternativen Abfallentsorgungsoptionen für den Fall, dass die benötigten Lagerkapazitäten nicht rechtzeitig zur Verfügung stehen sollten, nicht genannt worden.

Neue Forschungsergebnisse zur Kupferkorrosion führten dazu, dass die sogenannte KBS-3 Methode, die als Lagerungstechnologie für das Endlager für abgebrannte Brennelemente verwendet werden könnte, nun in die Kritik geraten ist. Es gilt daher zu klären, wie Finnland mit dem aufgetretenen Korrosionsproblem im Rahmen der KBS-3 Methode umgehen wird.

Langfristiger Betrieb des Reaktortyps WWER/440

Die Reaktorblöcke des KKW Loviisa wurden 1977 (Loviisa 1) und 1980 (Loviisa 2) ans Netz genommen und erreichten somit die ursprünglich für dieses Reaktordesign vorgesehene Lebensdauer von 30 Jahren im Jahre 2007 bzw. 2010. Die finnische Regierung erteilte im Juli 2007 neue Betriebsgenehmigungen. Bei den nun geplanten Verlängerungen würde es sich daher um die zweite Lebensdauerverlängerung handeln.

Bei Kernkraftwerken kommt es zu zwei Arten von alterungsbedingten Veränderungen:

- Physische Alterung der Strukturen, Systeme und Komponenten (SSCs), die in eine Degradierung, d.h. schrittweise Verschlechterung ihrer physikalischen Merkmale mündet
- Obsoleszenz von Technologie und Design, wenn die Anlagen gegenüber aktuellem Wissen, aktuellen Standards und aktueller Technologie veraltet sind

Um das alterungsbedingte Versagen zumindest bis zu einem gewissen Grad zu beschränken, wird ein umfassendes Programm für das Alterungsmanagement (AMP) benötigt. Die finnische Atomaufsichtsbehörde STUK publizierte 2013 eine YVL Anleitung zum Alterungsmanagement. Diese wurde seitdem aktualisiert und in ihrer jüngsten Version im Februar 2019 veröffentlicht. Die Arbeiten zur Umsetzung der aktualisierten Anforderungen an das Alterungsmanagement laufen bereits. Laut STUK ist der Stromversorger bei der Anpassung des KKW an die neuen Anforderungen auf einige Probleme gestoßen. Der UVP-Bericht geht nicht darauf ein, ob das aktuelle Alterungsmanagement für Loviisa die neuen Anforderungen erfüllt.

Finnland beteiligte sich an der Topical Peer Review (TPR) "Ageing Management", die 2017/18 gemäß der Richtlinie 2009/71/EURATOM über einen Gemeinschaftsrahmen für die nukleare Sicherheit kerntechnischer Anlagen – novelliert 2014/87/EURATOM – durchgeführt wurde. Die abschließende Bewertung bezeichnete das Alterungsmanagement als ausreichend. Dennoch wurden einige Problempunkte und Bereiche identifiziert, bei denen Verbesserungen erzielt werden könnten. Zur Umsetzung dieser Erkenntnisse hat Finnland einen nationalen Aktionsplan aufgesetzt. Dieser nationale Aktionsplan und die Fortschritte bei dessen Umsetzung werden im UVP-Bericht nicht angeführt.

Erhöhte Aufmerksamkeit und große Anstrengung vom Lizenzinhaber wie auch von STUK erforderte beim Alterungsmanagement für das KKW Loviisa die Versprödung der Reaktordruckbehälter (RDB). Obwohl es sich bei der Versprödung der Reaktordruckbehälter um eine wesentliche Sicherheitsfrage handelt, wird diese im UVP-Bericht nur allgemein beschrieben.

Auf Einladung der finnischen Regierung besuchte das IAEA Operational Safety Review Team (OSART), eine Mission internationaler ExpertInnen, das Kernkraftwerkwerk Loviisa im März 2018 und im Februar 2020. Die OSART-Missionen deckten Defizite bei der Wartung und dem Monitoring des Kraftwerks auf, die für die Lebensdauerverlängerung von Relevanz sind. Die Erkenntnisse der OSART-Missionen wie auch etwaige Verbesserungsvorschläge werden im UVP-Bericht nicht genannt.

In den Jahren 2019 und 2020 berichtete Fortum der Atomaufsichtsbehörde STUK über Analysen und Untersuchungen von Ereignissen. Die meisten der Ereignisse verwiesen darauf, dass Möglichkeiten für Verbesserungen bei den angewendeten Verfahren und Tätigkeiten bestehen. Von dieser Inspektion ausgehend forderte STUK den Betreiber Fortum auf, für eine verbesserte Lernkurve aus den Betriebserfahrungen zu sorgen.

Wissenschaft und Technik bringen laufend neues Wissen über Versagensmodi, Materialeigenschaften und Überprüfungs-, Test- und Computermethoden hervor. Dadurch tritt für die Sicherheitskonzepte der laufenden Kernkraftwerke eine technologische Alterung ein. Die Erkenntnisse aus den großen Reaktorunfällen wie Three Mile Island, Tschernobyl und Fukushima Dai-ichi führen gleichzeitig dazu, dass die früheren Sicherheitskonzepte obsolet werden (konzeptuelle Alterung).

Die Reaktoren des KKW Loviisa sind Druckwasserreaktoren der Generation II der russischen Reaktorserie WWER-440. Im ursprünglichen Design dieser Reaktoren wurden externe Gefährdungen wie Erdbeben, chemische Explosionen oder Flugzeugabstürze nicht berücksichtigt. Um die größeren Designdefizite abzufedern, sind beide finnische WWER-440/V-213 Reaktoren mit einem Containment und Steuerungssystem westlicher Provenienz ausgestattet.

Das alte Kernkraftwerk in Loviisa ist im Vergleich zum aktuellen Wissenstand sowie zu den aktuellen Standards und Technologien zunehmend veraltet. Die WWER-440 Reaktoren sind Doppelblockanlagen, die sich viele Betriebssysteme und Sicherheitssysteme miteinander teilen. Diese gemeinsamen Systeme erhöhen das Risiko für ein Versagen aus gemeinsamer Ursache und für die gleichzeitige Sicherheitsbeeinträchtigung beider Reaktoren. Der UVP-Bericht beschreibt nicht, ob Designänderungen für die Lebensdauerverlängerung geplant sind.

Die Western European Nuclear Regulator's Association (WENRA) hat die Safety Reference Level (SRL) für bestehende Reaktoren revidiert, um die Erkenntnisse und Lektionen zu integrieren, die aus dem Unfall von Fukushima Dai-ichi im Jahre 2011 gezogen wurden. Im Jahre 2014 wurde eine Liste von 342 SRLs veröffentlicht. Gemäß SRL F1.1 sollte eine Analyse der Erweiterten Auslegungsbedingungen (Design Extension Conditions, DEC) durchgeführt werden, um die Sicherheit des KKW zu erhöhen. Der UVP-Bericht enthält keinen Vergleich des Auslegungsdesigns und der Maßnahmen des KKW Loviisa mit allen Anforderungen, die sich aus den SRL F ergeben. Die WENRA Reference Level wurden 2020 noch einmal aktualisiert.

Die "Safety Objectives for New Power Reactors" der WENRA sollten als Referenz für die Identifizierung von vernünftigerweise praktikablen Sicherheitsverbesserungen für das KKW Loviisa herangezogen werden. Das ehrgeizigste Sicherheitsziel ist die Reduktion von potentiell radioaktiven Freisetzungen in die Umwelt in Folge von Kernschmelzunfällen. Kernschmelzunfälle mit früher oder hoher Freisetzung sind praktisch auszuschließen. Der Nachweis des praktischen Ausschlusses einer Unfallabfolge kann nicht auf der bloßen Einhaltung eines allgemeinen Wahrscheinlichkeitswerts basieren. Um das Risiko weiter zu reduzieren, sollte selbst bei einer sehr geringen Wahrscheinlichkeit für eine bestimmte Unfallabfolge jede zusätzliche vernünftigerweise praktikable Designänderung, betriebliche Maßnahme oder Vorgangsweise beim Unfallmanagement umgesetzt werden.

Das Prinzip der kontinuierlichen Erhöhung der nuklearen Sicherheit sieht Abschnitt 7a des finnischen Atomenergiegesetzes (990/1987) vor: „Die Sicherheit der Kernenergienutzung soll auf einem möglichst hohen, praktisch möglichen Niveau gehalten werden." Bei der Entscheidung darüber, ob eine neue oder aktualisierte Richtlinie der Aufsichtsbehörde für in Betrieb befindliche Nuklearanlagen anzuwenden ist, kann STUK allerdings eine Ausnahme genehmigen, wenn die Sicherheitserhöhung als nicht vernünftigerweise praktikabel angesehen werden kann. Unter Sicherheitserhöhungen für finnische in Betrieb befindlichen KKW, die als nicht vernünftigerweise praktikabel betrachtet werden, fallen u.a. Schutzmaßnahmen gegen Abstürze großer Verkehrsflugzeuge.

Unfallanalysen

Der UVP-Bericht enthält eine Beschreibung eines angenommenen schweren Reaktorunfalls. Die Bewertung beruht auf der Annahme einer in die Umwelt freigesetzten Menge an radioaktiven Stoffen (100 TBq Cs-137), die dem Grenzwert für einen schweren Unfall gemäß Abschnitt 22b der finnischen Kernenergieverordnung 161/1988 entspricht.

Die Regelung schreibt für die Auslegung für Kernkraftwerke vor, dass bei einem Unfall die durchschnittliche Freisetzungshäufigkeit von Cs-137 von mehr als 100

TBq in die Atmosphäre unter $5 \cdot 10^{-7}$/a bleiben muss. Die jüngste Aktualisierung der Probabilistischen Risikobewertung Level 2 für das KKW Loviisa erfolgte im Jahre 2018 und ging von einer Gesamthäufigkeit für große Freisetzungen (LRF) in die Umwelt von $7{,}8 \cdot 10^{-6}$ pro Reaktorjahr aus.

Die Unfallanalyse im UVP-Bericht sollte als möglichen Quellterm für einen schweren Unfall einen Wert verwenden, der sich aus der Berechnung des aktuellen PSA Level 2 ergibt. Wenn auch die Wahrscheinlichkeit für schwere Unfälle mit frühen und/oder großen Freisetzungen bei bestehenden Kraftwerken als sehr gering eingeschätzt wird, so ist doch der eintretende Schaden enorm, der durch diese Unfälle verursacht werden würde. Daher ist es in diesem Zusammenhang wichtig herauszustreichen, dass die berechnete Häufigkeit für hohe Freisetzungen aus dem KKW Loviisa über den Grenzwerten der STUK-Regelung liegt.

Der Erhalt der Containment-Integrität unter den Bedingungen schwerer Unfälle ist ein wichtiges Thema für das Unfallmanagement. Das Management des KKW Loviisa für die Beherrschung schwerer Unfälle (SAM) beruht weitgehend auf dem Rückhalt des Coriums innerhalb des Reaktordruckbehälters (in-vessel retention (IVR)). Allerdings gibt es einige Sicherheitsprobleme, die die Containment-Integrität beeinträchtigen könnten (Szenarien mit Containment-Bypass, Cliff-edge Effekte im abgeschalteten Zustand). Es wird an der Reduktion der Frequenzhäufigkeit von Bypass-Sequenzen kontinuierlich gearbeitet und diese Anstrengungen werden fortgesetzt. In diesem Zusammenhang ist festzuhalten, dass die Freisetzung von großen Mengen an radioaktiven Stoffen zum gegenwärtigen Zeitpunkt möglich ist. Der UVP-Bericht erläutert nicht, wie diese Sicherheitsfragen betreffend das IVR-Konzept gelöst werden.

Der Unfall von Fukushima Dai-ichi zeigte unter anderem die Wichtigkeit des Prinzips des tiefengestaffelten Sicherheitskonzepts, aber auch die anhaltende Notwendigkeit sicherzustellen, dass die Auslegung externe Gefährdungen ausreichend berücksichtigt.

Zur Zeit der Errichtung der Reaktorblöcke des KKW Loviisa gab es keine Vorschriften der Aufsichtsbehörden für die **seismische Auslegung,** Erdbebenlasten wurden in der Auslegung nicht gesondert betrachtet. Laut STUK erwies sich die erneute Bewertung der seismischen Gefährdung und des seismischen Risikos als Herausforderung für das KKW Loviisa. Die jüngsten Gefährdungsberichte für Loviisa zeigen erhöhte Bodenbeschleunigungswerte insbesondere bei langen Eintrittsperioden. Beim KKW Loviisa wurden die SAM-Systeme nicht so ausgelegt, dass sie gegenüber Erdbeben widerstandsfähig wären und daher kann auf keine ausreichende Betriebseignung dieser Systeme nach einem Erdbeben verwiesen werden. Laut dem UVP-Bericht sind die Verbesserungsmaßnahmen noch in Arbeit.

Das KKW Loviisa liegt an der Küste des Golfs von Finnland, etwa 90 km von Helsinki entfernt. Über die letzten Jahrzehnte hat sich die Gefährdung durch **Überflutungen** für viele KKW-Standorte erhöht. In Folge des Unfalls des KKW Fukushima Dai-ichi kam es auch beim KKW Loviisa zur Umsetzung von Maßnahmen zur Sicherheitserhöhung. Zur Absicherung der langfristigen Zerfallswärmeabfuhr bei einem Verlust des Meerwassers wurde eine alternative Wärmesenke eingerichtet. Diese Modifikation besteht aus zwei luftgekühlten Kühleinheiten pro Reaktoreinheit, die von einem luftgekühlten Dieselgenerator versorgt werden. Um eine entsprechende Auslegung für den verbesserten Schutz gegen Überflutungen sicherzustellen, beauftragte das KKW Loviisa beim Finnischen Meteorologischen Institut eine Aktualisierung der Verteilung extremer Werte des Meeresspiegels. Die neuen Ergebnisse für die erwarteten Meeresspiegelhöhen bei niedriger Eintrittshäufigkeit sind höher als ursprünglich angenommen.

Laut dem Intergovernmental Panel on Climate Change (IPCC) werden sich die Art, die Häufigkeit und die Intensität **von extremen Wetterereignissen** in Folge des Klimawandels ändern.

Im Kontext der Unfallanalysen bleiben einige Fragen offen, die es unmöglich machen, eine umfassende Bewertung über die mögliche Gefährdung Österreichs durchzuführen.

Unfälle mit der Beteiligung Dritter

Kernkraftwerke sind gegenüber einem breiten Spektrum möglicher Angriffe verletzbar, auch auf das KKW Loviisa ausgeübte Terrorattacken oder Sabotageakte können schwerwiegende Auswirkungen haben. Dennoch befassen sich die Scoping Dokumente nicht mit bösartigen Handlungen Dritter gegen das KKW Loviisa, mögliche Auswirkungen werden nicht behandelt. Im Gegensatz zu dieser Vorgangsweise berücksichtigten vergleichbare UVP-Verfahren diese Ereignisse bis zu einem gewissen Ausmaß.

Die Terrorgefährdung von Kernkraftwerken erfuhr in den letzten zwanzig Jahren beträchtliche öffentliche Aufmerksamkeit. Diese Aufmerksamkeit konzentrierte sich aus offensichtlichen Gründen auf die Gefahren eines beabsichtigten Absturzes eines großen Verkehrsflugzeugs.

Die Reaktorgebäude des KKW Loviisa sind nicht gegen einen Flugzeugabsturz ausgelegt und STUK bezeichnete eine derartige Nachbesserung als nicht "vernünftigerweise praktikabel". Im Zusammenhang mit der Lebensdauerverlängerung des KKW Loviisa sollte ein möglicher Terrorangriff auf die Abklingbecken mit den abgebrannten Brennelementen im UVP-Bericht bewertet werden, allerdings findet sich dazu keine Information.

Grenzüberschreitende Auswirkungen

Ein schwerer Unfall mit großen Freisetzungen kann zu signifikanten grenzüberschreitenden Auswirkungen auf Österreich führen. Für den UVP-Bericht wurde ein Unfall mit einem Quellterm von 100 TBq Cs-137 berechnet, die Ausbreitungsrechnungen berücksichtigten eine Entfernung von bis zu 1.000 km. Dies kann zu einer Unterschätzung der Auswirkungen auf Österreich führen. Einerseits ist nicht nachgewiesen, dass ein höherer Quellterm ausgeschlossen werden kann, und die Berechnung für die Distanz von 1.000 km ist zu gering, um Auswirkungen auf Österreich abschätzen zu können.

1 INTRODUCTION

The nuclear power plant Loviisa consists of two units, Loviisa 1 and 2. Loviisa 1 started commercial operation in 1977 and Loviisa 2 in 1980. The NPP is owned by Fortum Power and Heat Oy (in short: Fortum), a wholly owned subsidiary of Fortum Corporation. The current operating licence issued by the Finnish government is valid until the end of 2027 and 2030, respectively.

Fortum is now evaluating the extension of the operation time of Loviisa by approximately another 20 years once the current license will have expired. Another option would be the start of decommissioning of the plant.

For the purpose of this evaluation an Environmental Impact Assessment (EIA) is being conducted in accordance with the Espoo-Convention and the Finnish EIA Act which is based on the EU EIA Directive. Austria has been notified by Finland on this project. The coordinating EIA authority in Finland is the Ministry of Economic Affairs and Employment (MEAE), the project developer is Fortum, the EIA consultant is Ramboll Finland Oy. The Ministry of the Environment is in charge of the trans-boundary participation.

In 2020, the EIA Scoping which is also referred to as EIA Programme has been conducted. It was completed with the MAEA issuing its Statement on 23 Nov 2020. (MAEA 2020)

The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) commissioned the Environment Agency Austria to provide an expert statement for the scoping phase (UMWELTBUNDESAMT 2020), and again an expert statement for assessing the EIA Report that has been submitted in Oct 2021.

In the scoping expert statement, requirements for the EIA Report were formulated. In the expert statement at hand, the submitted EIA Report is being assessed and checked against the requirements from the scoping phase.

The objective of the Austrian participation in the EIA procedure is to minimise or even eliminate possible significant adverse impacts on Austria resulting from the project.

2 PROCEDURE AND ALTERNATIVES

In this chapter overall and procedural aspects of the Environmental Impact Assessment (EIA) procedure are discussed, including the evaluation of the completeness of the provided documents and the fulfilment of the requirements of the Espoo Convention.

The following documents were provided by the Finnish side and are quoted in this expert statement as follows:

- FORTUM (2021a): Loviisa nuclear power plant: Environmental Impact Assessment Report. September 2021.
- FORTUM (2021b): Loviisa Nuclear Power Plant: Environmental Impact Assessment. International Hearing Document. (Summary) September 2021.

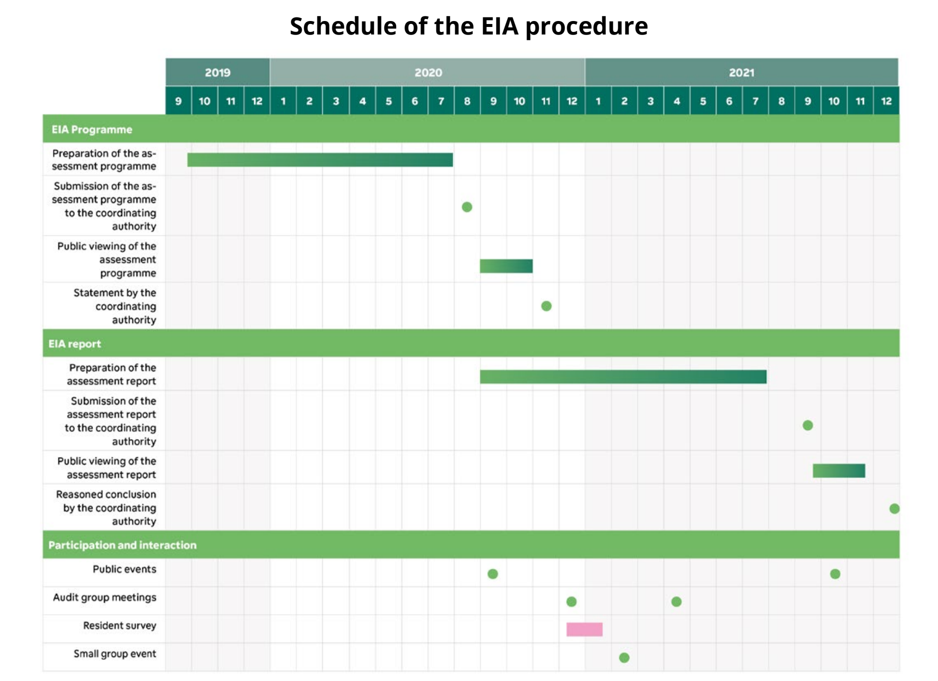
2.1 Treatment in the EIA documents

The **EIA procedure** is based on the Finnish EIA Act 252/2017. The EIA-Directive 2011/92/EU has been implemented in Finland by means of this Finnish EIA Act and the Government Decree on the Environmental Impact Assessment Procedure (the EIA Decree, 277/2017). The first EIA Directive dates back to 1985 (85/337/EEC), and took effect in Finland in 1995.

