Safe and Final Disposal of Spent Nuclear Fuel in Finland

Mr. Mika Pohjonen and Ms. Sanna Mustonen
Posiva Solutions

22 February 2023

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Meet the Presenters

Mr. Mika Pohjonen, Managing Director of Posiva Solutions Oy, has over 30 years of international experience in the energy sector. He has previously held various sales and management positions in the engineering and management consulting business. Mr. Pohjonen has broad experience in the nuclear energy business, acquired in numerous projects in Finland and in most European countries that utilize nuclear energy, as well as in the Middle East and China. He has also worked as an invited expert for the International Atomic Energy Agency (IAEA) in environmental and social impact assessment.

Ms. Sanna Mustonen, Safeguards Officer of Posiva Oy, has 20 years' experience in Posiva and Posiva Solutions. During her career in the program for geological disposal of spent nuclear fuel in Finland, Ms. Mustonen has worked in versatile projects concerning safeguards, data management, excavation works and machine development, among other things. She has been acting in Posiva's safeguards tasks since 2018. Prior to working in Posiva, Ms. Mustonen has worked in mining and in exploration companies.

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Safe final disposal of spent nuclear fuel in Finland

Mika Pohjonen
Managing Director
Posiva Solutions Oy

Posiva Oy

- Mission: safe and cost efficient final disposal of spent nuclear fuel of its owners
- Owners: Teollisuuden Voima Plc and Fortum Plc
- 90 employees
  - in addition, 100 external person years and 150 construction workers
- Turnover EUR 127 million (2021)
- Subsidiary Posiva Solutions (est. 2016) sells expertise on the final disposal of SNF

Complete Nuclear Waste Management on one island – Olkiluoto, Finland

Interim storage for spent fuel

Spent nuclear fuel brought from the plant unit cools down in water pools

Repository for operational waste (LILW repository)
Repository for low and intermediate-level radioactive Waste, in operation since 1992

Final disposal of the decommissioning waste of the power plant

Reservation for the radioactive decommissioning waste of the power plants

Final disposal of spent nuclear fuel ONKALO®
The construction is ongoing and the application for operating license has been submitted 30.12.2021

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The safe final disposal will be started first in the world in ONKALO®

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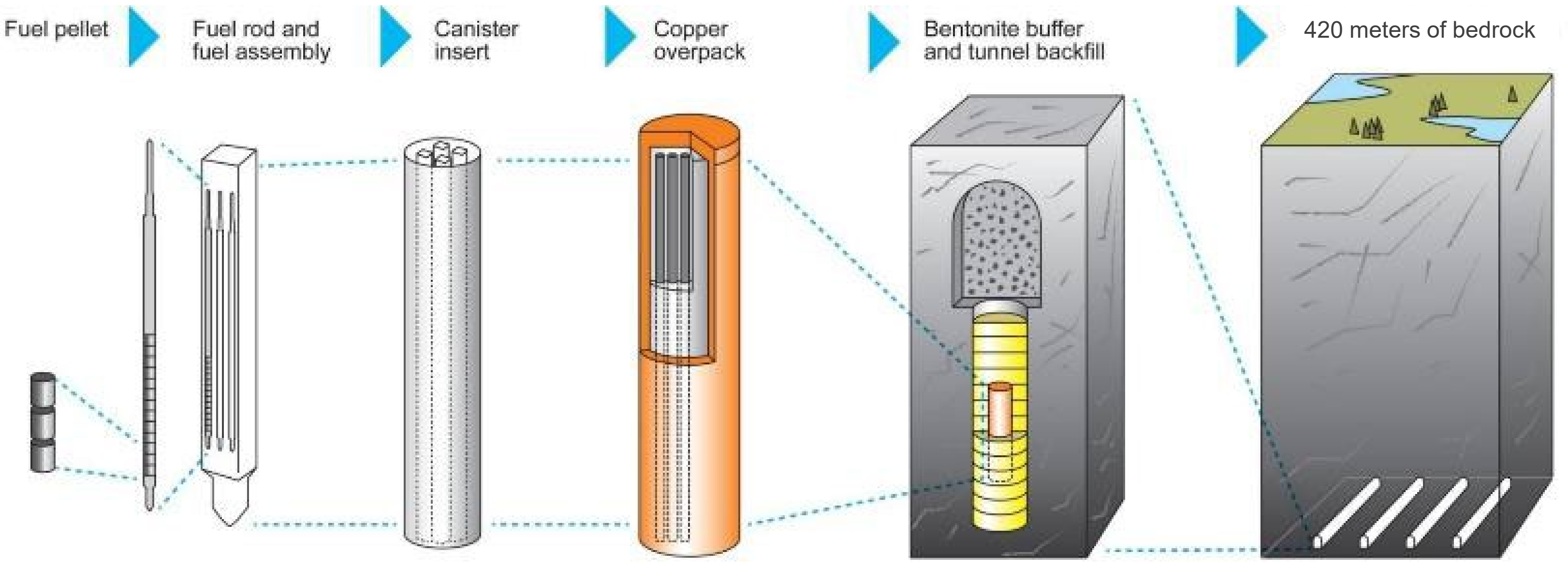
Only safe final disposal is possible

The principle of final disposal:
Several release barriers back up each other and ensure long-term safety.



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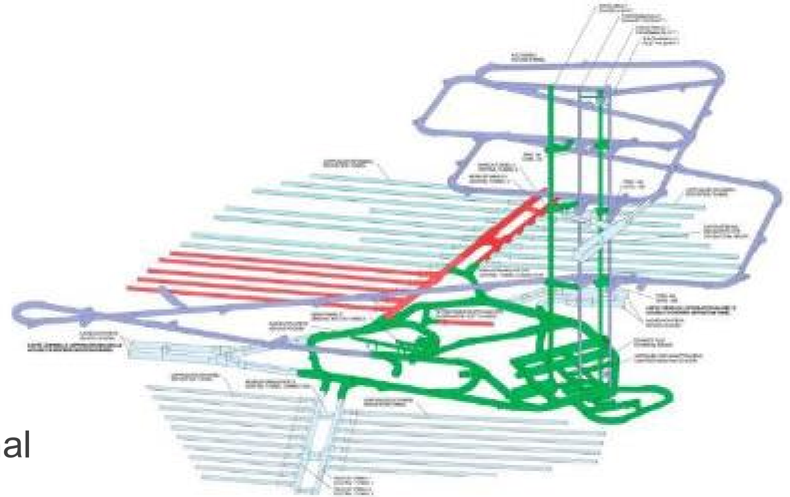
Investigations in ONKALO®

Since 2004, we have:

- investigated the bedrock in great detail
- developed rock construction methods
- implemented tens of tests and demonstrations
- drilled dozens of test holes above ground and underground



