Lessons learned from the design and implementation of nuclear liquid waste treatment installations – perspectives from a license holder and a service provider

International Conference on the Safety of Radioactive Waste Management, Decommissioning, Environmental Protection and Remediation: Ensuring Safety and Enabling Sustainability

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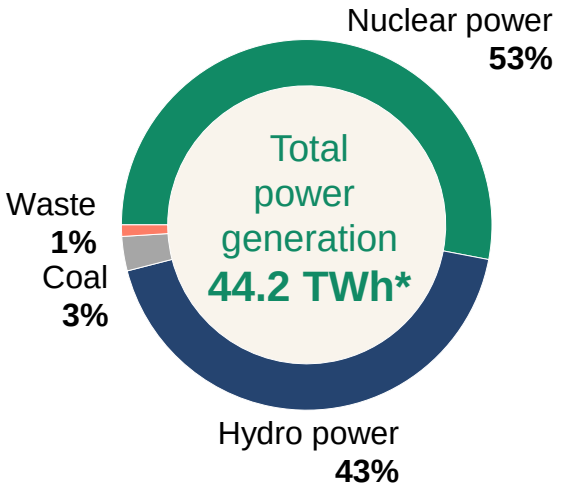
Fortum is a strong Nordic nuclear operator

Key figures 2022

Nuclear generation	**23.4 TWh**
Total nuclear capacity	**2.8 GW***
Share of Fortum's total power generation	**53%**
Nuclear professionals	**~750**

* When Olkiluoto 3 is in commercial operation, total capacity increases 0.4 GW to 3.2 GW.

Fortum's power generation in 2022



We have 40+ years' track record of safe nuclear operations and we are forerunners in responsible waste management

Fully-owned nuclear power plant in Loviisa, Finland	Co-owned nuclear power plants in Finland and Sweden	Spent fuel and waste mgmt (Posiva (FIN) and SKB (SWE))	We develop new, innovative products and services	Nuclear newbuild feasibility study Finland and Sweden

Expertise from new builds to decommissioning and final disposal of nuclear waste

Unit	Mwe (net)	Fortum Share %
Loviisa 1	507	100
Loviisa 2	507	100
Olkiluoto 1	890	26.6
Olkiluoto 2	890	26.6
Olkiluoto 3 (newb)	1600	25
Forsmark 1	988	23.4
Forsmark 2	1120	23.4
Forsmark 3	1172	20.1
Oskarshamn 3	1400	43.4
Oskarshamn 1	decom	43.4
Oskarshamn 2	decom	43.4

- Units fully owned by Fortum
- Co-owned units
- Units under decommissioning

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We support our customers throughout the entire nuclear power plant lifecycle

Strong in-house nuclear engineering department

Nuclear operator experience based proven solutions

Projects delivered to a global customer base

Proactive influencing and co-operation on international nuclear forums

Newbuild, licensing, commissioning

- Licensing and safety design capabilities, eg. ADLAS® concept
- Owner's engineering services for newbuild
- Plant design
- Small modular reactor consulting

Operating and maintenance

- Operational support, e.g. trainings
- Maintenance and outage optimization
- Procedures
- Owner's engineering for upgrade and plant modernization projects, e.g. automation renewal and human factors engineering design

Plant safety and process simulations

- Deterministic Safety Analysis with Apros®
- Severe Accident Management guidelines and analysis
- Probabilistic Risk Assessment
- Radiation safety analyses

Plant modernisation, lifetime management

- Apros® dynamic simulation to define technical requirements for new equipment
- Process and I&C design verification and testing
- Virtual commissioning

Waste management, decommissioning

- NURES® radioactive liquid purification
- Nuclear waste treatment, storage and disposal
- Expertise in final disposal of radioactive waste
- Extensive nuclear decommissioning services

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Liquid waste treatment
Overview

- Fortum´s own NURES® technology purifies liquid radioactive waste to a fraction of the original waste volume
- The technology was originally developed for the Cs removal process at the Loviisa NPP
- Fortum's NURES® technology is based on patented, 100% inorganic, highly selective ion exchange materials
- The cost of disposal is usually high per unit of volume. Radioactive waste cannot be eliminated, but the volume can be reduced

