Lessons Learned from Decades of Waste Characterisation, Management and Deposition in Finland

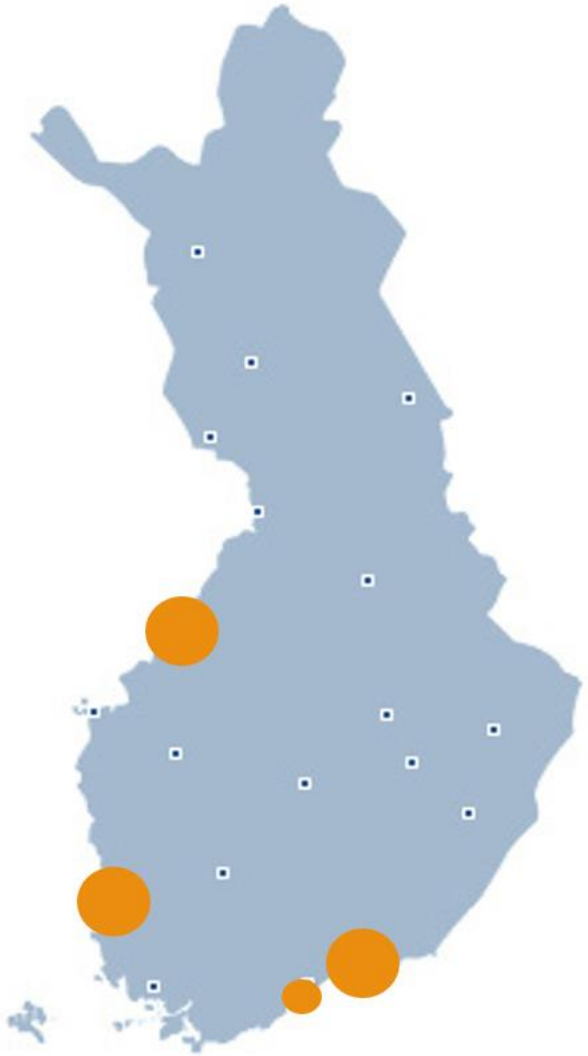
Petri Kotiluoto – VTT
Antti Ketolainen – Fortum

ICOND 2021

Overview and contents

- Nuclear in Finland
- Nuclear Waste management in Finland
  - Fortum’s experience and competences on radioactive waste management
  - VTT offering for nuclear decommissioning
  - HLW deep geological disposal
- VTT’s FiR 1 TRIGA Mark II research reactor decommissioning
  - Status of decommissioning and project timeline
  - Progress in waste characterization
- Summary