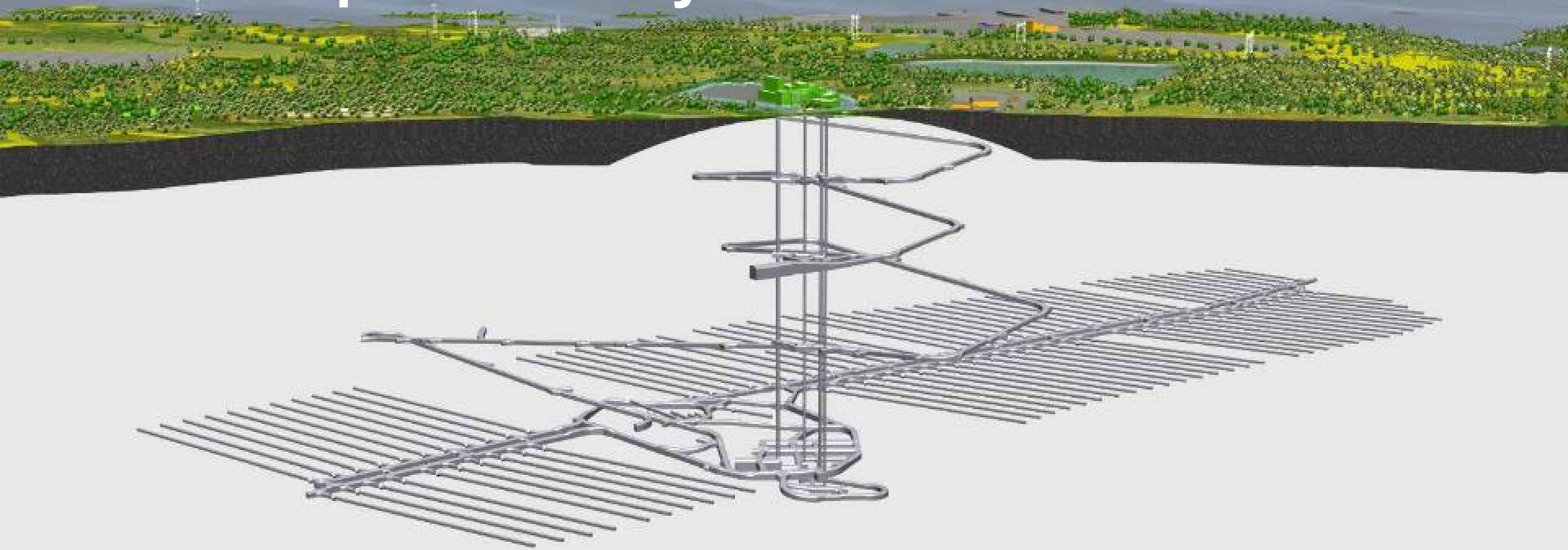
ONKALO has been designed to be a part of the final disposal facility

Approx. 6.5 km of excavated access tunnels and vehicle access

Demonstration facilities –420 m

Technical rooms –437 m

Final disposal facility around 2120



- Repository capacity is 6500 tU (about 3250 canisters)
- Depth of the tunnel system -400-450 m and the footprint is about 2 km^2
- Construction and operating time approximately 100 years
- The total excavation volume is about 2 million m^3
- Total tunnel length about 50 km

Pohjonen Mika

Project status above ground

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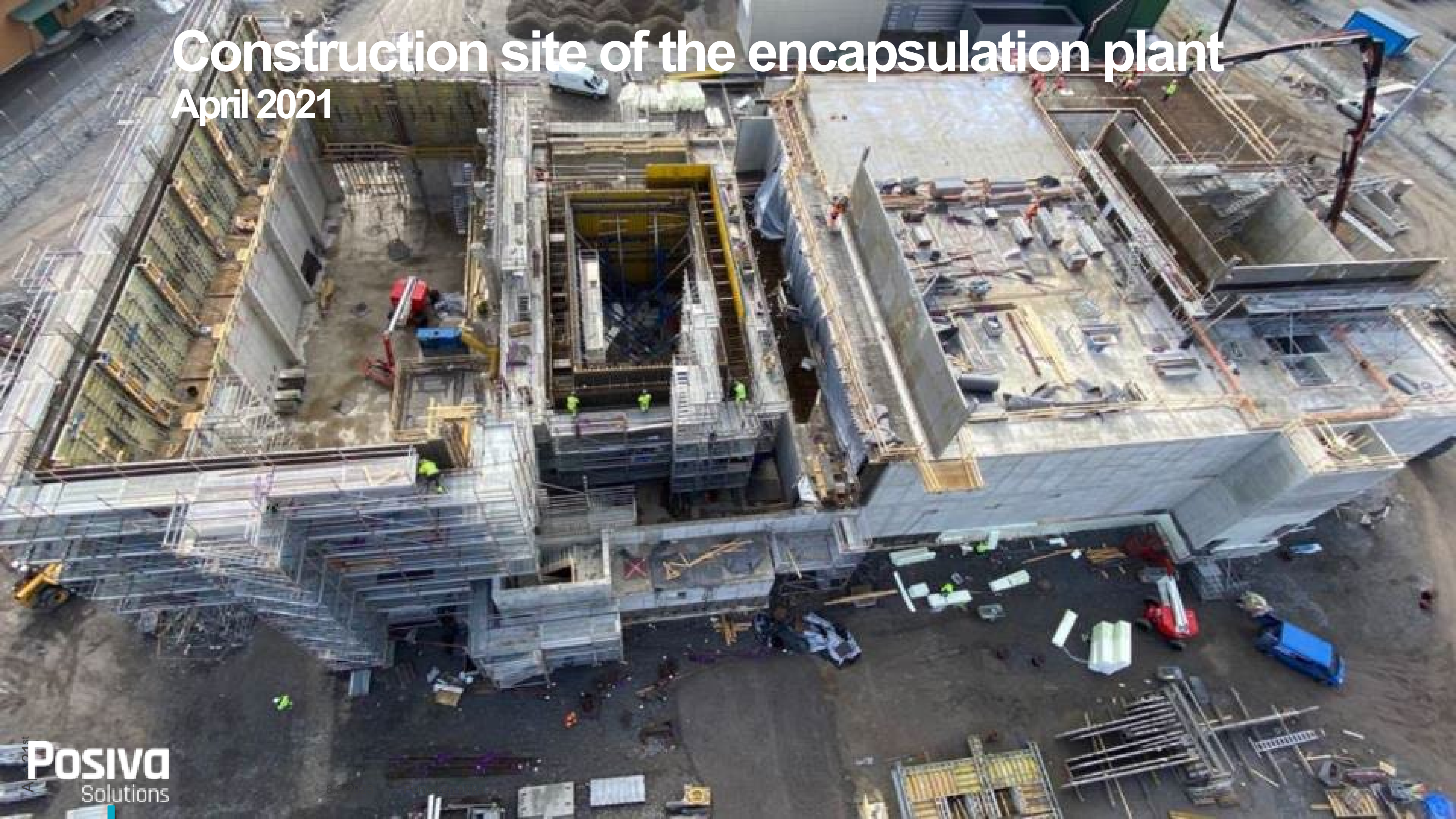
Construction site of the encapsulation plant