SELECTED RECENT CUSTOMER REFERENCES:

- ALPS system - Fukushima, Paks NPP – Hungary, Grafenrheinfeld NPP – Germany

Core of the technology is four different ion exchangers

CsTreat® SrTreat® CoTreat® SbTreat®

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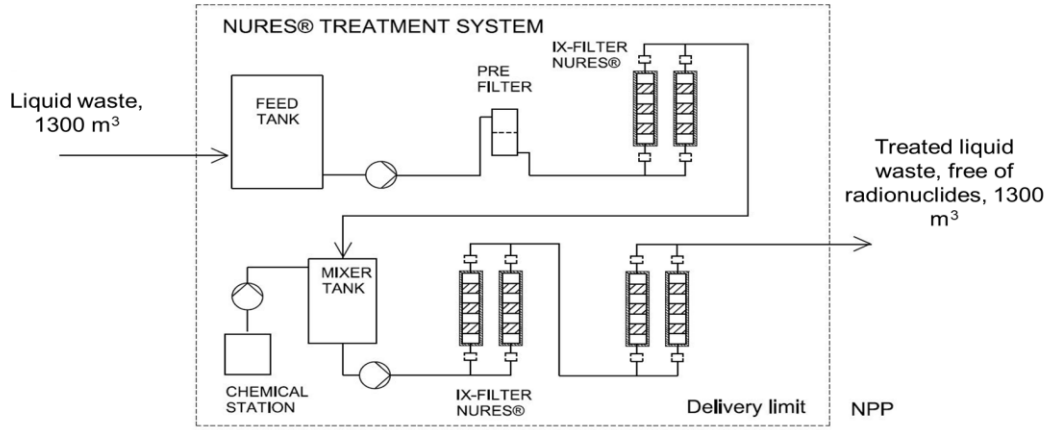
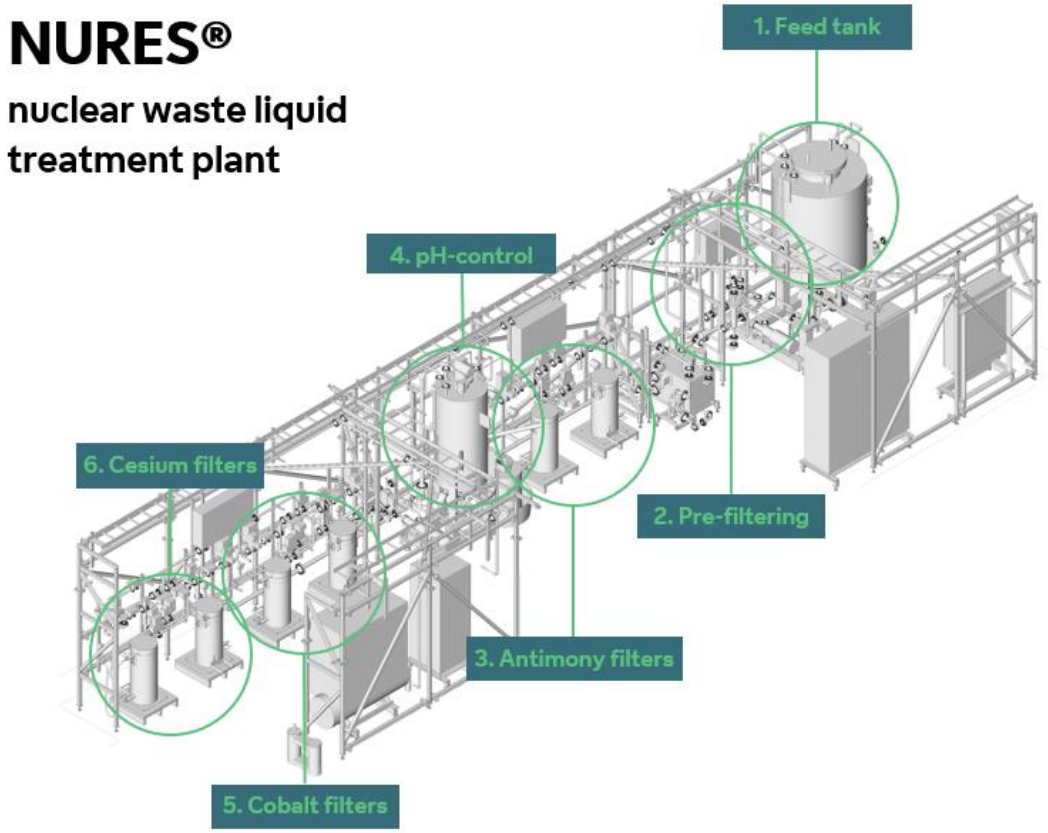
Use cases – Grafenrheinfeld NPP, Germany

