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Integration of Safety, Reliability and Technology based on experience of nuclear waste management in Finland

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Fortum



Fortum mid-sized European power generation player; major producer in global heat

> Our core Hydro and nuclear Combined heat and power production Circular economy Energy-related products and expert services

9,000 professionals in the Nordics, the Baltics, Russia, Poland and India

We are the largest electricity retailer in the Nordics with 2.4 million customers. And one of the leading heat producers globally

60% of our electricity generation is CO₂-free

power production is hydro and nuclear

2/3 of our

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Nuclear competence in Finland

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Decades of nuclear competence in Finland

- The growth in Finnish energy requirements was spurred by Finland's fast-paced industrialisation. A considerable amount of energy was required, as industry makes up a large percentage of the Finnish economy.
- To fulfil the increasing energy demands, the production of nuclear energy in Finland dates back to 1977, when the first nuclear plant unit began its operation in Hästholmen, Loviisa. The second unit in Loviisa became operational in 1981. Two more units were built in Olkiluoto, in 1979 and 1982.
- From first building nuclear power plants over 40 years ago: Fortum's long history allows it to now offer world-leading nuclear competence based services.



Fortum nuclear assets in Finland and Sweden









Loviisa

Two units 507 + 502 MW = 1009 MW

Fortum's ownership 100%

Olkiluoto

Two units, third under construction

880 + 890 MW = 1,770 MW Under construction 1,600 MW

Fortum's share: 27% (471 MW)

Oskarshamn

One operating unit 1,400 MW

Fortum's share: 43% (607 MW)

In addition, Unit 2 of 630 MW was permanently shut down in 2015 and Unit 1 of 473 MW in 2017

Forsmark

Three units 984 + 1,120 + 1,167 = 3,271 MW

Fortum's share: 22% (720 MW)



Loviisa NPP in Finland

- Two units with VVER-440 reactors
- Installed power capacity 507 + 502 = 1009 MW
- Unit 1 commissioned in 1977, Unit 2, in 1980
- Operation license valid through 2027 for unit 1 and through 2030 for Unit 2
- Annual generation about 8 TWh which covers about 10% of electricity consumption of Finland
- The power plant continuously employs about 500 Fortum employees and 100 subcontractors' employees





Loviisa NPP's high performance is one of indicators of our nuclear expertise



7 1. The Unit Capability Factor shows what could have been the annual electricity generation expressed in the percentage of the energy generation if the unit was operated continuously at full power, if there where no any limiting factors out of the control of plant management.

Policies and responsibilities for safe nuclear waste management in Finland



In Finland "Polluter Pays"- Principle implemented in regulation in a very early phase of nuclear era



Decisive arguments in Parliament 18 May 2001 to dispose of spent nuclear fuel

- "Aiming at final disposal is a better solution than just resorting to interim storing"
- "Option for retrievability of waste canisters must be maintained"
- "The present generation has to accept responsibility for nuclear waste"





Municipal veto-voting

- Vote in Eurajoki municipality council in 2000:
 - 20 YES
 - 7 NO





Annual poll by the Finnish Energy association 1983 – 2016

Nuclear waste can be safely stored in a final repository in the bedrock of Finland – do you agree?

Agree completely Somewhat agree Difficult to say Somewhat disagree Disagree completely



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The public trust in different actors in questions concerning nuclear waste management. Opinions of residents in Eurajoki and Pyhäjoki municipalities in 2017.







Fortum/Loviisa NPP
Nuclear Waste Management



Waste management at Loviisa NPP



Solidification plant at Loviisa NPP

- Solidification plant is an independent unit and designed to handle all liquid wastes during NPP operation (>50 a), decommissioning and interim storage of spent fuel
- The matrix is based on cement and blastfurnace slags
- Processes are operated from control room
- Main waste streams are ion exchange resins and sludge
- Waste and binders are dosed and mixed in a final disposal package





Solidification process at the Loviisa NPP





Developed at the Loviisa NPP matrix for solidification of radioactive liquids is twice as efficient as traditional cementation

- Developed by Fortum cement matrix is more than twice as efficient as the traditional matrix
 - Waste content of the solidified product is 40%-50%
 - The cost is practically the same as in case of traditional cementation
- The recipe development started yet in 1980 and the works on perfecting the recipe continue
 - Targeting over 55% waste content without diluting the matrix quality
- The tests of exposing the matrix to the underground water have shown that the matrix hasn't weakened after four years
- Suitable for all types of LILW