In addition, the Espoo Convention applies (the international hearing). (FORTUM 2021a, p. 125ff.)

The EIA schedule is presented in figure 1.

Figure 1: Schedule of the EIA procedure (FORTUM 2021a)



Source: FORTUM 2021a

The first step, the EIA Scoping (EIA Programme) was finalized with a Statement by the MEAE as coordinating authority on 23 Nov 2020. (MEAE 2020)

The reasoned conclusion is the last step of the EIA procedure and will be issued by the MEAE. This reasoned conclusion should be considered in the subsequent licensing process, both the EIA Report and the reasoned conclusion will be appended to the licensing application documents.

License and permit procedure

Loviisa 1 has an operating license which is valid until the end of 2027 and Loviisa 2 until the end of 2030.

Once the EIA procedure is concluded, the licence and permit phase of the project will start. (FORTUM 2021a, p. 339 ff.) The extension of the plant lifetime requires granting a new operating license. The decommissioning of the reactors requires that a decommissioning license is issued; both licenses are granted by the Government.

The operating license for the final LILW repository will end in 2055, a new license has to be obtained. Furthermore, the current operating licence of the LILW final repository does not include final disposal of certain types of waste like institutional waste, decommissioning waste and waste containing uranium (this does not refer to spent fuel but f.e. to instruments containing uranium).

The parts of the plant that will have to be made independent (fit for stand-alone operation) during decommissioning will also require a separate operational licence.

The project's implementation may also require other licences in accordance with the Nuclear Energy Act.

For receiving an operational license, a list of prerequisites listed in section 20 of the Nuclear Energy Act have to be met and confirmed by the Nuclear Regulator STUK. The MEAE needs to ensure that the funds for nuclear waste management will be provided. The request for the decommissioning license has to be filed well in advance before plant ends operations.

Besides the above listed licences, also a licence pursuant to the Radiation Act is required for handling unsealed sources, X-ray equipment and sealed sources. This safety license is valid until further notice, it is amended if necessary.

Small amounts of institutional radioactive waste may be stored at Loviisa under the current operating licence. When applying for a new operating licence the amount can be changed. Furthermore, decommissioning waste from VTT's FiR1 research reactor and the OK3 laboratories could be included.

The environmental permit and the water use permit of Loviisa 1&2 have become legally valid by a decision issued by the Supreme Administrative Court in 2012. No permit is required if the change in the activity does not increase environmental impacts or risk. (FORTUM 2021a, p. 342) The need for changes to the existing environmental and water permits will be assessed during the application for the new operating licence after 2027/2030.

Public Participation

The EIA Report is open for public review for 60 days. An international hearing will be held during this stage of the EIA.

A survey and an information event for a small group of residents in the area were held to gain information about their attitudes towards the life-time extension. Results are presented in chapter 9.19 of the EIA Report. The significance of impacts of the life-time extension was deemed minor and negative by the residents. (FORTUM 2021a, p. 280ff.) Furthermore, a result of this survey is that in extended operation, the possible concern over safety risks would continue and could grow as the waste volumes increase and the plant ages. Concerns were raised on the possible transports and disposal of institutional radioactive waste at the Loviisa site.

Alternatives

Three alternatives are discussed: Option VE1, and options VE0 and VE0+. The options VE0 and VE0+ are also the zero options. (FORTUM 2021a, p. 10f.)

Option VE1

Option VE1 foresees a lifetime extension of a maximum of approximately 20 years after the current licenses will have expired, followed by decommissioning.

An uprate of the thermal power is not planned. The construction of new buildings and structures might be included, also modernisations in the NPP site. Some old buildings might be replaced by new ones (concerning service and waste water). The interim storage for spent fuel has to be expanded or the storage density increased. Also the operation time of the LILW final repository has to be prolonged.

For small amounts of radioactive waste generated elsewhere in Finland, the option VE1 includes the possibility of receiving, processing, storage in the interim storage and depositing for final disposal.

Option VE0

Option VE0 foresees the decommissioning after the expiration of the current operation licenses (2027 and 2030, respectively). The decommissioning phase will include the following operations:

- The transport of spent fuel to Onkalo/Olkiluoto, where it will be encapsulated and deposited for final disposal.
- The LILW final repository will have to be expanded.
- The first dismantling phase of the NPP
- Some of the plant's systems and parts will be made independent to remain in function after the NPP shut-down.
- The second dismantling phase.
- The closure of the LILW final repository.

Decommissioning will be based on the Loviisa NPP's latest decommissioning plan from 2018. This plan covers the dismantling of the radioactive plant parts, and treatment and final disposal of the radioactive waste. Dismantling will only involve the radioactive parts, the other buildings will not be demolished ("brownfield principle").

Option VE0+

In addition to option VE0, the option VEO+ includes the possibility of receiving, processing, interim storage and depositing for final disposal small amounts of radioactive waste generated elsewhere in Finland.

This figure shows the time schedule for the various available options.

Figure 2: Time schedule of the project options (FORTUM 2021a, p. 11)

Time schedule of the project options

Source: FORTUM 2021a, p. 11

umweltbundesamt

Fortum will make the decision concerning the potential extension of the operation of the nuclear power plant and the application for new operating licences at a later date. (FORTUM 2021a, p. 9)

Loviisa power plant is used for the generation of base load electricity. The nominal thermal power of both power plant units is 1,500 MW, and the net electric power is 507 MW. The total efficiency of the power plant units is approximately 34%. The availability and load factors of Loviisa power plant have been excellent. (FORTUM 2021a. p. 9)

The role the NPP Loviisa plays in the Finish electricity supply is characterized in chapter 9.11. (FORTUM 2021a, p. 189ff.) In 2020, Loviisa NPP produced 7.8 terawatt hours (TWh) of electricity for the Nordic wholesale electricity market which covers Finland, Sweden, Norway and Denmark. The net production in 2020 in the Nordic electricity market was 402 TWh, and electricity consumption amounted to 378 TWh. (NORD POOL 2021, quoted from FORTUM 2021a) In Finland, 65.9 TWh electricity were produced in 2020, and 80.9 TWh were consumed. (FINNISH ENERGY 2021 quoted from FORTUM 2021a)

The Finnish climate objectives foresee carbon neutrality by 2035 and carbon negativity soon after. The future electricity consumption is expected to grow significantly in Finland and in the other Nordic countries due to the so-called power-to-X solutions by producing hydrogen from water with the help of electrolysis.

According to the low-carbon roadmaps by MAEA (MAEA 2020, quoted in FORTUM 2021a), Finland's climate objectives could translate into a 100% growth in the industrial sector's electricity consumption and a more than 50% growth in Finland's electricity consumption by 2050.

Nordic electricity consumption is also expected to grow significantly. In the scenarios drawn up by European transmission system operators (ENTSO-E), electricity consumption in the Nordic countries would be in the range of 436–472 TWh in 2030 and in the range of 468–558 TWh in 2040 (ENTSO-E & ENTSOG 2020, quoted in FORTUM 2021a).

The preparation of more precise reviews of Finland's energy markets and security of supply are described as the responsibility of the Finnish government.

Existing and new NPPs will support Finland's supply security and reduce import needs. At the same time, electricity exports are envisaged.

Alternative electricity sources that can be further explored are solar and wind power. Hydro and biomass are described as almost maxed out.

2.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

Completeness of the EIA Report

According to the Espoo Convention, an EIA Report (formerly called EIA documentation) has to analyse and assess information in accordance with Article 4. (ESPOO CONVENTION 1991)

The following table shows whether the required information was included in the EIA Report.

Table 1: Comparison of topics that have to be assessed in an EIA Report

Espoo Convention (ESPOO CONVENTION 1991, Appendix 2)	Fulfilment in the EIA Report (FORTUM 2021a)
(a) A description of the proposed activity and its purpose;	The proposed activity is described in an overview in chapter 1, and in detail in the other chapters in the EIA Report.
(b) A description, where appropriate, of reasonable alternatives (for example, locational or technological) to the proposed activity and also the no-action alternative;	In chapters 4, 5 and 6 three alternatives are discussed, including no-action (zero) alternatives.
(c) A description of the environment likely to be significantly affected by the proposed activity and its alternatives;	The assessment of each impacts was conducted as follows:

Espoo Convention (ESPOO CONVENTION 1991, Appendix 2)	Fulfilment in the EIA Report (FORTUM 2021a)
(d) A description of the potential environmental impact of the proposed activity and its alternatives and an estimation of its significance; (e) A description of mitigation measures to keep adverse environmental impact to a minimum; (f) An explicit indication of predictive methods and underlying assumptions as well as the relevant environmental data used;	identifying the origin of the impact, and describing the baseline data and methods used in the assessment; describing the present state of the aspect affected, and based on this, assessing its sensitivity, i.e. capacity to absorb the impact observed; describing the environmental impacts and the magnitude of the resulting change; assessing the impact's significance on the basis of the affected aspect's sensitivity and the magnitude of the change concerned and drawing conclusions on the significant impacts; comparing the different options and identifying the differences between them from the perspective of feasibility; presenting the potentially necessary measures for mitigating the adverse impacts; The impacts included in chapter 9 of the EIA Report are: land use, landscape and cultural environment, traffic, noise, vibration, air quality, emissions of radioactive substances and radiation, use of natural resources, waste and waste treatment, energy markets and supply security, greenhouse gas emissions and climate change, regional economy, soil and bedrock, groundwater, surface water, fish and fishing, flora, fauna and conservation areas, people's living conditions and comfort, people's health, severe reactor accidents, other incidents and accidents, combined impacts with other projects, transboundary impacts.
(g) An identification of gaps in knowledge and uncertainties encountered in compiling the required information;	In every chapter has been introduced a sub-chapter "uncertainties" describing specific uncertainties. This can be considered as good practice in an EIA procedure.
(h) Where appropriate, an outline for monitoring and management programmes and any plans for post-project analysis;	Chapter 11 informs about monitoring and observation of impacts.

Espoo Convention (ESPOO CONVENTION 1991, Appendix 2)	Fulfilment in the EIA Report (FORTUM 2021a)
(i) A non-technical summary including a visual presentation as appropriate (maps, graphs, etc.).	A summary is included, also a chapter with a summarizing description on the alternatives (chapter 2).

The provided EIA documents are in general complete.

For Austria, the most important possible impacts result from severe nuclear accidents and accidents in the nuclear waste facilities. Those will be subjected to a specific assessment in the next chapters.

EIA and licensing and permit procedures

A 20-year licence extension was granted by the Radiation and Nuclear Safety Authority (STUK) in mid-2007, extending the reactor lifetimes to 2027 and 2030, respectively. (WNA 2021) For this prolongation of the Loviisa lifetime no EIA has been conducted. Therefore it is welcomed that Finland undertakes an EIA for the now planned lifetime extension of Loviisa 1&2.

The definition of the **maximum lifetime extension** remains unclear – "a maximum of approximately 20 years" is not a clear.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should clearly state the maximum years of the planned lifetime extension.

On the decision for or against the lifetime extension, the EIA Documents only made the remark "at a later date" in the EIA.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should give the date when Fortum will take the decision for one of the options should be stated.

An **International Hearing** was held on 7 October 2021.[1] Presentations were given in Finnish and Swedish. Participants also had the opportunity to ask questions in English. The meeting was held in live and online. The MEAE website informs that any statements and opinions presented will be published at the Finnish website and will be taken into consideration in the coordinating authority's informed conclusion.

It would be welcomed if the presentations and the documentation of the international hearing will also be made available in English.

1 https://tem.fi/en/loviisa-eia-report, seen 01. Nov 2021

Alternatives

Two main options have been assessed – a 20-years lifetime extension followed by decommissioning or the start of decommissioning right after the current licenses will have expired.

In the EIA Scoping expert statement (UMWELTBUNDESAMT 2020) it was recommended that the EIA Report should include scenarios of future electricity demand in Finland, together with energy efficiency and saving measures and other electricity generating options for assessing alternative options. In the EIA report, results from scenarios were given that predicted significant increases in electricity demand.

Other publications like NORDIC ENERGY RESEARCH (2021) reach other conclusions concerning the role of life-time extension for the future energy demand. One of its results is that *"nuclear electricity could play a long-term role, but is unlikely to be a dealbreaker. The fundamental pathways to a decarbonised energy system are very similar no matter if nuclear is part of the Nordic electricity mix after 2040 or not. Necessary near-term decisions, such as those associated with strengthening the electricity grid and decarbonising industry and transport, are not essentially different. Furthermore, the significant expansion of variable renewable electricity generation in the Nordic countries is also likely to continue whether or not nuclear power is extended post 2040, even though there may be a certain degree of substitution effects between nuclear and renewables."*

According to the requirements formulated in the EIA Scoping expert statement, for assessing alternative options the EIA Report should include scenarios of future electricity demand in Finland, together with energy efficiency and saving measures and other electricity generating options. Only results for future electricity demand were provided, but no scenarios without life-time extension of NPP.

2.3 Conclusions, questions and preliminary recommendations

It is welcomed that Finland undertakes an EIA for the planned lifetime extension of Loviisa 1&2.

The provided EIA Documents are in general complete.

The provided information did not clarify when the decision for or against the life-time extension will be taken, and if 20 years will be final decision and the limit for life-time extension.

It would be welcomed if the presentations and the documentation of the international hearing which was held on 7 Oct 2021 in Finnish and Swedish language will also be made available in English.

2.3.1 Questions

Q1: *How should the wording of the envisaged life-time extension "a maximum of approximately 20 years" be interpreted: Could the life-time extension be also longer than 20 years?*

Q2: *When will the decision on one of the options be taken by Fortum*?

Q3: *What are the results from the international hearing on 7 October 2021?*

2.3.2 Preliminary recommendations

No preliminary recommendations

3 SPENT FUEL AND RADIOACTIVE WASTE

3.1 Treatment in the EIA documents

According to the Nuclear Energy Act, nuclear waste must be handled, stored and permanently disposed of in Finland. The Nuclear Energy Decree (161/1988) further defines the nuclear waste to be permanently disposed of in Finnish ground or bedrock. (FORTUM 2021a, p. 51)

Information on spent fuel and radioactive waste is given in chapter 9.10 of the EIA report (FORTUM 2021a, p. 179ff.) and in assessments of the different alternatives.

Spent Fuel

From 20 years of life-time extension about 3,700 spent fuel elements will be produced. The amount of spent nuclear fuel accumulated in the interim storage by the end of the current operating licence will be about 7,700 spent fuel elements, which is equal to roughly 960 tonnes of uranium. This results in a sum of about 11,400 spent fuel elements after the life-time extension of 20 years. But the maximum amount of spent fuel placed in interim storage will be 12,800 spent fuel elements, which is equivalent to around 1,600 tonnes of uranium. This is due to possible changes in the method of fuel loading and planning, and in the potential increase in the number of dummy elements[2]. (FORTUM 2021a. p.48)

The spent fuel from Loviisa is stored in the **spent fuel pools** next to the reactors for 1-3 years and then moved to the **interim storage** on the site. This interim storage is a wet storage system.

The interim storage capacity of spent nuclear fuel needs to be increased in case of life-time extension. This can be achieved by switching to high density storage of spent nuclear fuel in the pools of the current interim storage or by building a maximum of two additional pools to increase the current pool capacity. The growth of the total amount of spent fuel will have an effect of the heat production, which can be handled by increasing the flow of cooling water to the heat exchangers or by increasing the size of the heat exchangers.

Spent fuel must be kept in interim storage for a minimum of 20 years prior to final disposal. (FORTUM 2021 a, p. 49) In due course, the spent fuel will be taken out of the interim storage to the spent nuclear fuel encapsulation plant and then the **final repository** Onkalo that is operated by Posiva Oy at Olkiluoto in Eurajoki, Finland. Transport will take place either by road or by sea.

The encapsulation plant and final repository Onkalo are under construction. According to the current estimate, the final disposal of the spent fuel from Loviisa

[2] The dummy elements protect the pressure vessel from the neutron radiation emitted by the fuel.

would begin within the framework of the current operating licence period in the 2040s. (FORTUM 2021a, p. 37)

According to the original plan, spent fuel was to be held in interim storage at Loviisa power plant for three years before it would be returned to the Soviet Union/Russia. The original plan was therefore for the power plant to have one interim storage for spent fuel. A subsequent agreement set the minimum storage period at five years, due to which the interim storage capacity for spent fuel was increased with the construction of another interim storage for spent fuel in 1984. Following the amendment made to the Nuclear Energy Act in 1994, all nuclear waste generated in Finland has had to be stored and deposited for final disposal in Finland. As a result of this amendment, interim storage 2 for spent fuel was expanded with four additional pools in 2000. (FORTUM 2021a, p. 28)

The **low- and intermediate-level waste** (LILW) generated during the operation of the Loviisa NPP is processed on the power plant premises and deposited in the final LILW repository located at the Loviisa site 110 metres underground on the island of Hästholmen.

The operating license for this final LILW repository will end in 2055, a new license has to be obtained. The envisaged operation time of the LILW repository in case of lifetime extension of the reactors is approximately 2090, in case of decommissioning without lifetime extension 2065.

No major changes to the annual waste accumulation are predicted. An extension of about 20 years generates approximately 20-30 m^3 per year of low-level waste (up to 600 m^3 in total). The accumulated volume of LLW at the end of the current operation license is about 2,700 m^3 and will increase due to the life-time extension up to 3,300 m^3.

15-30 m^3 per year of intermediate-level waste are produced which result in 60-120 m^3 per year after solidification and packed into containers. Therefore, approximately 2,400 m^3 of intermediate-level waste (solidified and packed) will be generated by the life-time extension. The accumulated volume of ILW at the end of the current operation license is about 4,900 m^3 and will increase due to the life-time extension up to 7,300 m^3.

The methods for final disposal of the ILW may be changed in case of life-time extension. Concrete boxes could be used as support for the metal barrels to take ageing effects into account. These changes are already being studied.

The capacity of the final repository for low- and intermediate-level waste is sufficient for the final disposal of the low- and intermediate-level waste generated during the extension. (FORTUM 2021a, p.53)

For the decommissioning LILW, the final repository will be expanded by 71,000 m^3. The following waste volumes are expected from decommissioning:

- activated waste: 3,300 m^3
- contaminated waste: 19,000 m^3

- maintenance waste to be packed in barrels: 700 m^3
- solifidied liquid waste: 2,260 m^3
- crushed concrete (very low level waste or conventional waste from dismantling) as filling material: up to 50,000 m^3

The construction work related to the LILW repository's expansion is set to begin no later than two years before the start of the preparation phase of Loviisa 1's decommissioning and has been estimated to last roughly three years. This will allow decommissioning waste to be deposited in the LILW repository when the dismantling phase begins. (FORTUM 2021a, p. 70)

3.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

According to EIA Directive 2014/52/EU Annex IV, the description of the potential significant effects of the project on the environment must be provided in the EIA report, including a description of the disposal of waste. Such a description should include and assess the capacity and safety of interim and final storage facilities and methods.

The capacity currently available for the final storage of LILW is sufficient for storing the LILW generated during the lifetime extension but has to be enlarged to also accommodate decommissioning waste.

In the EIA Documents, the increase of the **density of the spent fuel interim storage** at Loviisa is described as one option for providing the necessary additional capacities for the lifetime extension. But according to the Finnish national nuclear waste management programme from 2015 and information from the Posiva website, the density already had been increased before by procurement of high-density racks in 2007, 2009 and 2011. (NATIONAL PROGRAMME 2015, POSIVA 2011).

According to the requirements formulated in the EIA Scoping expert statement, it was recommended to clarify the options for increasing the capacity in the spent fuel interim storage by introducing high-density storage.

The interim storage facility for the spent fuel uses a **wet storage system**, a dry storage system would be a safer solution.

According to the requirements formulated in the EIA Scoping expert statement, it should have been explained why no plans were set up to switch the storage system used for spent fuel interim storage to a state-of-the-art dry storage system. This explanations is lacking.

The point in time when interim storage capacity for spent fuel from lifetime extension will need to be expanded was not stated. The final repository is under construction. However, if it is not completed in time, **alternative waste management routes** have to be developed.