Nuclear in Finland



Nuclear in Finland

- **Loviisa**
  2 x VVER-440 500+ MW

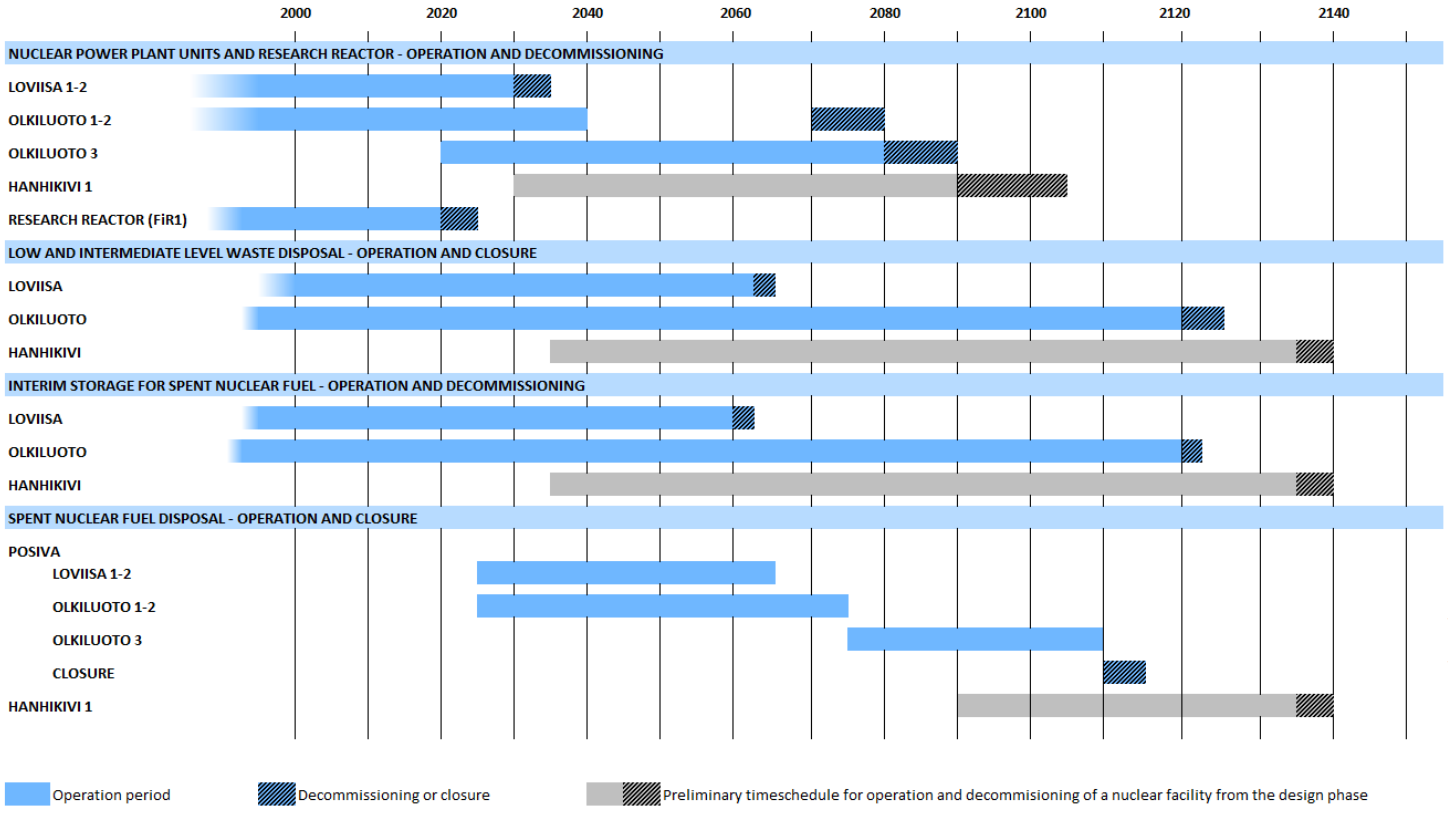
- **Olkiluoto**
  2 x BWR 880 & 890 MW
  ONKALO
  EPR 1600 MW (2022)

- **Hanhikivi**
  VVER-1200 (2028)

- **Otaniemi**
  FiR1 TRIGA (decom)

Waste management in Finland

Overall NWM schedule in Finland



Source: STUK

Waste management in Finland

- FORTUM’s experience and competences on waste management and nuclear decommissioning

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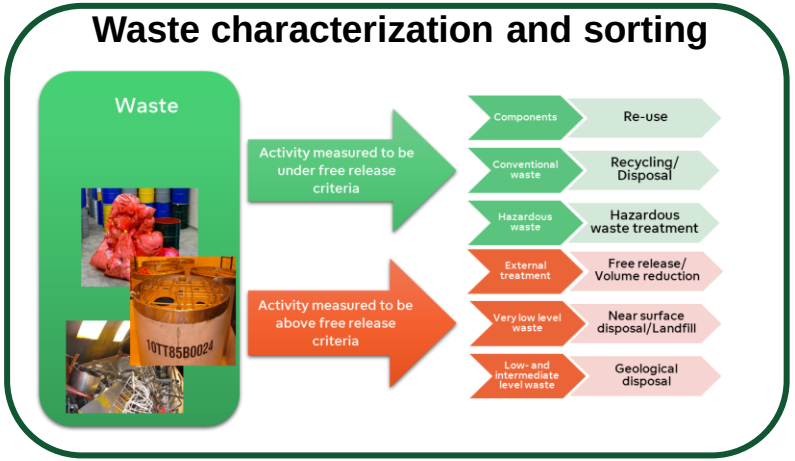
Fortum – nuclear operator, shareholder and service provider

- 3rd largest nuclear operator in Europe
- A license holder and operator of Loviisa NPP in Finland
- Shareholder of all commercial nuclear power plants in Nordics
- Shareholder of Posiva Oy – company responsible for the final disposal of spent nuclear fuel
- Experienced nuclear service provider with an offering that covers whole life-cycle of a nuclear facility