- Mobile system occupying a room of 40 m2 size
- Treatment capacity: 20 to 30 m3 / week
- Highly automated, less than 30-min manual work is needed per day
- Approximately one year from order to take-over
- Operation started in 2020 & finished in 2022
- A total of ~150 liters of ion-exchange material was used to decontaminate the active liquid





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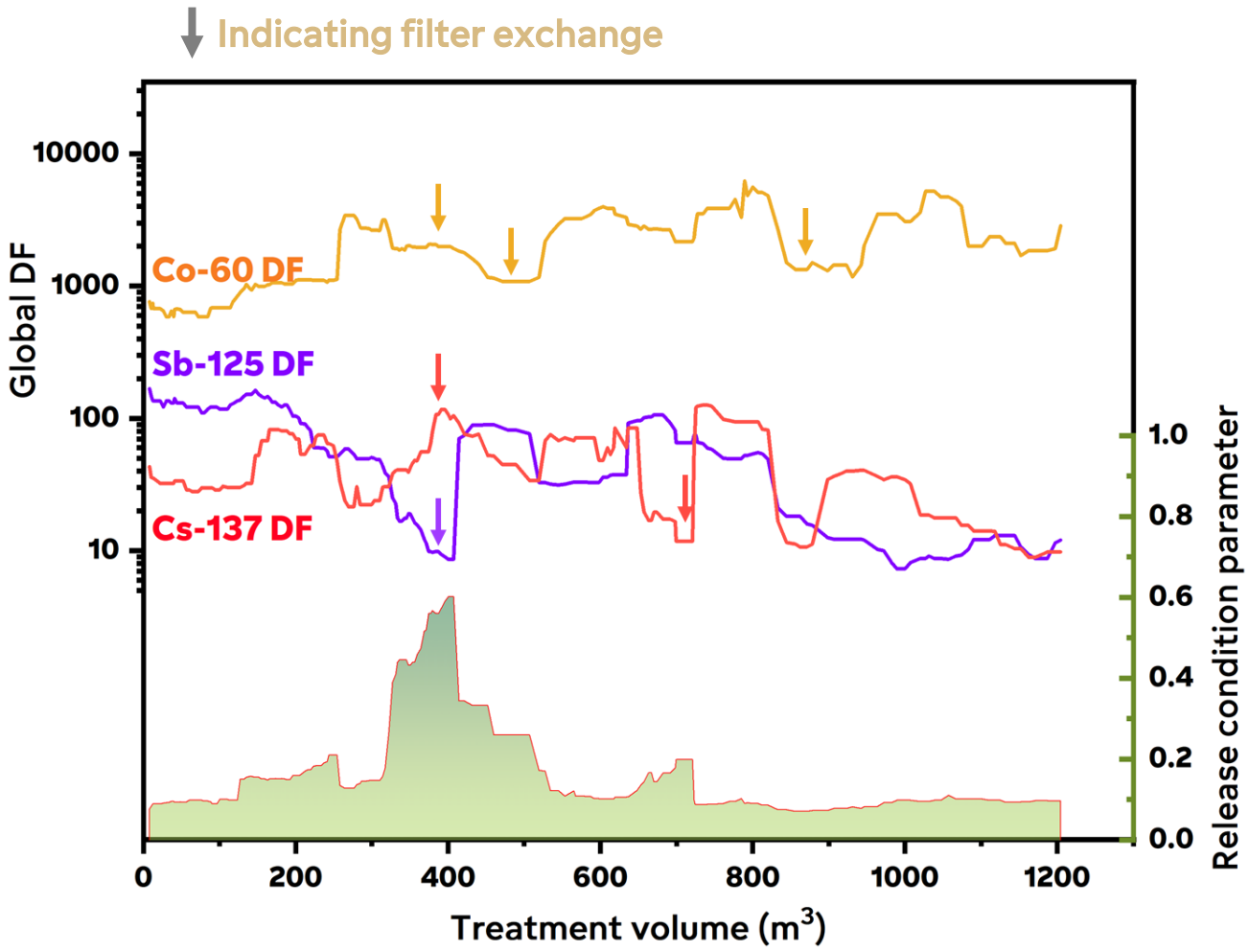
Use cases – Grafenrheinfeld NPP, Germany