According to the requirements formulated in the EIA Scoping expert statement, it was recommended to explain the timetables for the planned increase of the interim storage capacity for spent fuel, and give information on which alternative options are planned for the case that the interim and the final disposal facilities for spent fuel are not available when needed.

For the encapsulation of the spent fuel the **KBS-3 method** might be used (WNA 2021). This method includes using copper canisters and assuming that copper does not corrode significantly while covered in clay. But there are independent scientific studies showing that the copper canisters may corrode much faster than was assumed. This was also recognised by the Swedish Environmental Court in its opinion of 2018.[3]. Recent research results give even more proof of copper corrosion. It should be explained how Finland will solve the corrosion problem.

The EIA Scoping expert statement asked for clarification of the KBS-3 method, in particular how the copper corrosion problems will be solved.

3.3 Conclusions, questions and preliminary recommendations

The decommissioning of the NPP will generate low and intermediate level radioactive waste for which no capacities are available now. These additional capacities will have to be provided for both possible options, VE1 and VE0.

Additional spent fuel will arise from lifetime extension, the extension of the interim spent fuel storage is envisaged. However, information on timetables and alternative waste management options in case the capacities will not be available in time are lacking.

New results on copper corrosion led to criticism of the KBS-3 method which might be used in the final spent fuel repository. It should be explained how Finland will respond to the corrosion problem in connection with the KBS-3 method.

[3] http://www.mkg.se/en/translation-into-english-of-the-swedish-environmental-court-s-opinion-on-the-final-repository-for-sp, seen 02 Sept 2020

3.3.1 Questions

Q4: *What is the timetable for the planned increase of the interim storage capacity for spent fuel?*

Q5: *Can you please describe the options for capacity increasement of the spent fuel interim storage by high-density storage in more detail?*

Q6: *Why will the storage system used for spent fuel interim storage not be switched to a state-of-the-art dry storage system?*

Q7: *Which alternative options are planned for the case that the interim and the final disposal facilities for spent fuel are not available in time?*

Q8: *Will the KBS-3 method be used despite of problematic results of copper corrosion research? How will the copper corrosion problems be dealt with?*

3.3.2 Preliminary recommendations

No preliminary recommendations.

4 LONG-TERM OPERATION OF REACTOR TYPE VVER-440

4.1 Treatment in the EIA documents

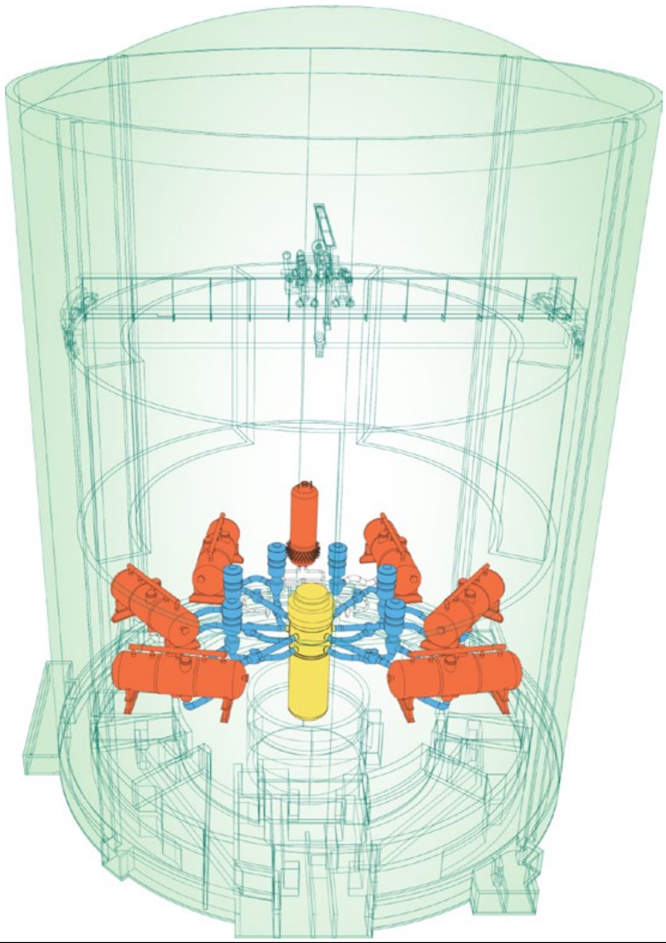
Reactor and containment building

Both of the power plant units have their own reactor and containment buildings, which house, among other things, the main coolant loop (primary system) and the related components, including the reactor pressure vessel (RPV), steam generators and the pressurizer.

The containment building is pressure containing and gas-tight. It consists of a hemispherical dome, a cylindrical mid-section and a bottom plate. The wall structures of the reactor cavity, in the bottom plate's mid-section support the RPV. The containment building is divided into an upper and lower compartment as well as the main service level separating them. Figure 3 is an illustration of the reactor building and the containment building within it.

Figure 3: Illustration of reactor building and the location of the primary system's main components. The reactor pressure vessel is shown in yellow, the six steam generators and the pressuriser in red, and the main coolant loops of the reactor's cooling system in blue. (FORTUM 2021a)

Illustration of reactor building and the location of the primary system's main components



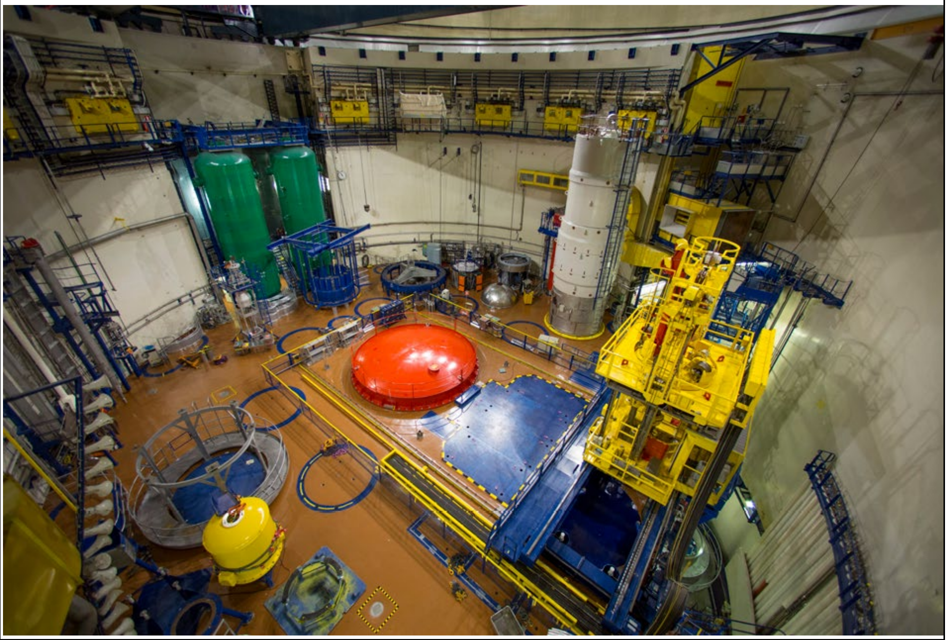
Source: FORTUM 2021a

umweltbundesamt

The containment building is enveloped by the reactor building, which protects the containment building from external phenomena and in the event of an accident, would function as a radiation shield. The reactor building's cylindrical section is built from reinforced concrete. In addition to the containment building, the reactor building houses the emergency cooling systems and the cooling system for the containment building's refueling pool. Figure 4 depicts the interior of the containment building.

Figure 4: The interior of the containment building. The green hydro accumulators can be seen on the left. The reactor's red cover can be seen in the middle and adjacent to it the refuel-ling pool, covered with blue plates. The yellow refuelling machine can be seen on the right-hand side of the picture. (FORTUM 2021a)

The interior of the containment building



Source: FORTUM 2021a umweltbundesamt

Both power plant units have their own auxiliary buildings, which house, among other things, the systems for treating the primary system's discharge waters, part of the service seawater system, the make-up water systems, the piping and equipment of other systems. The auxiliary buildings of Loviisa 1 and 2 are connected by a walkway which provides access to the units' shared staff building. The control room for serious accident management is also located next to the auxiliary building of Loviisa 2.

Ensuring power supply

Loviisa power plant has at its disposal a number of power sources which secure the execution of safety functions in incidents and accidents. Both power plant units have four 2.8 MW emergency diesel generators and a shared 9.7 MW diesel-powered emergency power plant. There is also a connection to the power plant from the nearby Ahvenkoski hydro power plant. These power sources can be used to operate the aforementioned systems and to recharge accumulators that secure the power supply of automation.

Cooling Water

Seawater is used for various cooling purposes at Loviisa power plant. The primary use is the condensation of steam in the turbines. If the power plant's operation is extended, cooling water would continue to be used in the same manner as it is currently. The cooling water for the power plant is taken from Hudöfjärden, west of the island of Hästholmen, using an onshore intake system, and is discharged back into the sea at Hästholmsfjärden, on the east side of the island. The thermal load to which the sea area is subject due to the cooling water would remain unchanged.

Life-time extension and power uprate

The project's Option VE1 covers the extension of the operation of Loviisa nuclear power plant by a maximum of approximately 20 years after the current license period. During the extension, the operation of the power plant would be similar to what it is currently; increasing the thermal power of the plant is not being planned. But it is also stated that the potential modernisation of the low-pressure turbines is considered, which would also increase the power plant's efficiency.

Ageing Management and Maintenance

Attention has been paid to the ageing management of Loviisa power plant throughout its operation. According to the EIA report, well-managed and professional ageing management and maintenance are prerequisites for ensuring the safe, reliable and profitable operation of a nuclear power plant. The equipment of these plant parts has been categorized according to its criticality. The monitoring, maintenance programmes and tasks of plant parts and equipment that have a high criticality class are the most extensive in scope. Ageing management also entails the monitoring of technical ageing and ensuring an adequate reserve of spare parts.

Loviisa power plant's maintenance organization and maintenance functions are responsible for ensuring that a system, piece of equipment or structure that is in operation or operable meets the requirements set for the operating conditions under normal operation. As the failure rate of a piece of equipment increases, the measures are determined on the basis of observations or other considerations, and in such cases, one option is to replace the piece of equipment with a new one. An increase in failure rate may also have an effect on the probabilistic safety analysis (PSA).

During the power plant's extended operation, the ageing management and the related procedures, as well as maintenance, would continue in the same manner as during the power plant's current operation, under the supervision of the Radiation and Nuclear Safety Authority (STUK). The measures are primarily carried out during annual outages to ensure the safety impact during work is as small as possible.

The following assessment, development and improvement targets have been identified on the basis of the power plant's operation and ageing management:

- measures resulting from the ageing of some automation systems, such as ensuring the availability of spare parts or a system's modernisation;
- ensuring the safety margins of the primary system and the RPV, particularly the safety margins applicable during operation;
- renovation of the existing buildings in the power plant area and the possible construction of new buildings.

Ageing management of the RPV

The ageing management of the RPV has been identified as a key measure for extending the power plant's service life. Over time, radiation embrittles the weld seam which is at the height of the bottom half of the RPV's core. A brittle fracture of the weld seam could occur if the RPV was exposed to a great change in temperature during an incident or accident. Safety margins have been defined for a brittle fracture of the weld seam, and the reduction of these margins is assessed on the basis of a research programme and analysis.

If the power plant's operation is extended, measures aiming to prevent the radiation embrittlement of the RPV's weld seam must be carried out. Such measures would include:

- limiting the weld seam's radiation dosage to decelerate the radiation embrittlement;
- the annealing of the weld seam;
- the reduction of any thermal load to which the weld seam would be subject during an incident or accident.

The radiation dose accumulated by the weld seam can be decelerated in various ways, for example, by the placement of fuel and adding dummy elements to the reactor core.

Loviisa power plant has experience of the annealing of a RPV's weld seam, given that this procedure was carried out on Loviisa 1's RPV in 1996. As a result of the annealing, the material properties of the embrittled area of the weld seam returned nearly to the original level.

The thermal loads of the weld seam were reduced in the automation modification carried out in 2019. The goal of the modification was to avoid the use of cold water in the spray system used for the containment building's pressure control when the spraying begins. Thermal loads can be further reduced with insulation, for example.

The measures presented above are examples of methods that allow the controlling of the RPV's ageing, thereby ensuring the power plant's safe extended operation. The investigations related to the measures will be continued, and the measures will be determined at a later date.

Nuclear Safety

Safety functions aim to prevent the emergence of incidents and accidents, prevent their spread, and mitigate the consequences of accidents. The principal short-term safety functions start up automatically. In the longer term, the necessary functions can be started up by an operator. The most important safety functions are as follows:

- reactivity control, which aims to stop the chain reaction generated by the reactor;
- the removal of the residual heat generated after the chain reaction is stopped, which aims to cool the fuel;
- prevention of the dispersion of radioactivity, which aims to isolate the containment building and ensure its integrity.

The general nuclear safety principles applicable to safety functions are the defence-in-depth principle, the redundancy principle, the diversity principle and the separation principle.

Defence-in-depth safety principle

In accordance with the defence-in-depth principle, safety at Loviisa power plant is ensured through a series of successive functional levels that are mutually redundant. The first two levels aim to prevent accidents, while the other levels intend to protect the plant and its users as well as the environment from the detrimental effects of an accident.

Redundancy principle

The most important safety systems of Loviisa power plant have been designed to meet the single failure criterion, even if the maintenance of an individual device or piece of equipment was underway at the same time. This means that the system executing the safety function can carry out its task even if two individual devices are disabled. The safety systems of Loviisa nuclear power plant are divided into two different redundancies.

Separation principle

At Loviisa nuclear power plant, the application of the separation principle means planning the placement of parallel devices and systems executing the same function and mutually redundant systems in such a way that a fire, or another internal or external event, cannot break them all simultaneously. In practice, this results in placing parallel partial systems in different spaces or their protection by physical means. The separation principle is also applied to automation and electric systems, and the different systems have been separated from one another to the extent necessary. This prevents a possible failure from spreading from one system to the next. Loviisa power plant's safety systems have been divided into two redundancies, separated from one another structurally and functionally.

Diversity principle

At Loviisa power plant, the diversity principle is applied, for example:

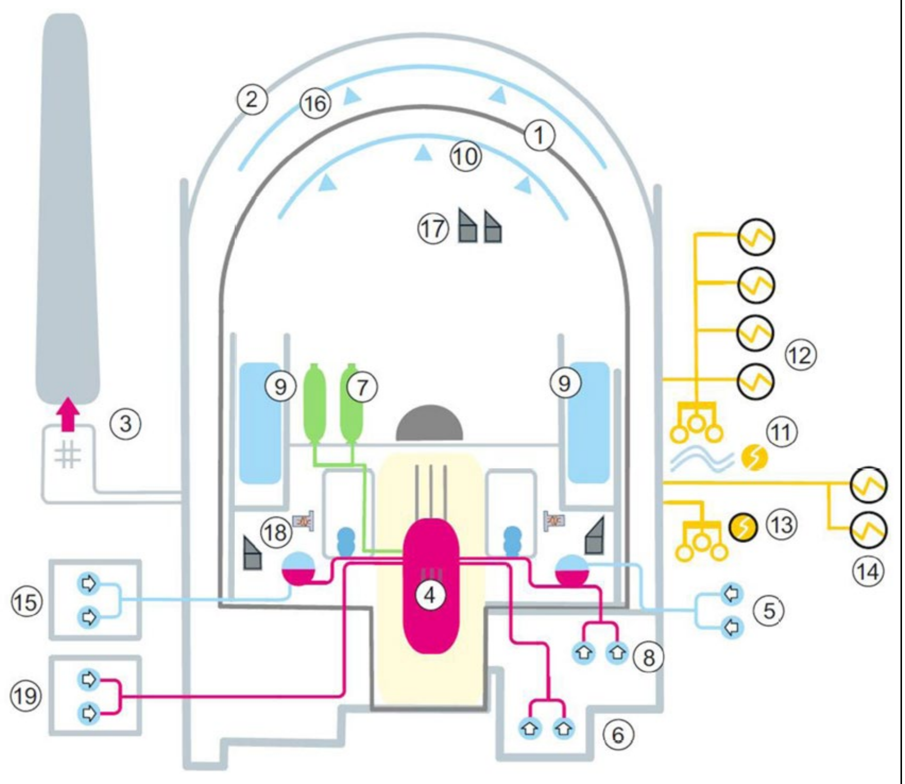
- a reactor shutdown with a control rod system or by feeding boron into the primary system;
- removing residual heat to the sea, and with the secondary system's blow-down valves or cooling towers, into the atmosphere;
- In exceptional situations, the electricity required by the safety functions can be produced with diesel generators cooled with either seawater or air;
- automation relies on both digital and analogue technology in such a way that the most important functions can be implemented with either technology.

Systems executing safety functions

The systems most relevant for the execution of the safety functions of Loviisa power plant's power plant units, their placement and the placement of the reactor building's structures are shown in Figure 5.

Figure 5: The most relevant systems related to the execution of safety functions at Loviisa NPP (FORTUM 2021a)

The interior of the containment building.



1. *Containment*
2. *Reactor building*
3. *Filters for ventilation exhaust*
4. *Reactor and control rods*
5. *Emergency feedwater system*
6. *Low-pressure safety injection system*
7. *Pressurised hydro accumulators*
8. *High-pressure safety injection system*
9. *Ice condenser*
10. *Containment spray system*
11. *Power supply from hydro power station*
12. *Emergency diesel generators*
13. *Diesel generators plant*
14. *Severe accident diesel generators*
15. *Auxiliary emergency feedwater pumps*
16. *Containment external spray system*
17. *Hydrogen removal (passive autocatalytic recombiners)*
18. *Hydrogen removal (igniters)*
19. *Boron supply system*

Source: FORTUM 2021a umweltbundesamt

Removal of residual heat

Following the reactor's shutdown, the fuel continues to produce heat. This "residual heat" is removed by various means, depending on the incident or accident. When the primary system is intact, the residual heat is removed through the steam generators to the secondary system, from which it is transferred into the atmosphere as steam, or with the aid of heat exchangers into the sea or the atmosphere. The steam blasting requires a constant feed of water to the steam generators, and this is achieved either with the emergency feedwater system or the auxiliary emergency feedwater system. The pumps of the auxiliary emergency feedwater system are equipped with their own diesel engines, which means their operation does not depend on electricity sources.

If there is a leak in the primary system, or if the systems of the secondary system are unavailable, the residual heat is removed by feeding water into the primary system. In the short term, the water supply for the pumps of these systems is the emergency cooling systems' separate water pool, and when the water in the pool runs out, the containment building's floor drains. The low-pressure emergency cooling system may be cooled, in which case the heat is transferred either into the sea or the atmosphere with the aid of heat exchangers. As the systems are used, residual heat is carried over to the containment building, increasing its pressure. In the short term, the ice condenser, with the structures of the containment building, absorbs heat and thereby effectively prevents pressure in the containment building from increasing. After this, the containment building's spray system is used if necessary, or the amount of heat entering the containment building is influenced by cooling the water fed into the primary system. The spray system may be cooled, in which case the heat is transferred either into the sea or the atmosphere with the aid of heat exchangers.

Containment of radioactivity

The dispersion of radioactive substances in an incident or accident is prevented by ensuring the fuel's sub-criticality and removing the residual heat from the fuel, whereby the fuel remains intact. The primary system's water normally contains a small quantity of radioactive substances. The aim is to contain these substances and any radioactive substances released from possibly leaking fuel rods or fuel rods damaged during the accident within the primary system or the containment building, thereby preventing the dispersion of radioactivity into the environment. This goal is achieved by isolating the primary system and the containment building – i.e. by closing the valves of the pipes leading to them, and the plates of the channels leading to the containment building.

Periodic Safety Review (PSR) and modernization

In 2020, Fortum submitted the periodic safety review (PSR) concerning Loviisa power plant to STUK. The review consists of 14 reviewed aspects and a summary. The content requirements for these aspects are provided in STUK's YVL Guide A.1, while the IAEA's document SSG-25, Periodic Safety Review for Nuclear Power Plants (IAEA 2013), provides more details on the objectives, methods and content of the review. One important aspect of the review relates to proving the fulfilment of the requirements. In the review, the fulfilment of the requirements is reviewed in terms of the relevant STUK Regulations and YVL Guides, encompassing more than 6,000 requirements.

For new nuclear power plants, the YVL Guides and requirements are valid as they are, whereas for existing nuclear facilities such as Loviisa power plant STUK prepares an implementation decision – i.e. how and to what extent a Guide's requirements are applied – for each YVL Guide. Based on these implementation decisions, Loviisa nuclear power plant meets the safety requirements pursuant to the Nuclear Energy Act.

