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Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

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E-mail replies should be sent to the above e-mail address, quoting the reference number

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Vienna, 29.10.2020

Espoo, NPP Loviisa 2020, AT Comments

Dear Ms Rantakallio,

Thank you for the notification according to Art. 3 para 2 Espoo Convention and Art. 7 para 1 EIA Directive regarding the lifetime extension of the nuclear power plant Loviisa by the Finnish developer Fortum Power and Heat Oy. The notification included the EIA programme (scoping phase) and further information on the EIA procedure.

Austria informs Finland pursuant to Art. 3 para 3 Espoo Convention and Art. 7 para 2 EIA Directive that it will take part in the transboundary procedure pursuant to the Espoo Convention and EIA Directive since significant transboundary effects on Austria’s environment cannot be excluded; as a consequence of severe accidents in particular.

The submitted EIA programme was made publicly available in Austria between 9 September and 23 October 2020. Please find enclosed the comments from the public and authorities as well as an expert statement, which was commissioned by the Federal Ministry for Climate Action. Austria requests Finland to take the comments and the recommendations of the expert statement for the elaboration of the EIA report into account.

Furthermore, Austria asks Finland to submit the EIA report with information on public participation (e.g. possibilities of the public to participate, time frames) in order to give the Austrian public equivalent opportunities according to Art. 2 para 6 Espoo Convention.

Kind regards,

On behalf of the Federal Minister:

Dr. Ursula Platzer-Schneider

PERSPEKTIVEN FÜR UMWELT & GESELLSCHAFT umweltbundesamt

LOVIISA 1&2

lifetime extension EIA

Expert Statement

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

pulswerk
Das Beratungsunternehmen des
Österreichischen Ökologie-Instituts

LOVIISA 1&2 LIFETIME EXTENSION

ENVIRONMENTAL IMPACT ASSESSMENT

SCOPING

Expert Statement

Oda Becker
Gabriele Mraz

Commissioned by
Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology,
Directorate VII/10 General Coordination of Nuclear Affairs
GZ: BMNT-UW.1.1.2/0019-I/6/2018

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

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Das Beratungsunternehmen des
Österreichischen Ökologie-Instituts

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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. The current phase of the EIA procedure is the scoping phase.

The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology commissioned the Environment Agency Austria to provide the expert statement at hand assessing the submitted scoping documents. The objective of the Austrian participation in the EIA Scoping procedure is to define requirements for the EIA Report, the document that will comprise the environmental impact assessment in the next stage of the EIA procedure. Austria participates in the EIA procedure to minimise or even eliminate possible significant adverse impacts on Austria resulting from the project.

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

The **assessment of alternatives** in the EIA Report should include, as appropriate, scenarios of future electricity need, energy efficiency and saving measures and other options to produce electricity.

Spent fuel and radioactive waste

The decommissioning of the NPP will result in low and intermediate level radioactive waste (LILW) for which no capacities are available yet. Additional LILW and additional spent fuel will arise from lifetime extension. In the EIA Report information should be provided on timetables and alternative waste management options for the case the needed disposal capacities are not available in time.

Due to new results on copper corrosion, the KBS-3 method which is to be used in the final repository for spent fuel came under criticism. It should be explained in the EIA Report how Finland will solve the corrosion problem.

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 should present the challenges in complying with the new requirements. The remaining issues and remedial measure should be explained.

An expert group dedicated to ageing management has been established in STUK to oversee how the licensees perform their duties in the ageing management of SSCs. The observations of the STUK expert group should be presented in the EIA Report.

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 should be 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). The very important safety issue of the embrittlement of the RPVs should be presented 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 should be presented in the EIA Report.

Fortum reported the results of 18 event analyses and investigations to STUK in 2019. 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 EIA Report should present an evaluation of safety relevant events including the lessons learned.

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 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 should list all shared safety and Severe Accident Management (SAM) systems.

According to FORTUM (2020a), life-time extension involves certain changes that may be implemented. The EIA Report should explain which changes are planned in the context of the envisaged 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. In addition to the updated SRLs, the Reactor Harmonization Working Group (RHWG) provides several guidance documents on issues F (Design Extension Conditions) and T (Natural Hazards).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 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 WENRA "Safety Objectives for New Power Reactors" have been elaborated for new reactors. Nevertheless, they should be also used as a reference for identifying reasonably practicable safety improvements for existing plants.

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 enough time to implement 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. 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 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).

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."* When making a decision how a new or revised regulatory guide is applied for operating nuclear facility, STUK can approve an exemption if the safety improvement is considered not reasonably practicable. Improvements considered not reasonably practicable at the Finnish operating NPPs include e.g. protection measures against large civil aircraft crash. The EIA Report should present all improvements to meet modern safety requirements that were considered not “reasonably practicable” at the Loviisa NPP.

All in all, 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.

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.

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 calculated frequency of large releases is above the limits set in STUK’s regulatory guide YVL A.7. This Guide states that 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.

Therefore, the accident analyses in the EIA procedure should use a possible source term derived by 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.

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 should 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.

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. The plant is more vulnerable to high seawater level if either of the plant units is in cold shutdown and the seawater system has been opened for maintenance.

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.

The current evaluation of the hazards of seismic, flooding and extreme weather events should be presented in the EIA Report. It should include safety margins, cliff-edge effects and envisaged improvement measures for the lifetime extension.

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.

Trans-boundary impacts

A severe accident with large releases can lead to significant trans-boundary impacts on Austria. In the EIA Report an accident will be calculated with a source term of 100 TBq Cs-137, dispersion calculations will be made up to a distance of 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. It would be welcomed if dispersion calculations for severe accidents would cover Austrian territory. It would also be welcomed if the dispersion calculation results would be provided to be comparable with the Austrian catalogue of countermeasures and with the Austrian Emergency Plan.

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 wurde, sind jeweils bis Ende 2027 bzw. 2030 gültig.

Fortum erwägt nun die Verlängerung der Betriebsdauer des KKW Loviisa um circa weitere 20 Jahre. Die Alternative dazu wäre der Beginn der Dekommissionierung des Kernkraftwerks.

Dafür wird ein Umweltverträglichkeitsverfahren gemäß der Espoo-Konvention und der UVP-Richtlinie der EU durchgeführt. Zurzeit befindet sich das UVP-Verfahren in der Scoping-Phase.

Das Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie beauftragte das Umweltbundesamt mit der Erstellung der vorliegenden Fachstellungnahme und der Bewertung der vorgelegten Scoping-Unterlagen. Ziel der österreichischen Beteiligung am Scoping-Verfahren ist die Definition von Anforderungen an den UVP-Bericht, der die Bewertung der Umweltauswirkungen in der nächsten Stufe des UVP-Verfahrens enthalten wird. Österreich beteiligt sich an diesem UVP-Verfahren, um mögliche signifikante negative Auswirkungen des Projekts auf Österreich zu minimieren oder zu beseitigen.

Es ist zu begrüßen, dass Finnland für die geplante Lebensdauerverlängerung der beiden Blöcke des KKW Loviisa eine UVP durchführt.

Die **Bewertung von Alternativen** in der Umweltverträglichkeitserklärung sollte, sofern möglich, entsprechende Szenarien zum künftigen Stromverbrauch, Energieeffizienz und Einsparmaßnahmen sowie andere Möglichkeiten zur Stromproduktion beinhalten.

Abgebrannte Brennelemente und radioaktiver Abfall

Bei der Dekommissionierung des KKW werden schwach- und mittelaktive Abfälle (LILW) anfallen, für die noch keine Lagerkapazitäten verfügbar sind. Wenn es zur geplanten verlängerten Betriebsdauer kommen sollte, so werden im Betrieb zusätzliche Mengen an LILW sowie an abgebrannten Brennelementen anfallen. Der UVP-Bericht sollte Zeitpläne und alternative Abfallentsorgungsoptionen für den Fall vorstellen, dass die benötigten Lagerkapazitäten nicht rechtzeitig zur Verfügung stehen sollten.

Neue Forschungsergebnisse zur Kupferkorrosion führten dazu, dass die sogenannte KBS-3 Methode, die als Lagerungstechnologie für das Endlager für abgebrannte Brennelemente verwendet werden soll, nun in die Kritik geraten ist. Es gilt daher im UVP-Bericht zu klären, wie Finnland mit dem aufgetretenen Korrosionsproblem 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. Auf diese Probleme sollte der UVP-Bericht eingehen, wie auch die übrigen Punkte und Maßnahmen zur Behebung der Defizite erläutert werden sollten.

Bei STUK wurde eine eigene ExpertInnengruppe zum Alterungsmanagement eingerichtet, die die Durchführung dieser Vorgaben bei den SSC durch die Betreiber überwacht. Der UVP-Bericht sollte auch die diesbezüglichen Beobachtungen dieser STUK-ExpertInnengruppe beschreiben.

Finnland beteiligte sich an der Topical Peer Review (TPR) "Ageing Management", die 2017/18 gemäß der Richtlinie 2014/87/EURATOM zur Nuklearen Sicherheit durchgeführt wurde. Obwohl die abschließende Bewertung das Alterungsmanagement als ausreichend bezeichnete, 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 sollten im UVP-Bericht Erwähnung finden.

