ROBOSTEAM
Nuclear R&D at Fortum

Sustainable Nuclear Energy Technology Platform

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Nuclear at Fortum

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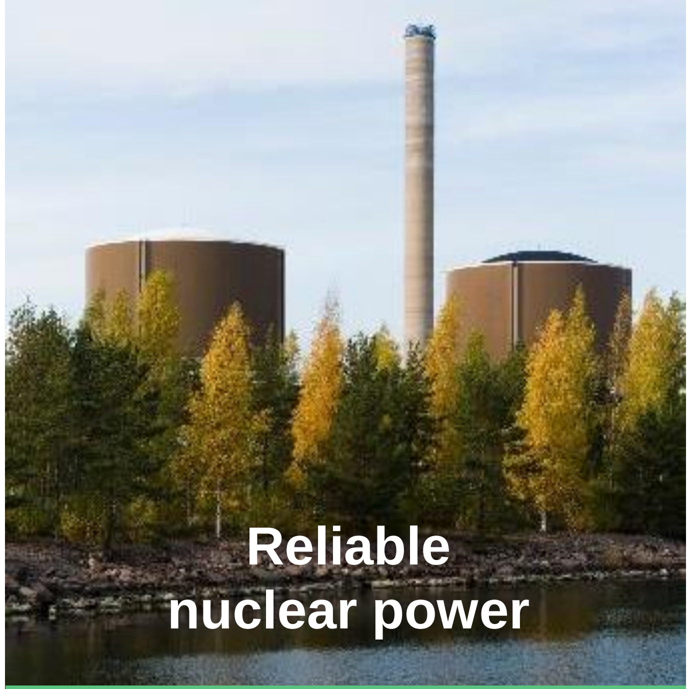
Renewables and CO_2-free power generation capacity of Fortum

16.4 GW

8.4 GW

3.4 GW



4.6 GW

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Nuclear power plays an important role in our energy production

1/3 of our electricity production is stable and reliable **nuclear power**

Nuclear power is needed to **combat climate change**.

Nuclear production in **Finland** and **Sweden**

Loviisa NPP has provided clean and reliable base production of electricity for **40 years**.

Domestically produced electricity to ensure **security of supply.**

Nuclear Services Transformation of the nuclear industry

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Nuclear at Fortum

Fully-owned nuclear power plant in Loviisa, Finland and co-owned nuclear power plants in Finland and Sweden

3rd largest Nuclear generator in Europe

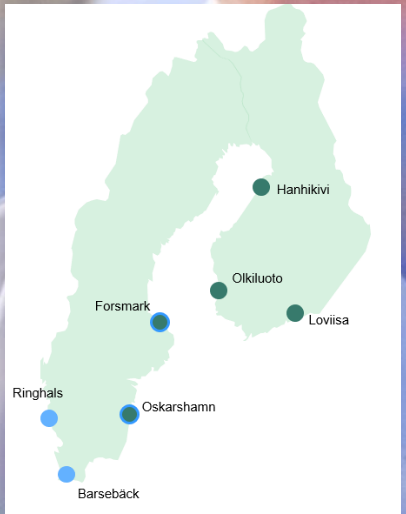
3rd largest CO_2-free power generator in Europe

Unit	Mwe (net)	Fortum Share %	Uniper Share %
Loviisa 1	507	100	
Loviisa 2	507	100	
Olkiluoto 1	890	26.6	
Olkiluoto 2	890	26.6	
Olkiluoto 3 (newb)	1600	25	
Hanhikivi 1 (newb)	1200	6,6	
Forsmark 1	988	23.4	9.3
Forsmark 2	1120	23.4	9.3
Forsmark 3	1172	20.1	10.8
Oskarshamn 3	1400	43.4	54.5
Oskarshamn 1	decom	43.4	54.5
Oskarshamn 2	decom	43.4	54.5
Ringhals 1	881		29.6
Ringhals 2	decom		29.6
Ringhals 3	1063		29.6
Ringhals 4	1103		29.6
Barsebäck 1	decom		100
Barsebäck 2	decom		100