April 2021



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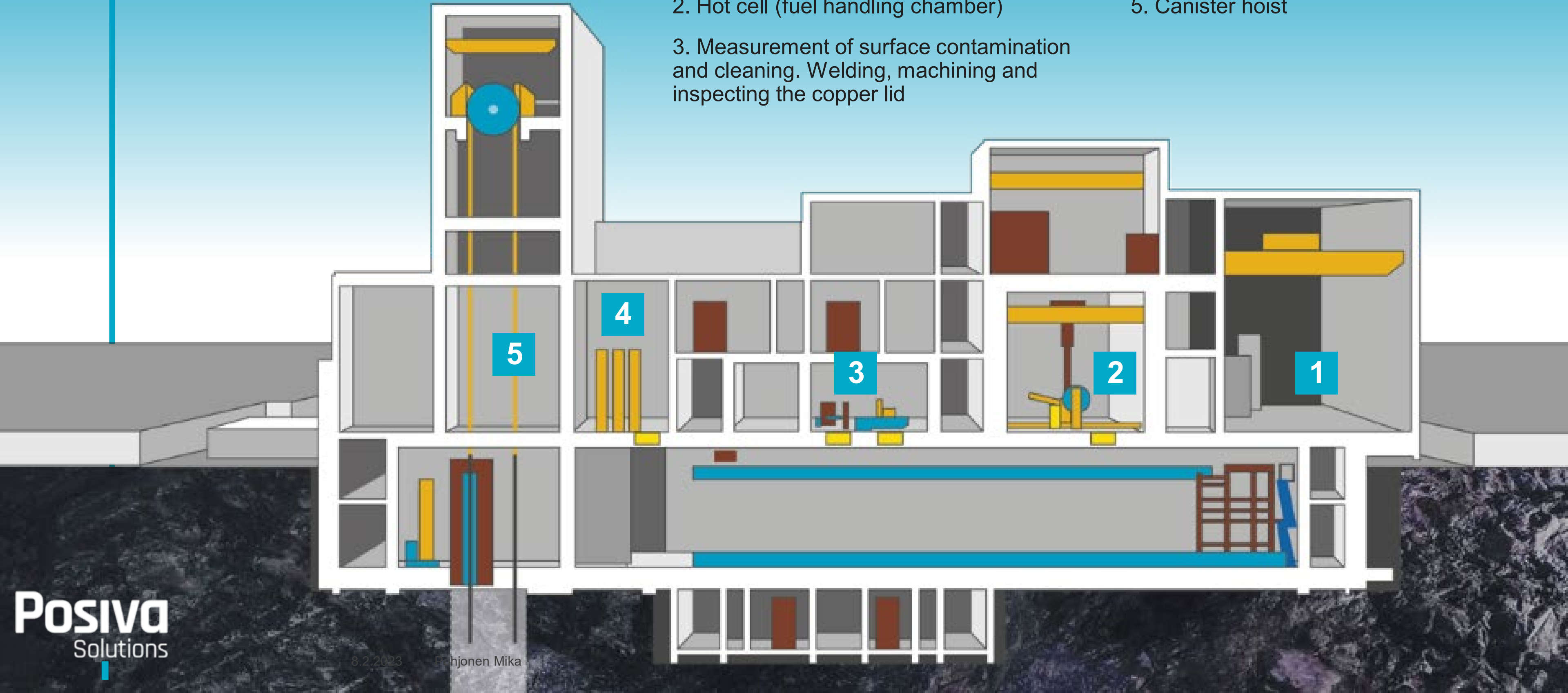
Operation of the encapsulation plant

1. Reception of fuel and storage of the transport cask
2. Hot cell (fuel handling chamber)
3. Measurement of surface contamination and cleaning. Welding, machining and inspecting the copper lid
4. Reception and storage of empty disposal canisters
5. Canister hoist



Construction site of the encapsulation plant
May 2022

Pohjonen Mika

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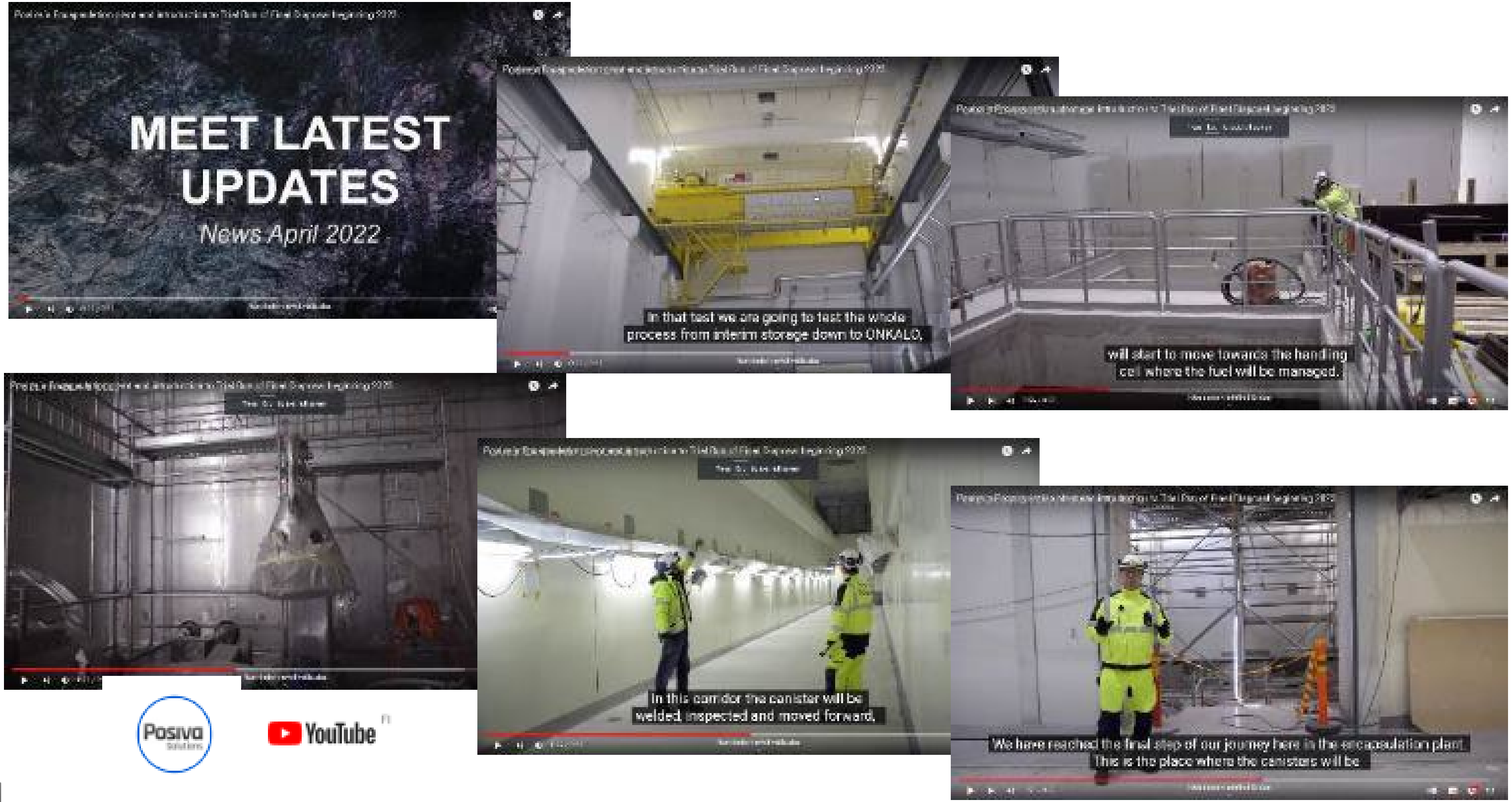
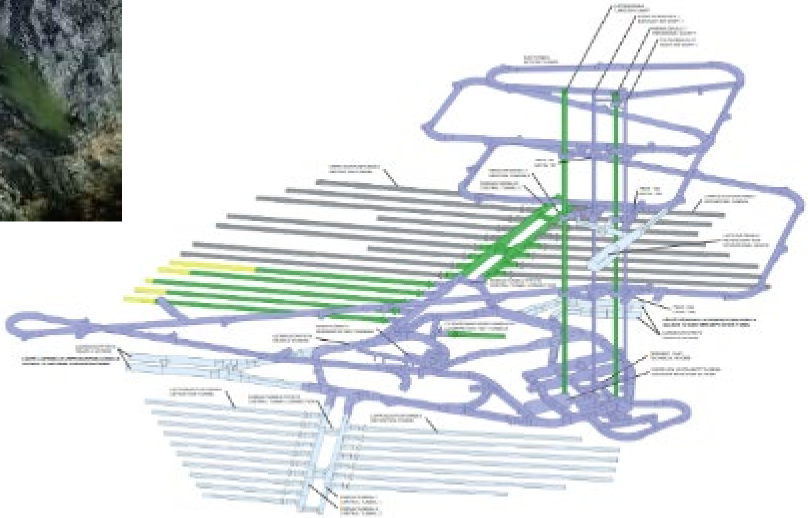
The Encapsulation Plant building is ready and equipment installation is ongoing