In addition to the requirements set by the authorities, the operations of Loviisa power plant account for international principles and guidelines such as the guidelines and recommendations published by the IAEA, and the recommendations of the World Association of Nuclear Operators (WANO).

The modifications carried out after the Fukushima accident included building an alternative heat sink independent of the sea, i.e. air-cooled cooling towers, and preparations for a high seawater level, improvements related to the availability of the fuel of diesel generators and engines, the implementation of an alternative residual heat removal of fuel pools, and increasing battery capacities. Extensive reforms have also been carried out on the plant's automation, and ageing systems and equipment have been modernised. An ongoing assessment focuses on the seismic resistance of the plant and its safety functions. The expectation is that the seismic resistance must be improved in some respects for the plant to meet STUK's requirement level.

Safety improvements will also be carried out at Loviisa power plant during the potential extension of operation. The requirements (YVL Guides) published primarily in 2019 and 2020 are not expected to result in significant modification work, given that the requirements have not been subject to any material changes. The measures with regard to some previously changed requirements are yet to be completed in some respects, including the improvement of seismic resistance.

4.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

The reactor units at the Loviisa nuclear power plant were connected to the electrical grid on February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The Loviisa plant reached its original design lifetime of 30 years in 2007 and 2010 respectively. The Finnish Government granted the new operating licences in July 2007.

Currently, Loviisa -1 is licensed to operate until 2027 and Loviisa -2 until 2030. The currently envisaged lifetime extension would be the second lifetime extension. If approval were given for a maximum 20 years additional operating time, the plant would be permanently closed in 2050.The original operating lifetime of 30 years would be more than doubled.

Nuclear power plants undergo two types of time-dependent changes:

- Physical ageing of structures, system and components (SSCs), which results in degradation, i.e. gradual deterioration in their physical characteristics.
- Obsolescence of technologies and design, i.e. the plants becoming out of date in comparison with current knowledge, standards and technology.

Physical Ageing and Ageing Management Program (AMP)

The term "physical ageing" encompasses the time-dependent mechanisms that result in degradation of component quality. Time-dependent phenomena (corrosion, cracking, wears, neutron embrittlement, relaxation of concrete pre-stressing…) can result in degradation of materials and equipment. Unexpected combinations of various adverse effects may result in the failure of technical equipment, leading to the loss of required safety functions. Life-limiting processes include the exceeding of the designed maximum number of reactor trips and load cycle exhaustion.

Even though the fundamental ageing mechanisms are well-known in principle, their potential to lead to incidents and accidents may not be fully recognized before the actual events take place. A number of undetected failures which threaten the plant's safety exist in old NPPs. Faults caused by ageing of material have the potential to aggravate an accident situation or trigger a dangerous incident.

Choice of materials, design and manufacturing process influence the occurrence and acceleration of ageing mechanisms. Due to lack of operational experience in the earlier years of construction of nuclear power plants, the choice of materials and production processes did not always give optimal outcomes.

Physical ageing of SSCs may increase the probability of common cause failures, i.e. the simultaneous degradation of physical barriers and redundant components, which could result in the impairment of one or more levels of protection provided by the defence in depth concept. Common-cause failure (CCF) events can significantly affect the availability of nuclear power plant safety systems and thus threaten the safety of the NPP.

To limit ageing-related failures at least to a certain degree, a comprehensive ageing management program (AMP) is necessary. AMPs include programs with accelerated samples, in-service inspections, monitoring of thermal and mechanical loads, safety reviews and also the precautionary maintenance or even exchange of components, if feasible. Furthermore, it includes optimizing of operational procedures to reduce loads.

In case of obvious shortcomings, the exchange of the components is the only possibility to prevent a dangerous failure. Even large components like steam generators and reactor pressure vessel heads can be exchanged. All components crucial for safety can be replaced – apart from the reactor pressure vessel (RPV), and the containment structure.

In many cases, non-destructive examinations permit to monitor crack development, changes of surfaces and wall thinning. But changes of mechanical properties often cannot be recognised by non-destructive examinations. Therefore, it is difficult to get a reliable, conservative assessment of the actual state of materials. Furthermore, the limited accessibility due to the layout of components and/or high radiation levels does not permit sufficient examination of all components. Therefore, it is necessary to rely on model calculations to determine the loads and their effects on materials.

The measures of the intensification of plant monitoring and/or more frequent examinations, coupled with appropriate maintenance both rely on the optimistic assumption that cracks and other damage and degradation will be detected before they lead to catastrophic failure. However, this is not always realistic. Tracking the condition of all the equipment is a complicated task for systems as complex as NPP. Once the reactors have passed their design lifetime, the number of failures could start to increase.

Ageing management is addressed particularly in WENRA safety reference levels Issue I (Ageing Management) and Issue K (Maintenance, Surveillance, In-Service Inspection and Testing). However, the WENRA reference levels are defined at a minimum consensus level. During the review of the 2008 WENRA RLs, no or very limited changes were identified in the SRL I and K. (WENRA RHWG 2014a) The recent revision of the SRL addresses issues not revised in the 2014 revision, including Issue I (Ageing Management). (WENRA RHWG 2021a)

On an international level, the IAEA has issued the Safety Guide SSG-48 with recommendations on ageing management for nuclear power plants. (IAEA 2018b) However, the IAEA's recommendations are not binding, the definition of an appropriate procedure, as well as specific arrangements to cope with the required level of safety for extended operation, depends on individual case-by-case decisions. (See UMWELTBUNDESAMT 2020)

According to requirements formulated in the EIA Scoping expert statement, the EIA Report should clarify to what extent international documents (IAEA, WENRA) will be taken into account for the lifetime extension in a binding form.

Ageing management in Finland

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 in progress. The utilities have encountered some challenges in complying with the new requirements. For example, inspections performed after the new guide was published in 2013 revealed that the number 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. (STUK 2020)

The EIA Report stated that measures resulting from the ageing of some automation systems, such as ensuring the availability of spare parts or a system's modernization is an issue. According to the EIA Report, the renovation of the existing buildings in the power plant area and also the construction of new buildings is possible. But it is not clarified which buildings are to be renovated or build new.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present the challenges in complying with the new requirements for *ageing management. The remaining issues and remedial measure should be explained. The EIA Report does not mention whether the ageing management now complies with the new requirements.*

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. 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 the findings from other countries and evaluates their possible applicability to the ageing management of the Finnish nuclear power plants. *According to requirements formulated in the EIA Scoping expert statement, the observations of the STUK expert group should be presented in the EIA Report. The EIA Report does not mention any evaluations made by this STUK expert group.*

Topical Peer Review

Finland participated in the 2017/18 Topical Peer Review (TPR) "Ageing Management" in the framework of the Council Directive 2009/71/EURATOM establishing a community framework for the nuclear safety of nuclear installations, amended by Directive 2014/87/EURATOM. 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 has established a national action plan to address the findings.

In STUK (2017a) the regulator's assessment of the overall ageing management program (OAMP) concluded: A generic lesson learned in Finland is that the closer nuclear power plants get to the end of their design lifetime, the more challenging it is for the licensees to start large and expensive investments to modernise or modify the NPPs. Instead of renewing a system or a component, modernisation may be postponed or realized only partially. A postponed decision to renew for instance an electrical system may result in an obsolescence of systems, i.e., spare parts or technical support are no longer available. This may lead to situations where the licensee may not be able to demonstrate the safety of operations to the regulator, or as far as the scope or adequacy of demonstration is concerned, opinions may differ between the licensee and the regulator. The licensees are obliged to demonstrate that the safety of the operations can be ensured and improved during the time before the next PSR. In a similar way, they have to commit to continuous safety improvements in terms of modernization projects in order to manage both physical and technological ageing in the long term. (STUK 2017a)

According to requirements of the EIA Scoping expert statement the national action plan and its progress should be presented in the EIA Report. However, neither the national action plan nor its progress is mentioned.

The findings of the TPR in Finland showed that ageing management of the Loviisa NPP should be developed in such a manner that individual SSCs or SSC groups of NPP are itemized for ageing management purposes covering all safety classified SSCs, and that necessary actions are clearly specified, such as regular maintenance, condition monitoring, qualification, risk of obsolescence and spare part procurement. Fortum was supposed to report on long-term trends in defects/failures, present operability, validity of qualifications etc. The revised ageing management program was to be issued by the end of 2019. However, Fortum was not able to finalize the OAMP on schedule. Review of the OAMP should be completed by the second third of 2021.

Another finding revealed that in terms of ageing management Fortum has not provided for extended outage periods for the Loviisa NPP. According to the updated action plan Fortum shall identify SSCs which are exposed to various degrading mechanisms during long plant outages, and specify actions to monitor, prevent or mitigate ageing in such SSCs by December 31, 2021. (STUK 2021b)

All in all, the actions for the necessary improvement of the national action plan for the Loviisa plant is still ongoing.

Ageing management of the reactor pressure vessel

The components in a nuclear power plant experiencing the highest stress are reactor pressure vessel (RPV) and its internals are The RPV is the main non-replaceable component of a nuclear power plant. At the time of their construction, knowledge of neutron-induced embrittlement was limited, so sometimes unsuitable materials were used. Replacement of the RPV is impossible for economic and practical reasons. Consequently, if ageing mechanisms threaten further safe operation of these components, the reactor has to be shut down. During power operation the RPV is not accessible for inspections or intervention measures. As a result, defects may remain undetected for longer periods of time. Unidentified degradation of RPVs, such as cracks and flaws, has the potential to escalate an incident into an uncontrollable accident. Huge uncertainties are involved in estimating and predicting the progression of ageing and the long-term behaviour of materials, especially under accident conditions.

One specific ageing management issue of the Loviisa NPP has over the years required significant amount of work and attention from the licensees and STUK as well. This issue is the irradiation embrittlement of Loviisa RPVs. The embrittlement rate of the critical core area welds of both RPVs has to be carefully monitored by the surveillance programmes as long as the RPVs are in operation. STUK stated: If the licensee plans to continue operating the plant units after 50 years, some measures may be necessary to confirm safe operation of the RPVs. (STUK 2017a)

STUK has had some concerns about the embrittlement margins of Loviisa 2 RPV before the expected end of life in 2030. Re-annealing has been done for Loviisa 1 in 1996, but not for Loviisa 2. Margins were analysed and LTO was approved in 2007. Annealing makes it possible to recover 80-85% of the operational characteristics of the metal shell of the reactor. Annealing is recognized worldwide as an effective way to ensure the safe and reliable operation of reactor facilities and this technology was applied for the first time by Rosenergoatom in 1987 to renovate the VVER-440 reactor at unit 3 of the Novovoronezh NPP. The technology was developed by the specialists of NPO TsNIITMASH. Recovery annealing has been carried out on VVER-440 reactors at the Kola NPP (Russia), Rovno NPP (Ukraine), Kozloduy NPP (Bulgaria), Loviisa NPP (Finland) and recently at the Armenian NPP. (NEI 2021)

According to STUK (2017b), the embrittlement temperature margins were sufficient for the Loviisa 1 but very close to the approval limit for Loviisa 2. The low margins at the Loviisa 2 are especially involved to the event where RPV's core area weld seam outer surface is cooling while unexpected start of the sprinkler system of the reactor building occurs. Concerning the licencee's report, one of the corrective actions consist of the modification of the sprinkler system's cooling unit function to increase the initial temperature of the sprinkled water (scheduled for implementation in 2019). The licensee also continues the investigation of the opportunities to isolate the RPV's core area weld seam outer surface. According to STUK (2017 b) the licensee will update the probabilistic and the deterministic embrittlement analyses before the next PSR so the influence of the corrective actions can be identified then. However, the results of this investigation are not mentioned in the EIA Report.

According to the requirements formulated in the EIA Scoping expert statement, the very important safety issue of RPV embrittlement should be presented in the EIA Report. The EIA Report stated that if the power plant's operation was extended, measures aiming to prevent the radiation embrittlement of the RPV's weld seam would have to be carried out. However, only the measures possible are listed, but not which of those would be taken.

According to STUK (2017a), an indication/failure has been detected in a **low-pressure safety injection (TH) nozzle** of Loviisa 1 RPV. It might turn into an ageing management issue if future inspections will detect new indications in other nozzles of the same kind. However, it is also possible that the existing indication turns out being a manufacturing defect. *According to requirements formulated in the EIA Scoping expert statement, the results of the inspections of all nozzles as well as envisaged remedial measures should be presented in the EIA Report. However, neither the results nor the envisaged remedial measures are mentioned in the EIA Report.*

Another issue is the **ageing of reactor pressure vessel internals** and the **reactor pressure vessel head** penetrations. The main function of RPV internals is to keep the nuclear fuel elements in the reactor core in a stable position. Distortion of internals due to cracks, as well as the release of fragments from internals, may affect the function of the control rods and thus prevent safe shutdown, and may also compromise the cooling of fuel elements. Particles or fragments of RPV internals which are released and transported into the primary circuit can damage other important components such as coolant pumps, pipes or steam generators tubes.

A further special problem arises from cracks in the RPV head penetrations – nozzles through which the control rods pass into the core. These nozzles are exposed to the high temperature and pressure of the RPV, the chemically aggressive primary coolant and intense radiation combined with changes of load.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present an evaluation of the conditions of the reactor pressure vessel internals and head penetrations including trends of events, and envisaged exchange measures. This issue is also not mentioned in the EIA Report.

Ageing of primary circuit components and of electrical installations

Leaks in the primary circuit components of PWRs due to ageing mechanisms such as stress corrosion cracking can lead to accidents involving loss of primary coolant. To prevent loss of coolant and consequentially loss of function, systems and components in the primary circuit are required to fulfil particularly high-quality standards. Testing and documentation of material properties must be carried out during the manufacturing processes and installation. The absence of this approach cannot be fully compensated subsequently. Good practice includes the exchange of parts of the primary circuit that do not have the required quality.

In the field of instrumentation and control equipment, cables are among the components of most concern in terms of ageing. During the operational lifetime of reactors, cable insulations are exposed to environmental influences that cause deterioration. Cables failures can cause short circuits followed by electrical failures or even cable fires. Ageing cables therefore have the potential for serious common-cause failures of instrumentation and control equipment, especially under accident conditions. Good practice consists of exchanging old components on a comprehensive scale.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present an evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.

The EIA Report only stated that ensuring the safety margins of the primary system and the RPV, particularly the safety margins applicable during operation have been identified on the basis of the power plant's operation and ageing management as one of the issues concerning lifetime extension.

IAEA Safety Reviews Team

At the request of the government of Finland, an IAEA Operational Safety Review Team (OSART) of international experts visited Loviisa Nuclear Power Plant from 5-22 March 2018. The purpose of the mission was to review operating practices. OSART missions in general review performance in the following areas: Management, organization and administration; training and qualification; operations; maintenance; technical support; operational experience feedback; radiation protection; chemistry; emergency planning and preparedness; severe accident management. (IAEA 2020a)

The conclusions of the OSART team were based on the plant's performance compared with IAEA Safety Standards. A number of proposals for improvements in operational safety were offered by the team. The most significant proposals include the following:

- The plant should improve the control and implementation of maintenance activities and procedures to ensure safe and reliable performance of systems and equipment.
- The plant should ensure a comprehensive set of condition monitoring and operability assurance programmes are in place. (IAEA 2018a)

The Operational Safety Review Team (OSART) concluded the five-day follow-up mission to Loviisa NPP on 14 February 2020. The team evaluated the plant's progress in addressing the findings of an IAEA review in 2018. The team noted further efforts are still required before some of the 2018 recommendations can be considered fully resolved. This includes maintenance work practices. (IAEA 2020b)

The OSART missions revealed that there were deficits concerning maintenance and monitoring of the plant. These deficits are relevant concerning the lifetime extension. *According to the requirements formulated in the EIA Scoping expert statement, the findings as well as the remedial plan should be presented in the EIA Report*. *Neither the findings of the OSART missions nor the remedial plan are presented in the EIA Report.*

It is good practice that different IAEA Peer Review Missions take place regularly. The resulting recommendations and suggestions should be followed-up in a timely manner. It is very important that the whole procedure will be performed in a transparent manner. The following IAEA Peer Review is also important with regard to LTO: The purpose of the Safety Aspects of Long-Term Operation (SALTO) peer review service is to assist Member States in ensuring the safe long-term operation of nuclear power plants, and to promote the exchange of experience and information on good practices. The peer review addresses the strategy and key elements of long-term operation (LTO) and ageing management programs. (IAEA 2020a) However, a SALTO mission was not conducted for the Loviisa NPP so far; there is also no SALTO mission envisaged.

Operational events and operating experience feedback

According to STUK (2020), Fortum reported the results of 18 event analyses and investigations to STUK in 2019. Some of the events took place in 2018. Most of the events revealed areas for improvement in procedures and activities. For example, one event surfaced shortcomings in the design and implementation of the updated cooling water lines of the emergency diesel generators.

STUK also stated it did not entirely share the Fortum's view on the nature of two events. STUK concluded that Fortum had not comprehensively analysed the reasons for the recurrence although problems had been clarified and corrected through event investigations. Based on the inspection, STUK required that Fortum improves learning from their operating experience. STUK also intensified regulatory oversight with regard to this topic and kept it up for the entire year 2019. (STUK 2020)

According to STUK (2021a), Fortum informed STUK of 8 events in 2020. In addition, STUK requested information on five other events identified by Fortum. Most of the events revealed again areas for improvement in procedures and activities. In two of the cases, STUK considered that investigation of the causes regarding the organisation's activities was insufficient and required supplementation to the reports. In other respects, STUK deemed Fortum's event investigations sufficient. Based on its observations, STUK focused on the activities of individuals and the organisation in the event investigation during its periodic inspection of the management of human factors. STUK observed that the use of expertise in this area had decreased since the 2017 inspection. STUK required Fortum to strengthen the utilisation of expertise in human and organisational activities in the investigation of internal operating events.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present an evaluation of safety relevant events including the lessons learned. However, this evaluation is not included in the EIA Report.

During the operating cycle 2019–2020, the Loviisa 1 reactor pressure tank's foreign material monitoring system detected additional noises, leading Fortum to carry out additional inspections. Despite the extensive inspections, no definitive cause could be established. Fortum will continue to monitor the matter during the 2020–2021 operating cycle and STUK will supervise Fortum's measures. (STUK 2021a)

Obsolescence (Conceptual and Technological Ageing)

The development of science and technology continuously produces new knowledge about possible failure modes, properties of materials, and verification, testing and computational methodologies. This leads to technological ageing of the existing safety concepts in nuclear power plants. At the same time, as a result of lessons learned in particular from the major accidents at Three Mile Island, Chernobyl and Fukushima Daiichi, earlier safety concepts are becoming obsolete. Furthermore the 9/11 terror attacks showed the need for increasing the protection against external hazards. Older nuclear power plants have not been designed to withstand the impact of commercial aircraft and/or other terror attacks. Very often, new regulatory requirements are applicable only to new nuclear reactors, while different criteria are applied for existing plants. This concerns, among others, the protection against fire.

The safety design of nuclear power plants is important for the prevention as well as the control of incidents or accidents. Therefore, the risk assessment of a nuclear power plant has to consider the design base including the operational experience of all other comparable plants. The Fukushima accident has revealed that old units with designs from the sixties or seventies might be burdened with basic safety problems, leading to growing concerns.

External hazards such as earthquakes, chemical explosions or aircraft impacts were not taken into account in the original design of these plants. To overcome major shortcomings of the design, both Finnish VVER-440/V-213 reactors were equipped with Western-type containment and control systems.

The units of the Loviisa NPP are Russian designed VVER-440 type pressurized water reactors, turbines, generators and other main components. Safety systems, control systems and automation systems are of western origin. The steel containment and its related ice condensers were manufactured using Westinghouse licenses.

The VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems, for example the emergency feedwater system, the central pumping station for the essential service water system, and the diesel generator station. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time.

Both units of the Loviisa NPP have their own dedicated severe accident management (SAM) systems with the exception of the containment external spray system cooling circuit. (STUK 2011) The containment external spray system installed in 1990-1991 to remove the heat from the containment in a severe accident when other means of decay heat removal from the containment are not operable (STUK 2019b) *According to requirements formulated in the EIA Scoping expert statement, the EIA Report should list all shared safety and SAM systems. However, the EIA Report did not mention the shared systems.*

According to FORTUM (2020a), life-time extension involves the implementation of certain changes. *Thus, it is a requirement formulated in the EIA Scoping expert statement, that the EIA Report should explain which changes are planned in the context of the envisaged lifetime extension. The EIA Report does not mention the envisaged changes.*

Theory and reality of safety design principles

To ensure the safety of nuclear power plants despite the failure probabilities of individual components, a number of safety principles exist for the design. For the most important safety principles, today's safety principles and the actual design in the old plants are compared in the following.