Erhöhte Aufmerksamkeit und große Anstrengung vom Lizenzinhaber wie auch von STUK verlangte beim Alterungsmanagement für das KKW Loviisa ein Punkt, nämlich die Versprödung der Reaktordruckbehälter (RDB). Da es sich bei der Versprödung der Reaktordruckbehälter um eine wesentliche Sicherheitsfrage handelt, sollte darauf auch im UVP-Bericht eingegangen werden.

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. Der UVP-Bericht sollte auf die Erkenntnisse der OSART-Missionen wie auch etwaige Verbesserungsvorschläge eingehen.

Im Jahre 2019 berichtete Fortum der Atomaufsichtsbehörde STUK über die Ergebnisse, die aus 18 Ereignisanalysen und Untersuchungen gewonnen wurden. Diese Analysen der Ereignisse verwiesen großteils darauf, dass Möglichkeiten für Verbesserungen für die im KKW angewendeten Verfahren und Tätigkeiten bestehen. Auch forderte STUK den Betreiber Fortum auf, für eine verbesserte Lernkurve aus den Betriebserfahrungen zu sorgen. Der UVP-Bericht sollte eine Evaluierung der sicherheitsrelevanten Ereignisse einschließlich der aus diesen gewonnenen Lehren präsentieren.

Wissenschaft und Technik bringen laufend neues Wissen über Versagensmodi, Materialeigenschaften und Überprüfung, Tests 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 dazu, dass die früheren Sicherheitskonzepte obsolet werden (konzeptuelle Alterung).

Die Reaktoren des KKW Loviisa sind Druckwasserreaktoren aus 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 wurden beide finnische WWER-440/V-213 Reaktoren mit einem Containment und Steuerungssystem westlicher Provenienz ausgestattet.

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 sollte alle gemeinsamen Sicherheitssysteme und SAM-Systeme (Severe Accident Management) auflisten.

FORTUM (2020a) führte an, dass einige Änderungen vorliegen, die im Rahmen der Lebensdauerverlängerung umgesetzt werden könnten. Der UVP-Bericht sollte diese behandeln.

Die Western European Nuclear Regulator’s Association (WENRA) hat die Safety Reference Levels (SRLs) für bestehende Reaktoren revidiert, um die Erkenntnisse und Lektionen zu integrieren, die aus dem Unfalls von Fukushima Dai-ichi im Jahre 2011 gezogen wurden. Im Jahre 2014 wurde eine Liste von 342 SRLs veröffentlicht. Zusätzlich zu den aktualisierten SRL hat die Reactor Harmonization Working Group (RHWG) der WENRA verschiedene Anleitungen zu den Issues F (Design Extension Conditions) und T (Natural Hazards) ausgearbeitet. Gemäß SRL F1.1 sollte eine Analyse der Erweiterten Auslegungsbedingungen (Design Extension Conditions, DEC) durchgeführt werden, um die Sicherheit des KKW zu erhöhen. Daher sollte der UVP-Bericht auch einen Vergleich des Auslegungsdesigns und der Maßnahmen des KKW Loviisa mit allen Anforderungen enthalten, die sich aus den SRL F ergeben. Für eventuell auftretende Abweichungen sind die Gründe anzuführen.

Die “Safety Objectives for New Power Reactors” der WENRA wurden zwar für neue Reaktoren ausgearbeitet, sollten aber dennoch als Referenz für die Identifizierung von vernünftigerweise praktikablen Sicherheitsverbesserungen bei bestehenden Reaktoren herangezogen werden.

Das ehrgeizigste Sicherheitsziel ist die Reduktion von potentiellen radioaktiven Freisetzungen in die Umwelt in Folge von Kernschmelzunfällen. Praktisch auszuschließen sind Kernschmelzunfälle mit früher Freisetzung ohne ausreichender Zeitdauer, die für die Durchführung von Notfallmaßnahmen außerhalb des Kraftwerkareals benötigt wird oder mit hohen Freisetzungen einhergeht, die räumlich und zeitlich unbeschränkte Schutzmaßnahmen für die Bevölkerung erfordern würden. Der praktische Ausschluss 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 vorgenommen werden.

Der UVP-Bericht sollte alle geplanten Maßnahmen für die Lebensdauerverlängerung präsentieren, die der vernünftigerweise praktikablen Erreichung des Sicherheitsziels O3 dienen (Unfälle mit Kernschmelze).

Das Prinzip der kontinuierlichen Erhöhung der nuklearen Sicherheit sieht Abschnitt 7a des finnischen Atomenergiegesetzes (990/1987) vor: „*Die Sicherheit der Kernenergienutzung soll auf einem 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 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. Der UVP-Bericht sollte alle Verbesserungen zur Erreichung moderner Sicherheitsanforderungen darstellen, die für das KKW Loviisa als nicht „vernünftigerweise praktikabel“ angesehen wurden.

Ebenso sollte der UVP-Bericht eine umfassende Präsentation und allgemeine Bewertung aller Abweichungen vom aktuellen Stand von Wissenschaft und Technik enthalten.

Unfallanalysen

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

Die jüngste Aktualisierung der Probabilistischen Risikobewertung, der PRA 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 berechnete Häufigkeit für große Freisetzungen liegt somit über dem Grenzwert laut STUK-Anleitung YVL A.7. Diese Anleitung schreibt für die Auslegung für Kernkraftwerke vor, dass die durchschnittliche Freisetzungshäufigkeit von Cs-137 von mehr als 100 TBq bei einem Unfall in die Atmosphäre unter $5 \cdot 10^{-7}$/a bleiben muss.

Daher sollte die Unfallanalyse für das UVP-Verfahren einen möglichen Quellterm verwenden, der sich aus der Berechnung des aktuellen PRA 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.

Der Erhalt der Containment-Integrität unter den Bedingungen bei schweren Unfällen ist ein wichtiges Thema für das Unfallmanagement. Die Strategie 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). In den Unterlagen wird betont, dass an der Reduktion der Eintrittshäufigkeit von Bypass-Sequenzen kontinuierlich gearbeitet wurde und diese Anstrengungen fortgesetzt werden. In diesem Zusammenhang ist festzuhalten, dass die Freisetzung von großen Mengen an radioaktiven Stoffen zum gegenwärtigen Zeitpunkt möglich ist. Der UVP-Bericht sollte aufzeigen, 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, die Auslegung gegenüber externen Gefährdungen ausreichend zu berücksichtigen.

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 zeigten erhöhte Bodenbeschleunigungszahlen 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.

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 von TEPCO 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 waren höher als ursprünglich angenommen. Das Kraftwerk ist gegenüber einem hohen Meeresspiegel verletzbarer, wenn das KKW entweder abgeschaltet ist (cold shutdown) oder das Meerwassersystem zwecks Wartungsarbeiten geöffnet ist.

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.

Die aktuelle Einschätzung der bestehenden Gefährdungen durch seismische Ereignisse, Überflutungen und extreme Wetterereignisse sollten im UVP-Bericht beschrieben werden. Der UVP-Bericht sollte Sicherheitsmargen, Cliff-edge Effekte und geplante Verbesserungen im Zuge der Lebensdauerverlängerung beinhalten.

Unfälle mit der Beteiligung Dritter

Im Allgemeinen sind Kernkraftwerke 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.

Grenzüberschreitende Auswirkungen

Ein schwerer Unfall mit großen Freisetzungen kann zu signifikanten grenzüberschreitenden Auswirkungen auf Österreich führen. Für den UVP-Bericht wird ein Unfall mit einem Quellterm von 100 TBq Cs-137 berechnet werden, die Ausbreitungsrechnungen werden eine Distanz von bis zu 1.000 km berücksichtigen. Dies kann zu einer Unterschätzung der Auswirkungen auf Österreich führen. Zunächst ist nicht nachgewiesen, dass ein höherer Quellterm ausgeschlossen werden kann, und zusätzlich ist die Berechnung für die Distanz von 1.000 km zu gering, um Auswirkungen auf Österreich abschätzen zu können. Es wäre begrüßenswert, wenn die Ausbreitungsberechnungen für schwere Unfälle auch österreichisches Staatsgebiet umfassen würden. Ebenso zu begrüßen wäre, wenn Ergebnisse der Ausbreitungsrechnungen zur Verfügung gestellt würden, die einen Vergleich mit dem österreichischen Maßnahmenkatalog für radiologische Notstandssituationen und gesamtstaatlichen Notfallplan ermöglichen.

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. 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. Austria has been notified by Finland on this project. The competent EIA authority in Finland is the Ministry of Economic Affairs and Employment, the project developer is Fortum Power and Heat Oy (in short: Fortum), the EIA consultant is Ramboll Finland Oy. The Ministry of the Environment is in charge of the transboundary participation.

The current phase of the EIA procedure is the scoping phase, which is also referred to as “EIA Programme” in the submitted scoping documents.

The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology commissioned the Environment Agency Austria to provide the expert statement at hand assessing the submitted scoping documents.

The objective of the Austrian participation in the EIA Scoping procedure is to define requirements for the EIA Report, the document that will comprise the environmental impact assessment in the next stage of the EIA procedure. Austria participates in the EIA procedure to minimise or even eliminate possible significant adverse impacts on Austria resulting from the project.