1488 MW_e

1336 MW_e

1988 MW_e



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

We develop new, innovative products and services

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

We employ ~700 nuclear professionals

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Loviisa Nuclear Power Plant

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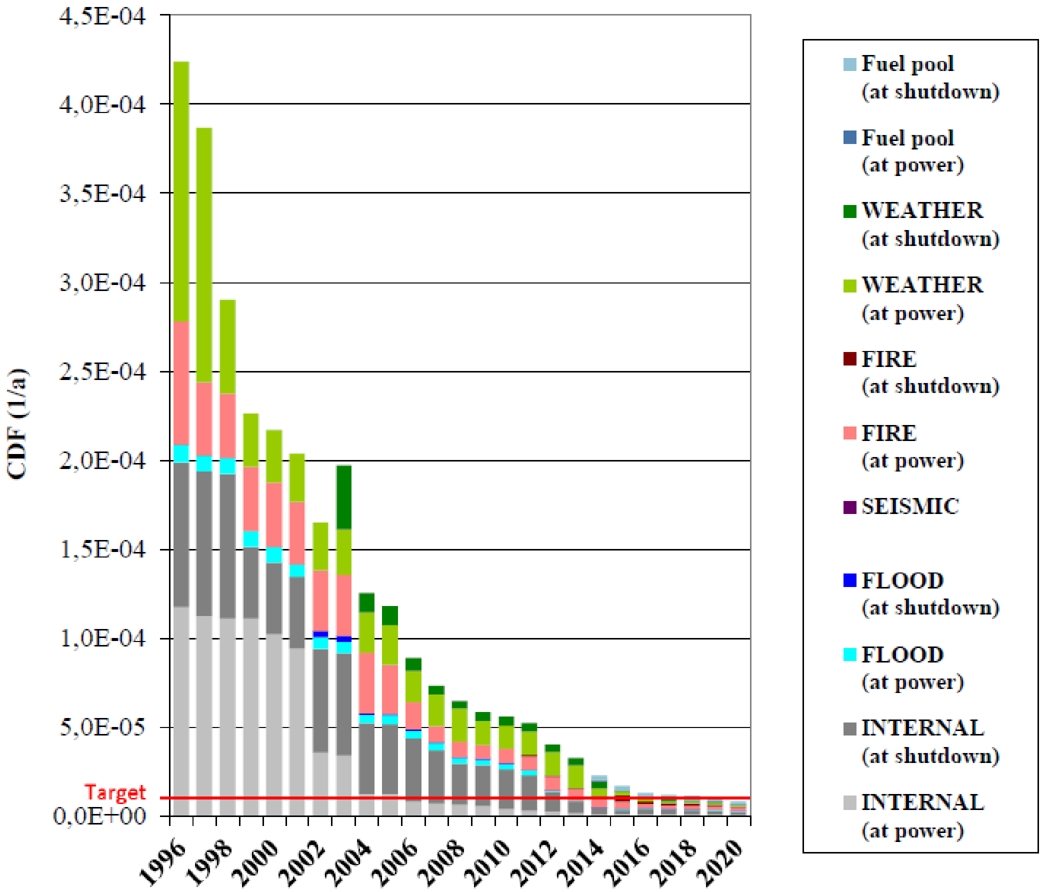
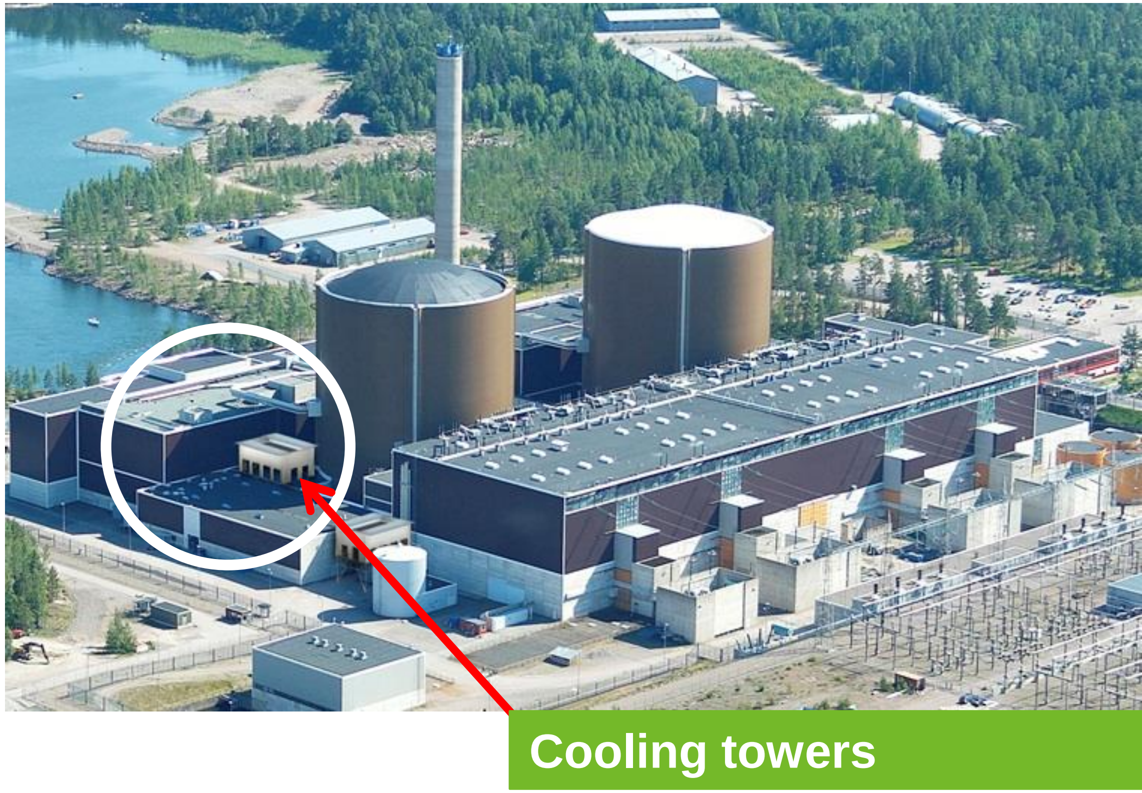
At Loviisa NPP, excellent safety performance and high availability go hand in hand

