OVERVIEW OVER AGING-RELATED SAFETY HAZARDS OF THE NPP LOVIISA UNITS 1 AND 2

EIA procedure for the lifetime extension Loviisa 1&2, Finland

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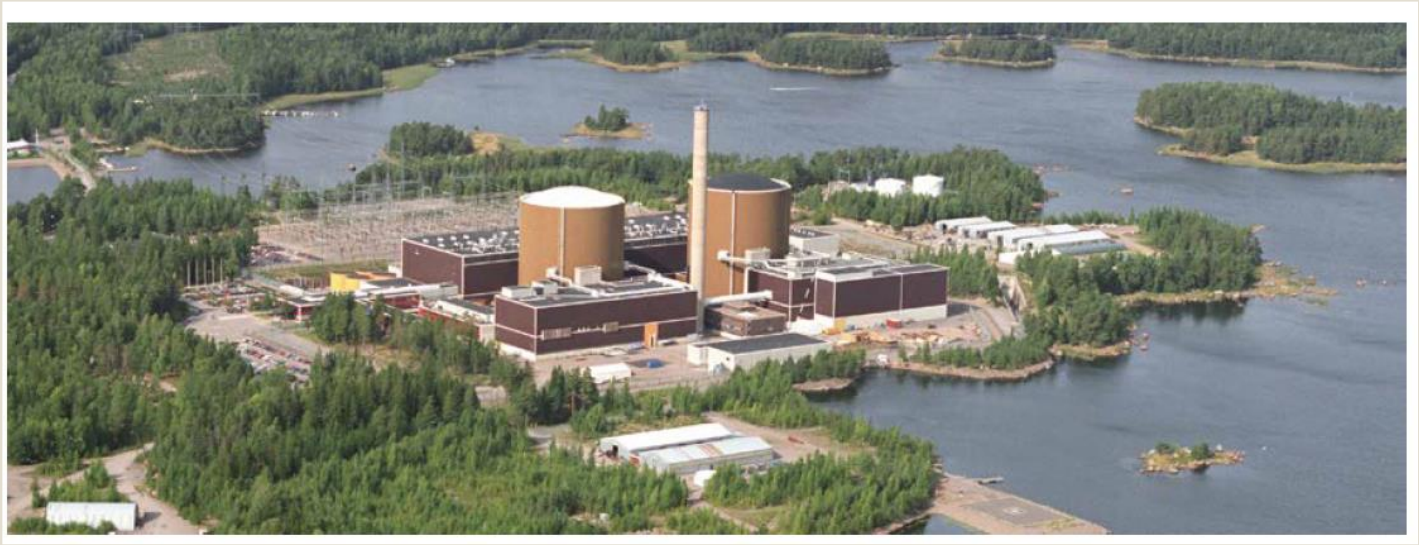