Solidification plant at the Loviisa NPP



Final repository for LILW at Loviisa NPP









Design of LILW final repository

- Design of a low and intermediate level waste final repository, its licensing, cost analysis, long-term evaluation of the repository and it's environment, safety analysis
- Same repository for lower and higher level waste but separate spaces inside the repository
- LILW repository is maintenance free after closure
- Minimized effort to get public acceptance of LILW repository due to location at the nuclear plant site
- References:
 - Loviisa, Posiva (FI)
 - STUK (FI)
 - Puram / Bátatom Ltd. / Batkontroll (HU)
 - EC/ PHARE (HU)
 - LSK RADON (RU)





Decommissioning planning for NPPs and research reactors

- Decommissioning strategy, licensing, waste management planning, waste inventory, work plan and cost estimate, safety analyses, estimation of radiation dose rates, resource planning
- Optimization of the whole process from waste collection, treatment to final disposal (e.g. cost optimization between decontamination and disposal)
- Cost efficient decommissioning methods, e.g. without cutting the reactor pressure vessel
- Strong capabilities also in recycling and safe disposal of hazardous waste by incineration
- References:
 - Loviisa NPP
 - Several contracts for decommissioning planning of Olkiluoto NPP (FI)
 - Executing the largest demolition project in Finland (Inkoo power plant demolition).





Nures® for purifying radioactive waters

- A solution developed for purification of radioactive liquids
- Based on highly selective ion exchange materials to remove, e.g., caesium, strontium and cobalt
- One of world's most effective:
 - Purest liquids
 - Smallest waste volumes
 - Significant economic savings
- Supplied to over 60 customers around the world since the 1990s
- Significant volumes to Fukushima, Japan, to solve the wastewater problem





NURES[®] - solution for purification of radioactive liquid waste

- NURES[®] solution is based on inorganic highly selective ion exchange materials to remove nuclides such as Cs, Sr, Co, Sb as well as other corrosion products or even plutonium and other transuraniums from liquids
 - Originally developed for treating challenging liquids such as evaporator concentrates
 - Also suitable for treating e.g. floor drain waters to a very high decontamination factor instead of traditional demineralizer system
 - NURES[®] cleans radioactive liquids leaving a smaller waste volume than any competing organic or inorganic ion exchanger on the market
 - The cleaned liquid has the lowest level of radioactivity compared to other sorbents
 - Efficient for different liquid characteristics (high or low pH-values and high salt concentrations)
- NURES[®] results in considerable cost savings due to reduced conditioning and final storage expenses
 - e.g. 2.5 mln eur a year savings in 2xVVER-440 Loviisa NPP since 1991 as the treated evaporator concentrate can be released to the sea







Multiples successful examples of NURES[®] use around the Globe (over 13 countries, over 30 clients)



Complete Nuclear Waste Management on one island – Olkiluoto, Finland

SPENT FUEL INTERIM STORAGE FACILITY

Cooling of fuel assemblies removed from reactor building in water pools excavated in rock **DECOMMISSIONING WASTE REPOSITORY** Space reservation for decommissioning waste

OPERATING WASTE REPOSITORY - VLJ Final disposal of intermediate and low level waste

SPENT NUCLEAR FUEL REPOSITORY

The underground research facility ONKALO[™]
Construction license for the final disposal facility was granted in 2015 and construction began in December 2016



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Full Scale In-Situ System Test 2018 - 2019

- Full Scale In-Situ System Test (FISST) is being constructed in ONKALO[™] demonstration area at the disposal depth of 420 metres
- Design, installation and comprehensive monitoring of EBS components:
 - 2 copper canisters (with heating equivalent to the fuel decay heat)
 - buffer in two deposition holes
 - about 50m backfill
 - deposition tunnel plug
- Installation started in June 2018
 - external partners are participating





FISST general status

- Rock works in the deposition tunnel and in the deposition holes are ready
- Instrumentation and sensors (except plug) are emplaced
 - Few remaining ones will be installed simultaneously with the heating system installation
 - Instrumentation installation to the neighbouring tunnel via leadthrough will be finished in May
- Infrastructure for tunnels ongoing
 - Electricity modifications will be ready in May
 - Concrete works (due to the test setup) will be finished in May





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FISST EBS component installation schedule

- Installation readiness will be achieved 28.5.2018
- First buffer will be installed 29.5.2018
- First canister will be installed 31.5.2018
- Backfill emplacement will be initiated in the end of June
- The plug will be installed before the end of the year









FISST-preparation in ONKALO™

Thank You!

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