2 OVERALL AND PROCEDURAL ASPECTS OF THE ENVIRONMENTAL IMPACT ASSESSMENT

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 (2020a): Loviisa nuclear power plant: Environmental Impact Assessment Programme. August 2020.
- FORTUM (2020b): Loviisa nuclear power plant: Summary of the environmental impact assessment programme for the international hearing. August 2020.
- FORTUM (2020c): Kernkraftwerk Loviisa. Zusammenfassung des Programms der Umweltverträglichkeitsprüfung für die internationale Anhörung. August 2020.

2.1 Treatment in the EIA Scoping Documents

EIA procedure and nuclear procedures

Loviisa 1 has an operating license which is valid until the end of 2027 and Loviisa 2 until the end of 2030. Currently the project developer Fortum is assessing the extension of the commercial operation of Loviisa nuclear power plant by a **maximum of approximately 20 years** in addition to the current operating licence period.

Fortum announced its intention to take the decision concerning potential extension of the operation of the nuclear power plant and the application for new operating licences **at a later date**. The other option is to proceed to the decommissioning phase when the power plant's current operating licences expire.

The extension of the plant lifetime requires granting **new operating licenses**. The decommissioning of the reactors requires that a **decommissioning license is issued**; both licenses are granted by the Government.

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 Ministry of Economic Affairs and Employment needs to ensure that cost for the nuclear waste management will be provided. Before the end of plant operation the decommissioning license has to be applied for; the requirements are defined in the Nuclear Energy Act. (FORTUM 2020a, p. 88f.)

The **EIA procedure** is based on the Finnish EIA Act 252/2017 which again is based on Directive 2011/92/EU. (FORTUM 2020a, p. 46).

The EIA schedule is presented in figure 1.

Quelle: FORTUM 2020a, p. 48

Figure 1: Schedule of the EIA procedure

The reasoned conclusion is the last step of the EIA procedure and will be issued by the Ministry of Economic Affairs and Employment. This reasoned conclusion has to be considered in the subsequent licensing process. (FORTUM 2020a, p. 47)

Alternatives

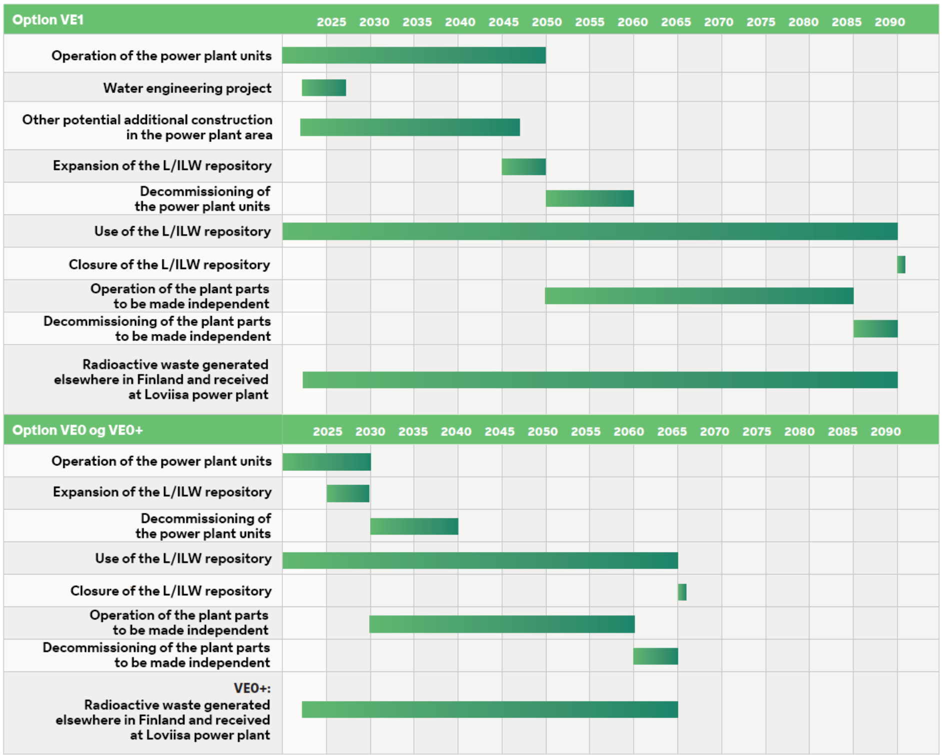
Three alternatives are discussed: Option VE1, and options VE0 and VE0+. Option VE0 is also the zero option.

Option VE1 covers the lifetime extension of a maximum of approximately 20 years after the currently licenses will have expired, followed by decommissioning. Increasing the thermal power is not planned. The construction of new buildings and structures might be included, also modernisations in the NPP site. 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. (FORTUM 2020, p. 20)

Option VE0 covers the decommissioning after the expiration of the current operation licenses (2027 and 2030, respectively). This option will be realised if Fortum does not apply for new operational licenses for lifetime extension. Decommissioning includes dismantling of the radioactive systems and disposing radioactive waste from decommissioning in the LILW final repository. Some of the plant's systems and parts will be made independent to remain in function after the NPP shut-down.

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

Figure 2: Time schedule of the project options



Quelle: FORTUM 2020b, p. 9

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

The role the NPP Loviisa plays in the Finish electricity supply is characterized in the chapter "Assessed impacts and assessment methods. Subchapter 6.18 Energy markets and security of supply": *"Loviisa power plant generates electricity for the Nordic wholesale electricity market and promotes Finland's security of supply by maintaining the national capacity. Extending the operation will not change the situation on the electricity market, but it will strengthen Finland's security of supply through reliable domestic production in potential exceptional situations, especially when the Nordic electricity market does not function for some reason."*

The assessment continues by stating that alternative forms of electricity production or alternative sites cannot be determined in a reliable manner in particular because Loviisa provides base load and renewable energies are weather-dependent. *"The impact on the electricity market and Finland's security of supply are assessed taking the schedules of the different options in the project into account."* (FORTUM 2020a, p. 79)

2.2 Discussion

EIA and licensing according to the Atomic law

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 2017) No EIA has been conducted for this prolongation of the Loviisa lifetime.

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

The announcement about **maximum lifetime extension** remains unclear– "a maximum of approximately 20 years" is not a clear definition. The EIA Report should make clear statements on the maximum years of the planned lifetime extension.

Regarding the decision for or against the lifetime extension there is only the reference "at a later date" in the Scoping Documents. This date should be placed in a schedule for the EIA and the licensing procedures according to the Atomic Bill.

Alternatives

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

It would be welcomed if the EIA Report includes an assessment of lifetime extension in the energy production for future electricity needs. A focus on energy efficiency and energy saving measures should be introduced as a viable option to fight climate change.

2.3 Conclusions and requirements for the EIA Report

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

The provided Scoping Documents are complete and the outline of the scope for the EIA Report has been defined.

Several questions remain unclear concerning the Environmental Impact Assessment and the subsequent licensing procedures according to the Atomic Bill and should be answered in the EIA Report. The assessment of alternatives should, as appropriate, also include scenarios of future electricity need, energy efficiency and saving measures and other options to produce electricity.

Requirements for the EIA Report

1. In the EIA Report, the maximum years of lifetime extension should be clearly stated.
2. The date when Fortum will take the decision for one of the options should be stated.
3. For assessing alternative options it is recommended to include scenarios of future electricity demand in Finland, together with energy efficiency and saving measures and other electricity generating options.

3 SPENT FUEL AND RADIOACTIVE WASTE

3.1 Treatment in the EIA Scoping Documents

According to the Nuclear Energy Act, nuclear waste must be handled, stored and permanently disposed of in Finland. (FORTUM 2020a, p. 27)

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 operating license will have to be applied for, firstly, because the repository will have to be operated longer than originally planned even without the envisaged lifetime extension (see Figure 2: Time schedule of the project options (FORTUM 2020b, p. 9)), and secondly, because the original license did not cover all planned purposes of use. (FORTUM 2020a, p. 8) 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 (FORTUM 2020a, p. 10).

No major changes to the annual waste accumulation are predicted. An extension of about 20 years generates approximately 600 m^3 of low-level waste and approximately 2,400 m^3 of intermediate-level waste when the waste is packed. The capacity of the final disposal facility for low- and intermediate-level waste is sufficient for the final disposal of the low- and intermediate-level waste generated during the extension. (FORTUM 2020a, p 34f.)

During decommissioning, waste is placed in the interim storage on the power plant premises for measurement and packaging, after which it is transported to the final disposal hall. During the operation of the power plant, the LILW repository will be enlarged by excavating approximately 57,000 m^3 for decommissioning waste. The estimated total volume of decommissioning waste to be deposited in final disposal is approximately 25,000 m^3. (FORTUM 2020a, p 35ff.)

In Finland, **spent fuel** is not reprocessed further[1], the highly radioactive nuclear waste needs to be stored safely in a final disposal. (FORTUM 2020a, p. 27)

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. This can be achieved, for example, by switching to high density storage of spent nuclear fuel in the pools of the current interim storage or by building additional pools to increase the current pool capacity. (FORTUM 2020a, p. 35)

[1] Fortum (formerly Imatran Voima) had negotiated an opportunity to repatriate the spent fuel generated at the Loviisa plants to the Soviet Union (to Russia since 1990). In 1994, the Nuclear Energy Act was amended by prohibiting the imports and exports of nuclear waste. Thus, the last consignments of spent fuel from the Loviisa plants were sent to Russia in 1996 after the transition period. (NATIONAL PROGRAMME 2015)

Later, 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. (FORTUM 2020a, p. 27) The encapsulation plant and final repository Onkalo are under construction.(FORTUM 2020a, p. 17) According to the current plans, the final disposal of spent nuclear fuel from Loviisa power plant would begin in Posiva's encapsulation plant and final disposal facility in the 2040s. (FORTUM 2020a, p. 28)

3.2 Discussion

To avoid environmental impacts proof of safe disposal of spent fuel and radioactive waste is necessary. This consists of evaluating 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 generating during the lifetime extension but has to be enlarged to accommodate further decommissioning waste.