Project status underground

Tunnel construction



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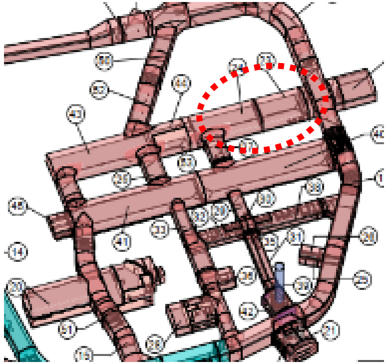
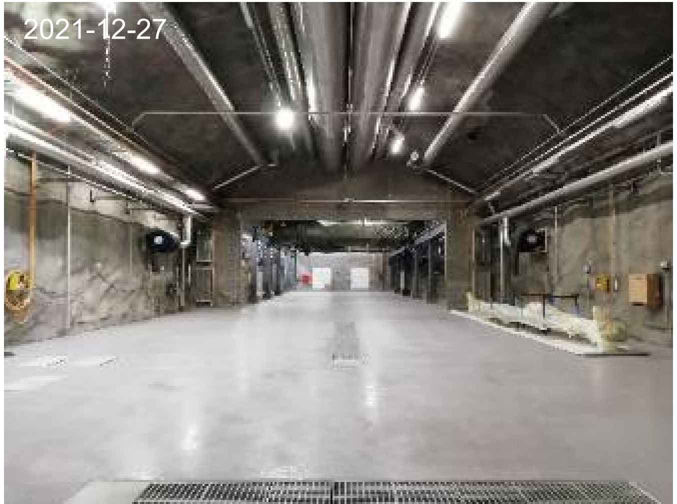
Shafts

- Personnel shaft
- Canister shaft
- Two shafts for ventilation

Technical rooms: maintenance and repair





Spent fuel transport

Transfer from the TVO's spent fuel storage to the encapsulation plant (2 km) in a standard cask:

From Loviisa NPP (300 km away) spent nuclear fuel will be transported either by road or sea.

World’s first Operation license application for a DGR was submitted 30.12.21

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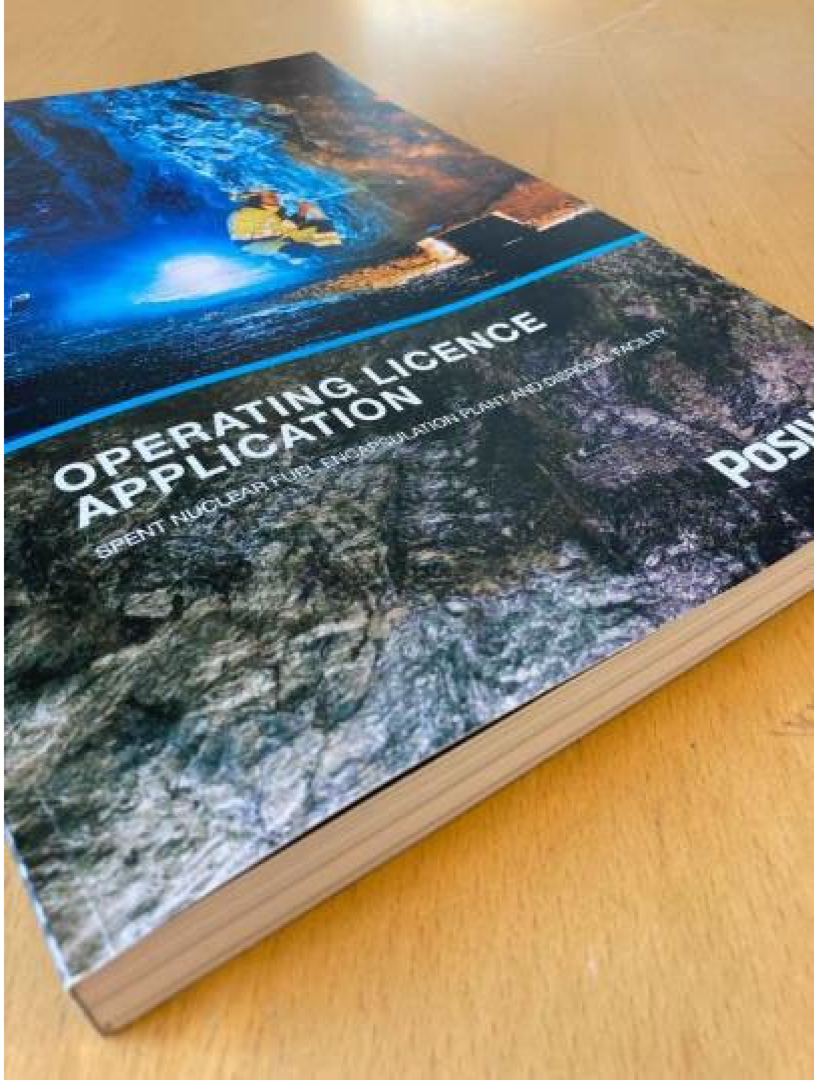
The Operating Licence Application was submitted to Finnish authorities 30.12.2021

- **17 000 pages e-document containing all needed information to grant a permit for a nuclear facility**

- **Posiva´s internal schedule to submit the application was held.**

- **2022 and H1/2023 are planned to be used to reply to STUK´s and other authorities' questions.**

- **H2/2024 considered to be the earliest time to receive the approval to start disposal.**



Trial Run of Final Disposal 2023 - 2024

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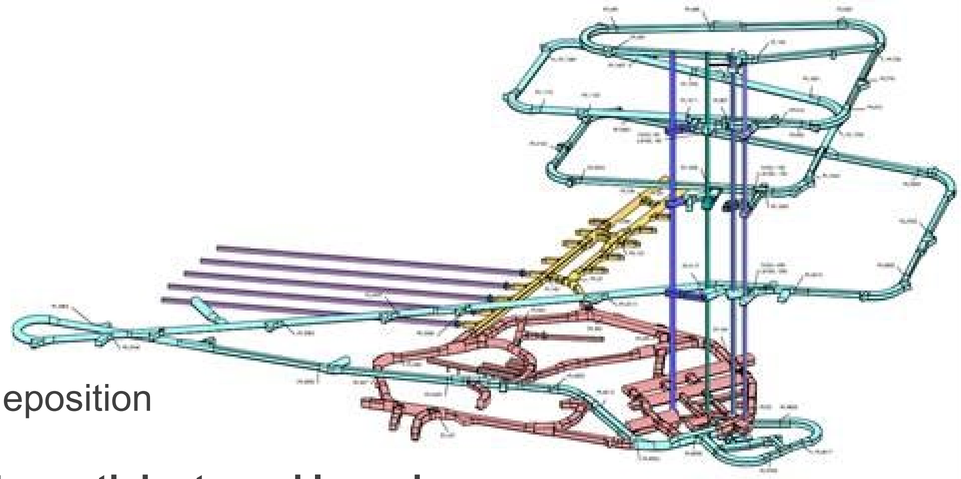
Trial Run of Final Disposal in 2023 - 2024

The Trial Run is the final phase of Posiva's preparing for the operation of the DGR. It will be carried out with the methods, procedures, equipment and personnel to be used in the operation phase

- fuel transports
- encapsulation
- final disposal
- retrieval of a ”damaged” canister back to the encapsulation plant



Consists of 4 canisters and about 70 m of deposition tunnel as well as the plug for the tunnel.