- Treatment finished in Sept 2022.
- Altogether 12 NURES filter columns are used to treat the 1220 m3 of liquid.
- Volume reduction factor > 1000.
- **Significant cost saving in final disposal.**

$$\textbf{Global DF} = \frac{c_i(\textbf{incoming})}{c_i}$$

$$\textbf{Release condition is met if } \sum_i \frac{c_i}{c_{E,i}} \leq 1$$

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Lessons learned from the design and implementation stages
From internal and external projects

- Fortum is experienced as nuclear owner and license holder and on the other hand also as a service provider for liquid waste treatment solutions. The lessons learned presented below and in the next slides take both viewing points into consideration.

1. The benefits of feasibility study
2. The benefits of testing and piloting
3. Open customer-centric communication & Project management
4. Mobile solutions enhance flexibility and cost savings in decommissioning projects

Lessons learned from the design and implementation stages

The benefits of feasibility study

- To secure a successful project and to ensure project's stakeholders to meet the goals of the project, the project lifecycle, boundary conditions and key drivers and expectations shall be defined and considered at the very early stages of the project
- Also holistic cost impact analysis covering the whole lifecycle of the facility shall be made in this stage of the project in order to understand and demonstrate the entire cost of the project

#1 - A feasibility study, incl. analysis of total cost of ownership, should be an entry point for any design and implementation project

Lessons learned from the design and implementation stages

The benefits of testing and piloting

- By executing adequate level testing and piloting phases in the beginning of the project, the processes can be optimized which can contribute to an overall better project or project experience of the customer
- Testing and piloting will also enable to remove, identify, specify and quantify potential risks, and will thus help the project team to focus on the right items and issues in the implementation phase

#2 - Testing and piloting can save costs in the project as these reduce risks for the later stages of the project