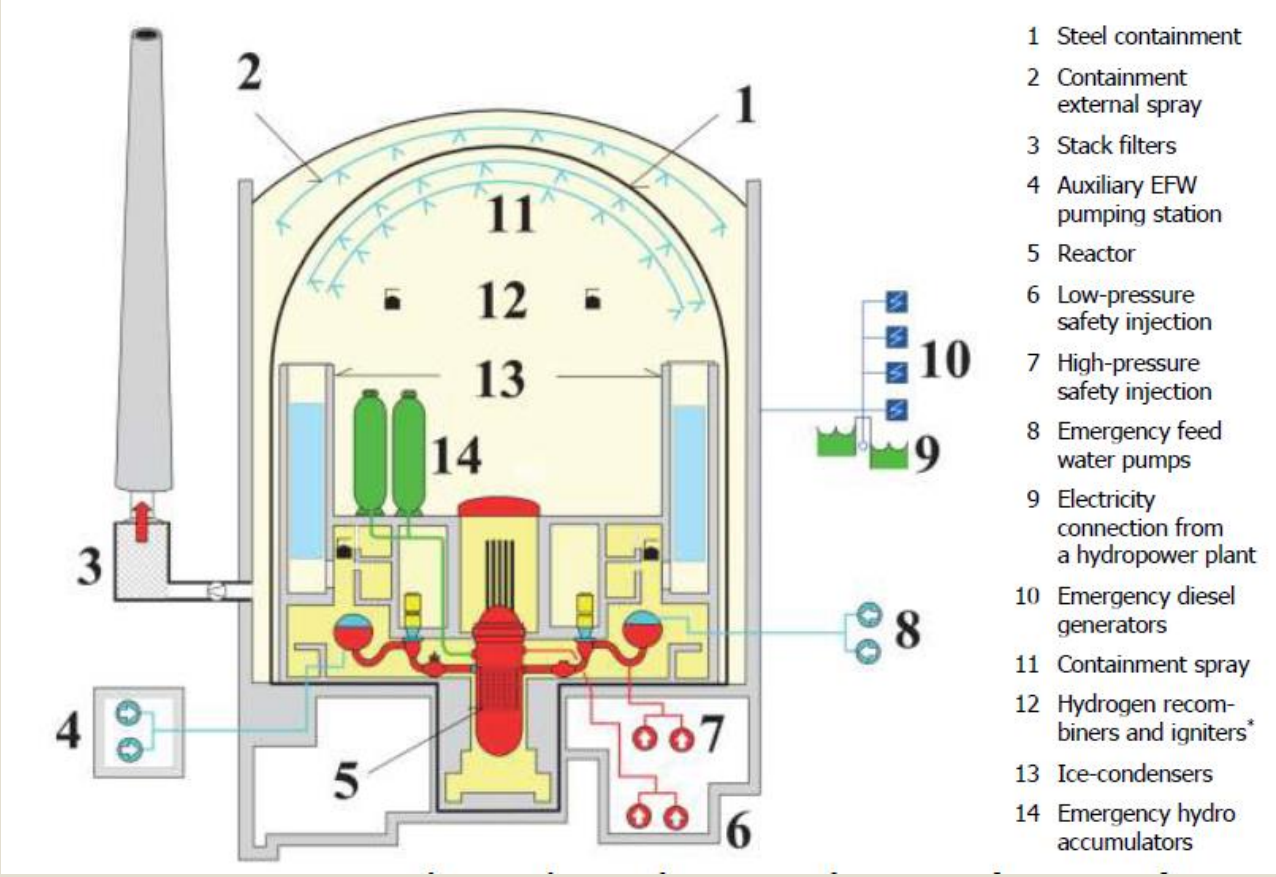
INTRODUCTION

Introduction

- Loviisa NPP is the first nuclear power plant in Finland.
- The power plant has two units operate since February 1977 and November 1980.
- Originally design life-time 30 years, prolonged to 50 years in 2007
- Now: Second lifetime extension to 70 years planned

- First time for an Environmental Impact Assessment (EIA) procedure for lifetime extension

REACTOR TYPE



Source: STUK: European Stress Tests for Nuclear Power Plants, National Report FINLAND; 3/0600/2011; Tomi Routamo (ed.) Radiation and Nuclear Safety Authority; December 30, 2011

Reactor type

- The units are Russian designed VVER-440 type pressurized water reactors (PWR) (turbines, generators and other main components are of eastern origin).
- The VVER-440/V-213 reactor design suffers design problems.
- To overcome major shortcomings of the design, both Finnish VVER-440/V-213 reactors are equipped with Western-type containment and control systems. The steel containment and its related ice condensers were manufactured using Westinghouse licenses.
- However, the VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems, increases the risk of common-cause failures affecting the safety of both reactors at the same time.

Reactor type

Loviisa 1 and Loviisa 2 are the oldest operating units of this reactor type.

Reactor unit	Country	Start of construction	Start of operation
Loviisa 1	Finland	01.05.1971	09.05.1977
Loviisa 2	Finland	01.08.1972	05.01.1981
Rovno-1	Ukraine	01.08.1973	22.09.1981
Rovno-2	Ukraine	01.10.1973	29.07.1982
Dukovany-1	Czech Republic	01.01.1979	03.05.1985
Dukovany-2	Czech Republic	01.01.1979	21.03.1986
Dukovany-3	Czech Republic	01.03.1979	20.12.1986
Dukovany-4	Czech Republic	01.03.1979	19.07.1987
Paks-1	Hungary	01.08.1974	10.08.1983
Paks-2	Hungary	01.08.1974	14.11.1984
Paks-3	Hungary	01.10.1979	01.12.1986
Paks-4	Hungary	01.10.1979	01.11.1987
Kola-3	Russia	01.04.1977	03.12.1982
Kola-4	Russia	01.08.1976	06.12.1984
Bohunice-3	Slovakia	01.12.1976	14.02.1985
Bohunice-4	Slovakia	01.12.1976	18.12.1985
Mochovce-1	Slovakia	13.10.1983	29.10.1998
Mochovce-2	Slovakia	13.10.1983	11.04.2000