There is also an opportunity for WMO´s to participate and learn how the entire disposal process functions. Discuss with Posiva´s experts and gain insights to benefit own national program.

Public acceptance

Everyone is an important stakeholder

Municipal veto-voting

According to the Finnish law, every municipality where a nuclear facility is proposed, has a veto-right in the decision-in-principle -process.

Vote in Eurajoki municipality council in 2000:

- 20 YES
- 7 NO

Ratification of Decision in Principle in the Parliament 18 May, 2001

Decisive arguments in the Parliament:

- "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"

Three “shafts of success”

Trust and transparency

– it takes years to earn the trust, and only minutes to lose it – we do not risk this under any circumstances

Independent and trusted authorities.

Clear processes, responsibilities and roles.

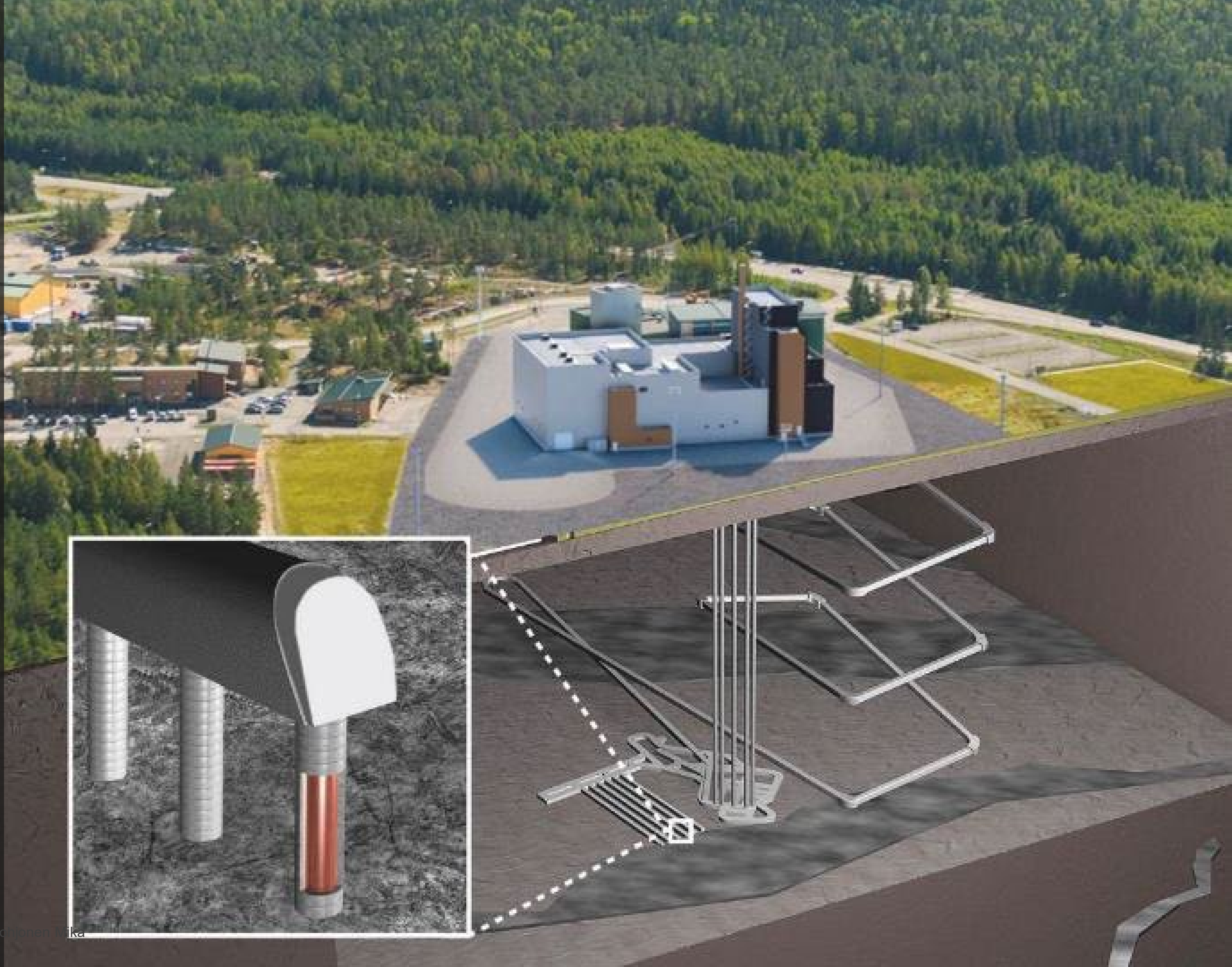
People’s own good, long experience of reliable, employing, tax-paying and transparent nuclear industry

Public acceptance of deep geological disposal of spent nuclear fuel

We have a solution for the final disposal of spent fuel

We have a significant role in climate protection as a part of the lifecycle of sustainable nuclear energy

#wehaveasolution



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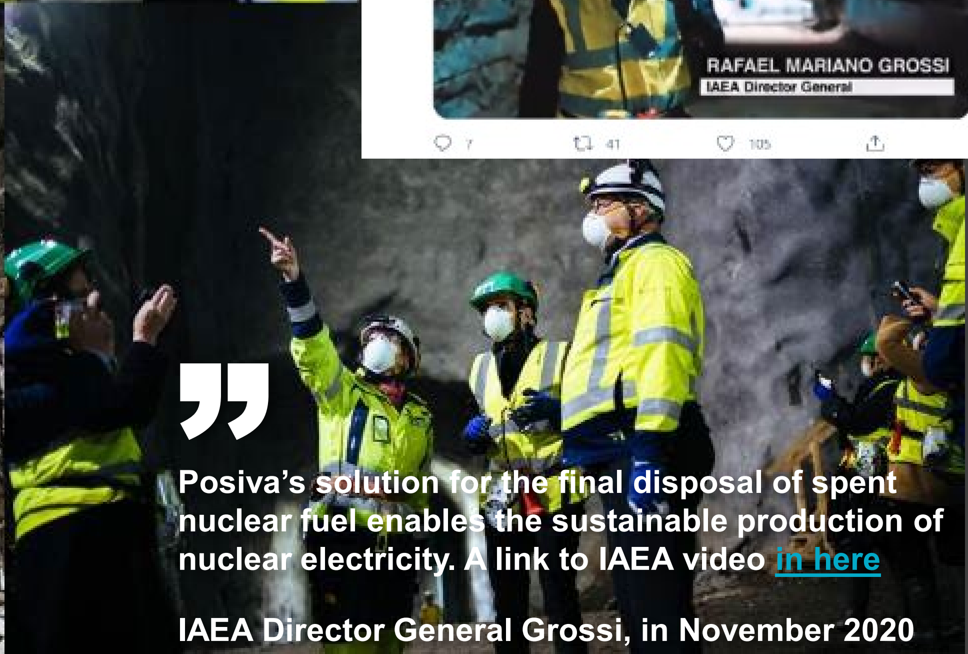
Posiva's ONKALO®
is a game changer.