In the Scoping 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) This should be clarified in the EIA Report.

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

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.

In the Scoping Document it is not mentioned that for the encapsulation of the spent fuel the **KBS-3 method** might be used (WNA 2020). 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.[2]. Recent research results give even more proof of copper corrosion. It should be explained how Finland will solve the corrosion problem.

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[2] 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 Conclusions and requirements for the EIA Report

The decommissioning of the NPP will result in LILW for which no capacities are available yet. These additional capacities will have to be provided in both options, VE1 or VE0.

Additional LILW and additional spent fuel will arise from lifetime extension. In the EIA Report information should be provided on timetables and alternative waste management options for the case the capacities are not available in time.

Due to new results on copper corrosion, the KBS-3 method which is to be used in the final repository for spent fuel came under criticism. It should be explained how Finland will solve the corrosion problem.

Requirements for the EIA Report

1. It is recommended to explain the timetables for the planned increase of the interim storage capacity for spent fuel.
2. The options of the capacity increasement of the spent fuel interim storage by high-density storage should be clarified.
3. Why is the storage system used for spent fuel interim storage not switched to a state-of-the-art dry storage system?
4. Which alternative options are planned for the case that the interim and the final disposal facilities for spent fuel are not available when needed?
5. Will the KBS-3 method be used despite of problematic results of copper corrosion research? How will the copper corrosion problems be solved?

4 LONG-TERM OPERATION OF REACTOR TYPE VVER440

4.1 Treatment in the EIA Scoping Documents

Loviisa nuclear power plant consists of two power plant units as well as the associated buildings and storage facilities required for the management of nuclear fuel and nuclear waste. Loviisa 1 began its commercial operation in 1977 and Loviisa 2 in 1980. The operation of Loviisa power plant ends after 50 years – when the current operating licence periods end in 2027 and 2030. In the case of the extension of the power plant operation (Option VE1), commercial operation would be extended by a maximum of approximately 20 years, making the total service life of the power plant units about 70 years. (FORTUM 2020a, p. 42)

Loviisa power plant is used for the production of **base load** electricity. In 1997, the modernisation project carried out at Loviisa power plant included power uprating, which increased the nominal thermal power of the reactors from 1,375 MW to 1,500 MW. This increased the nominal electrical power of the plant units to 488 MW. The efficiency of the power plant units has been improved several times, and the net electric power of each unit is currently 507 MW. (FORTUM 2020a, p. 26)

Extending the operation of the power plant involves certain changes that may be implemented. These may include:

- replacing some of the old buildings related to the support functions of the power plant;
- water engineering related to the intake of cooling water, and the depositing of the resulting dredging and excavation masses in a new embankment structure;
- changes to the power plant’s service water and waste water connections;
- expansion of the interim storage for spent nuclear fuel or alternatively increasing the capacity of the current interim storage. (FORTUM 2020a, p. 20)

Nuclear safety

In Finland, the requirements concerning nuclear and radiation safety of nuclear power plants are based on the provisions of the Nuclear Energy Act and Decree, which are specified in regulations issued by STUK. The most important areas of radiation and nuclear safety based on STUK’s Regulation on the Safety of a Nuclear Power Plant (Y/1/2018), the Regulation on the Emergency Arrangements of a Nuclear Power Plant (Y/2/2018) and the Regulation on the Security in the Use of Nuclear Energy (Y/3/2016). (FORTUM 2020a, p. 30)

According to the defence in depth principle, safety is ensured by means of a series of consecutive levels that are mutually redundant. The safety systems ensure the cooling of the fuel in the reactor also when the normal operating systems are unavailable. The most important safety systems are the boron feed of the primary system, emergency make-up water system and emergency cooling system, the containment spray system, emergency feed water systems and the diesel generators and automation that support their operation. (FORTUM 2020a, p. 31)

Several projects to improve nuclear safety have been implemented at Loviisa power plant throughout its operation. The safety improvements have been based, in accordance with a good safety culture, on the aim of achieving a safety level that is as high as possible, as well as the revised requirements issued by STUK. For example, several changes to improve safety have been implemented since the Fukushima accident. The changes 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 fuel for diesel machines, implementation of an alternative decay heat removal of the fuel pool, as well as the increase of the battery capacity. (FORTUM 2020a, p. 32)

In accordance with the good safety culture, safety improvements are also carried out at Loviisa power plant during the potential lifetime extension. The work is guided by the operation experience gained at Loviisa power plant and other nuclear power plants, changes to STUK's YVL Guides and technological advances. According to Fortum's estimate, the changes made to the requirements in recent years result in some new procedures in addition to those already implemented. For example, the improvement of the seismic conditions of Loviisa power plant is currently being planned.

A well-managed and professional **ageing management** and maintenance are prerequisites to ensure the safe and economical operation of a nuclear power plant. This objective can be met by continuously improving safety, availability, performance and cost-effectiveness. The systems, structures and equipment of Loviisa power plant are exposed to various stresses during operation. (FORTUM 2020a, p. 33)

Regulatory requirements concerning systems, structures and equipment, and other requirements, may change during the operation of the power plant, and the technology used may advance, meaning the systems, structures and equipment no longer meet the prevailing requirement level. These factors – in other words, the ageing of systems, structures and equipment – are prepared for in the planning phase by means of reasoned design solutions, and during operation, by monitoring and maintaining the operability of the systems, structures and equipment until they are decommissioned. Among other things, this refers to equipment test runs, quality control inspections and traditional maintenance measures, such as lubrication oil and grease changes. This helps ensure that the systems, equipment and structures function as planned. Equipment is replaced when required as a result of ageing. (FORTUM 2020a, p. 33)

Fortum has invested in the ageing management of Loviisa power plant and has carried out improvement measures throughout the operation of the power plant. Systematic maintenance and modernisations of the power plant ensure that the equipment stays abreast of the changing requirements. In 2014–2018, Loviisa power plant implemented the most extensive modernisation programme in the plant's history, in which Fortum invested approximately EUR 500 million. In recent years, extensive reforms have been carried out on the automation of the power plant, and ageing systems and equipment have been modernized. (FORTUM 2020a, p. 8)

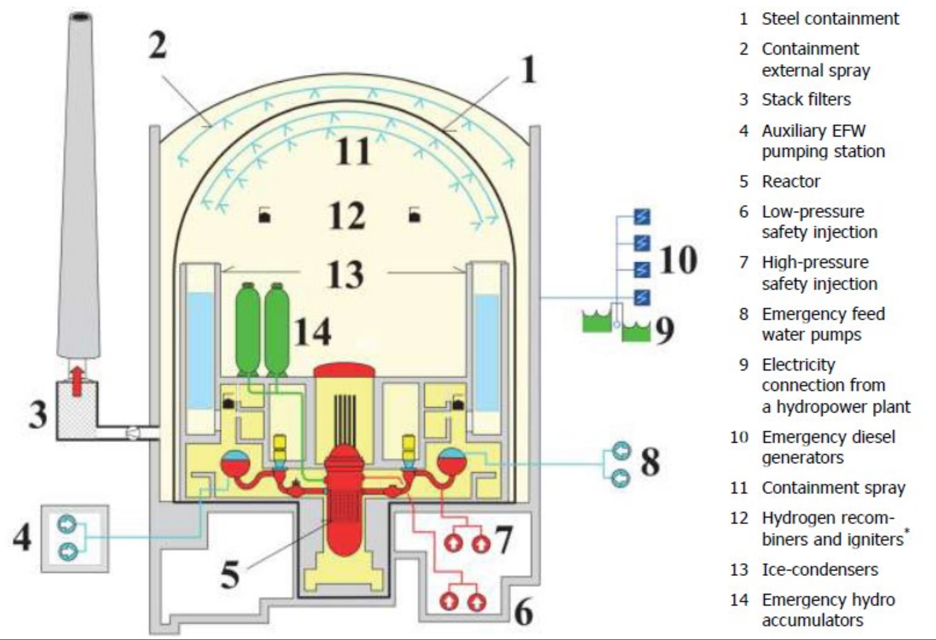
4.2 Discussion

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 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.

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.

According to the conditions of the operating licences, two periodic safety reviews are required to be carried out by the licensee (by the end of the year 2015 and 2023). STUK's assessment of the first periodic safety review was completed in February 2017. The second periodic safety review process has started in the end of 2018 and will be finalised before 2023. The project also includes the evaluation of the possibility to continue operation beyond the current operating licence, but no decision on the lifetime extension has been made yet.

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) Figure 3 shows the main layout of the Loviisa NPP.