Loviisa 1 risk distribution

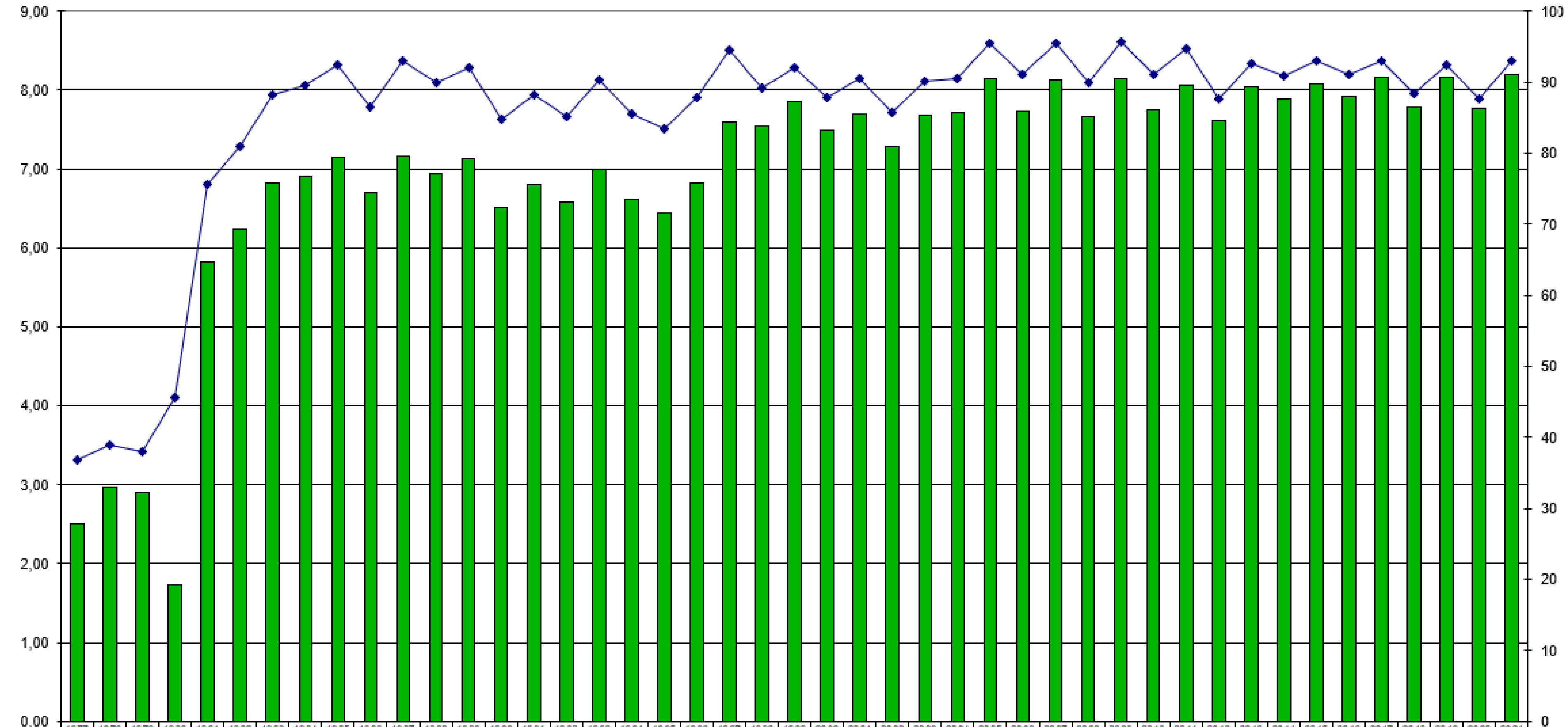




Loviisa NPP production and capacity factors 1977 - 2021

TWh, net

%, gross



	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
TWh	2,51	2,98	2,90	1,73	5,82	6,24	6,82	6,91	7,15	6,70	7,17	6,95	7,13	6,52	6,80
%	36,8	39	37,9	45,7	75,6	81	88,2	89,6	92,4	86,5	92,9	89,9	92,1	84,7	88,2

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TWh	6,58	6,99	6,62	6,45	6,82	7,60	7,54	7,86	7,50	7,70	7,29	7,68	7,72	8,14	7,73