PHYSICAL AGEING

Physical Aging

- Physical aging, degradation of structures, systems and components (SSC), increases the risk for abnormal operational occurrences and accidents.
- Aging management program (AMP) works only well with known aging mechanisms and accessible and replaceable SSCs
- However,
  - *some components cannot be replaced (example: reactor pressure vessel RPV),*
  - *some components are difficult to access (example: piping in concrete),*
  - *not all aging effects are known*
- Moreover, due to the economic situation operators intend to avoid comprehensive checks and maintenance.
- Additionally, now long-lasting heat waves can lead to unexpected acceleration of ageing processes
- **Thus, all in all ageing effects threaten the safety of old NPPs**

Ageing management of RPVs

- There is one ageing management issue that has over the years required significant amount of work and attention from the licensees and STUK as well:
- **Irradiation embrittlement** of Loviisa reactor pressure vessel (RPVs)
- Thermal Annealing has been done for Loviisa 1 in 1996, but not for Loviisa 2.
- In the recent deterministic analyses, the embrittlement temperature margins were sufficient for the Loviisa 1 but not for Loviisa 2
- STUK: 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.
- ENSREG criticized: Comprehensive non-destructive examination (NDE) is not performed in the base material of the beltline region in order to detect defects

OSART Missions 2018/2020

- 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.
- OSART missions aim to improve operational safety by objectively assessing safety performance using IAEA safety standards
- A number of proposals for improvements in operational safety were recommended by the team in 2018. The following problem of ageing management was highlighted, which had still not been solved in 2020:
  - *The plant should improve the control and implementation of maintenance activities and procedures to ensure safe and reliable performance of systems and equipment.*