Quelle: STUK 2011

Figure 3: Main layout and main safety systems o Loviisa NPP

Long Term Operation (LTO)

The currently envisaged lifetime extension would be the second lifetime extension. 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 in order to determine the loads and their effects on materials. (BECKER et al. 2013)

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 2014)

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.

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 underway. The utilities have encountered some challenges in complying with the new requirements. For example, inspections performed after publishing the new guide in 2013 revealed that the amount of **spare parts** can be inadequate for keeping the plant in a safe state also during prolonged transients and accidents, and that some of the spare parts in the storage have either aged or became obsolete. Another challenge had to do with knowledge and resources allocated for ensuring appropriate ageing management programme at NPPs. (STUK 2020)

The EIA Report should present the challenges in complying with the new requirements. The remaining issues and remedial measure should be explained.

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 findings from other countries and evaluates their possible applicability to the ageing management of the Finnish nuclear power plants. The observations of the STUK expert group should be presented in the EIA Report.

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, as well as good practices, were identified and Finland is establishing a national action plan to address the findings. The national action plan and its progress should be presented in the EIA Report.

In STUK (2017) the regulator’s assessment of the overall ageing management program 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. Finland has successfully applied periodic safety reviews (PSR) for the operating NPPs. The licensees are obliged to demonstrate that the safety of the operations can be ensured and improved also 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)

Ageing management of the reactor pressure vessel

The **reactor pressure vessel** (RPV) and its internals are the most stressed components in 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.

There is one ageing management issue of the Loviisa NPP that 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 and the thermal annealing of the core area weld of Loviisa 1 RPV in 1996. 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 reactor pressure vessel 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. In the recent deterministic analyses (used in PSR 2015) the deterministic embrittlement temperature margin was decreased because of the changes in Loviisa I&C renewal project.

The embrittlement temperature margins were enough for the Loviisa 1 but for Loviisa 2 very close to the approval limit. 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 (planned to implement in 2019). The licensee also continues the investigation of the opportunities to isolate the RPV's core area weld seam outer surface. The licensee will update the probabilistic and the deterministic embrittlement analyses before the next PSR 2023 so the influence of the corrective actions can be identified then. (STUK 2017b) The very important safety issue of the embrittlement of the RPVs should be presented in the EIA Report.

Furthermore, an indication has been detected in a **low-pressure safety injection (TH) nozzle** of Loviisa 1 RPV. It may become an ageing management issue if new indications will be detected in other nozzles of same kind in future inspections. However, it is also possible that the existing indication proves out to be a manufacturing defect. (STUK 2017a) The results of the inspections of all nozzles as well as envisaged remedial measures should be presented 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.

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.

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. For systems and components in the primary circuit, especially high-quality standards are required to prevent loss of coolant and consequent loss of function. Testing and documentation of material properties must be carried out during manufacturing processes and installation. The absence of this approach cannot be fully compensated subsequently. Good practice is to exchange the 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.

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.

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:

- Plant leadership should improve communications on their expectations and consistently reinforce the implementation in the field.
- 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 2018)

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. This is relevant for lifetime extension. The findings as well as the remedial plan should be presented in the EIA Report.

It is good practice that different IAEA Peer Review Missions take place regularly. The resulting recommendation and suggestions should be remedied in a timely manner. It is very important that the whole procedure will be performed in a transparent procedure. The following IAEA Peer Review is also important in regard of 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 done for the Loviisa NPP so far.

Operational events and operating experience feedback

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 did not entirely share the Fortum's view on the nature of two events. The view differences will be discussed between STUK and the licensee. In one case, STUK submitted its own observations to be taken into account in the more extensive investigation launched by Fortum. STUK inspected the effects of event investigations in 2018 because deviations relating to the same area had occurred. STUK concluded, based on the inspection, 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 improve learning from their operating experience. STUK also intensified regulatory oversight with regard to this topic and continued it for the whole year of 2019. (STUK 2020)

The EIA Report should present an evaluation of safety relevant events including the lessons learned.

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, a risk assessment of a nuclear power plant has to consider the design base including the operational experience of all other comparable plants. The concerns are growing due to the Fukushima accident, as it revealed that there could be basic safety problems with the old units, whose design was prepared back in the sixties or seventies. (BECKER et al. 2013)

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 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 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) The EIA Report should list all shared safety and SAM systems.

According to FORTUM (2020), life-time extension involves certain changes that may be implemented. The EIA Report should explain which changes are planned in the context of the envisaged lifetime extension.

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 RLs compared to 295 in the 2008 list has been endorsed by WENRA accompanied by a related WENRA statement. (WENRA RHWG 2014)

The i**ssue F (Design Extension of Existing Reactors)** was revisited, 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 (IAEA 2012).

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)

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.

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.

WENRA Safety Objectives for New Reactors

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

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.

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 enough time to implement 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 are mainly substantial design improvements of the containment.

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)

The document "Practical Elimination Applied to New NPP designs – Key Elements and Expectations" has been published last year (WENRA RHWG 2019)

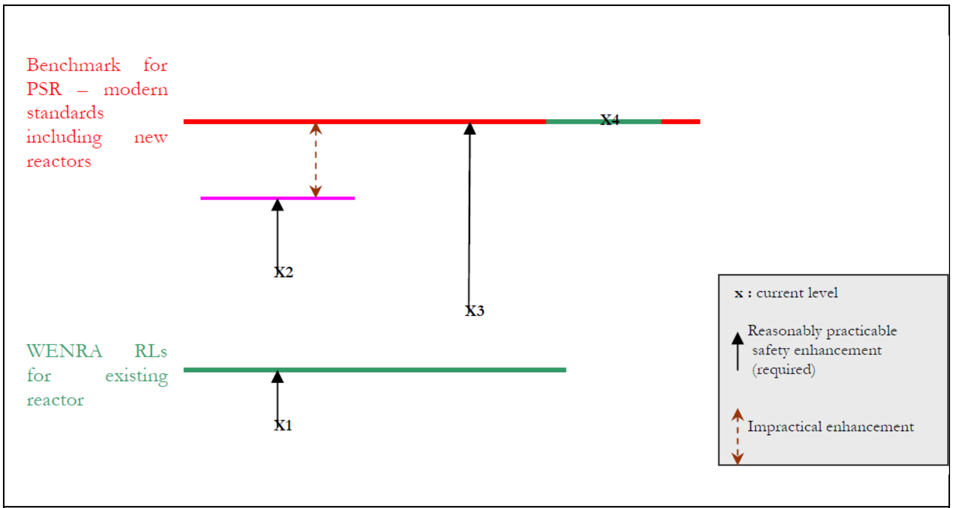
The EIA Report should present all envisaged measures for lifetime extension to come as close as reasonably practicable to meet the safety objective O3 (accidents with core melt).

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 are the main tool to reduce the gap between the safety standards of old and new power plants. The objectives of these reviews are the new standards. 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)



Quelle: WENRA RHWG 2011 umweltbundesamt

Figure 4: Diagram to illustrate the process of comparing existing reactors with modern standards

As for the horizontal lines:

- The green (lower) line represents WENRA SRLs, and the "X" represent illustrative levels for a variety of safety issue;
- The red (upper) line represents modern standards, including but not restricted to WENRA's new safety objectives, and is the bench mark for comparison in a PSR;
- The green and red lines may in some cases 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 there may be no identifiable reasonably practicable options for enhancement;
- The "X4" represents these cases where the existing situation is already meeting the modern standard.

The EIA document 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.

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 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.

The EIA Report should present all improvements to meet modern safety requirements that considered not "reasonably practicable" at the Loviisa NPP.

4.3 Conclusions and requirements for the EIA Report

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. 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.

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.

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, some challenges and areas for improvement were identified and Finland is establishing a national action plan to address the findings.

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 RPV and the risk of RPV brittle fracture. 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. The very important safety issue of the embrittlement of the RPVs should be presented 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 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.

According to Fortum (2020), life-time extension involves certain changes that may be implemented.

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 making a decision how new or revised regulatory guide is applied for operating nuclear facility, STUK can approve an exemption if the safety improvement is considered 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 to lower the risk further should be implemented.

Requirements for the EIA Report

1. Regarding the ageing management program, the following issues should be presented in the EIA Report:
   a. The challenges in complying with the new aging management requirements. The remaining issues and remedial measure should be explained.
   b. The observations of the STUK ageing management expert group.
   c. The national action plan relating to the Topical Peer Review (TPR) “Ageing Management” under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
   d. The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins
   e. The results of the inspections of all nozzles of the RPV as well as envisaged remedial measures.
   f. Evaluation of the conditions of the RPV internals and head penetrations including trends of events, and envisaged exchange measures.
   g. Evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.
2. The findings of the OSART missions as well as the remedial plan should be presented in the EIA Report.
3. Regarding operation experience, the EIA Report should present an evaluation of safety relevant events including the lessons learned.
4. The EIA Report should present all improvements to meet modern safety requirements considered not “reasonably practicable” at the Loviisa NPP.
5. The EIA Report should list all shared safety and shared Severe Accident Management (SAM) systems of the units.
6. The EIA Report should explain which design changes are planned in the context of the envisaged lifetime extension.
7. 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.
8. 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.
9. 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 (accident without core melt).
10. 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).