Loviisa NPP – waste

- Loviisa NPP consists of two VVER-440 type PWR units, LO1 and LO2.
- Decades of operating experience
  - Operating since late 70s - over 40 years of operating experience.
  - In-house engineering solutions in use for nuclide removal from liquid waste
  - In-house engineering solutions for solidification of liquid waste
  - Developed and optimised solid waste management solutions
  - Final disposal for operational and decommissioning waste (LILW) at the site



Loviisa NPP waste management – main milestones and lessons learned

1980-90s - Development and implementation of NURES® for liquid waste treatment

- Implementation of NURES® treatment to processes reduced significantly environmental releases

1996 - Final disposal facility constructed

- The whole waste treatment chain in control (production, handling and disposing/free releasing).

2008 - Organisational renewal → foundation of dedicated waste management group

- A dedicated group to take care of handling and treating of LILW, develop waste handling techniques, ensure on overall safety and make long term handling plans.

2010 - New treatment and handling facilities into usage

- Improved sorting and storing of wastes.

2010 - New drum measurement taken into usage

- Made the pre-classification more accurate and enabled to increase free release percentage

2011 - Own employees for waste packing activities

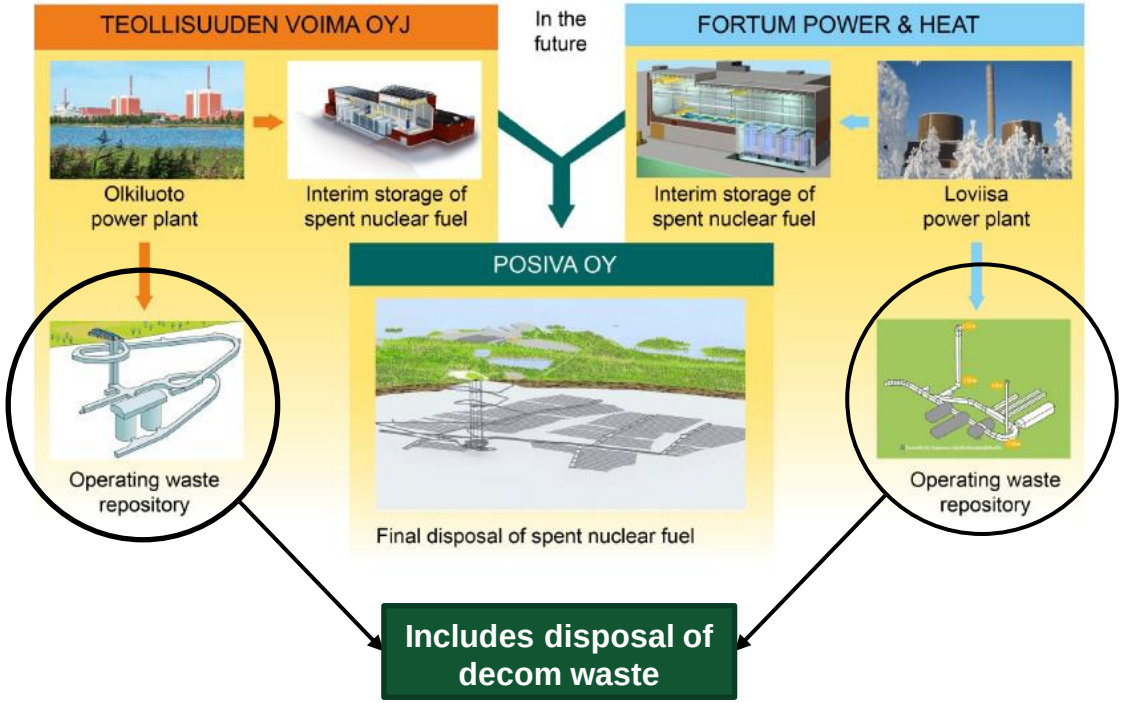
- Instead of using contractor's staff, the waste packing experts were hired to Fortum- development of organisation

2016 - Commencement of solidification plant

- Enabled the starting of liquid waste solidification

General lesson learned from decades of operation: waste management processes shall be controlled, monitored and lead via KPIs. However, it needs to be ensured that the indicators are correctly defined and measured

