SECURING NUCLEAR SAFETY – A FINNISH VIEWPOINT

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Efficient and safe use of nuclear energy implies competence, continuous investments to improve the plants, and proper attitude of all stakeholders.
A procedure in accident analysis

- Hazardous materials and/or threats in general
- Energy sources to release the materials
- Accident scenarios
- Release mechanisms and routes
- Consequences of the accident
- Quantitative risk assessment
- Dispersion models and assessment of effects

Deterministic or probabilistic methods

Risk = probability × consequence
Risk acceptability?
Nuclear safety and safety culture

Nuclear safety means the achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation hazards. The very complicated interrelations between technology, processes and actors and on the other hand the huge amounts of radioactivity and energy involved makes achievement of acceptable nuclear safety particularly demanding.

Safety culture means the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance.

IAEA safety glossary (IAEA Pub 1290)
Nuclear energy in Finland
25.4% of electricity by nuclear (2008)

Olkiluoto 1&2
BWR 2×880MW
1979, 1982
2008: 14.4TWh, 95%

Loviisa 1&2
PWR 2×488MW
1977, 1981
2008: 7.7TWh, 90%

Triga MkII
1962, Espoo

Helsinki
The 5th unit under construction
Commercial start in 2013
Main EPR Safety Features

- Double containment with ventilation and filtration
- Melt core cooling area
- Containment heat dispersion system
- Water reserves inside the containment
- Four redundant safety systems

www.tvo.fi
Nuclear waste management in Finland

Olkiluoto Power Plant

Spent fuel
Posiva

Operational waste
TVO

Loviiisa Power Plant

Operational waste
Fortum

Construction licence in 2012, disposal start in 2020

www.posiva.fi
All energy sources have their pros and cons. The mandatory Environmental Impact Analysis (EIA) discusses the risks and benefits.

The objective of the Nuclear Energy Act of Finland is to keep the use of nuclear energy in line with the overall good of society, and in particular to ensure that the use of nuclear energy is safe for man and the environment and does not promote the proliferation of nuclear weapons. Decision-in-principle.

The Nuclear Act states that ”the safety of nuclear energy use shall be maintained at as high a level as practically possible”. Safe operation means also efficient electricity production and therefore all the stakeholders have a common goal for continuous safety improvements.

Finnish regulations are up to date and the regulator STUK is independent and powerful. The licensee has the responsibilities.
Some indicators of OI1 and OI2

Collective occupational doses since the start of operation of the Olkiluoto units 1 and 2.

Annual radiation doses to the critical groups since the start of operation of the Olkiluoto units.

Daily average gross power of the Olkiluoto

INES classified events at the Olkiluoto plant

INES 1 = anomaly with safety significance

Source: STUK-B129
Modernization and modification projects in TVO

• "Always as good as new"
• Modernization and reactor uprating:
  660 → 710 MW  1983-1984
  710 → 840 MW  1995-1998
• Turbine plant modernization
  840 → 860 MW  2005-2006
  Turbine efficiency increase
  860 → 880 MW  2010-2011
• Construction of interim storage for spent fuel (KPA) 1984-1987
• Low- and intermediate level waste repositories 1988-1992
• Containment filtered venting system (SAM) 1986-1989
• Plant-identical training simulator at Olkiluoto 1988-1990
• Impacts from Fukushima?

www.tvo.fi
Improvements in the Loviisa NPP

- Considerable changes from the original Soviet VVER440/230 design to satisfy western safety standards (containment, ECCS)
- Layout deficiencies, fire protection, RPV embrittlement,
- SAM refurbishments
- Improvements in heat transfer, electricity, etc.
- Plant simulations, PRA studies, Apros simulator
- PLEX and digital I&C
- Operating license for 2027 and 2030 (50 years) with safety reviews at 2015 and 2023

www.fortum.com
• PRA levels 1 and 2
• Power, shutdown
• Seismic, weather, flooding, fire
• Living-PRA
• PRA is an efficient tool for priority
• PRA covers only the considered scenarios and therefore SAM and conservative beyond-DBA analysis are needed

**Loviisa PRA**

**Loviisa 1 Risk distribution**

(Not included: Fire at shutdown states)

![Risk distribution graph]

- CDF (1/a)
- WEATHER (at shutdown)
- WEATHER (at power)
- FIRE (at power)
- SEISMIC
- FLOOD (at shutdown)
- FLOOD (at power)
- INTERNAL (at shutdown)
- INTERNAL (at power)

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Lessons from TMI-2 and Chernobyl induced many plant improvements including severe accident management. Extreme weather conditions were already considered. September 11th lead to the double containment of newbuilds.

Has something been forgotten? Fukushima induced the present stress tests for all European power plants including Olkiluoto and Loviisa.
Fukushima and stress tests
Weather and floods

Extreme weather conditions
Anticipated in Loviisa NPP
Estimated core damage frequency $3 \times 10^{-6}/a$

Weather risks at power in Loviisa

Flood risk at power in Loviisa

Rainer Salomaa, 19th CAETS Convocation, Mexico City, 30.06.2011
Finns die because of bad habits: smoking, eating and drinking. Indoor radon is the most important factor concerning radiation.

Chernobyl has had measurable effects.

Neighboring NPPs in Kola, Sosnovy Bor, Forsmark, and Oskarshamn.
# Death risks of Finns (1997)

<table>
<thead>
<tr>
<th>Cause</th>
<th>Deaths/year</th>
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</thead>
<tbody>
<tr>
<td>Smoking</td>
<td>8000</td>
</tr>
<tr>
<td>Unhealthy food</td>
<td>8000</td>
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<tr>
<td>Alcohol</td>
<td>900</td>
</tr>
<tr>
<td>Traffic accidents</td>
<td>400</td>
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<tr>
<td>Air pollution (traffic)</td>
<td>300</td>
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<tr>
<td>Intoxication</td>
<td>500</td>
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<tr>
<td>Indoor radon</td>
<td>300</td>
</tr>
<tr>
<td>Pollution (energy)</td>
<td>100</td>
</tr>
<tr>
<td>Solar (UV radiation)</td>
<td>100</td>
</tr>
<tr>
<td>Mutagens (drinking water)</td>
<td>100</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>50</td>
</tr>
<tr>
<td>Chernobyl</td>
<td>5</td>
</tr>
</tbody>
</table>


*www.stuk.fi*
Primarily nuclear safety relies on humans. The devices are designed and fabricated by humans and they are operated by humans. That implies considerable challenges to nuclear safety.
The challenge: human factors

- Safety culture
- Organisations, competence and attitudes
- Public tolerance, political decision making
- Proliferation, terrorism

- Human resources: how to recruit and train new talented people.
  - Real things to do (modernisation, newbuild)
  - Include frontiers (Gen4, fusion, transmutation)
  - Efficient collaboration (R&D and E&T)
  - Long term visions and plans
  - Innovations, cross-disciplinary thinking
  - Knowledge transfer
Conclusions

- Nuclear safety requires attitude, competence and resources
- In normal operation nuclear energy is a viable solution.
- Nuclear waste problem can have a consistent solution. Safety case?
- Nuclear incidents and even anticipated accidents may still occur. R&D
- Severe accidents must be excluded. R&D
- Nuclear energy means a very long commitment implying strong changes of the environment during the next hundred years.

- Up to date regulations and a strong regulator assure safe operations.
- Continuous improvement of the plants - even EPR
- Proliferation, security etc. are open problems
- Functional infrastructure exists; increase collaboration.
- Knowledge transfer, risk of deterioration of international R&D.
- Consistent resources for R&D and E&T must be allocated.
Thank You!

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