%	85,2	90,4	85,6	83,5	87,9	94,5	89,1	92,1	87,9	90,6	85,8	90,2	90,5	95,5	91,0

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TWh	8,12	7,67	8,15	7,74	8,06	7,61	8,04	7,88	8,07	7,93	8,16	7,79	8,16	7,77	8,20
%	95,4	89,9	95,7	91,1	94,7	87,7	92,7	90,9	92,9	91,1	92,9	88,4	92,4	87,7	92,9

2021

Production: 8.2 TWh

Capacity factor: 92.9%

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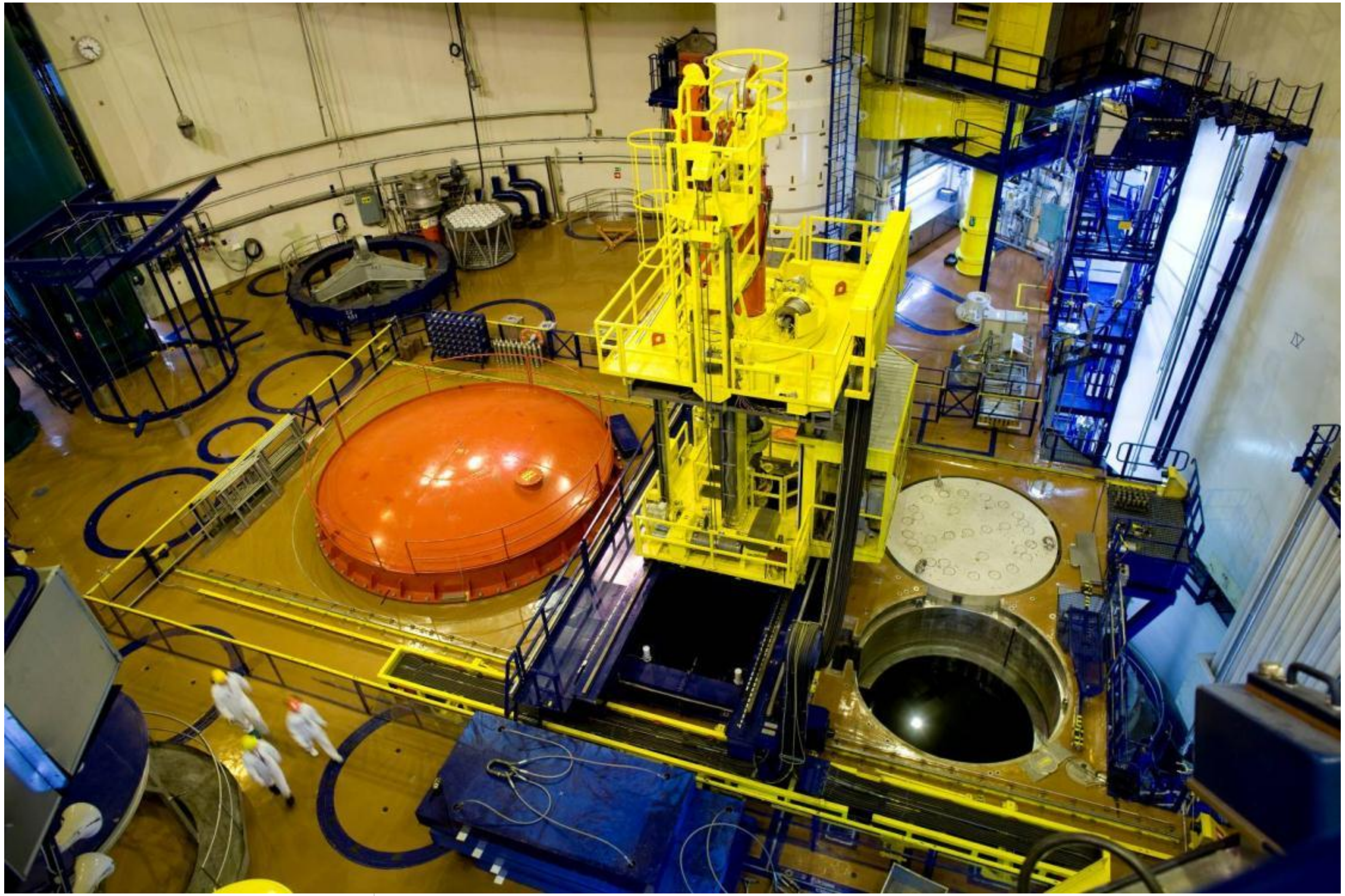
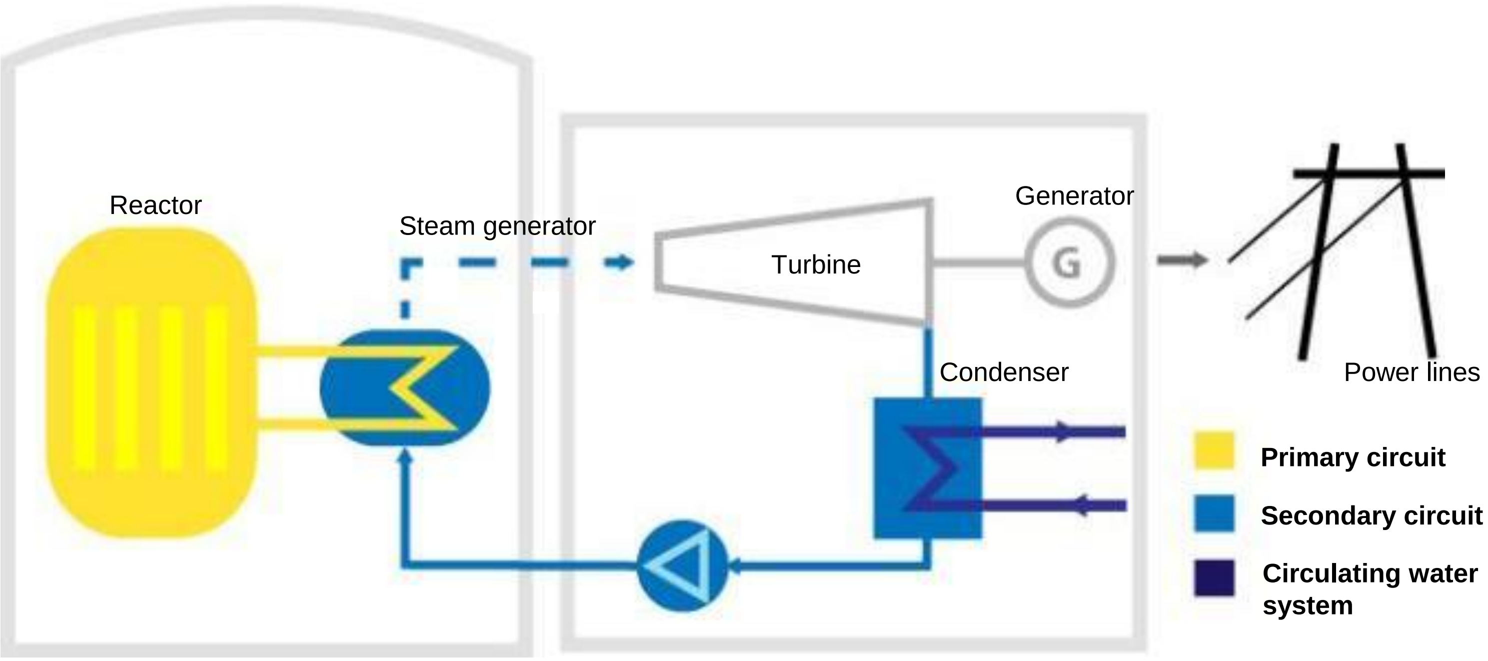
Reactor hall