Waste disposal in Loviisa

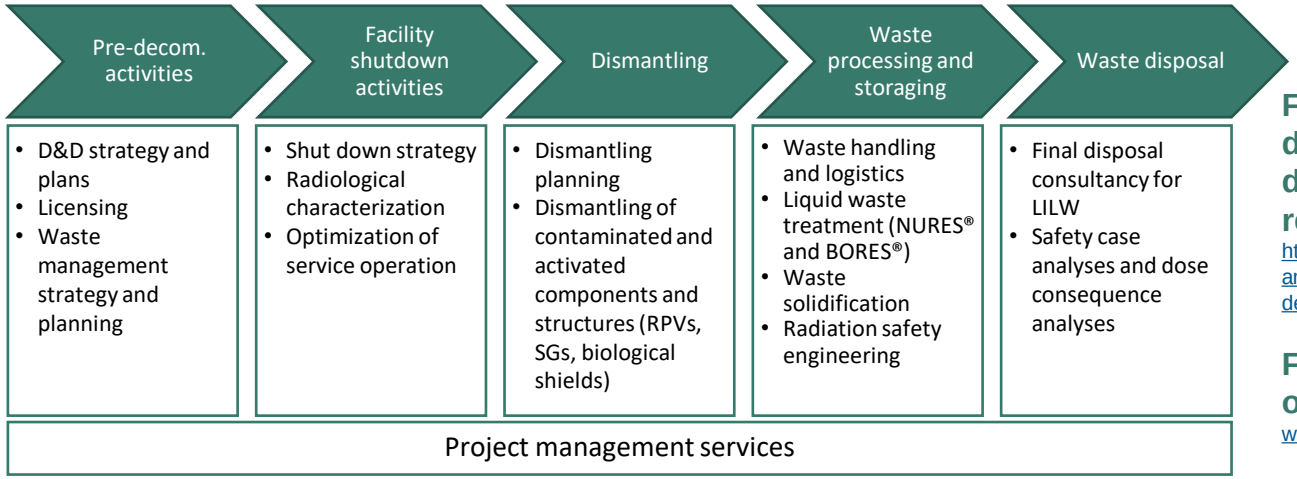


Loviisa final disposal facility

- Waste disposal facility for operational and decommissioning waste
- 110 meters underground at Loviisa NPP site
- Different premises for different wastes depending on
  - Material,
  - Radioactivity and contamination level,
  - Waste size

Fortum-Uniper offering for nuclear decommissioning and waste management

- Operator and license holder background, long experience in nuclear service business and Fortum-Uniper cooperation in nuclear decommissioning and dismantling provides basis for unparalleled wide offering covering the whole value chain of nuclear decommissioning and waste management



Fortum and Uniper nuclear decommissioning and dismantling services press release:
https://www.fortum.com/media/2021/09/fortum-and-uniper-start-cooperation-nuclear-decommissioning-and-dismantling-services

Fortum Nuclear Services offering:
www.fortum.com/nuclearservices

Waste management in Finland

- VTT offering for nuclear decommissioning

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VTT offering for nuclear decommissioning

1. Management and planning of research reactor decommissioning, supported by R&D
2. Radionuclide inventory calculations – structures and spent fuel
3. Radiological characterization and sampling programme development
4. Beta and alpha nuclide measurements – for radwaste characterization and waste routes planning incl. disposal
5. Gamma activity measurements and spectroscopy
6. Analytical capabilities in VTT Centre for Nuclear Safety
7. Business, Innovation and Foresight

See more what VTT can offer:
http://www.vttresearch.com/nuclear

CNS Laboratories

- Clay laboratories
- Gloveboxes & controlled atmosphere
- Radiochemistry
- Microscopes
- Hot Cells
- Clean room
- ICP-OES & ICP-MS

Finnish expertise in nuclear decommissioning

- Building Information Models
- Virtual and Augmented Reality
- Radiation transport and dose modelling
- Artificial Intelligence applications
- Human Factors – control rooms and organization
- Operating and licensing framework