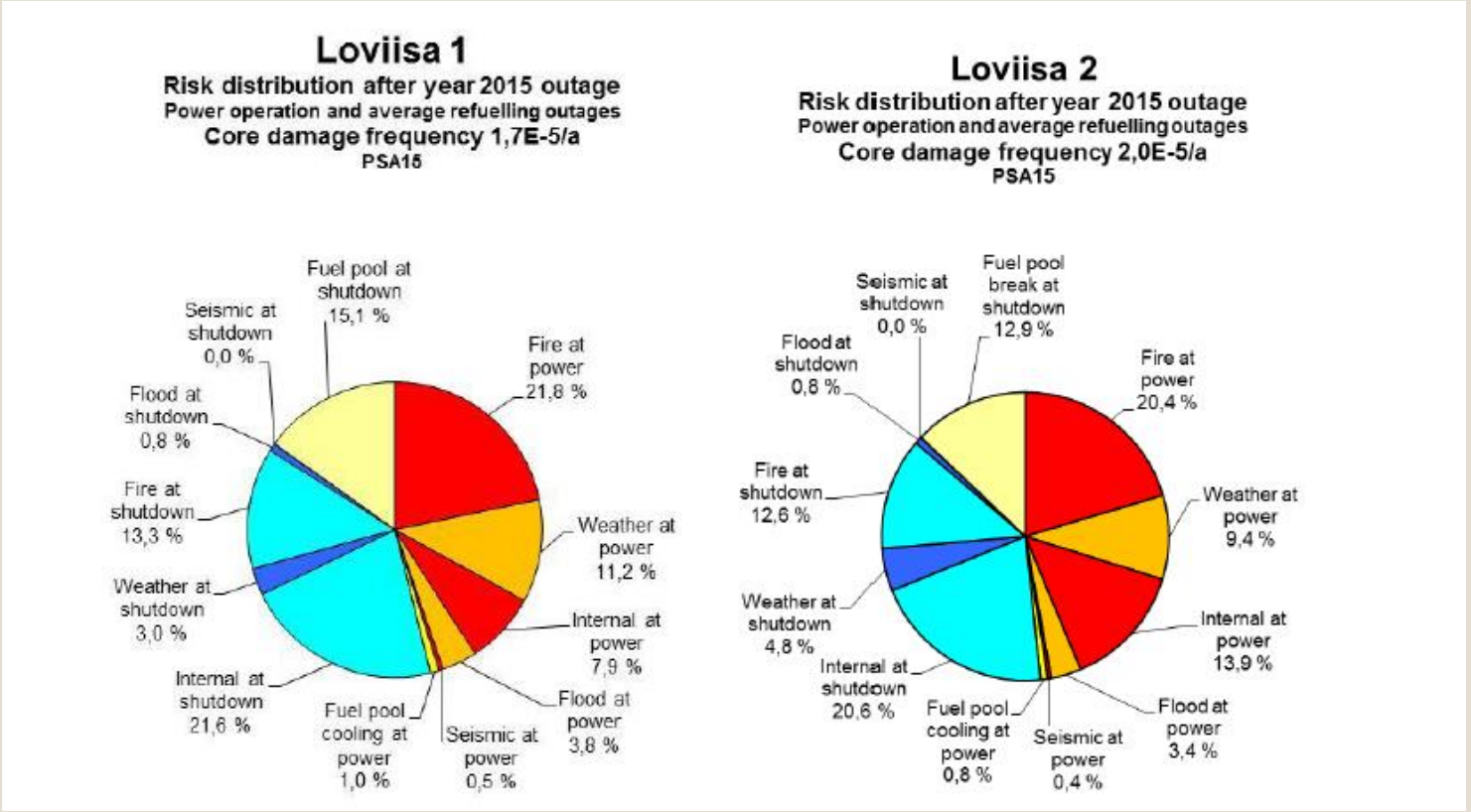
OBSOLESCENCE

Obsolescence (Conceptual/Technological Ageing)

- Safety design of NPPs is very important to prevent as well as to deal with accidents.
- 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 of the last century.
- Their safety design is outdated and showing deficiencies, which cannot be resolved by performing back-fitting measures.
- There are less requirements for redundancy, diversity, physical separation of safety systems; for protection against external hazards and to manage a core melt accidents.
- Therefore, compared to current safety standards, the probability of an accident is high and the ability to prevent a major release of radioactive materials is very low.

Core Damage Frequencies (CDFs)

- The Core Damage Frequency is high, because of the obsolescence of the design
- Despite extensive modernisation measures, not all deficits could be eliminated. This will not be possible in the future either.



Source: *Analysing and Decreasing external event risks of Loviisa NPP; 13th International Conference on Probabilistic Safety Assessment and Management (PSAM 13), Kalle E. Jänkälä (Fortum); 2-7 October, 2016 Seoul, Korea.*

NATURAL HAZARDS

Flooding

- To ensure adequate design basis, Loviisa NPP contracted updating of the seawater level extreme value distribution by the Finnish Meteorological Institute.
- According to the results the expected seawater levels at low frequencies of occurrence are higher than previously estimated.
- Estimation of probabilities and intensity for extreme events resulting from climate change is extremely difficult due to fact that there is no sufficient database.
- Furthermore, because the situation is constantly evolving, any data may be outdated by the time their evaluation is concluded.
- The time lag is still more drastic for the drafting of new rules and regulations by the authorities, and their implementation by the NPP operators.
- It seems hardly possible to win this race against time – particularly in face of economic pressure that might lead to result that only low-cost measures are realized.

Source: Loviisa nuclear power plant: Environmental Impact Assessment Programme. Fortum August 2020.