11. 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:
    a. All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
    b. Incompleteness of the database and plant documentation used.
    c. Presentation of all safety assessments or parameter definitions by personal expert assessments (“engineering judgement”).
    d. Presentation of the general dealing of uncertainties and non-knowledge and its effects on risk
    e. Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
    f. The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.
12. The EIA should also include the following general information:
    a. Technical description of the plant
    b. detailed descriptions of the safety systems, including information on requirements for the important safety-relevant systems and components
    c. detailed description of the measures taken to control severe accidents or to mitigate their consequences.

5 ACCIDENT ANALYSIS

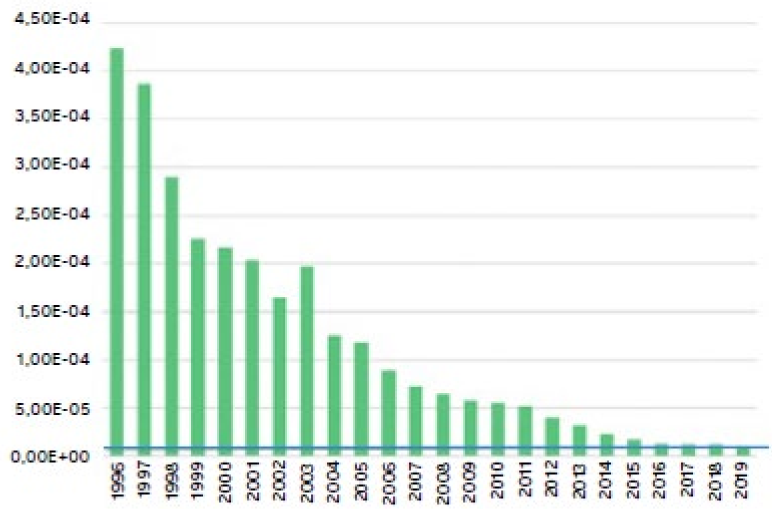
5.1 Treatment in the EIA Scoping Documents

A nuclear power plant should be prepared for a severe reactor accident. A severe reactor accident refers to an accident in which the fuel in the reactor is considerably damaged. Although such an accident is highly unlikely, Loviisa power plant is equipped with systems intended to manage a severe reactor accident. These systems are used to ensure that no radioactive substances are released from the power plant to the extent that they would cause serious harm to the environment. (FORTUM 2020a, p. 31)

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. The impact of the dispersion of the release in the accident is studied over a distance of 1,000 km from the power plant. (FORTUM 2020a, p. 79)

The combined impacts of the project functions with other functions and projects in the vicinity are assessed by impact area in the EIA Report. In addition, the report describes the impact of the associated projects on the basis of existing published environmental impact assessments. These include Posiva's encapsulation plant and final disposal facility for spent nuclear fuel and the potential organisation of waste management related to the decommissioning of the FiR 1 research reactor. (FORTUM 2020a, p. 79)

The probabilistic risk assessment (PRA) of the nuclear power plant is an analytical method referred to in the requirement. In accordance with STUK's Guide YVL A.7, the design of a nuclear power plant unit shall be such that the mean value of the frequency of reactor core damage is less than 10^{-5}/year. Figure 5 shows the frequency of considerable reactor core damage and the nuclear fuel damage of spent fuel in the fuel pools in Loviisa nuclear power plant, assessed by means of the PRA for 1996–2019. Over the course of the past 20 years, the frequency has decreased considerably, in other words, the safety level of the NPP has improved as a result of the safety-improving modifications. (FORTUM 2020a, p. 32)



Quelle: FORTUM 2020a, p. 27

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

Loviisa lies on the coast of the Gulf of Finland, approximately 90 km east of Helsinki. In 2018, Loviisa had approximately 15,000 inhabitants. Loviisa nuclear power plant is located approximately 12 km from the centre of the town of Loviisa, on the island of Hästholmen. (FORTUM 2020a, p. 67)

Seawater is used for various cooling requirements at Loviisa power plant. The cooling water for the power plant is taken from Hudöfjärden on the west side of the island of Hästholmen, using an onshore intake system, and the warmed cooling water is discharged back into the sea at Hästholmsfjärden, on the east side of the island. The cooling water intake is located at an approximate depth of 8.5–11 metres. The volume of cooling water used by Loviisa power plant is an average of 44 m^3/s. (FORTUM 2020a, p. 27)

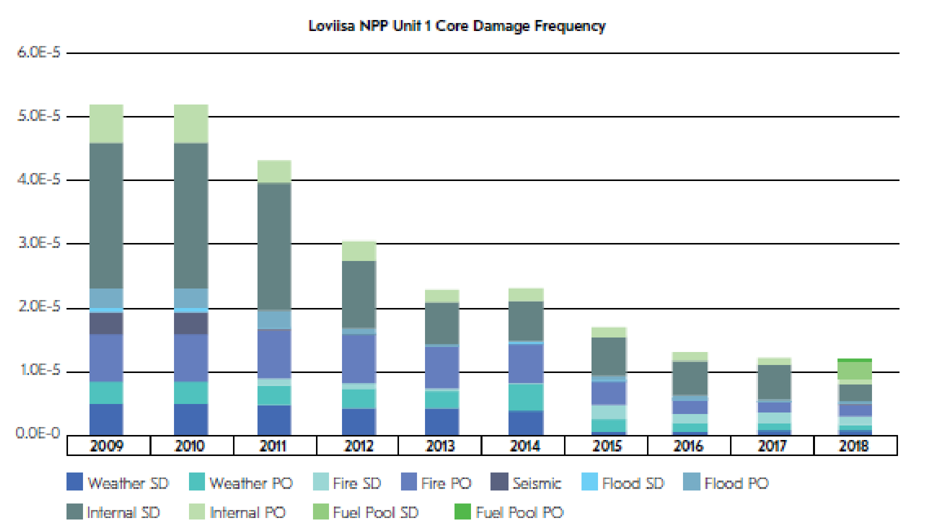
5.2 Discussion

Probabilistic risk assessment of Loviisa NPP

The first Level 1 internal events PRA Fortum made available in 1989. Since 1990 Fortum has extended the PRA with 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 systems and a major modernisation programme in mid 1990ies. Thus, the core damage frequency (CDF) decreased. (STUK 2019a)

The development of the core damage frequency since 2008 is shown in Figure 6. 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.

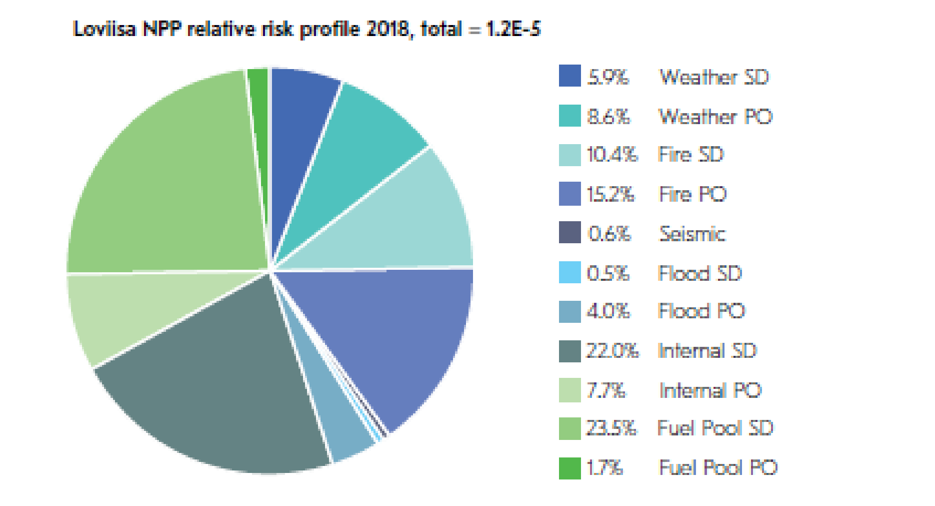
Figure 6: Development of core damage frequency (CDF) of Loviisa unit 1



Quelle: STUK 2019a

For unit 1 the relative contribution to the annual CDF from different groups of initiating events is shown in Figure 7Figure 7.

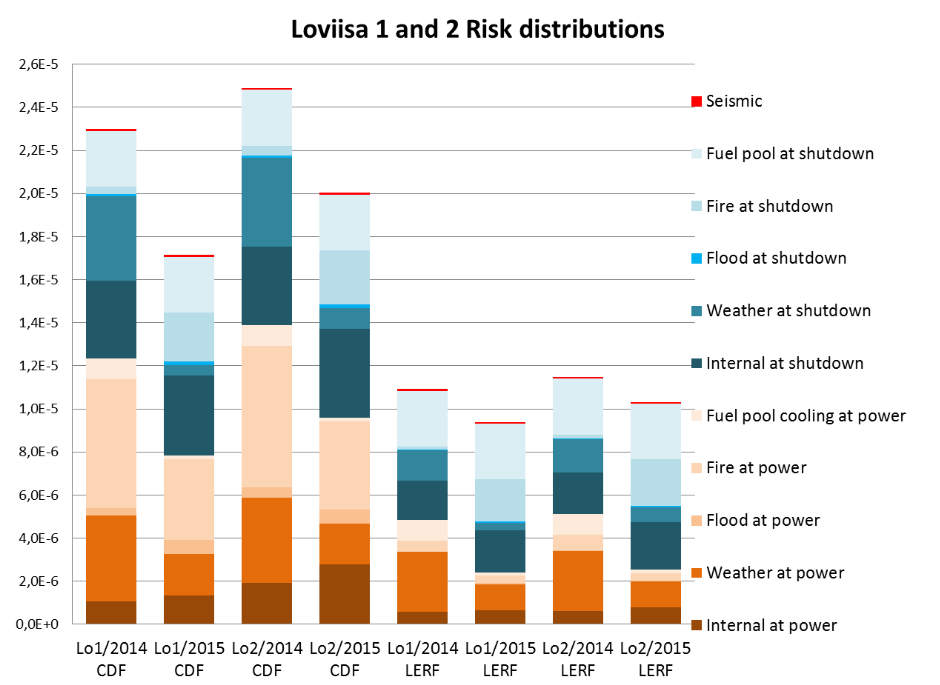
Figure 7: Relative contribution of different initiating event types to the annual core damage frequency in 2018 for Loviisa NPP unit 1. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".