VTT
BMH Technology
Ekonia
TVO
Lotus Demolition
Sweco
Fortum

Funded by BF + partners
https://www.decomm.fi/

Topics in digital decommissioning

- Distribution of radionuclide concentrations
  in components and structures subjected to neutron irradiation
- Radiation fields (gamma dose rates)
  near the activated components and structures
- Sensor information, e.g. radiation distribution around the plant,
  synthetic diagnostics and separation of radiation components
- State of the plant's devices and processes (Facility Asset Management)
- BIM based planning for the decommissioning work task
  (Lean construction)
- Visualizing how different equipment fit into the plant (Collision detection)
- Smart sampling, verification differences with the real and 3D model
  (Discrepancy checking)
- Estimations of costs of methods and equipment, efficiency of work etc.

dECmm

VTT
BMH Technology
Ekonia
TVO
Lotus Demolition
Sweco
Fortum

Waste management in Finland

- HLW deep geological disposal

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HLW deep geological repository ONKALO - POSIVA Oy

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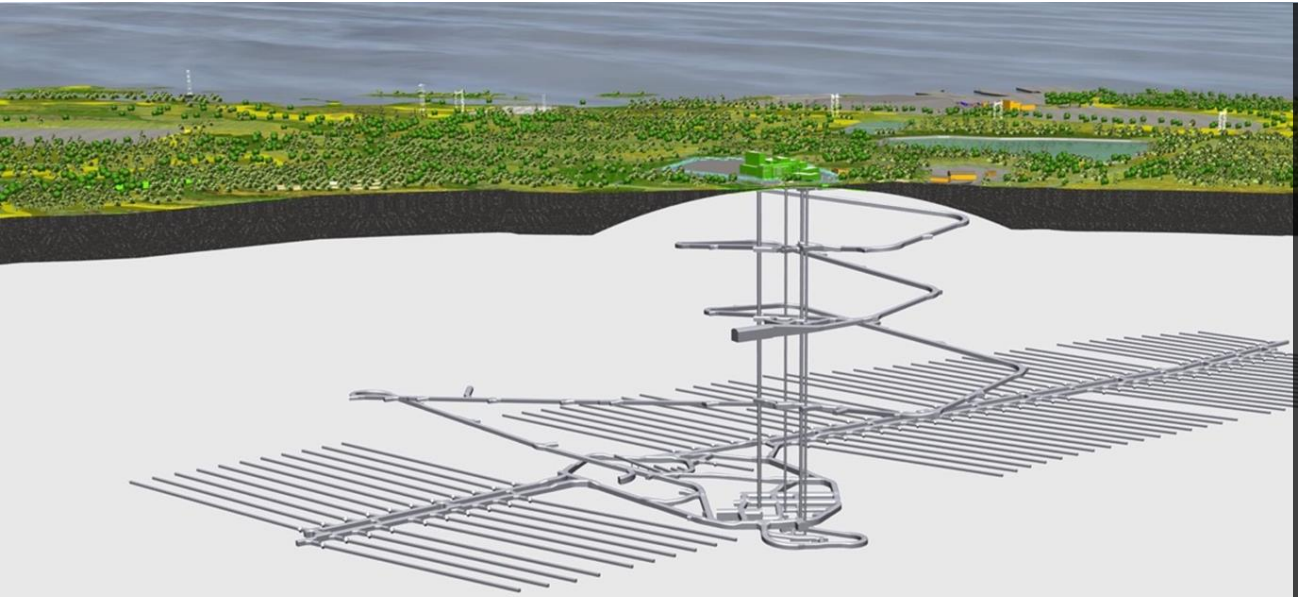
HLW deep geological repository ONKALO – Posiva Oy



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Disposal facility in 2120

- Disposal facility capacity 6,500 tU (approx. 3,250 canisters)
- Construction time and service life approx. 100 years
- Repository volume approximately 1.5 million m^3
- Length of tunnels approximately 50 km
- The disposal facility will remain safe without external actions once it has been closed off