Operating Principle of a Pressurized-Water Reactor



Generator

The turbine rotates the generator, changing the kinetic energy in the turbine into electricity.
The electricity is transmitted through generator transformer to the national grid at 400 kV voltage.

Reactor

The water is heated to about 300 °C in the reactor. Due to the high pressure in the primary circuit (123 bar), the water does not boil. It is circulated in liquid form to steam generators and then back to the reactor.

Turbine

The heat transmitted through the steam generator walls heats a separate secondary circuit (44 bar) of water, which turns into steam. The steam is led to the turbines.

Circulating Water System

After the turbines the steam is condensed back into water with the help of cold seawater. When both units are in operation, 40 cubic meters of seawater per second is needed for steam condensation. The cooling water warms up by about 10 °C during the process.

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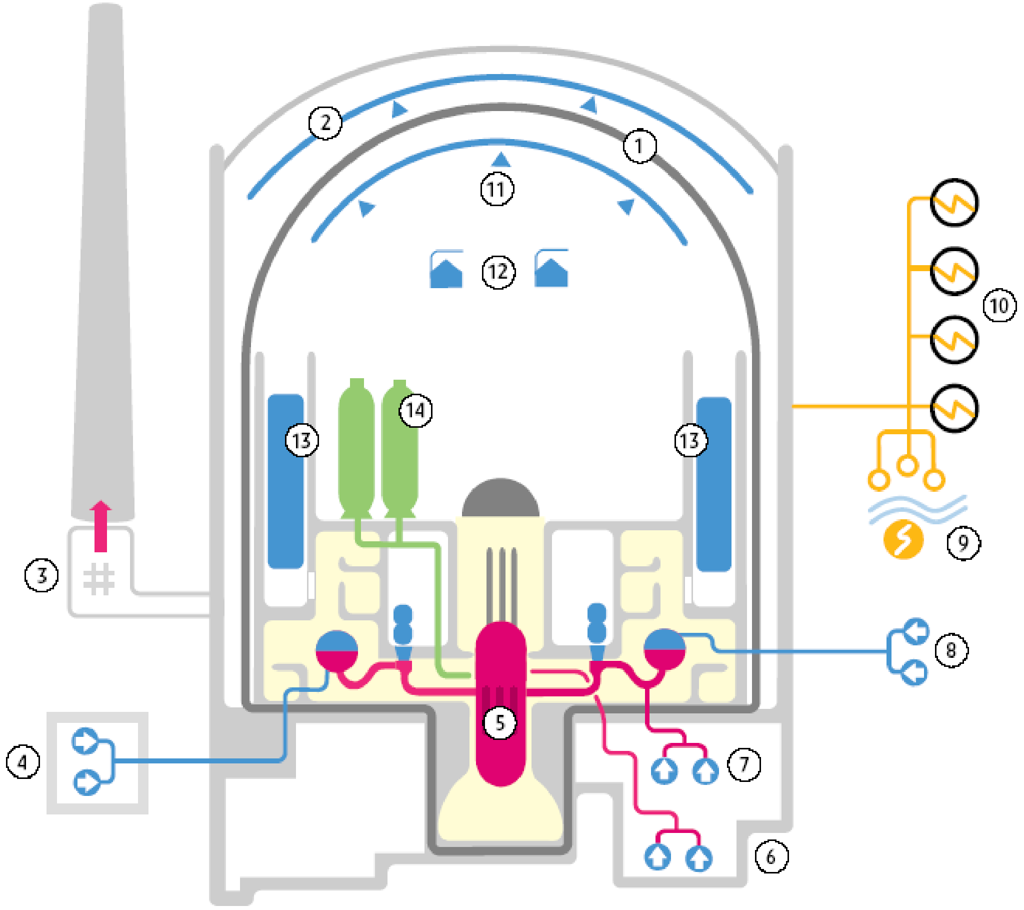
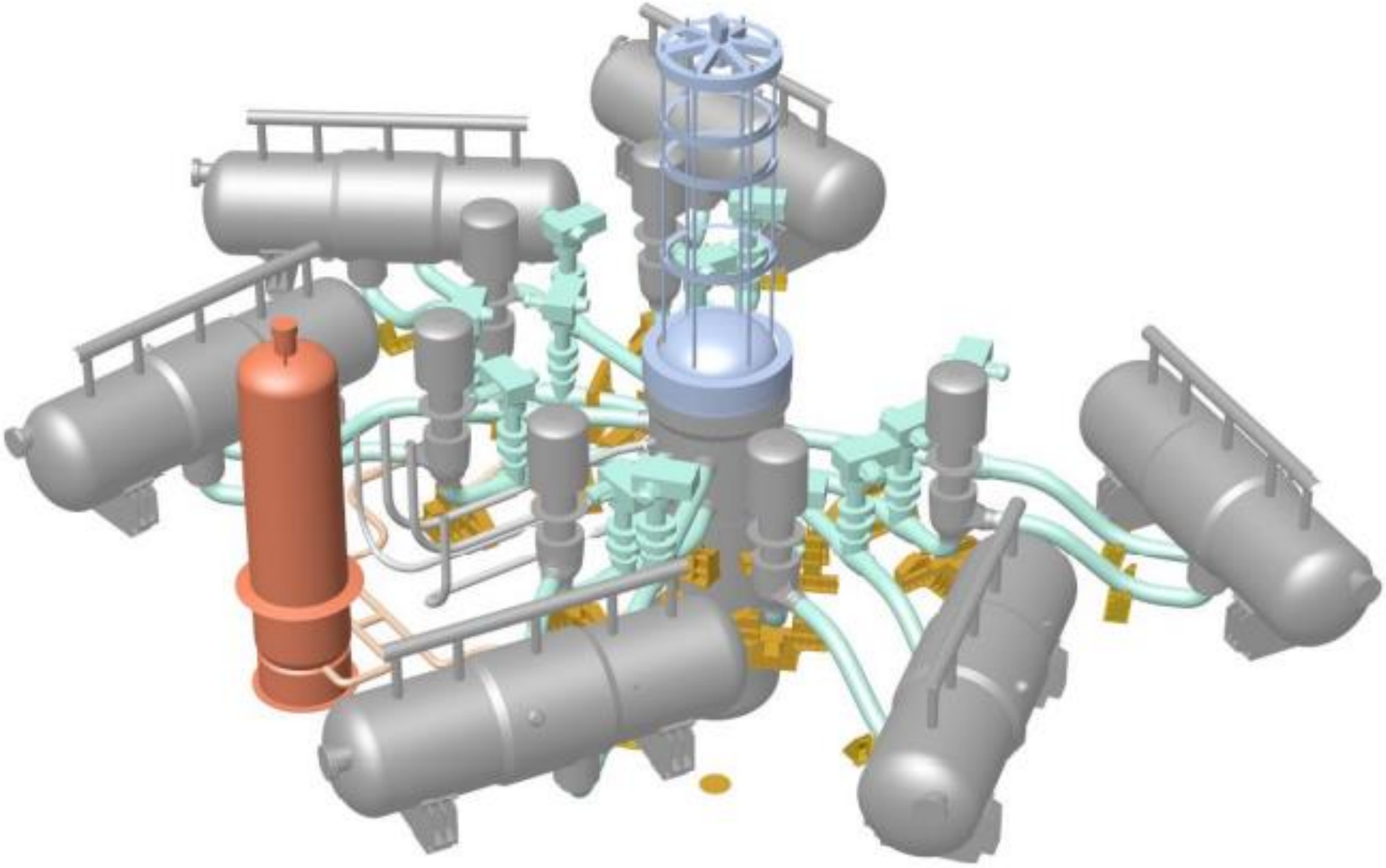
Safety systems at Loviisa power plant



Most Important Safety Systems:

1. Steel containment
2. External containment cooling
3. Air filters
4. Auxiliary emergency feed water pumping station
5. Uranium core
6. Low-pressure safety injection pumps
7. High-pressure safety injection pumps
8. Emergency feed water pumps
9. Power supply from hydropower station
10. Reserve power diesel generators
11. Sprinklers
12. Hydrogen release and recombiners
13. Ice condensers
14. Safety hydro accumulators

VVER-440 Nuclear Power Primary Circuit



Source: VVER-type nuclear power plants and evolution of their safety, Laaksonen, November 14 2013

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Inspection and cleaning robot of Steam Generators of Loviisa NPP

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Background – Cleaning and Inspection Robot of Steam Generator of Loviisa NPP

Steam generator of **Loviisa VVER-440 type Nuclear Power Plant (NPP) is cleaned and visually inspected every four years.** Cleaning means hoovering of magnetite from a bottom of the steam generator. **Work is unpleasant including high radiation doses and other occupational health and safety risks.**

During 2019 and 2020 first version of a cleaning and inspection robot of the steam generators was developed. The first version of the robot was tested in outage of Loviisa NPP in September 2020. So far the **robot is not autonomous, but manually controlled** outside of the steam generator.