Quelle: STUK 2019b

At shutdown (SD) the most significant initiating events are drop of heavy loads and various fire events. (STUK 2019a) *Note: Initially the design and the lay-out design of the Loviisa plant did not adequately taken 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 essentially improved. But the protection against fire remains an issue.*

The following figure illustrate the risk reduction in 2015 compared to 2014.



Quelle: Jänkälä 2016

Figure 8: The effects of the risk reductions per year in 2015

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)

The frequency of large releases for the Loviisa NPP is above the limits set in STUK's regulatory guide YVL A.7. (STUK 2019b)

Guide YVL A.7 states that a nuclear power plant unit shall be designed in a way that:

- the mean value of the frequency of a release of radioactive substances from the plant during an accident involving a Cs-137 release into the atmosphere in excess of 100 TBq is less than $5 \cdot 10^{-7}$/year;
- the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency. (STUK 2019a)

According to STUK (2019b), 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. 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 by 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.

The most ambitious safety objective for new NPPs is the reduction of potential radioactive releases to the environment from accidents with core melt. 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”*. 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)

The overall SAM approach at 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.

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. A filtered venting system was not seen as feasible for Loviisa NPP, since steel shell containments are vulnerable to pressures, which may arise after large amounts of non-condensable gases have escaped the containment.(STUK 2019b).

There are different approaches for cooling and stabilizing molten core 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. Early actions are included in the EOPs and they are checked when entering the SAM Guidelines.

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 still continues, to reduce the probability and safety significance of these sequences.
- 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 in order 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.

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.

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.

The licensee has also planned to install additional water injection capabilities into the pools in both spent fuel buildings and in the in-containment pool. Water injection will be provided through new internal connections or mobile water injection systems in order to recover the loss of water from the pools. However, using mobile devices was not evaluated as being necessary once the other plant improvements are implemented. The project for mobile devices was terminated in 2017. (STUK 2019b)

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:

To 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. 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.

To 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. During the storage time of the spent fuel the shorter-lived radionuclides are reduced, in particular the highly volatile iodine-131. However, the inventory of the relevant radionuclide caesium-137 remains high. 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)

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.

In Finland, generally, it is required that external events considered shall include exceptional weather conditions, seismic events, man-made hazards etc. The licensee/applicant shall justify the conditions or events and their frequencies in detail. External events and conditions with an estimated frequency of occurrence less than 10^{-5}/year shall be considered as DEC C.

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, 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)

At the Loviisa site there is no 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 level 2 PSA and therefore there is no confirmation on the sufficient operability of these systems after an earthquake. (STUK 2019b)

The current seismic hazard evaluation should be presented in the EIA Report. It should be explaining the safety margins of the design and all safety and SAM systems, cliff-edge effects and envisaged improvement measure for the lifetime extension.

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, by implementing 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 as 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 less than 10^{-8}/year.

The plant is more vulnerable to high seawater level 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)

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.

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, increases in 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.

In addition, the regulatory body required the licensee to reassess the present design basis and protection regarding the impacts of extreme high and cold air temperature on plant safety systems including their auxiliary systems. (STUK 2011)

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.

5.3 Conclusions and requirements for the EIA Report

The calculated frequency of large releases of the Loviisa NPP is above the limits set in STUK's regulatory guide YVL A.7. Therefore, the accident analyses in the EIA Report 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.

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. 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.

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 plant is more vulnerable to high seawater levels if one of the plant's units is in cold shutdown and the seawater system has been opened for maintenance.

Requirements for the EIA Report

In the context of accident analyses, the EIA Report should contain the following information in order to be able to assess in a comprehensible way if Austria is potentially affected:

1. Results of the current PSA analyses (levels 1, 2 and 3):
   a. frequencies for core damage (CDF) and severe accidents with (early) large releases (LRF or LERF);
   b. information on the contributions of internal and external events to CDF, LRF and LERF;
   c. information on the most important accident scenarios including accidents from the fuel pool;
   d. detailed presentation of the measures taken to control severe accidents or to mitigate their consequences;
2. Comprehensible presentation of the dispersion calculations and the determination of radiation doses for incidents and accidents:
   a. information on the methods and programmes chosen for the dispersion calculations;
   b. information on the input parameters used for the dispersion calculations (source term, release level and duration, meteorological data) and their justification;
   c. information on the results of the dispersion calculations in the form of radiation doses and soil contamination (in particular of the nuclides Cs-137 and I-131);
   d. presentation of the probability distribution of the results, not only information of the calculated mean values.
3. The EIA Report should explain how the safety issues of the in-vessel retention concept that could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) are solved.

4. 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.
5. 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.
6. The current evaluation of the flooding hazard has to be presented in the EIA Report. It should include safety margins, cliff-edge effects and envisaged improvement measures for the lifetime extension.
7. 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.

6 ACCIDENTS WITH INVOLVEMENT OF THIRD PARTIES

6.1 Treatment in the EIA Scoping Documents

Security arrangements refer to advance preparations for a threat of illegal activity directed against the nuclear power plant or its operations. Nuclear energy legislation sets requirements for the security arrangements of a nuclear power plant. STUK has set detailed requirements concerning the security arrangements in the YVL Guidelines and in STUK regulations (Y/3/2016). (FORTUM 2020a, p. 30)

The security organisation of Loviisa power plant, which comprises persons trained for the tasks, has at its disposal the appropriate premises, communications connections and equipment. 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. (FORTUM 2020a, p. 32)

6.2 Discussion

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 minor radiological impact as defined in the Safety Objective O2 for new nuclear power plants. (WENRA RHWG 2013)

According to STUK, it is stated that 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.

6.3 Conclusions and requirements for the EIA Report

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.

Requirements for the EIA Report

1. 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 Scoping Documents

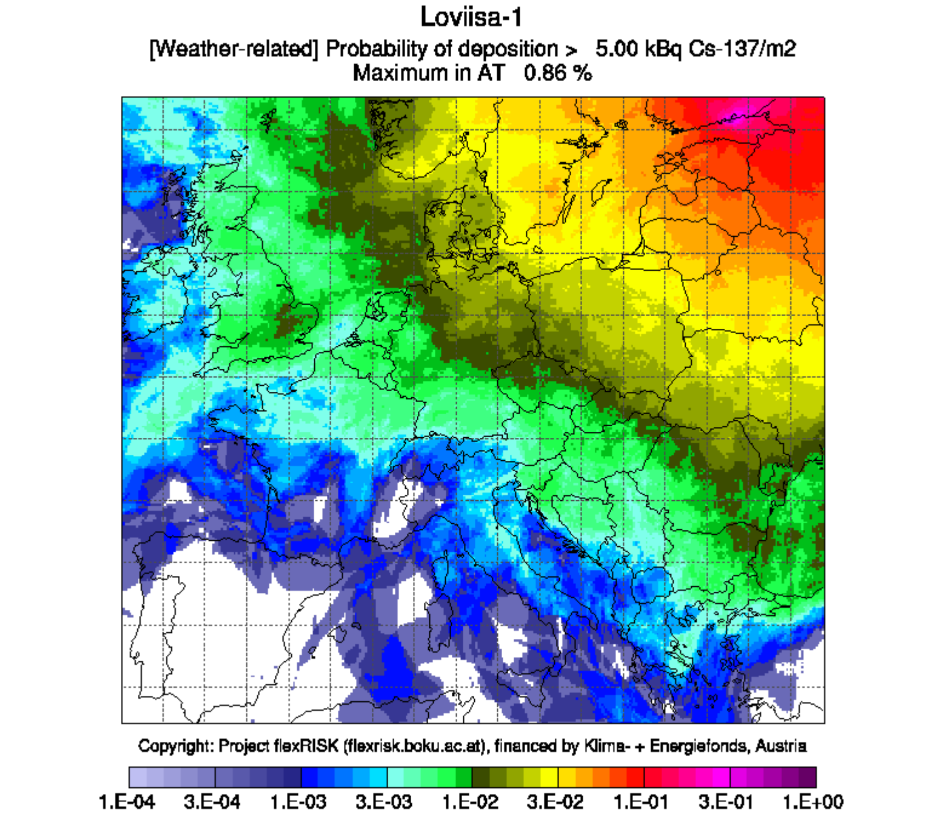
According to a preliminary assessment which reviewed the options in the EIA procedure, the only transboundary impact would be the release of radioactive substances from a severe reactor accident during the power plant's life-extended operation (option VE1). No transboundary impacts have been identified with regard to decommissioning (VE0 and VE0+).