www.Posiva.fi

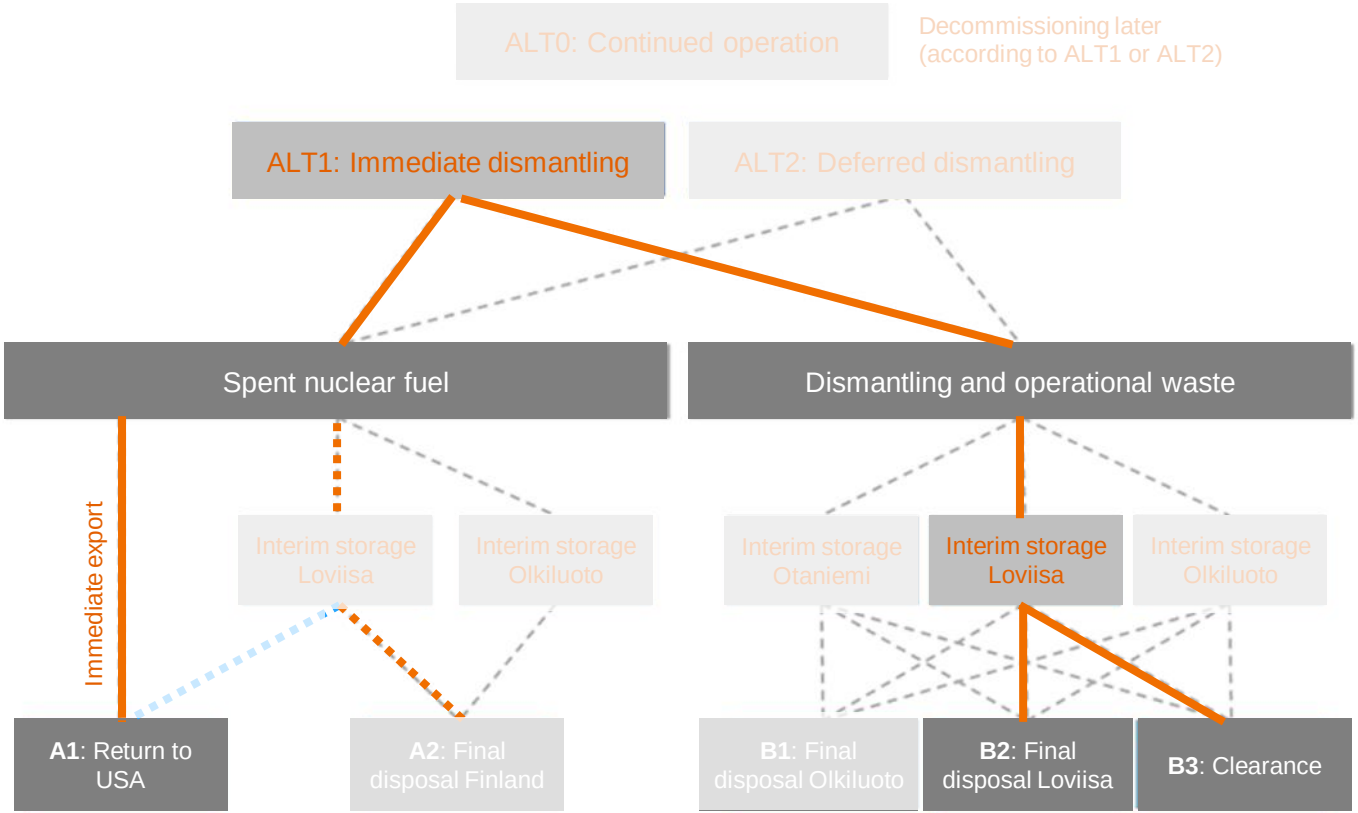
FiR 1 TRIGA Mark II research reactor decommissioning

FiR 1 Status of decommissioning

2012	VTT’s decision to shut down FiR 1
2013–15	EIA for decommissioning
2015	End of operations
2016	Dismantling planning
2017	License application for decommissioning
2019	Procurement of decom and WM services
2020	Fortum contract and transfer of SNF to U.S.
2021	Government grants the license
2022	Dismantling expected to begin
2023	FiR 1 dismantled and site released