Redundancy: To ensure that the failure of one system does not have any safety implications, more than one system must be available for the same function. The degree of redundancy in old plants is lower than in newer plants. The so-called single-fault concept (redundancy level n+1) should ensure that, in the event of failure of one train of a safety system, the safety-related function is completely fulfilled by the corresponding redundant string. The design of newer reactors takes into account operating experience, which has shown that the application of the single-fault criterion is not sufficient. Newer plants have a higher degree of redundancy (n+2).

Spatial separation: Safety systems with the same function must be installed as far as possible spatially separated so that they cannot be destroyed by the same event. Multiple safety systems (redundancies) only guarantee a higher level of safety if they are spatially separated (and not linked). This is often not the case in old plants like Loviisa.

Independence: To prevent errors in one system from affecting the other redundant systems, the individual redundant safety systems should be completely independent of each other without interconnection. Above all, there must be no common active components. This also applies to all associated auxiliary systems, such as cooling and power supply. The goal is to ensure that a failure and even multiple failures at one level of safety do not affect components at the next level of safety. In fact, in old plants, safety systems have often common components, so that the failure of one component can have far-reaching consequences. This applies to systems of the same safety level, but also to systems of different safety levels of the staggered safety concept. It is not mentioned the approach applied to the Loviisa NPP.

WENRA Safety Reference Levels (SRLs)

One of the objectives of WENRA is the development of a harmonized approach to nuclear safety and regulation in Europe. A significant contribution to this objective was the publication of a report on harmonization of reactor safety in WENRA countries in 2006. This report addressed the nuclear power plants in operation and it included "Safety Reference Levels", which reflected expected practices to be implemented in the WENRA countries. The SRLs were updated twice in 2007 and again in 2008.

WENRA mandated its Reactor Harmonization Working Group (RHWG) to review and revise the SRLs for existing reactors with the aim to integrate the lessons learned from the 2011 Fukushima Dai-ichi accident. A list of 342 SRLs compared to 295 in the 2008 list has been endorsed by WENRA accompanied by a related WENRA statement. (WENRA RHWG 2014) As of 1 January 2021 the status (regulatory side) reported by Finland is that all of this SRL are implemented. (WENRA RHWG 2021b)

The **issue F (Design Extension of Existing Reactors)** was revisited in 2014, and its structure was changed. Interfaces with issue E (Design Basis Envelope for Existing Reactors) and the new issue T (Natural Hazards) warranted specific attention, as well as the use of the concept of "Design Extension Conditions" (DEC) as established in IAEA SSR-2/1 safety standard.

According to the SRL F1.1 as part of defence in depth concept, analysis of Design Extension Conditions (DEC) shall be undertaken with the purpose of further improving the safety of the nuclear power plant by

- enhancing the plant's capability to withstand more challenging events or conditions than those considered in the design basis,
- minimizing radioactive releases harmful to the public and the environment as far as reasonably practicable, in such events or conditions.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should include a comparison of the design and measures of the Loviisa

NPP with all requirements of SRL F; in case of deviations, the reasons should be explained. The EIA Report does not discuss this issue.

In addition to the updated SRLs, RHWG provides several guidance documents on issues F and T (Natural Hazards). (WENRA RHWG 2014b, 2015, 2016a, b, c)

Most recently, in 2020, the RHWG has revised the SRLs again to address issues not revised in the 2014 revision. Review against changes in knowledge, international standards and other factors have identified the need to introduce the notion of leadership into Issue C (Leadership and Management for Safety) and obsolescence into Issue I (Ageing Management), which also addresses the outcome of the recent ENSREG Topical Peer Review on the topic. There was also a need to complete the hazards to be addressed in the safety demonstration. To achieve this Issue S (Protection against Internal Fires) has been extended to cover all internal hazards (Issue SV), and Issue T (Natural Hazards) has been extended to address all external hazards (Issue TU). All other issues remain unchanged from the previous version. (WENRA RHWG 2021a)

WENRA Safety Objectives for New Reactors

The "Safety Objectives for New Power Reactors" published by the reactor harmonization working group (RHWG) of the Western European Nuclear Regulator's Association (WENRA) can be understood as the state of the art. (WENRA 2010)

The WENRA Safety Objectives O1-O7 covers the following areas (WENRA RHWG 2013):

- O1. Normal operation, abnormal events and prevention of accidents
- O2. Accidents without core melt
- O3. Accidents with core melt
- O4. Independence between all levels of Defense-in-Depth
- O5. Safety and security interfaces
- O6. Radiation protection and waste management
- O7. Leadership and management for safety

The safety objectives O2 and O3 are discussed in more detail because they are of particular importance for the safety of the nuclear power plant.

O2: Accidents without core melt

This safety objective is directed at three targets: Very low off-site radiological impact of accidents without core melt (no iodine prophylaxis, no sheltering or evacuation), reduce core damage frequency (CDF) as far as reasonably achievable and reduce the impact of external hazards and malevolent acts. In the defense-in-depth concept these tools belong to level 3.

Another area for improvement highlighted by WENRA to meet this safety objective is the reduction of human-induced failures particularly through more automatic or passive safety systems and longer "grace period" for operators. Human errors bear a potential for jeopardizing defense-in-depth. They have a considerable potential to trigger common cause failures (meaning they affect all redundancies of a specific safety system) as has been observed during several safety significant events.

According to the requirements formulated in the EIA Scoping expert statement the EIA Report should present all envisaged measures for lifetime extension (including reduction of CDF, reduction of the impact of external hazards and malevolent act, reduction of human-induced failures) to meet the safety objective O2. However, the EIA Report does not mention this issue.

O3: Accidents with core melt

The most ambitious safety objective is to reduce potential radioactive releases to the environment from accidents with core melt. Accidents with core melt which would lead to early releases without allowing time necessary for the implementation of off-site emergency measures or large releases which would require protective measures for the public that could not be limited in area or time have to be practically eliminated. Occurrence of certain severe accident conditions can be considered as practically eliminated "**if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise**".

Even though the probability of severe accidents with an early and/or large release for existing plants is estimated to be very small, the damage caused by these accidents is very large. Therefore, the risk of existing NPP for the public is relatively high and has to be reduced urgently. Furthermore, the frequency of occurrence of severe accidents, calculated on the basis of the failure rates in all assessed event scenarios, is afflicted with high uncertainties. Technical improvements which are highlighted by WENRA to meet this safety objective mainly consist of substantial improvements of the containment design.

Practical elimination of an accident sequence cannot be claimed solely based on compliance with a general cut-off probabilistic value. Even if the probability of an accident sequence is very low, any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented. (WENRA RHWG 2013)

According to the requirements formulated in the EIA Scoping expert statement the EIA Report should present all envisaged measures for lifetime extension to come as close as reasonably practicable to meet the safety objective O3 (accidents with core melt). However, the EIA Report does not mention this issue.

Safety Objective for new NPPs – Benchmark for LTO

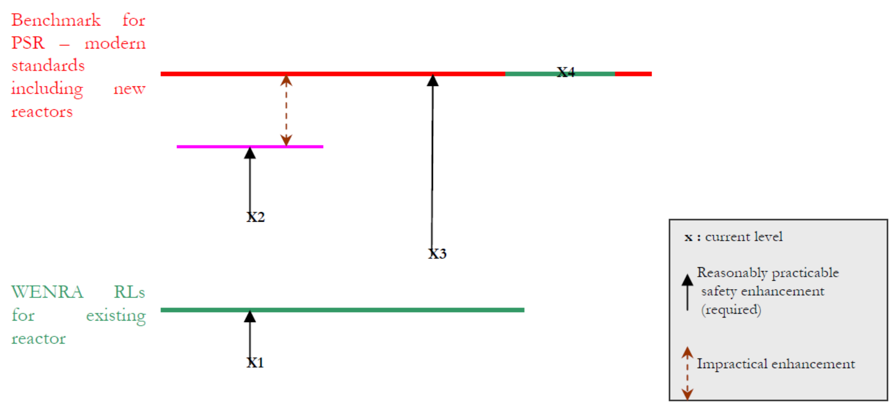
These safety objectives, formulated in a qualitative manner to drive design enhancements for new plants, should be also used as a reference for identifying reasonably practicable safety improvements for existing plants during periodic safety reviews.

Periodic Safety Reviews (PSR) are the main tool to reduce the gap between the safety standards of old and new power plants. Issue P of the WENRA Reference Levels for existing plants states that the periodic safety review shall "identify and evaluate the safety significance of deviations from applicable current safety standards and internationally recognized good practices currently available". It continues by demanding that "all reasonably practicable improvement measures shall be taken by the licensee as a result of the review in a timely manner." (WENRA RHWG 2014a)

The following picture illustrates the gaps between the requirements for new and old plants. (WENRA RHWG 2011)

Figure 6: Diagram to illustrate the process of comparing existing reactors with modern standards (WENRA RHWG 2011)

Diagram to illustrate the process of comparing existing reactors with modern standards



Source: WENRA RHWG 2011 umweltbundesamt

As for the horizontal lines:

- The green (lower) line represents WENRA SRLs, and the "X" represent illustrative levels for a variety of safety issues;
- The red (upper) line represents modern standards, is the benchmark for comparisons conducted in a PSR; it contains WENRA's new safety objectives but is not restricted to them.
- In some cases the green and red lines may be at the same level (e.g. safety management);

As for the "x":

- The "X1" below the green line reflects the transition period to implement WENRA SRLs allowed for in national plans for implementation;
- Those "X" below red line are safety issues that have to be compared to modern standards.
  - In some of these cases it will be reasonably practicable to enhance safety to reach the targets (redline) as in "X3";

  - In some cases, e. g. "X2", it will be reasonable to enhance safety to a level represented by the (purple) line, but further enhancement toward the benchmark is not reasonably practicable;
  - In other cases no identifiable reasonably practicable options for enhancement might exist;
- The "X4" represents these cases where the existing situation is already meeting the modern standard.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should contain a comprehensible presentation and overall assessment of all deviations from the current state of the art in science and technology. This presentation should include:

- *All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.*
- *Incompleteness of the database and plant documentation used.*
- *Presentation of all safety assessments or parameter definitions by personal expert assessments ("engineering judgement").*
- *Presentation of the general dealing of uncertainties and non-knowledge and its effects on risk*
- *Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.*
- *The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.*

None of these issues are mentioned in the EIA Report.

Reasonably Practicable

The wording "reasonably practicable" is used in terms of reducing risk as low as reasonably practicable or improving safety as far as reasonably practicable. For some design expectations, "reasonable practicability" should be taken, meaning that in addition to meeting the normal requirements of good practice in engineering, further safety or risk reduction measures for the design or operation of the facility should be sought and that these measures should be implemented unless the utility is able to demonstrate that the efforts to implement the proposed measures are grossly disproportionate to the safety benefit they would confer.

The principle for continuous improvement is laid down in Section 7a of the Finish Nuclear Energy Act (990/1987): "*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, safety research and advances in science and technology*." When making a decision how a new or revised regulatory guide is applied for operating nuclear facility, STUK approves improvement measures proposed by the licensee or STUK can require additional improvement measures or STUK can approve an exemption if the safety improvement is considered not reasonably practicable. Time schedule for improvement measures is agreed in the decisions. Implementation of the improvement measures are followed in STUK's continuous oversight. Improvements considered not reasonably practicable at the Finnish operating NPPs include e. g. protection measures against large civil aircraft crash.

According to the requirements formulated in the EIA Scoping expert statement the EIA Report should present all improvements to meet modern safety requirements that considered not "reasonably practicable" at the Loviisa NPP. However, the EIA Report does not mention this issue.

PSR and Modernisation

According to the conditions of the operating licences, two periodic safety reviews (PSR) are required to be carried out by the licensee (by the end of the year 2015 and 2023). STUK's assessment of the first PSR was completed in February 2017. So far, comprehensive modernisation measures have been performed. The most recently completed large improvements – the renewal of the plant I&C safety systems and the renewal of the secondary circuit safety functions – were completed during the outages in 2018. (STUK 2019a)

Fortum spent 500 million Euro between 2014 and 2018 to modernize and upgrade the Loviisa units, which are Soviet-designed VVER-440 units but with significant Western safety and control systems. Among the major parts of the upgrade project was complete digitalization of the instrumentation and control system. (NUCLEONICS WEEK 2021)

The second PSR process has started in the end of 2018 and will be finalised before 2023. In June 2020, Fortum submitted most of the periodic safety review reports in accordance with the terms of the Loviisa nuclear power plant's operating license, the rest Fortum submitted at the end of 2020.

The EIA Report explained that safety improvements will also be carried out at Loviisa power plant during the potential extension of operation. But the requirements (YVL Guides) published primarily in 2019 and 2020 are not expected to result in significant modification work, given that the requirements have not been subject to any material changes.

One key issue in lifetime extension at Loviisa is the condition of the two ice condensers designed and installed by Westinghouse in the containment, which help cool the units. The condensers are a safety system which is intended to absorb steam and reduce containment pressure in the event of a loss of coolant accident or mainline steam break. Westinghouse also manufactured the containment structure. Loviisa Deputy Director said in August 2020 that attempting to replace the condensers and support systems would be "challenging." (NUCLEONICS WEEK 2021)

Power uprates

The nominal thermal power output of both Loviisa units is 1500 MW (109% compared to the original output of 1,375 MW). The increase of the power level was implemented and licensed in 1998.

According to the EIA Report, no further increase of the thermal output is planned. However, the EIA Report also states that a possible modernization of the low-pressure turbines is being considered, which would increase the efficiency of the power plant. It should be noted that even increasing efficiency in old nuclear power plants can have negative effects. In the German Krümmel NPP, there was a fire in a transformer (2007), which was caused in part by the increase in electrical power.

4.3 Conclusions, questions and preliminary recommendations

A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. In 2013 the Finnish Nuclear Regulator STUK published a guide dedicated to ageing management. The guide has been updated since and the most recent version was published in February 2019. According to STUK, the utilities have encountered several challenges in complying with the new requirements. The EIA report does not make clear whether the current AMP for Loviisa meets the new requirements.

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 stated that the ageing management was satisfactory. However, several challenges and areas for improvement were identified and Finland has established a national action plan to address the findings.

One ageing management issue at the Loviisa NPP has required a significant amount of work and attention from the licensee and STUK over the years. This issue is the irradiation embrittlement of Loviisa RPV. Several modifications to reduce this risk have been implemented. During the latest operating licence renewal process Fortum submitted a comprehensive analysis concluding that the brittle fracture risk can be managed until the end of the 50-year plant lifetime. However, the very important safety issue of the embrittlement of the RPVs is only presented in a general manner in the EIA Report.

At the request of the government of Finland, an IAEA Operational Safety Review Team (OSART) of international experts visited Loviisa Nuclear Power Plant in March 2018 and in a follow up mission in February 2020. The OSART missions revealed deficits in plant maintenance and monitoring; this is relevant for lifetime extension.

The old Loviisa NPP is increasingly out of date in comparison with current knowledge, standards and technology. The VVER-440 reactors are designed for example as twin units, sharing many operating systems and safety systems. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time. The EIA report does not explain whether there are any design changes envisaged for the lifetime extension.

The WENRA safety reference level F1.1 requires analysis of Design Extension Conditions (DEC) with the purpose of further improving the safety of the nuclear power plant. When deciding how a new or revised regulatory guide is applied for a specific operating nuclear facility, STUK can approve an exemption when it considers a safety improvement not reasonably practicable. Improvements considered not reasonably practicable at the Finnish operating NPPs include e.g. protection measures against large civil aircraft crash.

The WENRA "Safety Objectives for New Power Reactors" should be used as a reference for identifying reasonably practicable safety improvements for the Loviisa NPP. The most ambitious WENRA safety objective is to reduce potential radioactive releases to the environment from accidents with core melt. Accidents with core melt which would lead to early or large releases would have to be practically eliminated. Practical elimination of an accident sequence cannot be claimed solely based on compliance with a general cut-off probabilistic value. Even if the probability of an accident sequence is very low, any additional reasonably practicable design features, operational measures or accident management procedures should be implemented to lower the risk further.

4.3.1 Questions

Q9: *Does the aging management program now comply with the new requirements from 2019 and 2020?*

Q10: *When will the STUK regulation implement the updated 2020 WENRA reference level for existing reactors?*

Q11: *Has the STUK ageing management expert group made recent observations/conclusions?*

Q12: *When will the two remaining issues from the national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM be completed?*

Q13: *Which measures will be performed concerning the very important safety issue of the reactor pressure vessels (RPVs) ageing (embrittlement)? Is re-annealing of the RPV of Loviisa 2 envisaged? What are the remaining safety margins?*

Q14: *What are the recent results of the inspections of all nozzles of the RPV? Are there any measures envisaged?*

Q15: *Are the results of the evaluation of the conditions of the RPV internals and head penetrations (including trends of events, and envisaged exchange measures) already available?*

Q16: *Are there any problems with aging of the ice condensers (as mentioned by the Loviisa Deputy Director in August 2020)?*

Q17: *Is information about the conditions of components of the primary circuit and the electrical installations (including trends of events, and envisaged exchange measures) already available?*

Q18: *What are the findings of the OSART follow up mission 2020? Have any recommendations or suggestions not yet been resolved?*

Q19: *Has the cause for the noise of the Loviisa 1 reactor pressure tank's foreign material monitoring system already been clarified?*

Q20: *Which technically possible improvements to meet modern safety requirements have been considered not "reasonably practicable" for the Loviisa NPP?*

Q21: *Which safety systems/components and Severe Accident Management (SAM) systems/equipment are shared between Loviisa 1 and 2?*

Q22: *Which design changes are planned in the context of the envisaged lifetime extension?*

Q23: *Which existing buildings should be renovated or new constructed in framework of the lifetime extension?*

Q24: *Which documents of WENRA will be taken into account for the lifetime extension in a binding form?*

Q25: *Are the results from comparing the design features and measures of the Loviisa NPP with all requirements of SRL F already available?*

Q26: *Have measures been planned to meet the safety objective O2 (accident without core melt) for lifetime extension?*

Q27: *Will lifetime extension measures been planned to come as close as reasonably practicable to meet the safety objective O3 (accidents with core melt)?*

Q28: *Has STUK already finished the review of the submitted PSR? What results did the PRS deliver? Will all requirements stemming from the results be applied as preconditions for the lifetime extension approval?*

4.3.2 Preliminary recommendations

PE1: It is recommended to implement all technically available safety improvements to prevent accidents.

PE2: It is recommended that all requirements of WENRA Reference Level F be met. In case of deviations, the reasons should be explained.

5 ACCIDENT ANALYSIS

5.1 Treatment in the EIA documents

Incidents and accidents and their environmental impacts were reviewed on the basis of the requirement for nuclear facilities set by the authorities and on the investigations carried out. The assessment on extended operation covered, in addition to a severe reactor accident, a major leak from the primary system to the secondary system, which is an INES level 4 event.

Severe Accident

According to the EIA Report, a severe accident at a NPP is a highly unlikely extreme event that is also prepared for in the plant's design and operations. The assessment of the environmental impacts of a severe accident is based on the postulation that 100 terabecquerels (TBq) of the caesium-137 (Cs-137) nuclide is released into the environment as referred to in section 22 b of the Nuclear Energy Decree (161/1988). The reviewed fictitious severe accident would be equal to an INES level 6 accident.

Based on the results of the modelling of a severe reactor accident, the greatest radiation dose at a distance of one kilometre, accounting for all age groups, would be approximately 27 mSv during the first week. The doses would decrease as the distance increases. Health effects on humans resulting from the radiation caused by the reviewed severe reactor accident are highly unlikely.

The impact of the release can be mitigated during the initial stage by various actions that aim to protect the population, such as the administration of iodine tablets, seeking shelter indoors and evacuations carried out at different times. The long-term consequences of the fallout would include the clean-up of the built environment, restrictions to the recreational use of the natural areas and arranging contamination measurements for the people residing in the area, up to a distance of less than 15 km from the power plant. The use of built-up recreational areas should also be restricted up to a distance of 80 kilometres. The authorities would likewise impose restrictions on the use of food products.

Effects of radioactive fallout

When reviewing the effects of the fallout, one should especially account for the long-lived Cs-137 nuclide and for the Cs-134 nuclide, with a slightly shorter half-life. The shorter-lived isotopes of iodine in their different states are also often examined in connection with fallout, as is the Sr-90 nuclide. In addition, the review included the nuclides Te-132 and the short-lived I-132, which is the radioactive decay product of the Te-132 nuclide.

Among other things, the effectiveness of seeking shelter indoors depends on the material used in the building and the location of the space used as a shelter within it. STUK has estimated that even at its minimum, seeking shelter indoors can reduce the radiation dose to one-third of what it would be without seeking shelter indoors.