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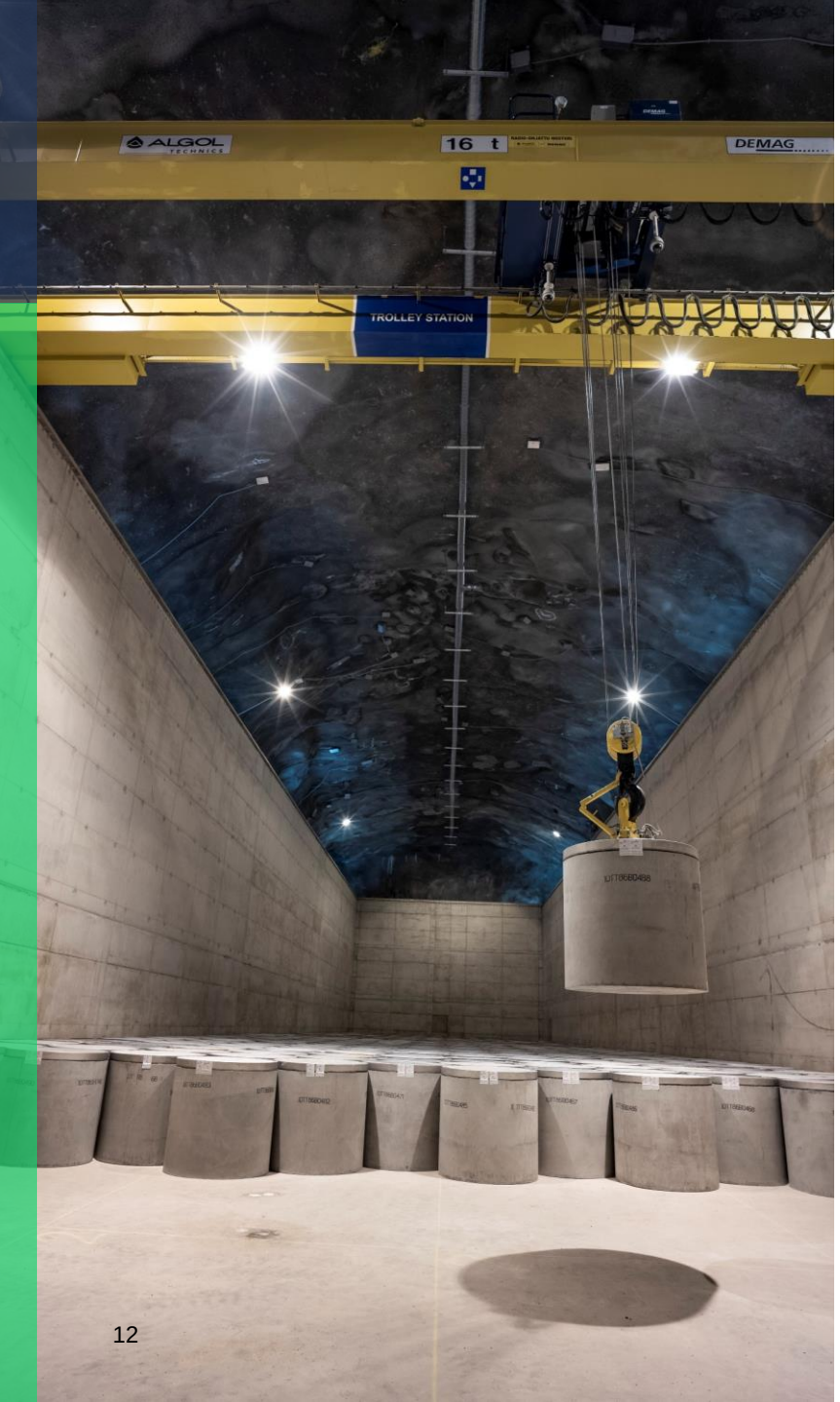
Lessons learned from the design and implementation stages

Open customer-centric communication & Project management

- To maximise the results of the project, contractor shall understand the needs of the client license-holder. The needs of the customer are better understood and can easier be implemented into the project when assigned Project Management groups regularly and openly discuss the project proceedings
- The overall waste routes and preconditions of those, including also waste acceptance criteria, shall be discussed at an early stage of the project in order to optimize the solutions.

#3 – Open, customer-centric communication between the service provider and license holder organisation helps the project to face challenges together



Lessons learned from the design and implementation stages

Mobile solutions enhance flexibility and cost savings in decommissioning projects

- Implementation of mobile liquid waste treatment solutions to nuclear decommissioning projects enable flexibility and project benefits e.g. from project planning and scheduling point of view.
- Especially in multi-unit, fleet level decommissioning projects, overall costs of the customer can be lowered by adopting mobile treatment solution that can be transferred from one plant to another. Overall decommissioning costs/decontamination costs are lowered significantly, as the whole fleet is taken into account at an early stage of the project

#4 – Applying mobile solutions to liquid waste treatment of decommissioning projects enables flexibility, significant project benefits and cost savings, especially in multi-unit decom projects

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Thank you!

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