Options for nuclear waste management

FiR 1 Environmental Impact Assessment 2013–15

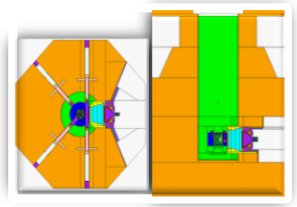


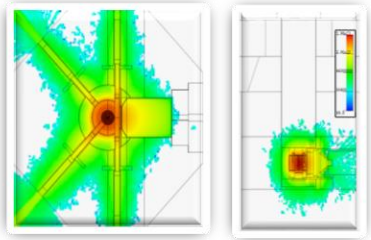
FiR 1 - Progress in characterization

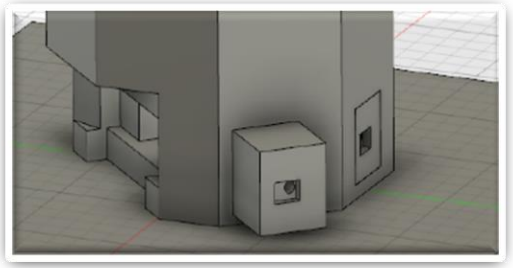
- Data on radionuclides and their activities is needed for choosing correct methods for dismantling, waste packaging, transportation and waste final disposal
- Aim is ensure: **safety** (minimize radiation doses) and **cost-efficiency** (optimise the amount of waste and choosing efficient waste management methods)
- Fixing the boundary conditions to Loviisa waste acceptance criteria has enabled converging the plans from optioneering to more practical level
  - Optimizing packing, waste handling procedures and logistics
  - Compatible measurement methods and bookkeeping
  - Repository-specific final disposal safety case assessment

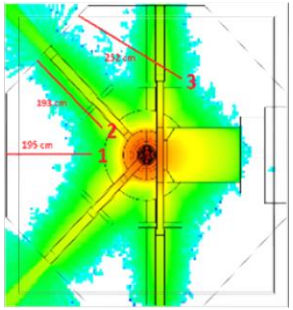
Characterisation by sampling

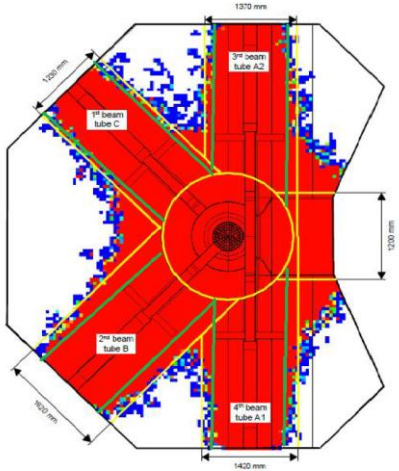
- Earlier calculated concrete activity inventories were validated with sampling