The impacts of the fallout can be mitigated in several ways, depending on the area in question. Land areas can also be modified so that the soil material on their surface containing the most fallout is removed and transported to a controlled storage location.

Comparison of radiation doses and dose criteria

The dose criteria for both seeking shelter indoors and evacuation are exceeded in the zone located at a distance of less than five kilometres from the power plant.

Lifetime doses

- When examining the radiation dose at the outer limit of the power plant's precautionary action zone – i.e. at a distance of five kilometres from the power plant – the estimated radiation doses caused by a severe reactor accident throughout an entire lifetime are roughly 60 mSv for a child aged one, roughly 66 mSv for a child aged 10 and roughly 73 mSv for an adult.
- At a distance of 20 km from the power plant, the radiation doses are in the range of 1 mSv during the first days, regardless of age group. The radiation doses estimated for entire lifetimes are, at a 20-kilometre distance, in the range of 15 mSv at maximum.
- In the case of the adult, the radiation dose was also estimated for a fisherman, the lifelong radiation dose was expected to be 164 mSv at most (50-year exposure period).

The radiation doses resulting from a severe reactor accident are shown in Table 2. The radiation doses have been estimated for children aged one and 10, and for an adult, at a 1–1,000 km distance from Loviisa power plant. For the assessment of civil protection actions, the radiation doses are shown according to two-day and seven-day exposure periods. In addition, the radiation doses were assessed in terms of a year's and an entire lifetime's exposure periods.

Table 2: The radiation doses caused by a severe reactor accident to a one-year-old, 10-year-old and an adult at a distance of 1–1,000 km from the emission's release point over two days, seven days, one year and the person's lifetime. (FORTUM 2021a)

The radiation doses caused by a severe reactor accident

	Estimated dose of the one-year-old [mSv]				Estimated dose of the 10-year-old [mSv]				Estimated dose of the adult [mSv]			
Distance (km)	2 d	7 d	1 a	70 a	2 d	7 d	1 a	60 a	2 d	7 d	1 a	50 a
1	24.1	26.1	121.0	267.0	25.2	27.4	105.0	292.0	19.5	21.6	88.8	320.0
5	4.4	4.8	26.1	60.1	4.5	4.9	22.9	65.7	3.8	4.1	20.1	73.1
10	2.0	2.2	15.0	27.7	2.1	2.2	10.6	30.0	1.8	1.9	10.0	34.1
15	1.3	1.4	11.7	21.3	1.4	1.5	7.9	20.1	1.2	1.3	7.0	22.1
20	1.0	1.1	8.0	14.5	1.0	1.1	5.4	13.9	0.9	1.0	4.8	15.2
50	0.35	0.37	2.08	3.91	0.36	0.38	1.49	3.78	0.32	0.35	1.35	4.26
100	0.23	0.23	0.31	0.41	0.23	0.23	0.28	0.40	0.22	0.23	0.27	0.43
300	0.07	0.07	0.11	0.16	0.07	0.07	0.10	0.16	0.07	0.07	0.09	0.17
500	0.04	0.04	0.06	0.09	0.04	0.04	0.05	0.09	0.04	0.04	0.05	0.10
700	0.02	0.02	0.04	0.06	0.02	0.02	0.03	0.06	0.02	0.02	0.05	0.06
1,000	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.04

Source: FORTUM 2021a umweltbundesamt

According to the modelling, the radiation dose that an adult living 20 km from the emission's release point would be subject to as a result of a severe reactor accident would be around 4.8 mSv with a one-year exposure period. The radiation dose caused by a severe accident during an exposure period of one year outside Loviisa power plant's emergency planning zone of 20 km would remain smaller than the average annual radiation dose of an individual residing in Finland (5.9 mSv).

Management of a severe accident

A severe accident refers to a situation in which a considerable part of the reactor fuel fails. Systems for the management of a severe accident are in place at Loviisa power plant. These systems ensure the containment building's integrity and prevent it from breaking down.

A melt-through of the reactor pressure vessel (RPV) and any resulting steam explosion in the reactor cavity, and any interaction between the reactor cavity's concrete and the core melt, is prevented by confining the core melt within the RPV. The residual heat arising in the melt will transfer, through the RPV's wall, into the water in the reactor cavity. To ensure this, the primary system has special depressurisation lines for a severe reactor accident which help reduce the stress on the RPV's wall. Routes along which water can flow have been ensured, allowing the water discharging from the primary system and the water melting from the ice condenser to reach the reactor cavity via the steam generator space and come into contact with the RPV's external surface. Coupled with the structures of the containment building, the ice condenser is effective in limiting the containment building's pressure increase, resulting from the increased temperature and steam generation. In the long run, the containment external spray system which transfers heat into the sea will also be employed.

As the core melts down, it produces hydrogen which, should it explode, would risk the containment building's integrity. The containment building has passive autocatalytic recombiners, which remove hydrogen from the entire containment building. The ice condenser's doors can also be opened, allowing the containment building's airspace to blend, diluting the high local concentrations of hydrogen. If hydrogen is generated very rapidly, this hydrogen is removed with the hydrogen igniters in the steam generator space, which enables the controlled creation of small hydrogen burns that do not pose a risk to the containment building's integrity.

For the purpose of a severe accident, the plant has an automation system that is separate from other safety systems and two diesel generators, shared by the power plant units and intended for the management of a severe reactor accident. These secure the required equipment's power supply.

Extended operation

In extended operation, the estimate concerning the radiation doses was prepared for a milder case, in which the safety functions worked as planned. The case pertains to a major leak from the primary system to the secondary system during operation. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. In accordance with the categorisation of the Nuclear Energy Decree (161/1988), the accident falls under the event category B – design extension condition. Based on the activity released in the emission, the event is an INES level 4 event according to the international categorisation.

Chapter 9.22.2. deals with this accident. The case covers a broad group of various incidents and accidents of a nuclear power plant in the majority of which the impacts are significantly milder than in the case presented here, or in some cases, of the same magnitude. These also include fires and explosions occurring in the power plant's premises, which could result in radioactive emissions into the environment.

In addition, the review in terms of extended operation and decommissioning covers other potential incidents and accidents in which a small quantity of radioactive substances could spread into the environment.

The estimates on the radiation doses were prepared with the Tuulet programme. Instead of 1,000 km, the impacts of the emissions' dispersal are reviewed up to a distance of 1–100 km from the power plant, because the emissions are significantly smaller than the emission of a severe reactor accident would be, due to which the impact area of the emissions would not extend as far.

It is possible in pressurised-water plants, such as Loviisa power plant, for the water cooling the reactor to enter the secondary system as a result of damage occurring in the steam generators. Should such a leak be big, some of the water and steam would be blown into the atmosphere until the pressures of the systems level off. Such an accident would cause residents in the power plant's environment (at a distance of one kilometre from the power plant) a radiation dose of 3.3 mSv at a one-year exposure period. Of this dose, 1.5 mSv would be the result of an emission into the air and 1.8 mSv of a discharge into the sea. The radiation dose resulting from this accident would be around 55% of the average annual radiation dose of a person residing in Finland (5.9 mSv).

Fires, explosions, oil and chemical accidents

In chapter 9.22.2.2 fires, explosions, oil and chemical accidents are discussed. The reasons for these accidents include equipment failures, human error and earthquakes. In some cases, they could also result in radioactive substances spreading into the environment. The events are prepared for in the power plant's design and instructions. The impacts of individual events are limited to a small area, and the emissions of radioactive substances are minor. In events of a larger scale, which could occur if some of the preparedness measures fail, the emission could be greater. Even in this case, the emission and its impacts are nevertheless expected to remain significantly below category B of the postulated accident's design extension condition.

A fire can cause an initiating event at the power plant in such a way that a normally used device/piece of equipment is incapacitated due to the fire, or that a function may start up unnecessarily. The impact of fires is limited by applying the redundancy and separation principles, in which case only some of the required equipment can be damaged by the fire. The safety systems' parallel subsystems are widely separated into different rooms or located at a sufficient distance from one another. The equipment and cables are treated with fire retardants if necessary. A fire's spread between rooms is prevented by wall structures, fire doors and fire dampers.

In addition to fire protection, the tasks of the plant fire brigade include protection against chemical and oil accidents. The plant fire brigade maintains firefighting equipment and machinery and material preparedness of the kind that allow it to handle small incidents and start damage control in big events before the regional fire service arrives.

External threats and climate change

Some external events could lead to the power plant's temporary shutdown, at which point commercial electricity production would be suspended and the power plant would be shifted to a shutdown state. Work would also be stopped if necessary. Examples of such events include an oil accident in the sea area, a high air or seawater temperature, or a high or low level of seawater.

The original planning of Loviisa power plant's safety systems did not account for extreme external events in an entirely exhaustive manner. The impact of external events has subsequently been assessed extensively, and the changes necessary to reduce their impact have been made. In terms of the key safety systems, natural phenomena manifesting at a frequency of once every ten thousand or a hundred thousand years are accounted for, depending on the consequences of such an event. Events that recur once every ten million years are prepared for with the systems, and if necessary, in the special arrangements of Loviisa power plant. Special arrangements include additional inspections, the preventive shutdown of the plant, flood control measures and special instructions related to an event's management.

Climate change has an impact on the strength of external events and the probability of powerful phenomena. As a result of climate change, the average temperatures of seawater and air close to the surface of the earth will increase in the future, for example, in addition to which heatwaves in air and seawater will become more common. Precipitation is also likely to increase. For example, according to climate models, temperatures and total rainfall in Finland will increase most during winters.

One of the threats posed by climate change is a rise in sea levels. In Finland, the surface of the earth is still rising after the most recent Ice Age, and in the Loviisa region, the land is currently rising by approximately 3.5 mm a year. Thanks to this rate of rebound, the average sea level in Loviisa was actually declining until the 1990s. Nowadays, however, the rate at which the sea level is rising around Loviisa is already slightly faster than the prevailing rate at which the land is rising. In the future, the global sea level will probably continue to rise faster than landmasses.

According to the Intergovernmental Panel on Climate Change (IPCC 2018), the global rise in sea levels would be roughly 0.3 m in 2050 compared to the average level in 1986–2005, even according to the worst climate change scenario. At the location of the power plant, the impact would be less than half of this due to the rising landmass. The temporarily high level of seawater is attributable to weather phenomena, which are monitored and forecast continuously at Loviisa power plant. In the event of a high level of seawater, the plant will be shut down at an early stage, and flood control will be installed for some systems.

Loviisa power plant has prepared for a sea level of + 4.01, a level which, with the expected climate of 2030, will be exceeded once in a hundred million years.

There are two further effects of climate change mentioned in the EIA Report:

- In the future, the increase in the temperature of the air and seawater may result in power restrictions at the power plant due to the conditions of the environmental permit and the requirements imposed on the equipment's cooling capacity.
- Increasing violent storms may cause disruptions in the main grid, which the plant has prepared for in the form of numerous diesel generators and engines securing the safety functions.

Studies related to climate change are monitored continuously, and modifications are carried out as necessary on the basis of the assessed effects.

Combined impacts with other projects

No new projects are being planned or are currently underway in the power plant area or its vicinity that could contribute to a combined impact in the event that Loviisa power plant's operation is extended, or the plant is decommissioned. However, in the future, the project may have an interface with the potential recovery of thermal energy or the further use of transmission lines, but there is still insufficient information about these possibilities, due to which their review is not included in this EIA Procedure.

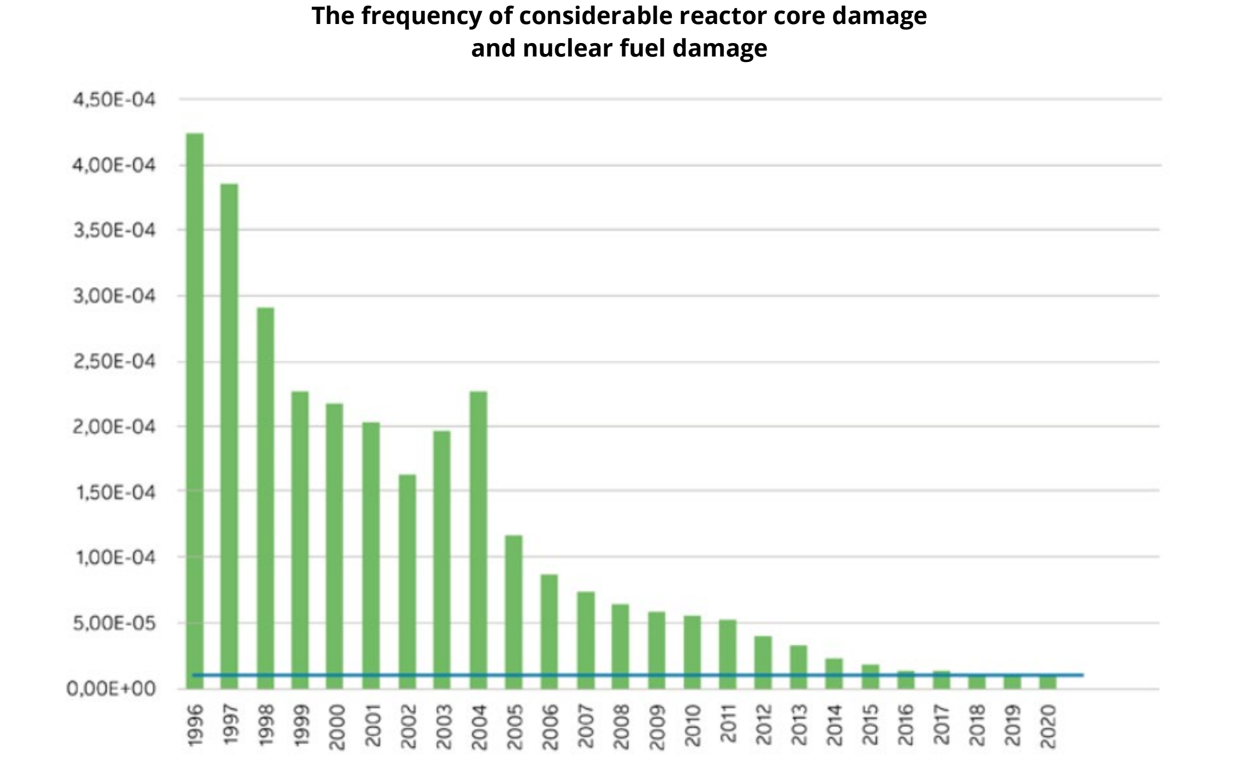
Probabilistic Risk Assessment

In accordance with STUK Regulation Y/1/2018, the nuclear facility's safety and the technical solutions of its safety systems must be assessed and substantiated analytically and experimentally if necessary. Incident and accident analyses verify the fulfilment of the set approval criteria. The principal analysing tool at Loviisa power plant is the Apros® simulation software, developed in cooperation with VTT Technical Research Centre of Finland. Other analytical methods include strength analyses, fault and effect analyses as well as Probabilistic Risk Assessment (PRA).

According to STUK's YVL Guide A.7, a new nuclear power plant must be designed in such a way that in the PRA, the mean value of the frequency of reactor core damage is less than once in a hundred thousand years. Figure 7 shows the frequency of considerable reactor core damage and fuel failure of the spent fuel in the fuel pools in Loviisa power plant unit 1 in 1996–2020, assessed by means of PRA.

Regardless of the analysis model's development over time and the expanded risk assessment, the frequency has, with the exception of some individual years, reduced significantly, and nowadays corresponds to the level required of new nuclear power plants.

Figure 7: The frequency of considerable reactor core damage and nuclear fuel damage of spent fuel in the fuel pools in Loviisa power plant unit 1, assessed by means of PRA. The blue line indicates the requirement level (10–5/year) for new nuclear power plants presented in STUK's YVL Guide A.7. (FORTUM 2021a)



Source: FORTUM 2021a

umweltbundesamt

Storages for Spent Fuel

There is one fuel pool within the containment building next to the reactor of both Loviisa power plant units. In addition, the auxiliary building of the power plant unit Loviisa 2 houses two interim storages for spent fuel, each containing several fuel pools. Sub-criticality is ensured with the structures of the fuel pools and is further supported by the use of boron water in the storage pools.

If the cooling of the pools is interrupted, the removal of residual heat from the fuel is not compromised in the short term due to the fuel's very low residual heat power. To remove residual heat in the long term, the cooling systems normally used must be restored to working order or alternative cooling systems – such as the system for treating pool water or feeding make-up water– must be employed. The make-up water can be fed with the plant's active systems or through the connection points made for fire trucks, for example. The systems' power supply is ensured with emergency diesel generators and a diesel-powered emergency power plant. Furthermore, the feed of the make-up water of the fuel pool within the containment building is secured with diesel generators intended for a severe reactor accident.

The radioactive substances in the containment building's pools can also be effectively isolated within the containment building in the event of the pools boiling. A small amount of the radioactivity in the waters of the pools of the interim storages for spent fuel, located outside the containment building, may be released into the environment in a situation involving boiling.

Incidents and accidents related to the handling and storage of waste, including spent nuclear fuel, are discussed in Chapter 9.22.4. It is explained that situations causing minor radioactive emissions may occur during the operation of the fuel storages in the same manner as during the power plant's operation. Even so, there are only a few systems, which means that the likelihood of such situations is also smaller than it is in connection to the power plant units.

The transports of spent fuel between the reactor buildings and the storages for spent fuel are not subject to the IAEA's safety requirements (IAEA 2018) or the Act on the Transport of Dangerous Goods (719/1994), because the transports take place within the power plant area. For all intents and purposes, the requirements are nevertheless accounted for; for example, the dose rate of the radiation on the surface of a transfer cask meets the requirements set for transports outside the power plant area. Several of these transfers take place each year during operation – and will take place during the initial phase of decommissioning – in a transfer cask.

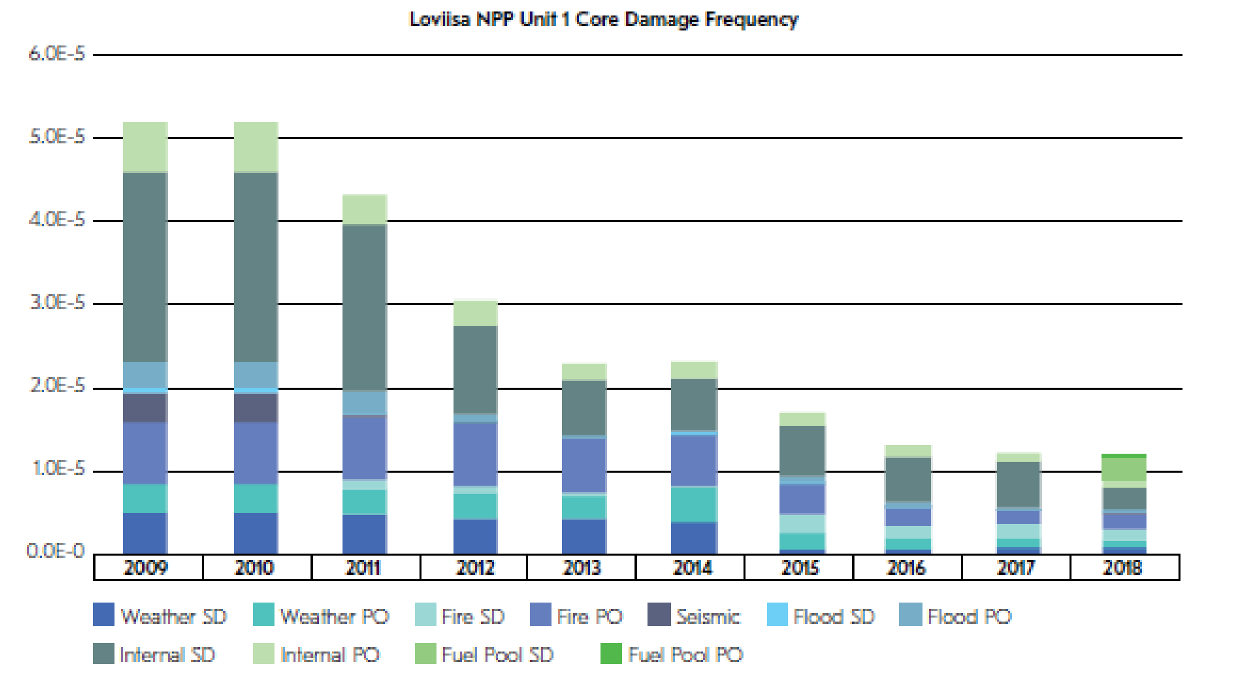
5.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

Probabilistic risk assessment of Loviisa NPP

In 1989 for the first time, Fortum made available a Level 1 internal events PRA. Since 1990 Fortum has extended the PRA when adding analysis of risks related to fires, floods, earthquakes, severe weather conditions and outages and conducting a 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 (SAM) systems and a major modernisation programme in mid - 90s. Thus, the core damage frequency (CDF) decreased. (STUK 2019a)

The development of the core damage frequency since 2008 is shown in *Figure 8*. At the end of year 2018 the calculated CDF 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.