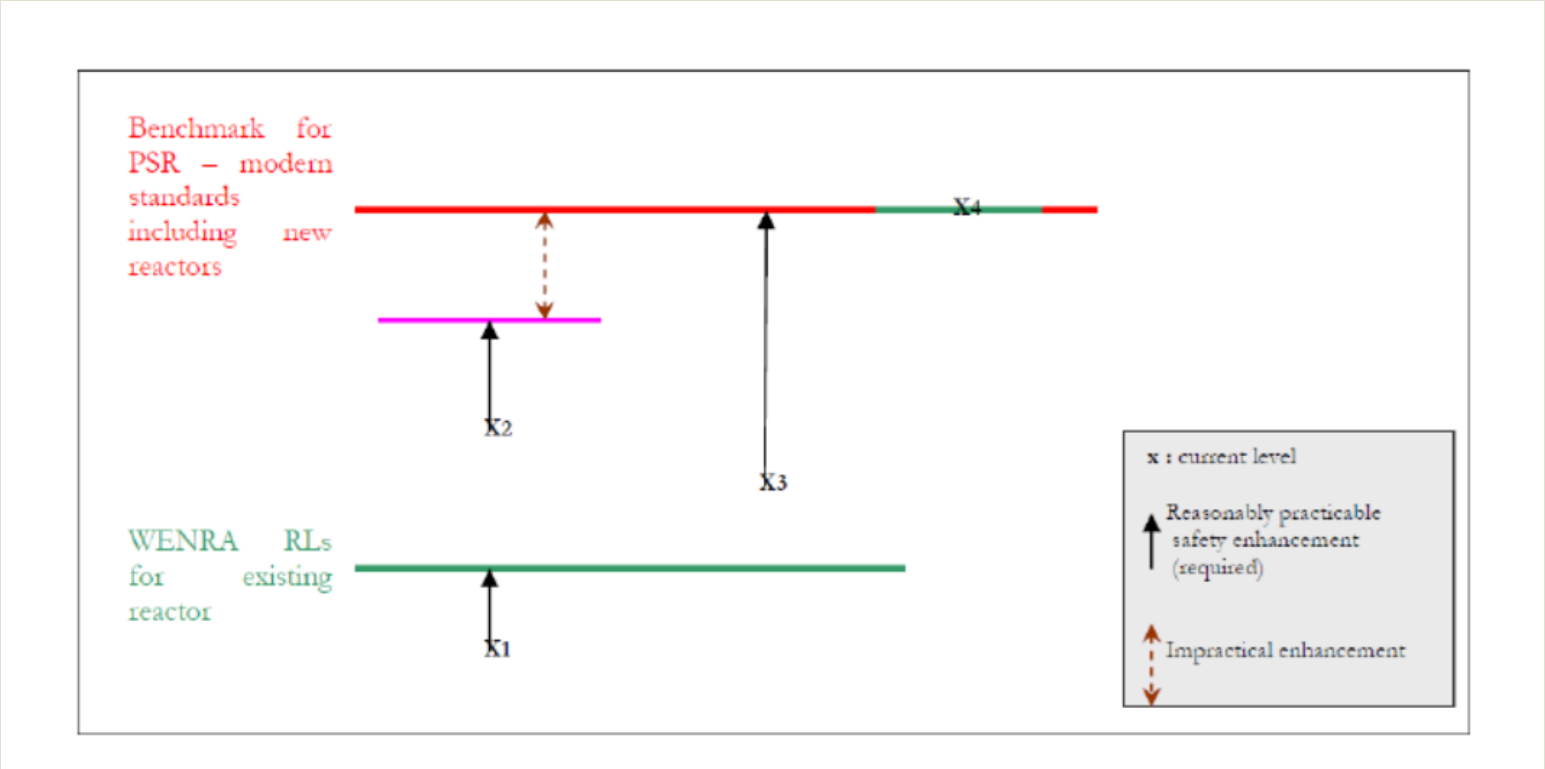
Earthquakes

- When the Loviisa NPP units were built there were no regulatory requirements on seismic design
- The new systems, structures and components (SSC) critical to safety constructed after 1997 are designed and qualified to withstand the DBE. The corresponding horizontal PGA is 0.10 g.
- The reassessment of the seismic hazard and seismic risk has turned out to be challenging.
- Recent hazard updates for Loviisa show increased values of ground accelerations especially at long return periods. However, the input data and results of hazard calculations involve large uncertainties.
- NOTE: The Severe Accident Management systems are not designed to withstand earthquakes.
- Therefore there is no confirmation on the sufficient operability of these systems after an earthquake.

DEVIATIONS OF MODERN STANDARDS

Safety Objective for new NPPs –Benchmark for Long-term operation (LTO)

The WENRA safety objectives, for new NPP should be used as a reference for identifying **reasonably practicable** safety improvements.