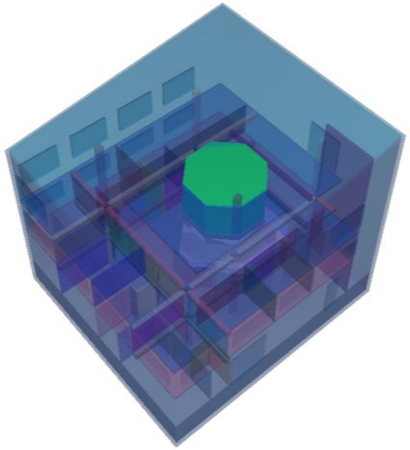


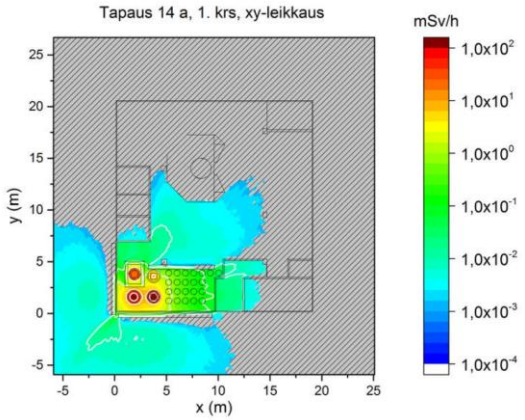


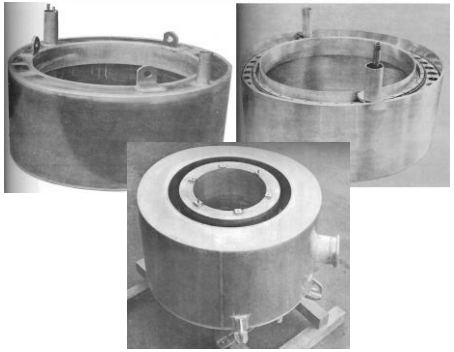


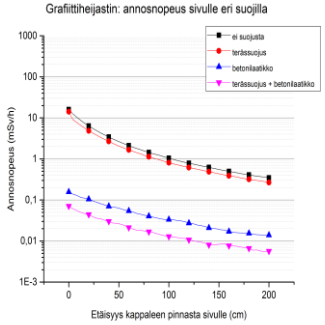


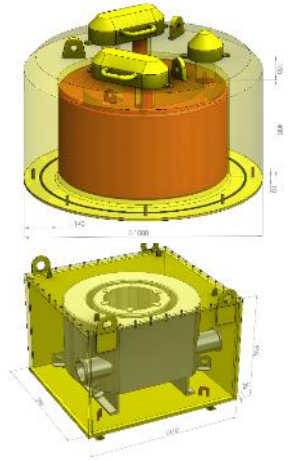
Radiation safety and waste packages

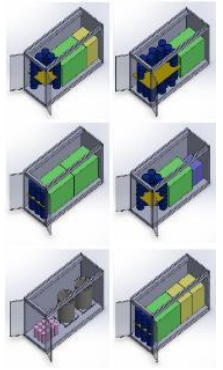






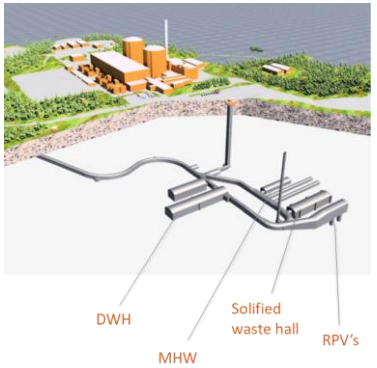


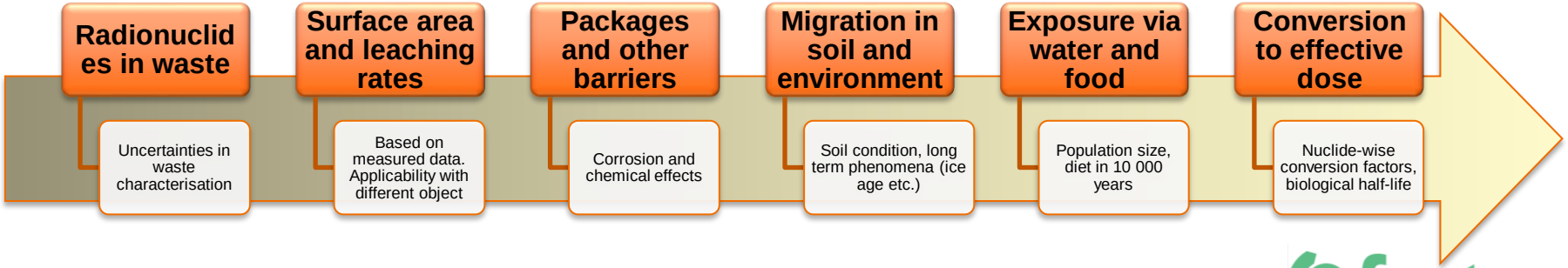




Waste final disposal

- Proper characterization enables optimizing the selection of barriers still fulfilling the requirements of repository-specific safety assessment.
- Nuclide vectors need to include long-lived DTM nuclides, e.g. Cl-36, C-14, Ni-59,…
- Radiochemical methods have been developed also via international sample intercalibration
- Research reactors contain special materials that are not used in Finnish NPP's (graphite, aluminium etc.) ➡ long-term chemical effects





Summary

Summary

- In general, radioactive waste management in Finland is proceeding well, including the world's first high level radioactive waste repository under construction
- VTT has developed competences e.g. in radionuclide inventory calculations and waste characterisation, including radiochemistry, and has unique infrastructure such as CNS
  - VTT is also carrying out a decommissioning co-innovation ecosystem project
- Fortum has decades of experience on management, treatment and handling of radioactive wastes
  - Fortum operates LILW repository in Loviisa
  - In addition, Fortum's competences have recently being strengthened and extended via intensified Fortum-Uniper cooperation
- VTT and Fortum are in the process of decommissioning the FiR 1 TRIGA Mark II research reactor
  - First nuclear facility facing decommissioning in Finland
  - FiR 1 decommissioning and waste management will benefit from the long history of the waste management in Finland

Thank you!

Dr. Petri Kotiluoto
Research Team Leader
VTT
petri.kotiluoto@vtt.fi

https://www.vttresearch.com/en

Antti Ketolainen
Senior Manager, Decommissioning and Waste
Fortum, Nuclear Services
antti.ketolainen@fortum.com
www.linkedin.com/in/anttiketolainen

www.fortum.com/nuclearservices