The first test was a success. The raft was easy to control. Photos and videos were taken above a water level and from bottom of the steam generator by endoscope. Quality of photos and videos was very good and they can be easily used for visual inspections. **Cleaning (hoovering) system was not yet tested, but hoovering tube was successfully lowered to the bottom of the steam generator.**

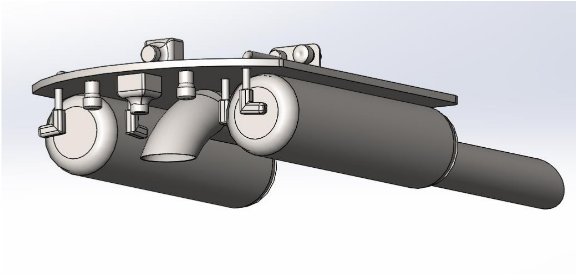
After the first test, inspection functionality was considered to be the most relevant and development efforts were concentrated on inspection robot. **In 2021 the concept was developed to fulfil all necessary requirements.**

Project phases

- **Project kick-off** with Jyväskylä University of Applied Sciences (JAMK)
- Case and requirement analysis
- Robot alternatives and selection a raft for a basement of a robot

- **Robot design update** based on site test experiences
- **Factory tests** of the new design. (Site tests were not possible)
- Studies of commercialization possibilities

2019	2020	2021	2022



- Basic planning of the robot and IPR studies
- **Factory tests** in swimming hall of Jyväskylä
- **Site tests** in outage of Loviisa NPP
- Summary of experiences

- Finalising of the design
- Factory tests of the design
- Building pilot test rig and pilot tests
- **Site tests in outage of Loviisa NPP**

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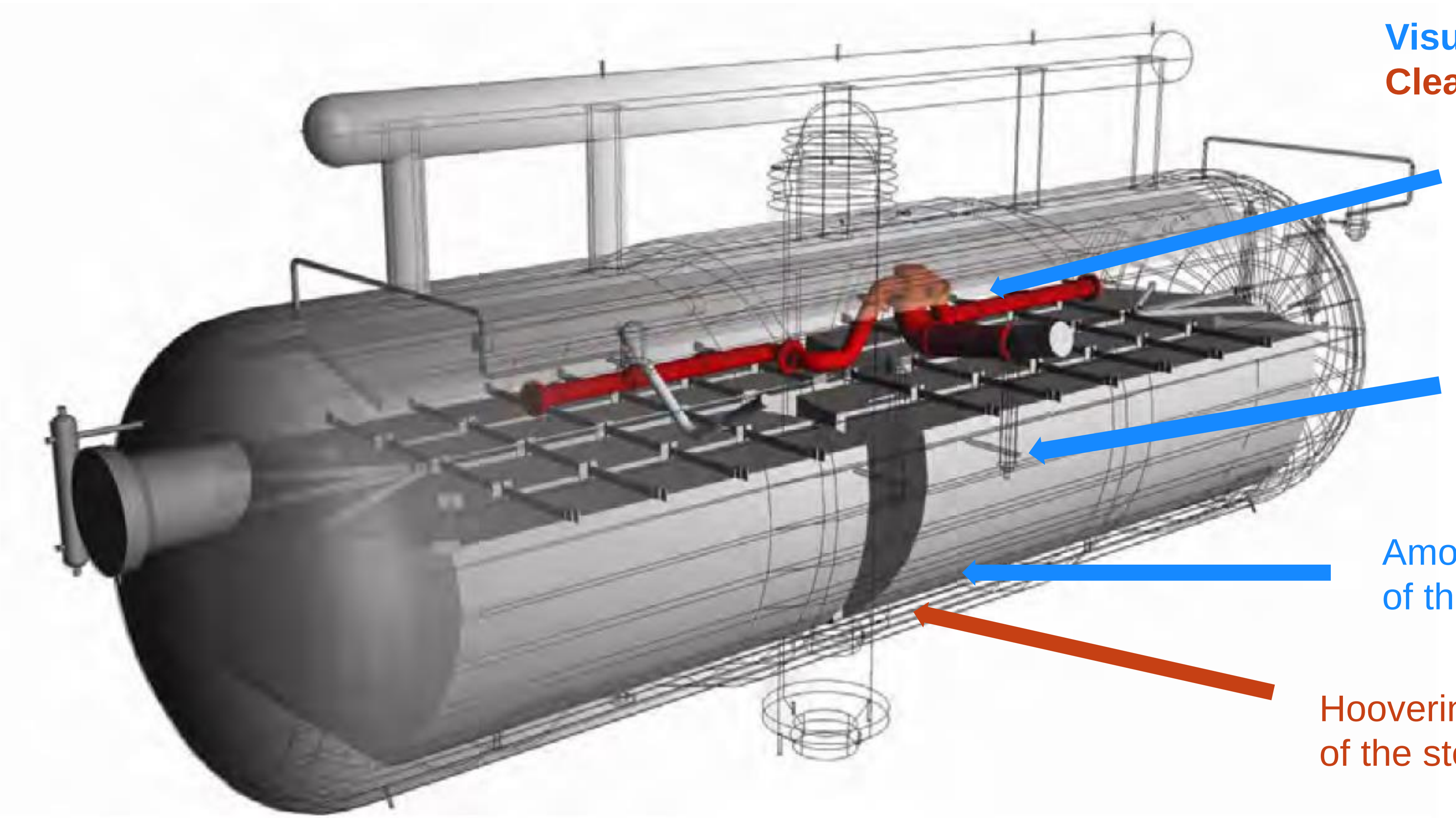
Outage operations in Loviisa Steam Generator