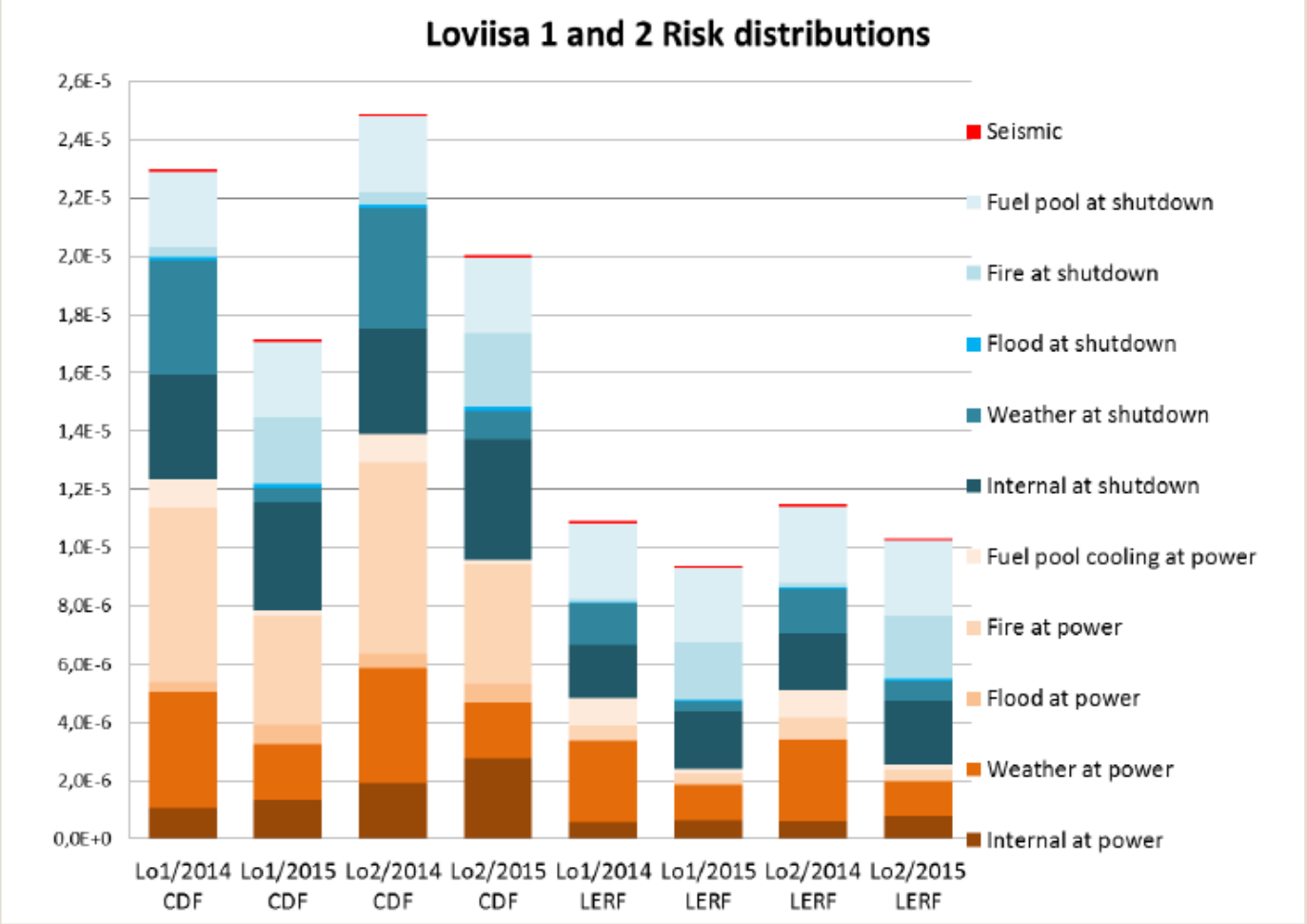
Source: Pilot study on Long term operation (LTO) of nuclear power plants; Study by WENRA Reactor Harmonization Working Group. March 2011.

Severe Accidents

- 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.
- The most ambitious safety objective for new NPPs is to reduce 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.

Large Release Frequency (LRF)

- Frequency of large releases is higher than the limits set in STUK's regulatory guide
- 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.
- Despite the fact that higher releases are possible, the environmental study will only evaluate the impact of the limited release according to the STUK guidance



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Reasonably Practicable Improvement

- Principle for continuous improvement is laid down in Section 7 a 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 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.*
- Improvements considered not reasonably practicable at the Finnish operating NPPs include e.g. protection measures against large civil aircraft crash or layout changes.

Risk Report

- A risk report should be submitted as part of the EIA procedure for lifetime extension.
- **This risk report would have to contain a comprehensible presentation and overall assessment of all deviations from the current state of science and thus of the remaining risks:**
  - *All deviations from the requirements for redundancy, diversity and independence of the security levels.*
  - *Incompleteness of the database and plant documentation used.*
  - *Presentation of all safety assessments or parameter definitions by personal expert opinions.*
  - *Presentation of uncertainties and their effects on risk deviations from the state of the art in science and technology with regard to the detection methods used, technical estimates and calculation procedures.*
  - *The safety margins available for the safety-relevant components and their respective changes compared to the original condition.*

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