Posiva's personnel and network are making history with the work that they do.



Posiva's solution for the final disposal of spent nuclear fuel enables the sustainable production of nuclear electricity. A link to IAEA video in here

IAEA Director General Grossi, in November 2020

Posiva Solutions´ capabilities to support the Client

Posiva Solutions

Safeguards measures in final disposal of spent fuel

GIF webinar 22.2.2023

Sanna Mustonen

Content

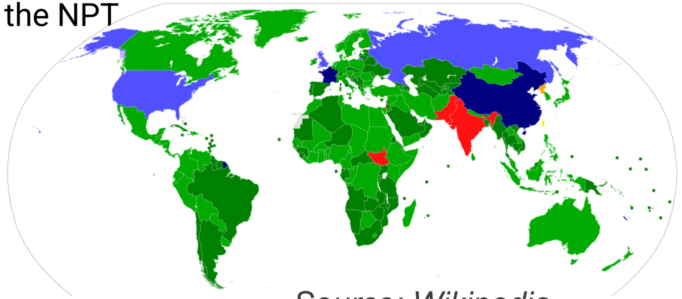
- Introduction, development for safeguards concept for geological disposal
- Nuclear material storage, transfer routes and means of transfers
- Specific requirements related to the disposal of spent nuclear fuel

Nuclear material safeguards and non-proliferation

Safeguarding nuclear materials aim at preventing the proliferation of nuclear weapons, ensures that nuclear materials and other nuclear products remain in peaceful use, and that nuclear facilities and nuclear technology are used only for peaceful purposes.

Nuclear material regulation is based on the international Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

- Finland signed a safeguards agreement with the IAEA in 1971
- When Finland joined the European Union in 1995, this agreement was replaced by a safeguards agreement between the European Union's non-nuclear weapon member states, the European Atomic Energy Community (EAEC), and the IAEA
- Finnish Radiation and Nuclear Safety Authority, STUK, maintains and develops the national nuclear material regulation system, with the aim of fulfilment of the obligations of the NPT



Source: Wikipedia

Development of nuclear material safeguards for disposal in Finnish case

Posiva's operations have been subject to safeguards since the start of construction of the underground research facility

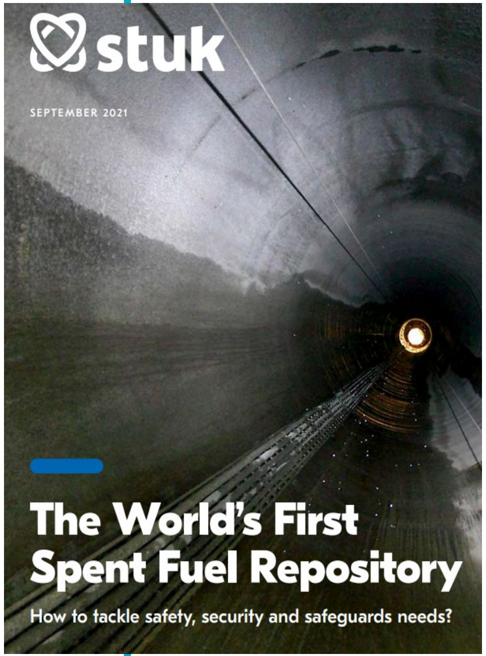
- Posiva already has national and international reporting and notification obligations
- STUK, the IAEA and Euratom carry out design information verifications at Posiva site

Final disposal safeguards concept has been actively developed for more than ten years

Joint IAEA / Euratom plan on the safeguards concept and surveillance equipment to be installed

- transfer routes and storage locations of the transport cask, fuel assemblies and disposal canisters will be continuously monitored by parallel and complementary methods
- new kind of safeguards equipment that have not been used in Finland before

Ongoing discussion on operator declarations during disposal operations



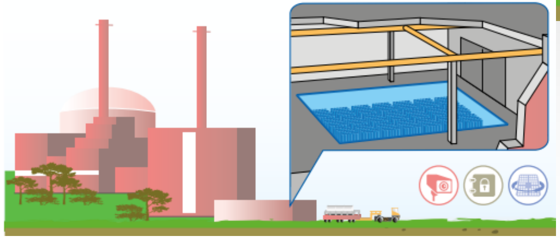
https://www.stuk.fi/en/web/en/publications

Safeguards Methodology

- Camera
- Seals
- 3D laser mapping
- Seismic monitor
- Passive Gamma Emission Tomography (PGET)
- Kr 85 detector
- Laser curtains
- Ground penetrating radar
- Radiation monitor
- Camera and radiation detector mounted on vehicle

1 Spent Fuel Storage at the Nuclear Power Plant

At the spent fuel storage authorities inspect that the spent fuel is consistent with declarations.



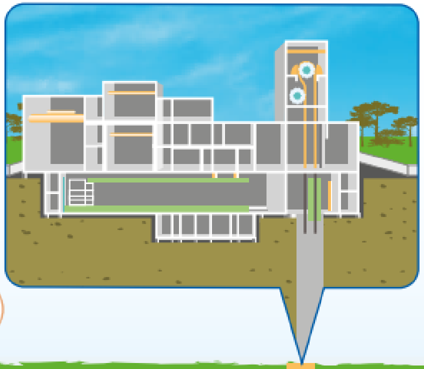
2 Transportation of Spent Nuclear Fuel

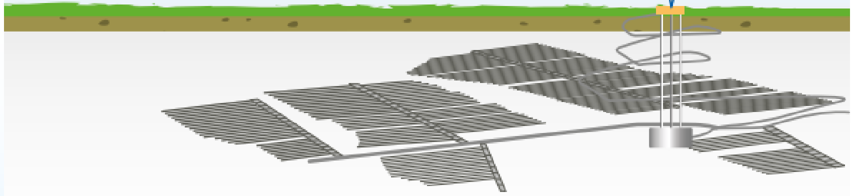
The authorities use seals and monitoring devices to ensure, that spent fuel remains untouched during transfer.

3 Encapsulation Plant

At the encapsulation plant, the authorities ensure that fuel assemblies are placed in the right canisters.

Movement of spent fuel canisters from the encapsulation plant to the final repository is monitored continuously.





The spent fuel repository is located approximately 450 meters underground.

4 Spent Fuel Repository

Inside the spent fuel repository the authorities supervise, that there are no undeclared activities in the tunnels, such as a secret reprocessing facility.

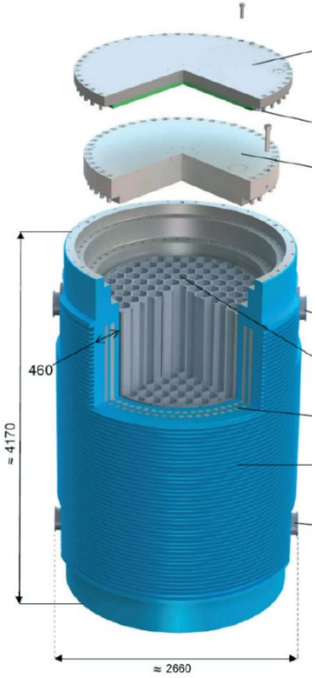
After the spent fuel has been encapsuled and disposed of it can no longer be verified.