Visual inspections

Cleaning operations

Structures above water level

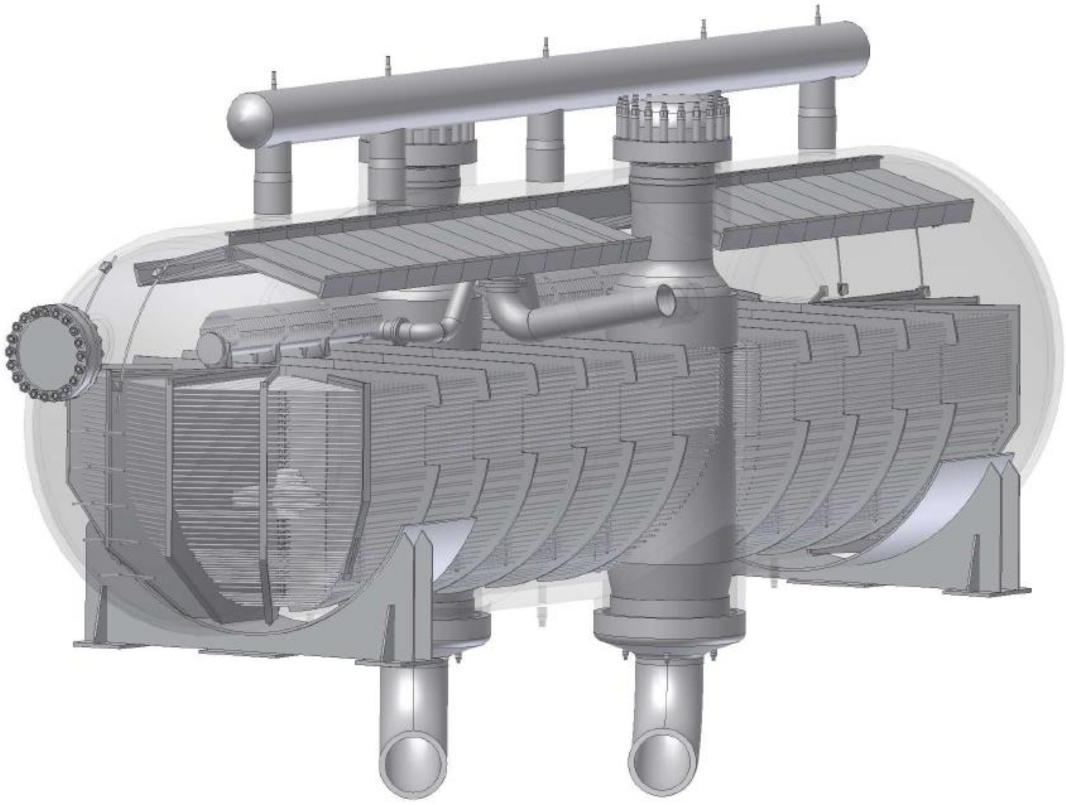
Old inlet water nozzles
inside tube bundles

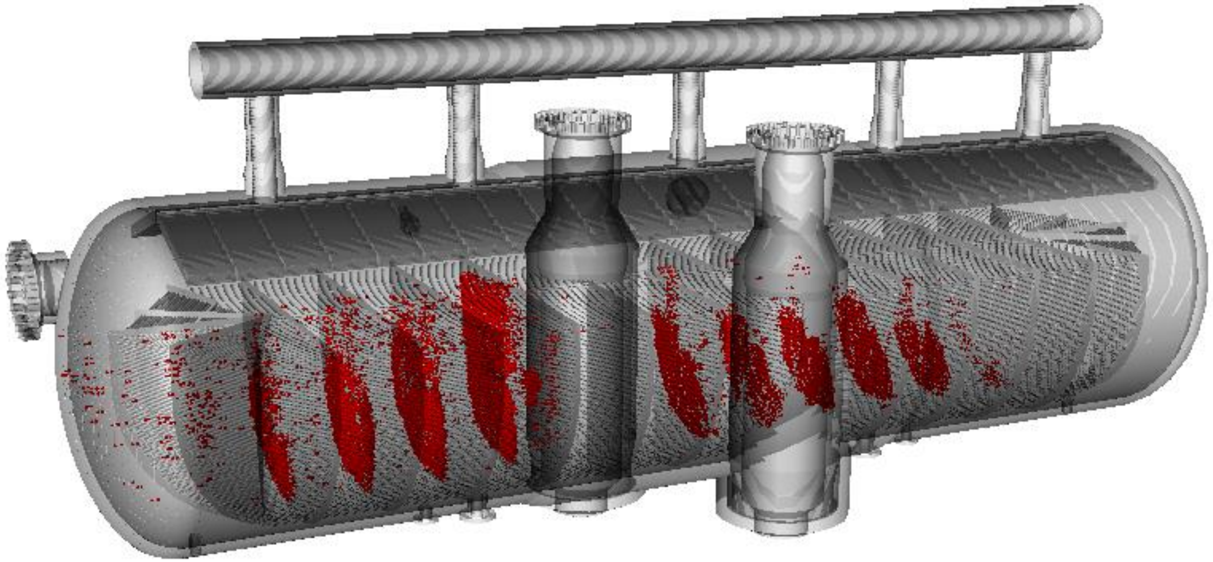
Amount of magnetite on the bottom
of the steam generator

Hoovering magnetite from the bottom
of the steam generator

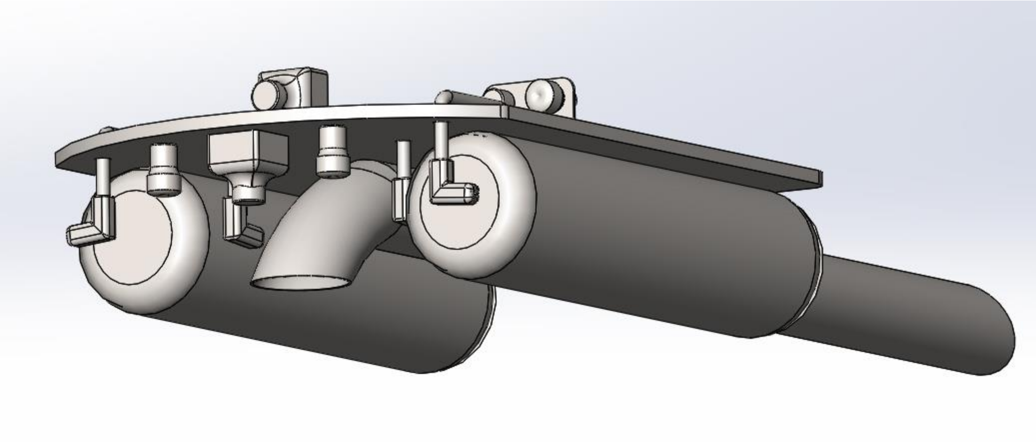
Source: [Nuclear Power - Deployment, Operation and Sustainability, Tamas Janos Katona, 2011]