The EIA Report will include the assessment of a severe reactor accident. This assessment will be based on a source term of 100 TBq Cs-137. This is corresponding to the limit value of a severe accident in accordance with section 22 b of the Nuclear Energy Decree 161/1988. The impact of the dispersion of the release in the accident is examined over a distance of1,000 km from the power plant. (FORTUM 2020a, p.79)

7.2 Discussion

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 for Loviisa-1 and 2 31.5 PBq Cs-137, each. In flexRISK, dispersion calculations were made for Europe, without 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.



Quelle: flexRISK

Figure 9: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m2

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 triggers 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:

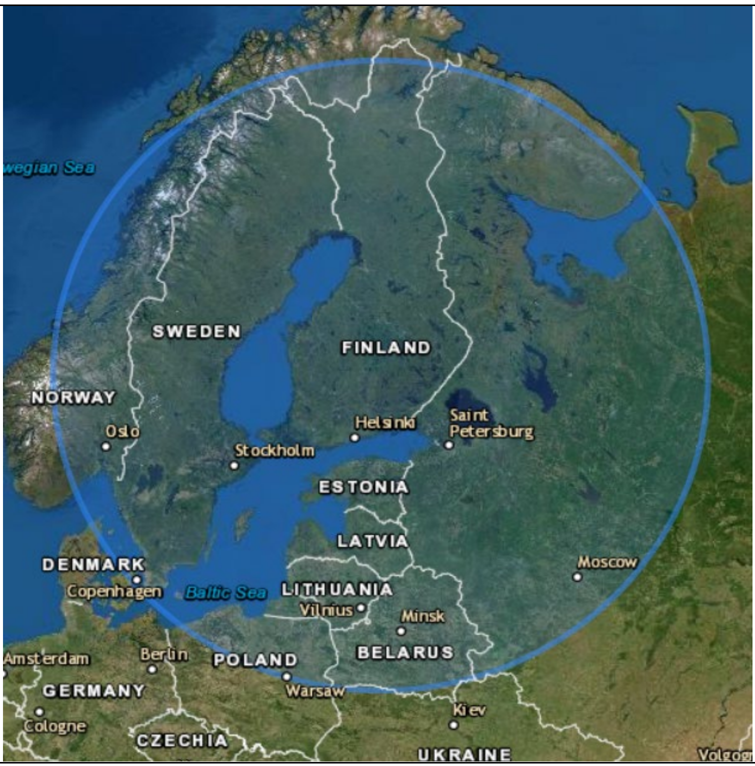
Table 1: Levels for the agricultural countermeasures A07 (BMLFUW 2014)

	I-131 Bq*h/m^3	**I-131 Bq/m^2**	**Cs-137 Bq*h/m^3**	**Cs-137 Bq/m^2**
Start of measure A07	170	700	350	650

A contamination of 5 kBq Cs-137/m^2 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 following figure shows a 1,000 km radius around the Loviisa site.

Figure 10: 1,000 km radius around Loviisa



Quelle: Google Maps umweltbundesamt

This circle clearly does not cover Austria. To exclude the possibility of trans-boundary severe impacts, including the necessity of agricultural countermeasures, dispersion calculations should be 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[3] (BMK 2020).

Also proof has to 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 are necessary.

[3] The criteria for intervention measures in the new Austrian Emergency Plan (BMK 2020) are the same as in the former Intervention Regulation (IntV 2017, attachment 1). In the new Intervention Regulation (IntV 2020) the values are no longer published, but a reference is made to the Austrian Emergency Plan. The Austrian Emergency Plan will be available online by end of 2020. The link to IntV (2017) is documented in the References (chapter 9).

7.3 Conclusions and requirements for the EIA Report

A severe accident with releases reaching Austrian territory can lead to significant trans-boundary impacts on Austria. In the EIA Report an accident will be calculated with a source term of 100 TBq Cs-137, dispersion calculations will be made up to a distance of 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.

Requirements for the EIA Report

1. It would be welcomed if dispersion calculations for severe accidents would cover Austrian territory.
2. It would be welcomed if the dispersion calculation results would be provided to be comparable with the Austrian catalogue of countermeasures (BMLFUW 2014, see also table Table 1: Levels for the agricultural countermeasures A07 (BMLFUW 2014), and also with the Austrian Emergency Plan (BMK 2020, INTV 2017).
3. Proof has to 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.

8 REQUIREMENTS FOR THE EIA REPORT

8.1 Overall and procedural aspects of the Environmental Impact Assessment

Requirements for the EIA Report

1. In the EIA Report, the maximum years of lifetime extension should be clearly stated.
2. The date when Fortum will take the decision for one of the options should be stated.
3. For assessing alternative options it is recommended to include scenarios of future electricity demand in Finland, together with energy efficiency and saving measures and other electricity generating options.

8.2 Spent fuel and radioactive waste

Requirements for the EIA Report

1. It is recommended to explain the timetables for the planned increase of the interim storage capacity for spent fuel.
2. The options of the capacity increasement of the spent fuel interim storage by high-density storage should be clarified.
3. Why is the storage system used for spent fuel interim storage not switched to a state-of-the-art dry storage system?
4. Which alternative options are planned for the case that the interim and the final disposal facilities for spent fuel are not available when needed?
5. Will the KBS-3 method be used despite of problematic results of copper corrosion research? How will the copper corrosion problems be solved?

8.3 Long-term operation of reactor type VVER440

Requirements for the EIA Report

1. Regarding the ageing management program, the following issues should be presented in the EIA Report:
   a. The challenges in complying with the new aging management requirements. The remaining issues and remedial measure should be explained.
   b. The observations of the STUK ageing management expert group.
   c. The national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
   d. The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins
   e. The results of the inspections of all nozzles of the RPV as well as envisaged remedial measures.

   f. Evaluation of the conditions of the RPV internals and head penetrations including trends of events, and envisaged exchange measures.
   g. Evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.
2. The findings of the OSART missions as well as the remedial plan should be presented in the EIA Report.
3. Regarding operation experience, the EIA Report should present an evaluation of safety relevant events including the lessons learned.
4. The EIA Report should present all improvements to meet modern safety requirements considered not “reasonably practicable” at the Loviisa NPP.
5. The EIA Report should list all shared safety and shared Severe Accident Management (SAM) systems of the units.
6. The EIA Report should explain which design changes are planned in the context of the envisaged lifetime extension.
7. 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.
8. 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.
9. 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 (accident without core melt).
10. 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).
11. 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:
   a. All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
   b. Incompleteness of the database and plant documentation used.
   c. Presentation of all safety assessments or parameter definitions by personal expert assessments (“engineering judgement”).
   d. Presentation of the general dealing of uncertainties and non-knowledge and its effects on risk
   e. Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
   f. The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.
12. The EIA should also include the following general information:
   a. Technical description of the plant
   b. detailed descriptions of the safety systems, including information on requirements for the important safety-relevant systems and components

   c. detailed description of the measures taken to control severe accidents or to mitigate their consequences.

8.4 Accident analysis

Requirements for the EIA Report

In the context of accident analyses, the EIA Report should contain the following information in order to be able to assess in a comprehensible way if Austria is potentially affected:

1. Results of the current PSA analyses (levels 1, 2 and 3):
   a. frequencies for core damage (CDF) and severe accidents with (early) large releases (LRF or LERF);
   b. information on the contributions of internal and external events to CDF, LRF and LERF;
   c. information on the most important accident scenarios including accidents from the fuel pool;
   d. detailed presentation of the measures taken to control severe accidents or to mitigate their consequences;
2. Comprehensible presentation of the dispersion calculations and the determination of radiation doses for incidents and accidents:
   a. information on the methods and programmes chosen for the dispersion calculations;
   b. information on the input parameters used for the dispersion calculations (source term, release level and duration, meteorological data) and their justification;
   c. information on the results of the dispersion calculations in the form of radiation doses and soil contamination (in particular of the nuclides Cs-137 and I-131);
   d. presentation of the probability distribution of the results, not only information of the calculated mean values.
3. The EIA Report should explain how the safety issues of the in-vessel retention concept that could endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) are solved.
4. 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.
5. 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.

6. The current evaluation of the flooding hazard has to be presented in the EIA Report. It should include safety margins, cliff-edge effects and envisaged improvement measures for the lifetime extension.
7. 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.

8.5 Accidents with involvement of third parties

Requirements for the EIA Report

1. 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

Requirements for the EIA Report

1. It would be welcomed if dispersion calculations for severe accidents would cover Austrian territory.
2. It would be welcomed if the dispersion calculation results would be provided to be comparable with the Austrian catalogue of countermeasures (BMLFUW 2014, see also table Table 1: Levels for the agricultural countermeasures A07 (BMLFUW 2014), and also with the Austrian Emergency Plan (BMK 2020, INTV 2017).
3. Proof has to 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.

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12 GLOSSARY

AMP .... Ageing Management Programme

Bq .... Becquerel

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 Value

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

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

LOCA .... Loss of Coolant Accident

LRF .... Large Release Frequency

NPP .... Nuclear Power Plant

NTI .... Nuclear Threat Initiative

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

TBq .... Tera-Becquerel, E12 Bq

TPR .... Topical Peer Review

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

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