Authorities also supervise, that new tunnels are not excavated from the outside to the repository. All entry and exit routes to the repository are monitored.

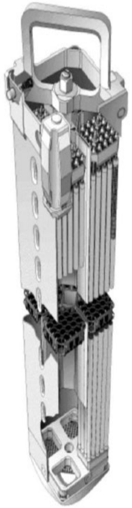
Monitoring of the spent fuel repository continues also after its closure.

Data retention will be ensured.

Nuclear materials at disposal facility complex



Transport casks



Fuel assemblies

Disposal canisters

Specific requirements related to the disposal of spent nuclear fuel

YVL Guide D.1 Nuclear material safeguards

The life cycle of a final disposal facility for spent nuclear fuel may be over 100 years. It is challenging to organise nuclear safeguards control and nuclear security arrangements because spent nuclear fuel is being placed in the final disposal facility at the same time as the facility is being constructed; moreover, the **spent nuclear fuel cannot be verified underground after disposal**

The operator shall give due consideration to ensure efficient coordination of the safety, nuclear security arrangements and nuclear safeguards measures

The operator shall make the **necessary provisions for nuclear safeguards when designing, constructing and operating a nuclear waste facility** and the associated underground facilities in particular.

The transfer routes, buffer stores, handling processes and accountancy and control system shall be designed and planned so that the **continuity of knowledge** is assured at every stage. Control of nuclear material flows in and out of the underground facilities shall be feasible.

The operator shall communicate to STUK the plans and designs for the construction of the nuclear waste facility to the level of detail agreed upon with STUK and report on the progress made. The **operator shall also demonstrate that no undeclared activities of nuclear safeguards relevance take place in the disposal area**.

Specific requirements related to the disposal of spent nuclear fuel

The operator shall demonstrate during the construction of the nuclear waste facility and the associated underground facilities that the **facility is being constructed in compliance with the notifications filed**

The operator shall design the nuclear waste facility in such a way that **nuclear fuel items and final disposal canisters can be uniquely identified** during the operation of the nuclear waste facility until the final disposal canister is finally disposed of.

The operator shall design the encapsulation plant in such a way that, during the operation of the facility, the authorities will be able to **verify the nuclear material data** (source data and usage history) **of each fuel item** by means of non-destructive methods prior to the encapsulation of the fuel items.

The operator shall design the nuclear waste facility and its operations in such a way that the continuity of control data after the verification of the fuel items can be assured every step of the way. If the continuity is lost, it shall be possible to re-verify the fuel items.

Requirements and solutions

Operator shall make **necessary provisions** for nuclear safeguards when designing, constructing and operating a nuclear waste facility

→ **handbook for instructing obligations and reporting**

operator shall demonstrate that **no undeclared activities** of nuclear safeguards relevance take place in the disposal area

→ **microseismic monitoring is used for verifying underground excavations**

operator shall demonstrate that **facility is being constructed in compliance with notifications filed**

→ **laserscanning provides detailed 3D data of underground openings**

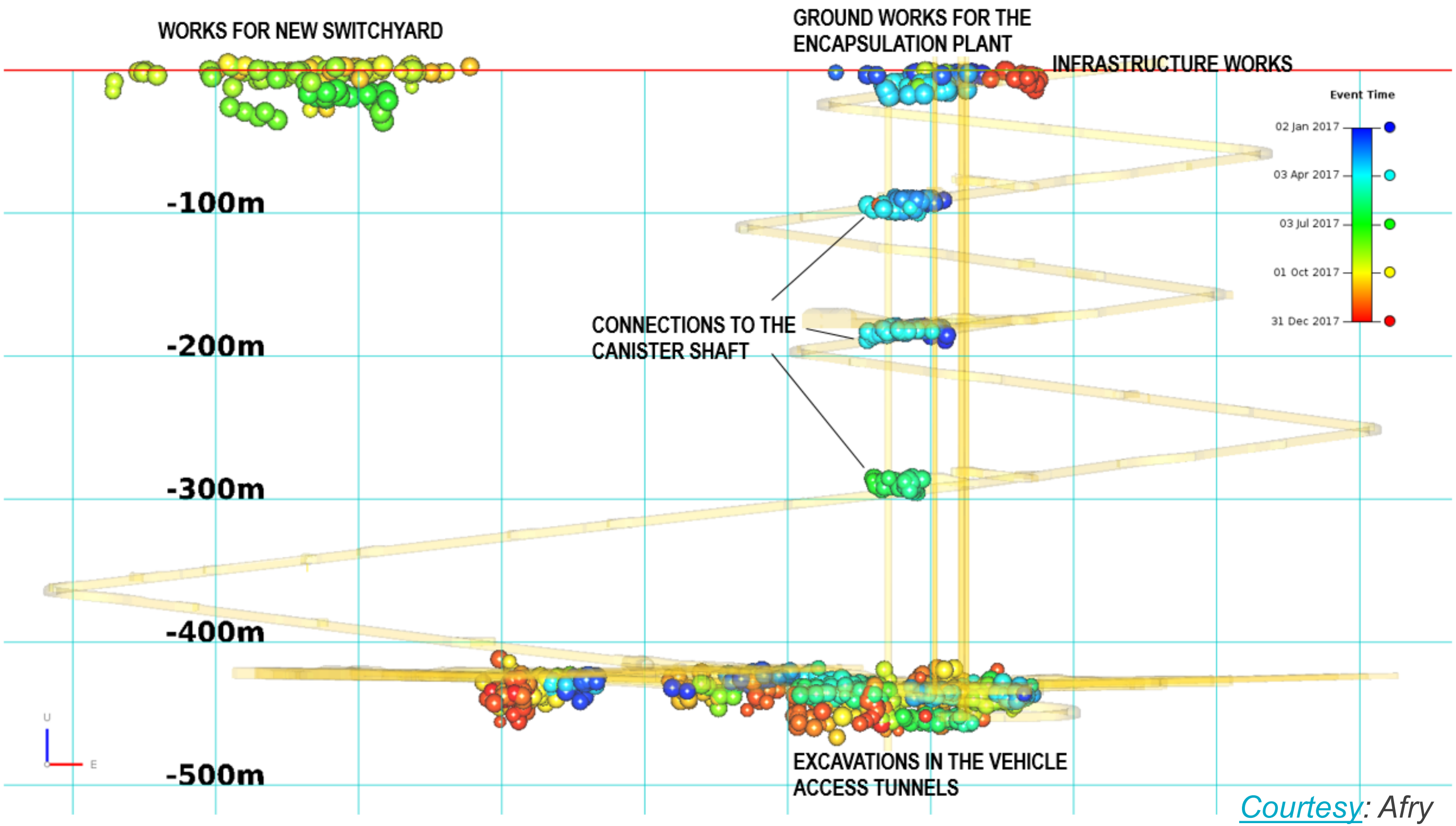
nuclear fuel items and final disposal canisters need to be **uniquely identifiable**

→ **fuel assemblies and disposal canisters have visually readable ID markings**

the authorities will **verify the nuclear material data** (source data and usage history) of each fuel item

→ **fuel verification stations will be integrated to interim storage pool and encapsulation plant**