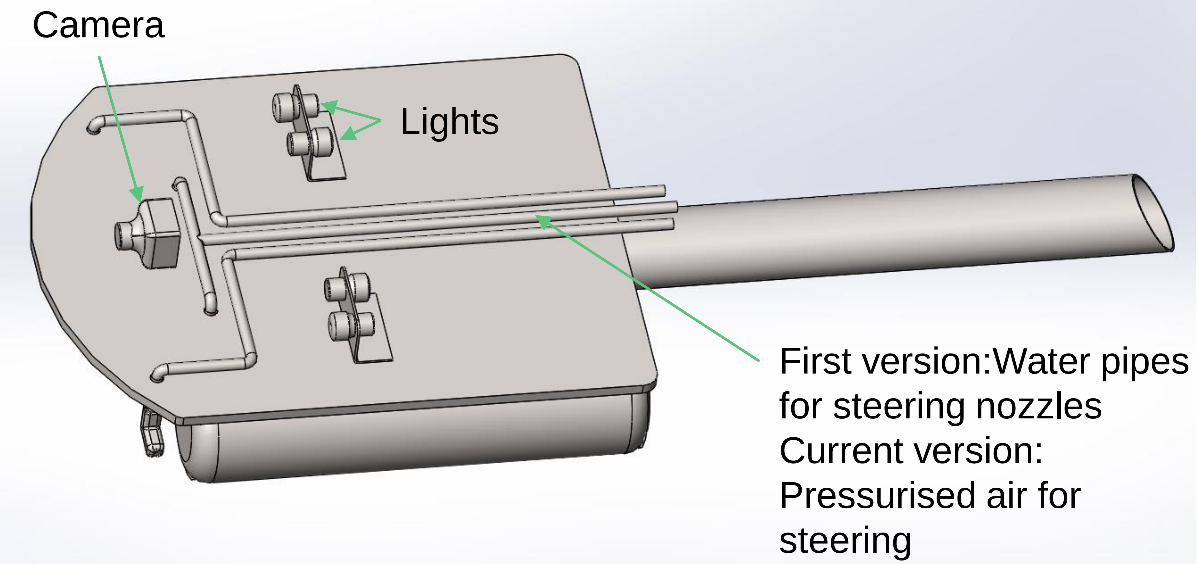
Loviisa Steam Generator and magnetite accumulation

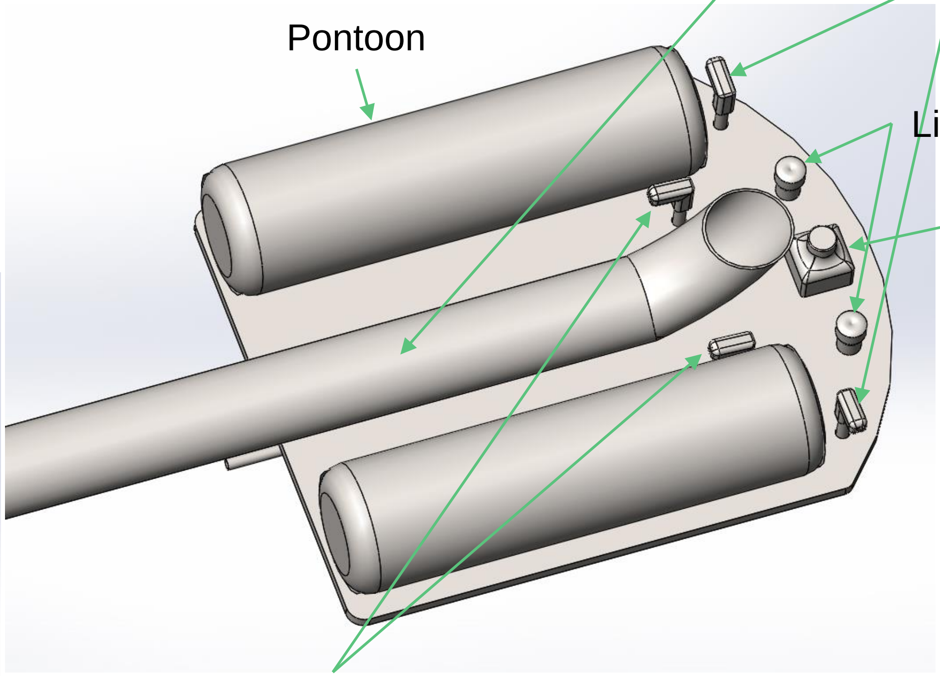




Sketch of the robot







Testing experiences

Current version of the robot

Future plans

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Future plans – Cleaning and Inspection Robot of Steam Generator of Loviisa NPP

Main focus of current and future robot will be operation in hazardous and dangerous places. First business cases could be around inspection of pools, containers and all other waterways. Next step will be cleaning tasks and after that more functions and tools can be added to the robot. **Target is to develop multipurpose robot, which can be easily and with low investment costs used in many kind of places and industries.**

In the first phase competitiveness of the robot will be dependent on case specific development costs as well as availability of alternative choices (traditional working process and other robots or other tools) It would be beneficial to find out application where current robot can be used without remarkable development costs, but it would also be important to find out all possible areas where modified robot could be used in future. **Roadmap for possible future development activities and their cost effects are listed in the next slide.**

Possible target industries in addition to nuclear industry for the robot could be: Oil, gas and chemical, Water supply and sanitation, Energy generation and distribution, Urban and suburban infrastructures and transport, Paper and pulp industry…

Development vs costs

Development tasks / Price evaluation	0 – 10 k €	10 - 100 k€	100 - 1 000 k€
New cameras to existing float	X		
Other additional tools to existing float	X	X	
New kind of float with updated steering system (2021)		X	
Updated vacuum cleaner system for water pools (2022)		X	
New kind of moving capabilities in water (diving)		X	
Autonomous functionalities to the current robot		X	X
Other moving capabilities to the robot (crawling, flying)		X	X
Modifying existing cameras and other tools to new versions	X	X	
Developing new tools to new versions	X	X	X
???			
…			
…			

Thank you!

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