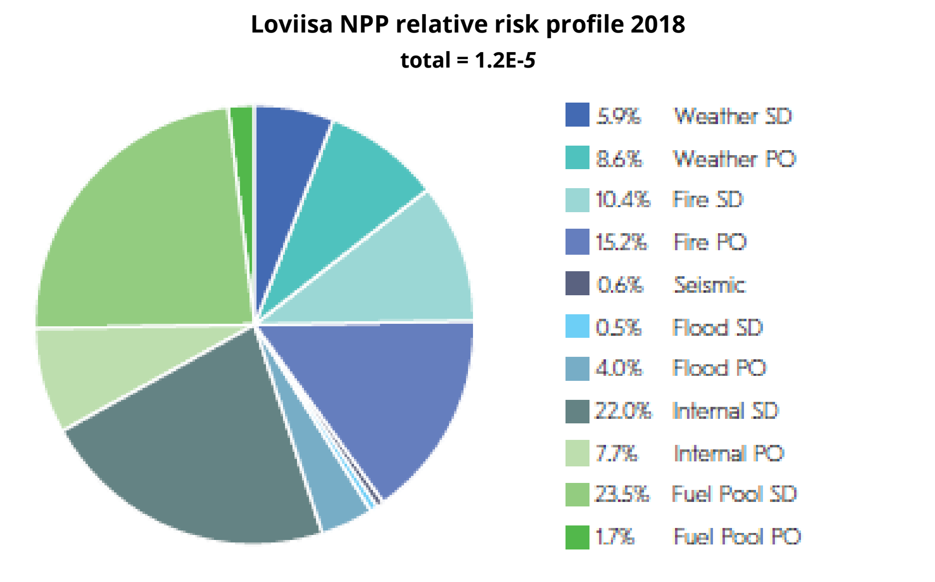
Figure 8: Development of core damage frequency (CDF) of Loviisa unit 1 (STUK 2019a)



Source: STUK 2019a umweltbundesamt

For unit 1 the relative contribution to the annual CDF from different groups of initiating events is shown in Figure 9.

Figure 9: 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". (STUK 2019b)



Source: STUK 2019b umweltbundesamt

In shutdown status (SD) the most significant initiating events are drop of heavy loads and various fire events. (STUK 2019a) Note: Initially the design and the layout design of the Loviisa plant did not adequately take into account possible fires. Several measures implemented at the Loviisa plant after the plant's commissioning improved fire safety. As a result, the plant safety against the effects of fires has been significantly improved. But the protection against fire remains an issue.

It is stated in STUK (2017a) that an increase in failure rate may also have an effect on the probabilistic safety analysis (PSA).

PSA 2 results

In the latest update of the Level 2 in 2018, it was estimated that the total frequency of a large release (LRF) to the environment is about $7.8 \cdot 10^{-6}$ per reactor year. The estimate includes all initiating event groups, except of seismic events. (STUK 2019a)

These values show that the majority of core melt accidents result in severe accidents with large releases.

According to STUK (2019b), the frequency of large releases for the Loviisa NPP is above the limits set in STUK's regulatory guide YVL A.7. 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 below 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, only make a small contribution to the reactor core damage frequency. (STUK 2019a)

The frequency limits as such apply for new NPP units to be built in Finland, and for old units the principle of continuous improvement of nuclear safety is applied. (STUK 2019b)

As mentioned above, the frequency of large releases is higher than the limits set in STUK's regulatory guide, therefore the accident analyses in the EIA procedure should use a possible source term derived from the calculation of the current PRA 2.

Even though the probability of severe accidents with an early and/or large release for existing plants is estimated to be very small, the damage caused by these accidents is very large.

Thus, any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented. (WENRA RHWG 2013)

The overall SAM approach at the Loviisa NPP was the prevention of core melt sequences which leads to an imminent threat of large releases. Continuous efforts have been made to reduce frequencies of bypass sequences and this work will continue in the future as well. However, large releases of radioactive substances cannot be excluded.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should contain the following information in order to be able to assess in a comprehensible way if Austria is potentially affected:

- *Results of the current PSA analyses (levels 1, 2 and 3):*
- *frequencies for core damage (CDF) and severe accidents with (early) large releases (LRF or LERF);*
- *information on the contributions of internal and external events to CDF, LRF and LERF.*

However, only the results of the probabilistic safety analyses level 1 are presented in the EIA Report. No further information is provided.

Severe Accident

In the context of safety, the issue of foremost interest from the Austrian point of view are severe accidents since they can potentially lead to adverse effects on Austrian territory.

According to the EIA Report, the radiation dose to the population was calculated on the basis of a postulated severe accident. The source term used in the model has been defined according to the Nuclear Energy Decree (161/1988) as a release containing 100 TBq Cs 137. According to STUK's safety guides, the expectation value for a release above this value should remain below the frequency of once in 2,000,000 years (5E-7/yr).

Severe accidents with releases considerably higher than the limit of 100 TBq Cs-137 cannot be excluded for the Loviisa NPP, and their calculated probability is higher than required (less than 5E-7/yr). Moreover, for rare events the probability of occurrence as calculated by a Probabilistic Safety Analysis (PSA) should not be taken as face value, but as an indicative number only. Such analyses are beset with considerable uncertainties, and some risk factors are difficult to include in a PSA.

The release of the postulated severe accident corresponds to an INES level 6 accident, because the magnitude of the release is approximately 10,000 TBq of I-131 equivalents. An accident will be categorized as INES level 6 in case of a release of some 1,000 to a couple of 10,000 TBq I-131 equivalents.

The source term of 100 TBq of Cs-137 for severe accidents can only be seen as justified if severe accident scenarios with higher releases can be considered as "practically eliminated", but this is not the case. Only results of detailed safety assessments for the reactor would permit to exclude a larger source term – in case it can be proven with a high degree of confidence that such a larger source term is extremely unlikely. However, as mentioned above, the PSA 2 shows that higher releases are possible and also that the calculated frequency is higher than stated in the STUK requirement.

Containment integrity

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for accident management. Filtered containment venting is a well-known approach to prevent containment overpressure failure in most light water reactor (LWR) and has already been implemented in several countries. It is not implemented at Loviisa 1 and 2. According to STUK (2019b), a filtered venting system was not seen as feasible for Loviisa NPP.

For the cooling and stabilizing of the molten core several approaches are available. For some of the smaller reactors in Europe in-vessel retention (IVR) is considered, and in some plants, it has already been implemented, among those is the Loviisa NPP (in 2000-2001). The modifications should enable the in-vessel retention of corium by external cooling of the RPV.

In-vessel retention is mostly ensured by passive means, such as flap valves at inlet and outlet of reactor cavity and strainers. Active operations are required only to lower neutron and thermal shield. After the initial lowering no electricity is needed.

The Loviisa NPP SAM strategy strongly relies on retaining corium inside the pressure vessel. However, if all means to cool corium inside the pressure vessel would fail, a situation might arise where the bottom part of the reactor pressure vessel is damaged and molten corium falls to the reactor cavity. Primary circuit depressurisation prevents high pressure scenarios and vessel failure itself should not jeopardize the containment integrity in case the reactor cavity is dry. But if water is present in the reactor cavity, it is pressurized by interaction between molten corium and water. According to STUK (2011), analyses show that this could break the reactor cavity cylindrical wall. In a situation where molten corium is in the reactor cavity, all efforts to supply water into reactor cavity must be done to get situation under control. In practise this is done by supplying water to the primary circuit or containment.

For successful execution of SAM strategy some actions need to be executed in certain timeframe.

According to STUK (2011), the following safety issues need attention in future:

- In bypass sequences, where the RCS water could leak outside of the containment through some interfacing system, the coolant is lost outside the containment and the ice in the ice-condensers does not melt. In these sequences the water is not accumulated in the bottom of the containment, and thus required RPV external cooling for in-vessel retention (IVR) is not possible. Significant risk reductions have been made, and the work to reduce the probability and safety significance of these sequences continues.
- Shutdown states need additional safety assessment from the severe accident management point of view, as a part of the safety systems is not available and the containment is open in some situations during shutdown. Procedural changes to improve the availability of the safety systems

have been made, and the work is on-going to make the accident management more reliable in shutdown states. Recovery of SAM systems and containment leak-tightness in shutdown states can be considered as a cliff edge. If the recovery fails, also the SAM strategy might fail.

- In case of loss of heat removal capability from the RCS, the primary coolant pump seal water system needs to be isolated to protect the seal from overheating. In case this failed, the initial situation with only loss of the heat sink may degenerate to a small-break LOCA.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should explain how the above-mentioned safety issues that endangered the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) of the IVR concept are solved. However, the EIA Report does not mention these issues.

Spent fuel pools

Regarding spent fuel pools, the approach in Finland is to “practically eliminate” the possibility of fuel damage. The licensees have evaluated alternative means of decay heat removal from the spent fuel storage pools in case of loss of existing systems, and to supply coolant to the spent fuel storage pools.

At the Loviisa NPP, independent air-cooled cooling units with no connections to seawater systems were implemented in 2014. The cooling units will take care of the decay heat removal of reactors and spent fuel storage pools inside and outside the containment in case the ultimate heat sink is lost.

Water injection will be provided through new internal connections as well as mobile water injection systems to recover the loss of water from the pools. Original target date for implementation was 2018. Due to many overlapping plant modifications (I&C renewal, improvement of secondary circuit safety functions), the licensee had to make the decision to postpone Fukushima modification finalization to 2020. The last installations were performed and tested in 2020. (STUK 2021c)

The threat of a large breach of the spent fuel pool (after an earthquake) was also highlighted during the Fukushima accident in 2011. To consider the (radiological) consequences of an attack or extreme hazards it is important to distinguish two different scenarios:

- a): If the basin remains intact, but the pool cooling system fails and water gradually boils off, it will take days or weeks (depending on amount and age of the spent fuel in the pool) until the tops of the fuel assembles are exposed. During this period of time, intervention could provide sufficient cooling of the fuel. However, in case the entire core has been unloaded into the pool at the time of the attack intervention measures would have to be implemented during a few hours.
- b): An external event resulting in major damage to the building would cause cooling water loss. If the water drains off and refilling of water is not foreseen or possible, very severe radioactive releases begin within hours.

> This leads to a dangerous challenge: As soon as the water has drained out of the pool, not only the cooling, but also the shielding effect of the water is lost. Fuel that has been extracted only a short time earlier from the reactor would generate a relatively high amount of heat and can reach a temperature of 900 °C within a few hours. At that temperature, the fuel cladding made of zircaloy would burn in the air. The fire is very hot and cannot be extinguished with water. Within the cooling pool it could spread to older fuel assembles that would otherwise not heat up so rapidly. Thus, the entire inventory of the cooling pool could melt. (ALVAREZ 2003).
> In this situation, the population would have to be evacuated during an extremely short time. Severe damage to the cooling pools would lead to considerable release of radioactive substances According to a recent U.S. study, about 75 percent (10-90 percent) percent of the caesium-137 inventory could be mobilized in the plume from the burning spent fuel pool. (HIPPEL AND SCHOEPPNER 2016)

According to Safety Reference Levels F4.1, the plant shall be able to prevent the release of the radioactive material. WENRA Guidance on Issue F requires special efforts to make severe accident in a spent fuel storage extremely unlikely with a high degree of confidence, since measures for sufficient mitigation of severe accident consequences in spent fuel storages could be difficult to realize. Extreme unlikeliness with a high degree of confidence is an element of the concept of practical elimination. To demonstrate extreme unlikeliness with a high degree of confidence, both probabilistic and deterministic elements are required. The demonstration should not be claimed solely based on compliance with a general cut-off probabilistic value. (WENRA RHWG 2014b)

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present results of the current PSA analyses (levels 1, 2 and 3) including information on the most important accident scenarios including accidents from the fuel pool.

External hazards

The Fukushima Dai-ichi accident highlighted inter alia the importance of the Defense-in-Depth principle and the continued need to ensure that the design basis adequately addresses external hazards. (ENSREG 2015)

In September 2014, the WENRA published its Safety Reference Levels (SRLs), including a new SRL T for Natural Hazards introduced as lesson learned from TEPCO Fukushima Dai-Ichi accident. (WENRA RHWG 2014a). A guidance for this SRL was published on 21 April 2015.

The SRLs within the new issue natural hazards (issue T) address:

- the need to develop a protection concept to minimize threats to the plant, relying preferably on passive features;
- the consideration of events that may exceed the design basis, to ensure that the design basis chosen is sound and that sufficient margins exist before cliff edge effects may occur.

According to the EIA Report, the original design of Loviisa power plant's safety systems did not account for extreme external events in an entirely exhaustive manner. The impact of external events has subsequently been assessed extensively, and the changes necessary to reduce their impact have been made. Natural phenomena with frequency of 10^{-4} per year or 10^{-5} per year are accounted for, depending on the consequences of such an event.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should contain the following information on possible external impacts at the site:

a. *Results of current studies on earthquakes, floods and extreme weather conditions;*
b. *methodology for the determination of relevant external events;*
c. *list of the external events to be considered and their characteristics;*
d. *details of the combinations of external events considered.*

None of this information is provided in the EIA Report.

Earthquake

New insights into earthquake risk require higher protection standards which cannot be fully met by modification of old nuclear power plants.

When the Loviisa NPP units were built no regulatory requirements on seismic design existed and earthquake loads were not considered separately in the design. The new systems, structures and components (SSC) critical to safety constructed after 1997 are designed and qualified to withstand the Design Basis Earthquake (DBE). The corresponding horizontal PGA is 0.10 g. According to the PSA results, the risk caused to the operating units by external events was a relatively small fraction of the total risk, but the uncertainties were large. (STUK 2019b)

According to STUK (2019b), the reassessment of the seismic hazard and seismic risk has turned out to be challenging for the Loviisa plant. Recent hazard updates for Loviisa show increased values of ground accelerations especially for long return periods. However, the input data and results of hazard calculations involve large uncertainties. A seismic walkdown of the Loviisa plant has been undertaken in 2018 in cooperation with international consultants, and an observation report has been submitted to STUK. Final decisions on safety improvements will be made based on extensive dynamic analyses of safety related buildings and main components including re-evaluation of the boundary conditions. (STUK 2019b)

The Loviisa site is not equipped with a seismic measuring system. Decision on installation of a seismic monitoring system will be made when the seismic hazard assessment and seismic risk assessment have been completed.

At the Loviisa NPP, the SAM systems are not designed to withstand earthquakes. Seismic analyses of these systems are not included in PSA level 2 and therefore there is no confirmation on the sufficient operability of these systems after an earthquake. (STUK 2019b)

According to the EIA Report, the measures with regard to some previously changed requirements are yet to be completed in some respects, including the improvement of seismic resistance.

According to the requirements formulated in the EIA Scoping expert statement, the current seismic hazard evaluation should be presented in the EIA Report. It should explain the safety margins of the design and all safety and SAM systems, cliff-edge effects and envisaged improvement measure for the lifetime extension. This information is missing in the EIA report.

Flooding

In the past decades the threat posed by flooding has increased for many nuclear power plant sites. The reason for this is both a change in external factors (e.g. climate change, construction of dams, reduction of natural flood plains) and a change in assessing the threat. The observation of trends is essential to ensure an appropriate assessing of the flooding risk.

Flooding events which have occurred at nuclear power plants showed that water has damaged safety equipment located below site level, because the water resistance of doors was miscalculated, or seals of cable penetration were corroded.

In consequence of the TEPCO Fukushima Dai-ichi accident, safety improvements have been implemented at the Loviisa NPP. 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 the flood protection of the most safety-relevant buildings. Physical modifications have already been implemented and final updates for procedures should be finalized by the summer 2019.

To ensure the long-term decay heat removal in case of loss of seawater an alternative ultimate heat sink has been implemented. The modification consists of two air-cooled cooling units per plant unit powered by an air-cooled diesel-generator.

To ensure adequate design basis for the improved flood protection, Loviisa NPP contracted updating of the seawater level extreme value distribution by the Finnish Meteorological Institute.

According to the new results the expected seawater levels at low frequencies of occurrence are higher than previously estimated. The exceedance frequency of the critical +3.0 m level was estimated at about $5 \cdot 10^{-6}$/year taking into consideration also the effect of waves. (The statistically estimated frequency for exceeding the critical level +3.0 m was before $4 \cdot 10^{-7}$/a.)

The design basis seawater level for the improvements was set as +4,1 m., corresponding to exceedance frequency of below 10^{-8}/year.

The plant is more vulnerable to high seawater levels if either of the plant units is in cold shutdown and the seawater system has been opened for maintenance. In addition, Loviisa NPP has in 2012-2018 gradually improved flood protection during certain annual outage states with open hatches in the condenser cooling seawater system, the design water level was increased from +2.1 m first to +2.45 m and later to +2.95 m. (STUK 2019b)

Improving the protection against high seawater levels according to the National Action Plan to remedy the shortcoming identified after the Fukushima Accident in the framework of the EU Stress Tests was completed in 2019. (STUK 2021c)

According to the requirements formulated in the EIA Scoping expert statement, the current evaluation of the flooding hazard should be presented in the EIA Report. It should be including safety margins, cliff-edge effects and envisaged improvement measures for the lifetime extension. This information is only partly provided in the EIA Report.

Extreme weather events

According to the Intergovernmental Panel on Climate Change (IPCC), the type, frequency and intensity of extreme weather events are expected to change as Earth's climate changes. These changes could occur even with relatively small mean climate changes. Changes in some types of extreme events have already been observed, for example in increases of the frequency and intensity of heat waves and heavy precipitation.

Many of the design standards of NPP were based on an understanding of a climate system that is now 40 years out of date. Today, it is known that climate change makes floods, droughts, and hurricanes stronger and more frequent. This means the safety standards of the NPPs, even if followed through completely, are likely to turn out as being in-sufficient to prevent disaster.

Estimation of probabilities and intensity for extreme events resulting from climate change is extremely difficult due to fact that there is no sufficient database. Because the situation is constantly evolving, data may be outdated by the time their evaluation is concluded. The time span lag is still more drastic for the drafting of new rules and regulations by the authorities, and their implementation by the NPP operators. Therefore, comprehensive safety measures are necessary.

According to the results of PSA for the Loviisa NPP, the total core damage frequency resulting from extreme weather phenomena is $6.6 \cdot 10^{-6}$/a, which is roughly 14% of the total current risk. The most significant risks related to external hazards, other than seismic or external flooding, found by the licensee, are related to algae combined with wind exceeding 39 m/s and wind exceeding 45 m/s.

According to the requirements formulated in the EIA Scoping expert statement, the current evaluation of extreme weather events should be presented in the EIA Report. It should explain the safety margins, cliff-edge effects and envisaged improvement *measure for the lifetime extension. The EIA report does not discuss potential extreme weather events and their consequences in sufficient detail.*

5.3 Conclusions, questions and preliminary recommendations

The accident analyses in the EIA Report should use a possible source term for a severe accident derived from the calculation of the current PSA 2. Even though the probability of severe accidents with a large release for existing plants is estimated to be very small, the damage caused by these accidents is very large. In this context it is important to emphasize that the calculated frequency of large releases of the Loviisa NPP is above the limits set in STUK's regulatory guide YVL A.7.

The source term used in the EIA Report should be justified on the basis of existing PSA results. In any case, the EIA Report should contain a comprehensible justification for the source term used. In principle, possible beyond-design-basis accidents should be part of the EIA, irrespective of their probability of occurrence.

Maintaining containment integrity under severe accident conditions is an important issue for accident management. The Loviisa NPP severe accident management (SAM) strategy strongly relies on retaining corium inside the pressure vessel (in-vessel retention (IVR). However, there are some safety issues that could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states), thus large releases are possible.

When the Loviisa NPP units were built no regulatory requirements on seismic design existed and earthquake loads were not considered separately in the design. According to STUK, the reassessment of the seismic hazard and seismic risk has turned out to be challenging for the Loviisa plant. Recent hazard updates for Loviisa show increased values of ground accelerations especially for long return periods. According to the EIA Report the improvement measures are still ongoing. At the Loviisa NPP, the SAM systems are not designed to withstand earthquakes, therefore there is no confirmation on the sufficient operability of these systems after an earthquake.