Microseismic monitoring detects underground excavations



Courtesy: Afry

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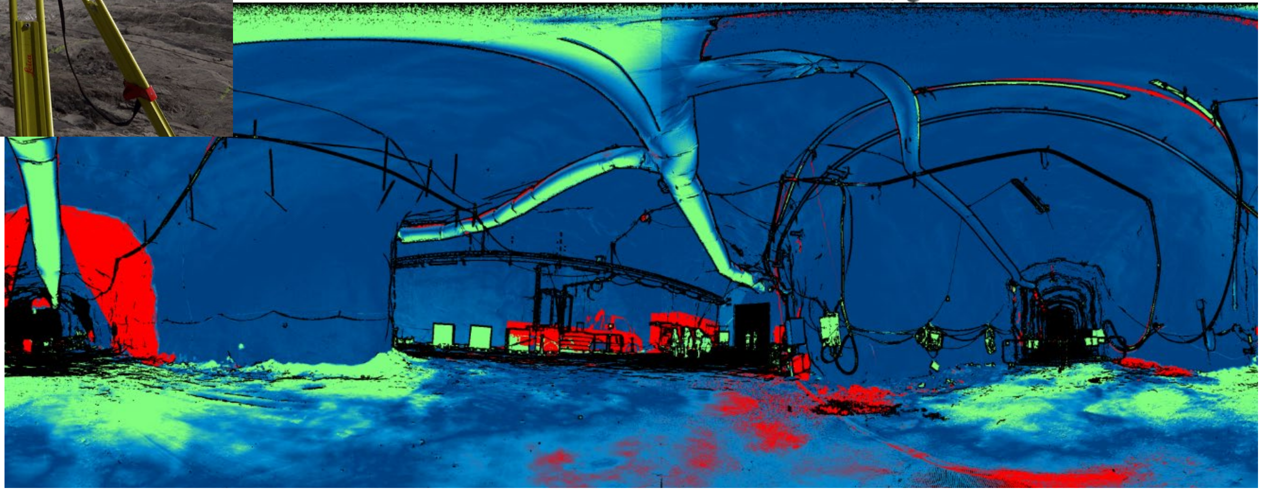
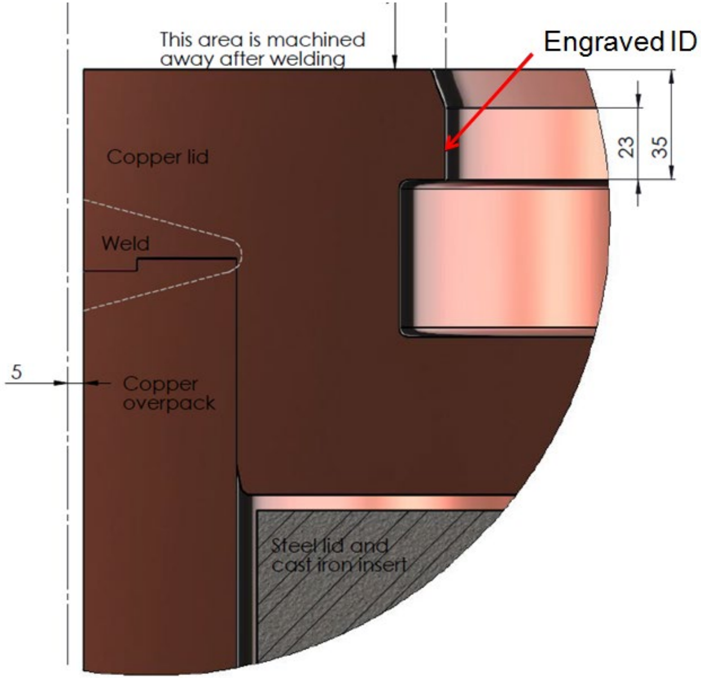
Laserscanning is an effective mapping tool



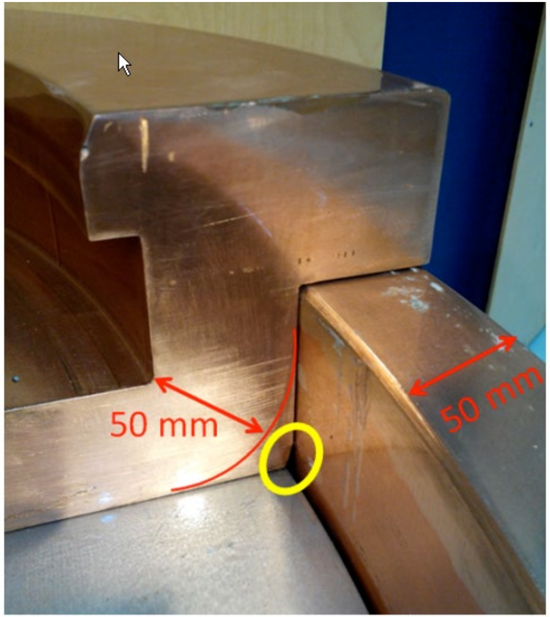
Courtesy: JRC

Disposal canisters will be identified

Visually readable ID in copper lid



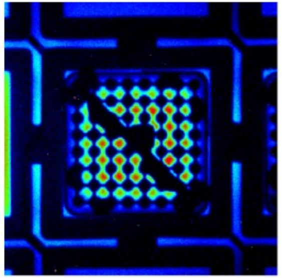
Marking inside copper lid readable by NDA



Courtesy: SKB / JRC

Spent nuclear fuel will be verified prior to encapsulation

- Primarily at interim storage pool
- Possibility for reverification at encapsulation plant
- Planned method Passive Gamma Emission Tomography
- Target pin-level detection



ANF 8 x 8

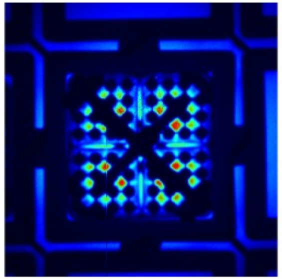
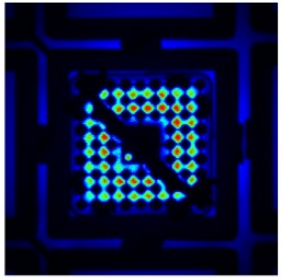


ABB Atom SVEA-64



Siemens Atrium 9 x 9

Figure 6: False-colour DCVD images of BWR spent-fuel assemblies

Figure 1. GE-12 fuel. CT=9.9y and BU=39.7GWd/tU

Figure 2. ATRIUM-10B fuel. CT=17.9y and BU=36.5 GWd/tU

Figure 3. SVEA-100 fuel. CT=13.9y and BU=39.9 GWd/tU

Figure 4. SVEA-96 fuel. CT=1.87y and BU=47.0GWd/tU. Notable low intensity of the pin in pos. I-9

Figure 5. SVEA-96 fuel. CT=2.83y and BU=45.1 GWd/tU. The pin in pos. F-5 is missing

Figure 6. SVEA-96 fuel. CT=8.9y and BU=40.7 GWd/tU. Pins in pos. A-9 and H-9 are missing

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Protecting the biosphere

Upcoming Webinars

Date	Title	Presenter
30 March 2023	Advanced Reactors Safeguards and Materials Accountancy Challenges	Dr. Ben Cipiti, Sandia National Laboratories, USA
05 April 2023	Overview of Nuclear Graphite R&D in Support of Advanced Reactors	Dr. Will Windes, Idaho National Laboratory, USA
24 May 2023	Graphite-Molten Salt Interactions	Dr. Nidia Gallego, Oak Ridge National Laboratory, USA