The Loviisa NPP is located on the coast of the Gulf of Finland, approximately 90 km east of Helsinki. In the past decades the threat posed by flooding has increased for many nuclear power plant sites. In consequence of the TEPCO Fukushima Dai-ichi accident, safety improvements have been implemented at the Loviisa NPP. However, according to new results the expected seawater levels at low frequencies of occurrence are higher than previously estimated.

In the context of accident analyses, several questions remain open, making it impossible to assess in a comprehensible way if Austria is potentially affected.

5.3.1 Questions

Q29: *Are the results from the PSA analyses (levels 2) including source terms and frequencies for severe accidents with (early) large releases (LRF or LERF) already available?*

Q30: *How much is contributed by internal and external events to CDF, LRF and LERF?*

Q31: *Has been performed a probabilistic safety analyses (PSA) level 3?*

Q32: *In which manner have the safety issues of the in-vessel retention concept which could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) been solved?*

Q33: *What are the results of current studies on earthquakes, floods and extreme weather conditions? When have these studies been performed?*

Q34: *Which external events have been considered in the recent PSR?*

Q35: *Which combinations of external events have been considered in the last PSR?*

Q36: *Which safety margins, cliff-edge effects and envisaged improvement measures are applied for the lifetime extension concerning seismic hazard, flooding hazards and extreme weather events?*

5.3.2 Preliminary recommendations

PE3: It is recommended to apply the WENRA safety objectives for new NPPs to identify reasonably feasible safety improvements for Doel 1&2. Even if the probability of an accident scenario is very low, all additional reasonably feasible safety improvements to reduce the risk should be implemented. It is recommended that the concept of practical exclusion for accidents with early or large releases will be used for this approach.

PE4: It is recommended to consider all natural hazards relevant to the site, as required by WENRA RHWG (2021a) and further explained by WENRA RHWG (2015).

PE5: It is also recommended to consider all hazard combinations as required by WENRA RHWG (2021a) and further explained by WENRA RHWG (2015). It is recommended that a hazard correlation diagram (e.g., DECKER & BRINKMAN 2017) be used as a starting point to ensure that all relevant combinations are considered.

6 ACCIDENTS WITH INVOLVEMENT OF THIRD PARTIES

6.1 Treatment in the EIA documents

Chapter 7.7 of the EIA Report explained that Loviisa power plant has a separate security organisation. The plans and guidelines concerning the security arrangements have been prepared in cooperation with the relevant police authorities and aligned with the rescue, emergency and abnormal situation plans prepared by the authorities. Security arrangements and their related plans and guidelines are maintained and continuously developed, and the operations are regularly practised with the authorities, both in separate drills and as part of the emergency exercises.

6.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

Nuclear power plants are vulnerable to a broad spectrum of possible attacks. Terrorist attacks or acts of sabotage on Loviisa may have significant impacts. However, in the EIA program malicious acts of third parties against Loviisa NPP and their possible effects are not discussed. In comparable EIA procedures such events were addressed to some extent. (UMWELTBUNDESAMT 2018)

The terror threat to nuclear power plants has received considerable public attention in the last twenty years. This attention has – for obvious reasons – focused on the hazard of the deliberate crash of a large airliner.

Accidental crashes of airplanes have been considered in the design of reactors for several decades. However, according to the estimated frequencies of crashes, only crashes of small airplanes and/or military airplanes were generally taken into account. After the 9/11 terror attack, the consequences of an intentional crash of a commercial airplane were considered. For such a crash WENRA assumes that a core melt can be avoided and would cause only a mi-nor radiological impact as defined in the Safety Objective O2 for new nuclear power plants. (WENRA RHWG 2013)

According to STUK (2017a) the reactor buildings at the Loviisa NPP are not designed against the airplane crash and improvements are not “practically reasonable”.

No studies about the consequences of a deliberate aircraft crash against the Loviisa NPP are available. It is, however, possible to draw conclusions from the results of studies carried out in other countries e.g. Germany and general considerations regarding the possible effects of such an aircraft crash. A generic study commissioned by the German Federal Environment Ministry (BMU) revealed, that even a small commercial aircraft (e.g. an Airbus A320) would cause major damage to the reactor building with a wall thickness of 0.6 to 1 metres. (BMU 2002)

Certain protective measures against terror attacks are conceivable. However, their use appears to be rather limited. However, there are plant-specific differences, for example regarding vulnerability of spent fuel pools, robustness of the reactor building. Because of the importance of this topic, and because of the existing variations between NPPs regarding vulnerability that give rise to the requirement of plant-specific analyses, the issue of terror attacks and sabotage should be considered in the further course of the environmental impact assessment of the lifetime extension of the Loviisa NPP.

Although precautions against terror attacks cannot be discussed in detail in public in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA Report.

According to the requirements formulated in the EIA Scoping expert statement, the EIA Report should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage. However, the EIA Report provided no information about this issue.

6.3 Conclusions, questions and preliminary recommendations

Terrorist attacks and acts of sabotage can have significant impacts on nuclear facilities and cause severe accidents – also on the Loviisa NPP. Although precautions against sabotage and terror attacks cannot be discussed in detail in public in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents. Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. The EIA Report only provides very limited information on this topic.

6.3.1 Questions

Q37: *Are there any studies about the consequences of a commercial airplane crash against the Loviisa NPP available?*

6.3.2 Preliminary recommendations

PE6: The EIA Report should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.

7 TRANS-BOUNDARY IMPACTS

7.1 Treatment in the EIA documents

The EIA Report includes an assessment of a severe reactor accident based on a source term of 100 TBq Cs-137 and other nuclides of the reactor inventory to a proportionate degree. This is corresponding to the limit value of a severe accident in accordance with section 22 b of the Nuclear Energy Decree 161/1988. This accident is an INES level 6 event. (FORTUM 2021a, p. 320.)

Radiation doses were calculated up to a distance of 1,000 km. Austria is outside of this distance. The EIA report informs that at distances of more than 1,000 km, the radiation doses have not been reviewed in detail, but based on the results of the modelling and an expert assessment, they are expected to be smaller or no greater than 0.03–0.04 mSv for children and adults in places like eastern/northeast Germany and southern/southwest Poland. (FORTUM 2021a, p. 320.)

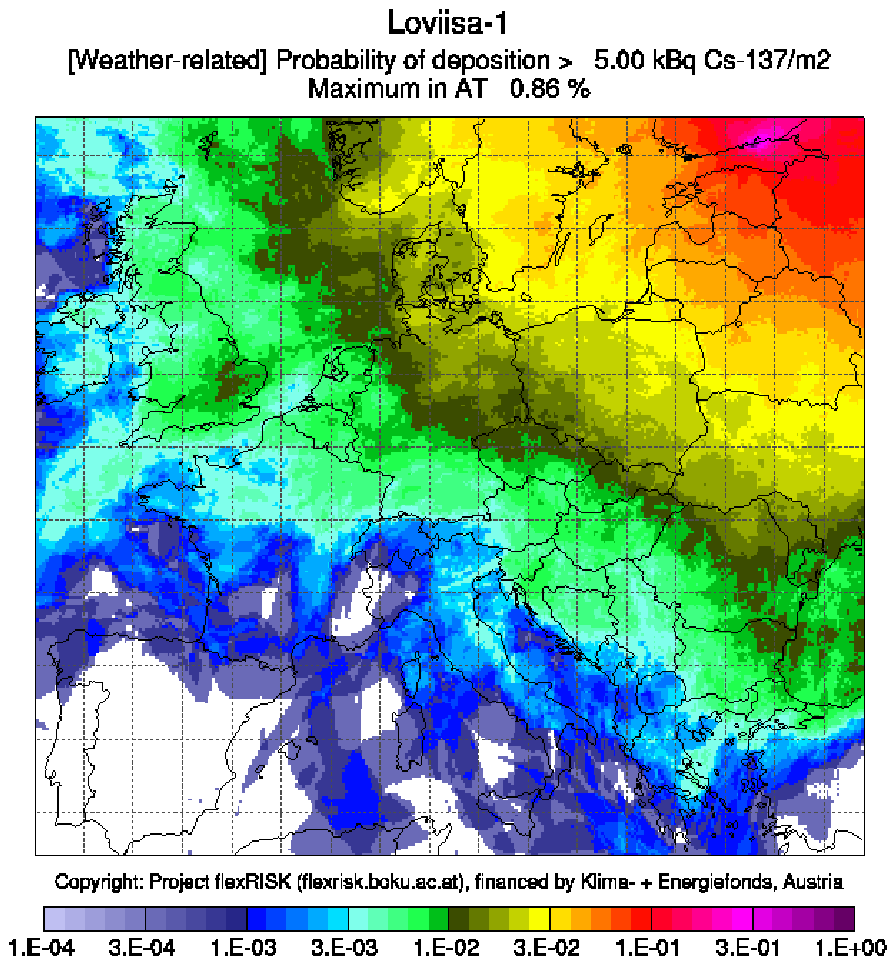
No other trans-boundary impacts are expected.

7.2 Discussion (including a comparison with the requirements formulated in the EIA Scoping expert statement)

A source term of 100 TBq Cs-137 is not **the largest possible source term** for a severe accident in Loviisa.

The project flexRISK made an assessment of source terms and identified the value of 31.5 PBq Cs-137 for Loviisa-1 and 2, each. The flexRISK project made dispersion calculations for Europe without applying the restriction of 1,000 km from any NPP site. In the following figure, flexRISK results for the weather-related probability of a contamination over 5 kBq Cs-137/m^2 can be seen.

Figure 10: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m²



Source: *Project flexRISK flexrisk.boku.ac.at, financed by Klima- + Energiefonds, Austria*

umweltbundesamt

flexRISK determined the weather-related probability for a contamination of Austrian territory with more than 5 kBq Cs-137/m2 with 0.86%. The weather-related probability for a contamination with more than 37 kBq Cs-137/m^2 is 0.29%, and for more than 185 kBq Cs-137/m^2 0.07%, respectively.

These probabilities might be low, but in Austria even lower contamination levels trigger agricultural countermeasures. These measures include earlier harvesting, closing of greenhouses and covering of plants, putting livestock in stables etc. A catalogue of countermeasures for radiological crisis situations is used (BMLFUW 2014), which requires the introduction of agricultural protection measures even in the case of low levels of contamination. This catalogue includes, among others, measure A07 ("Immediate harvesting of marketable products, in particular of storable products") with its associated (forecast) levels:

Table 3: Levels for the agricultural countermeasures A07 (BMLFUW 2014)

	I-131 Bq*h/m³	**I-131 Bq/m²**	**Cs-137 Bq*h/m³**	**Cs-137 Bq/m²**
Start of measure A07	170	700	350	650

A contamination of 5 kBq Cs-137/m² like in the above figure is much higher than the level for the Cs-137 contamination in the above table, therefore agricultural countermeasures could be necessary on Austrian territory in case of a severe accident at the Loviisa site.

The 1,000 km circle does not cover Austria. To exclude the possibility of trans-boundary severe impacts, including the necessity of agricultural countermeasures, dispersion calculations should have been performed also for distances beyond 1,000 km, with the goal to compare the results to the Austrian levels from the catalogue of countermeasures (BMLFUW 2014), but also the Austrian Emergency Plan (BMK 2020).

Also proof should have been provided that accident releases over 100 TBq Cs-137 are excluded; otherwise calculations with the highest possible source term and under the assumption of the most negative weather condition for Austrian territory are necessary.

These three points were defined as requirements for the EIA Report in the expert scoping statement: that the dispersion calculations for severe accidents cover Austrian territory; that the dispersion calculation results would be provided to be comparable with the Austrian catalogue of countermeasures (BMLFUW 2014) and also with the Austrian Emergency Plan (BMK 2020); and that proof be provided that accident releases over 100 TBq Cs-137 are excluded; otherwise calculations with the highest possible source term and under the assumption of the most negative weather condition for Austrian territory would be necessary.

7.3 Conclusions, questions and preliminary recommendations

A severe accident with releases reaching Austrian territory can lead to significant impacts on Austria. In the EIA Report an accident was calculated with a source term of 100 TBq Cs-137, dispersion calculations were made to cover a distance of up to 1,000 km. This might underestimate impacts on Austria. Firstly, it is not proven that the occurrence of a higher source term can be excluded; and secondly, a calculation distance of 1,000 km is insufficient to assess impacts on Austria.

7.3.1 Questions

Q38: *Please provide data of the largest source term identified in the probabilistic safety analyses (PSA) (regardless of its probability)?*

Q39: *Please provide the results of the dispersion calculation for this source term.*
It would be welcomed if these results were also presented for Austrian territory.
It would be welcome if the results of the dispersion calculation were comparable with the Austrian catalogue of countermeasures (see also table 3: Values for agricultural countermeasures A07 (BMLFUW 2014), and with the Austrian national emergency plan (BMK 2020).

7.3.2 Preliminary recommendations

No preliminary recommendation.

8 SUMMARY OF QUESTIONS AND PRELIMINARY RECOMMENDATIONS

8.1 Procedure and alternatives

8.1.1 Questions

Q1: *How should the wording of the envisaged life-time extension "a maximum of approximately 20 years" be interpreted: Could the life-time extension be also longer than 20 years?*

Q2: *When will the decision on one of the options be taken by Fortum?*

Q3: *What are the results from the international hearing on 7 October 2021?*

8.2 Spent fuel and radioactive waste

8.2.1 Questions

Q4: *What is the timetable for the planned increase of the interim storage capacity for spent fuel?*

Q5: *Can you please describe the options for capacity increasement of the spent fuel interim storage by high-density storage in more detail?*

Q6: *Why will the storage system used for spent fuel interim storage not be switched to a state-of-the-art dry storage system?*

Q7: *Which alternative options are planned for the case that the interim and the final disposal facilities for spent fuel are not available in time?*

Q8: *Will the KBS-3 method be used despite of problematic results of copper corrosion research? How will the copper corrosion problems be dealt with?*

8.3 Long-term operation of reactor type VVER.440

8.3.1 Questions

Q9: *Does the aging management program now comply with the new requirements from 2019 and 2020?*

Q10: *When will the STUK regulation implement the updated 2020 WENRA reference level for existing reactors?*

Q11: *Has the STUK ageing management expert group made recent observations/conclusions?*

Q12: *When will the two remaining issues from the national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM be completed?*

Q13: *Which measures will be performed concerning the very important safety issue of the reactor pressure vessels (RPVs) ageing (embrittlement)? Is re-annealing of the RPV of Loviisa 2 envisaged? What are the remaining safety margins?*

Q14: *What are the recent results of the inspections of all nozzles of the RPV? Are there any measures envisaged?*

Q15: *Are the results of the evaluation of the conditions of the RPV internals and head penetrations (including trends of events, and envisaged exchange measures) already available?*

Q16: *Are there any problems with aging of the ice condensers (as mentioned by the Loviisa Deputy Director in August 2020)?*

Q17: *Is information about the conditions of components of the primary circuit and the electrical installations (including trends of events, and envisaged exchange measures) already available?*

Q18: *What are the findings of the OSART follow up mission 2020? Have any recommendations or suggestions not yet been resolved?*

Q19: *Has the cause for the noise of the Loviisa 1 reactor pressure tank's foreign material monitoring system already been clarified?*

Q20: *Which technically possible improvements to meet modern safety requirements have been considered not "reasonably practicable" for the Loviisa NPP?*

Q21: *Which safety systems/components and Severe Accident Management (SAM) systems/equipment are shared between Loviisa 1 and 2*?

Q22: *Which design changes are planned in the context of the envisaged lifetime extension?*

Q23: *Which existing buildings should be renovated or new constructed in framework of the lifetime extension?*

Q24: *Which documents of WENRA will be taken into account for the lifetime extension in a binding form?*

Q25: *Are the results from comparing the design features and measures of the Loviisa NPP with all requirements of SRL F already available?*

Q26: *Have measures been planned to meet the safety objective O2 (accident without core melt) for lifetime extension?*

Q27: *Will lifetime extension measures been planned to come as close as reasonably practicable to meet the safety objective O3 (accidents with core melt)?*

Q28: *Has STUK already finished the review of the submitted PSR? What results did the PRS deliver? Will all requirements stemming from the results be applied as preconditions for the lifetime extension approval?*

8.3.2 Preliminary recommendations

PE1: It is recommended to implement all technically available safety improvements to prevent accidents.

PE2: It is recommended that all requirements of WENRA Reference Level F be met. In case of deviations, the reasons should be explained.

8.4 Accident Analysis

8.4.1 Questions

Q29: *Are the results from the PSA analyses (levels 2) including source terms and frequencies for severe accidents with (early) large releases (LRF or LERF) already available?*

Q30: *How much is contributed by internal and external events to CDF, LRF and LERF?*

Q31: *Has been performed a probabilistic safety analyses (PSA) level 3?*

Q32: *In which manner have the safety issues of the in-vessel retention concept which could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) been solved?*

Q33: *What are the results of current studies on earthquakes, floods and extreme weather conditions? When have these studies been performed?*

Q34: *Which external events have been considered in the recent PSR?*

Q35: *Which combinations of external events have been considered in the last PSR?*

Q36: *Which safety margins, cliff-edge effects and envisaged improvement measures are applied for the lifetime extension concerning seismic hazard, flooding hazards and extreme weather events?*

8.4.2 Preliminary recommendations

PE3: It is recommended to apply the WENRA safety objectives for new NPPs to identify reasonably feasible safety improvements for Doel 1&2. Even if the probability of an accident scenario is very low, all additional reasonably feasible safety improvements to reduce the risk should be implemented. It is recommended that the concept of practical exclusion for accidents with early or large releases will be used for this approach.

PE4: It is recommended to consider all natural hazards relevant to the site, as required by WENRA RHWG (2021a) and further explained by WENRA RHWG (2015).

PE5: It is also recommended to consider all hazard combinations as required by WENRA RHWG (2021a) and further explained by WENRA RHWG (2015). It is recommended that a hazard correlation diagram (e.g., DECKER & BRINKMAN 2017) be used as a starting point to ensure that all relevant combinations are considered.

8.5 Accidents with involvement of third parties

8.5.1 Questions

Q37: *Are there any studies about the consequences of a commercial airplane crash against the Loviisa NPP available?*

8.5.2 Preliminary recommendations

PE6: The EIA Report should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.

8.6 Trans-boundary impacts

8.6.1 Questions

Q38: *Please provide data of the largest source term identified in the probabilistic safety analyses (PSA) (regardless of its probability)?*

Q39: *Please provide the results of the dispersion calculation for this source term.*
It would be welcomed if these results were also presented for Austrian territory.
It would be welcome if the results of the dispersion calculation were comparable with the Austrian catalogue of countermeasures (see also table 3: Values for agricultural countermeasures A07 (BMLFUW 2014), and with the Austrian national emergency plan (BMK 2020).

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12 GLOSSARY

AMP .... Ageing Management Programme

Bq .... Becquerel

BMK .... Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology

CDF .... Core Damage Frequency

Cs-137 .... Caesium-137

DBE .... Design Basis Earthquake

DEC .... Design Extension Conditions

DiD .... Defence in Depth

EIA .... Environmental Impact Assessment

ENSREG .... European Nuclear Safety Regulators Group

EOP .... Emergency Operating Procedures

EU .... European Union

g .... Gravitational Acceleration

GRS .... Gesellschaft für Anlagen- und Reaktorsicherheit, Germany

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

ILW .... Intermediate level waste

IVR .... In Vessel Retention

LILW .... Low and intermediate level waste

LLW .... Low level waste

LOCA .... Loss of Coolant Accident

LRF .... Large Release Frequency

MAEA .... Ministry of Economic Affairs and Employment

NPP .... Nuclear Power Plant

NTI .... Nuclear Threat Initiative

OAMP .... Overall ageing management program

PGA .... Peak Ground Acceleration

PSA ....Probabilistic Safety Assessment

PWR...................................Pressurized Water Reactor

RCS ....Reactor Coolant System

RHWG................................Reactor Harmonization Working Group

RL.......................................Reference Level

RPV ....Reactor Pressure Vessel

SAM ....Severe Accident Management

SC.......................................Sealed Containment

SSC ....Structure, Systems and Components

STUK..................................Radiation and Nuclear Safety Authority

TBq ....Tera-Becquerel, E12 Bq

TPR ....Topical Peer Review

TWh ....Tera Watt hour

UNECE...............................United Nations Economic Commission for Europe

VVER ....Water-Water-Power-Reactor, Pressurized Reactor originally developed by the Soviet Union

WENRA..............................Western European Nuclear Regulators´ Association

umweltbundesamt

Umweltbundesamt GmbH
Spittelauer Laende 5
1090 Vienna/Austria

Tel.: +43-(0)1-313 04
Fax: +43-(0)1-313 04/5400

office@umweltbundesamt.at
www.umweltbundesamt.at

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