DOPAS
Training Workshop 2015

DOPAS

D1 1.1.2
The Purpose of Plugs and Seals in Crystalline Rock

Pär Grahm, SKB

14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

update 2016

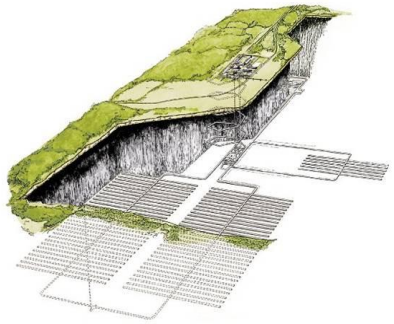
Well, who is ”Pelle”?

- **B.Sc. Mechanical engineering (1993)**
- **B.Sc. Energy systems and environment (1995)**

Experience:

- **2 years Consultant/Designer**
- **11 years Oskarshamn NPP (Project Manager)**
  - **Design, licensing and construction of a repository for Low-Level Waste**
  - **Re-licensing of NPP including power upgrades of unit 2 and 3**
  - **Advanced security upgrade of the NPP site (checkpoints, S-systems, UPS)**
- **6 years SKB (Project Manager, Team Manager)**
  - **Technical development of Engineered Barrier Systems (several projects)**
  - **DOPAS experiment leader**

Now, say something about SKB…



SKB

POSIVA

nagra.

ČVUT FSv

NRG

UJV

igd-tp
safe solutions for radioactive waste

SÚRAO
Správa úložišť radioaktivních odpadů
Radioactive Waste Repository Authority

B+TECH

SKB
Svensk Kärnbränslehantering AB

Radioactive Waste Management

VTT

GRS

EURATOM

Galson Sciences Ltd

DBETEC
DBE TECHNOLOGY GmbH

ANDRA

Outline of this lecture

- **Waste types to be disposed**
- **The KBS-3 system**
- **Engineered Barriers Systems (EBS) for passive safety of the repository**
- **Host rocks (European geologies, focus on crystalline rock)**
- **The Swedish and Finnish repositories for Spent Fuel**
- **Different types of plugs and seals needed**
- **Closure of a repository**

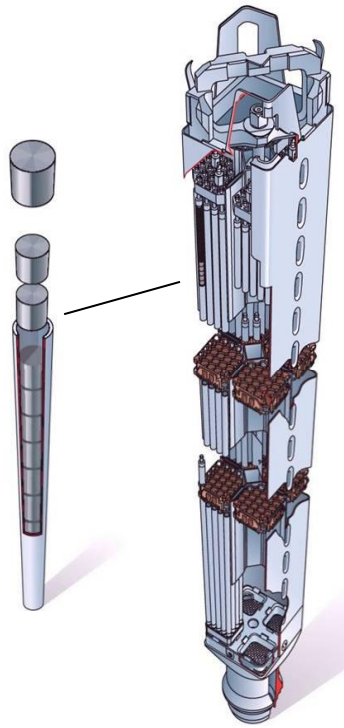
Different waste types – different solutions

Waste from Operation and Decommissioning

Spent Nuclear Fuel

Long Lived Waste categories:

- **Spent Fuel**
- **Control rods**
- **Reactor vessel (PWR)**
- **Core components**
- **Legacy waste (Transuranic waste, TRUW)**

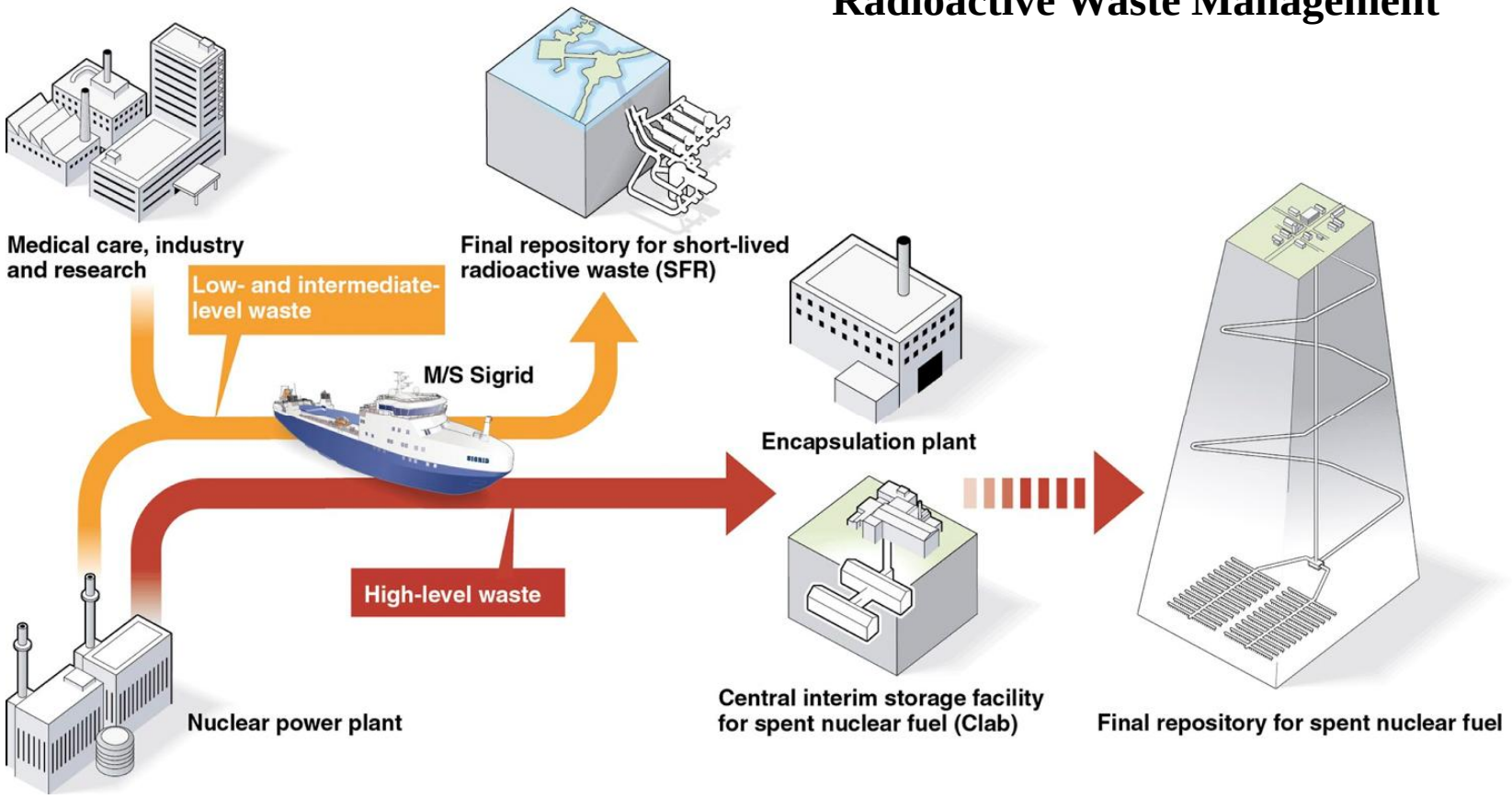


Low - & Intermediate Level Waste (L&ILW)

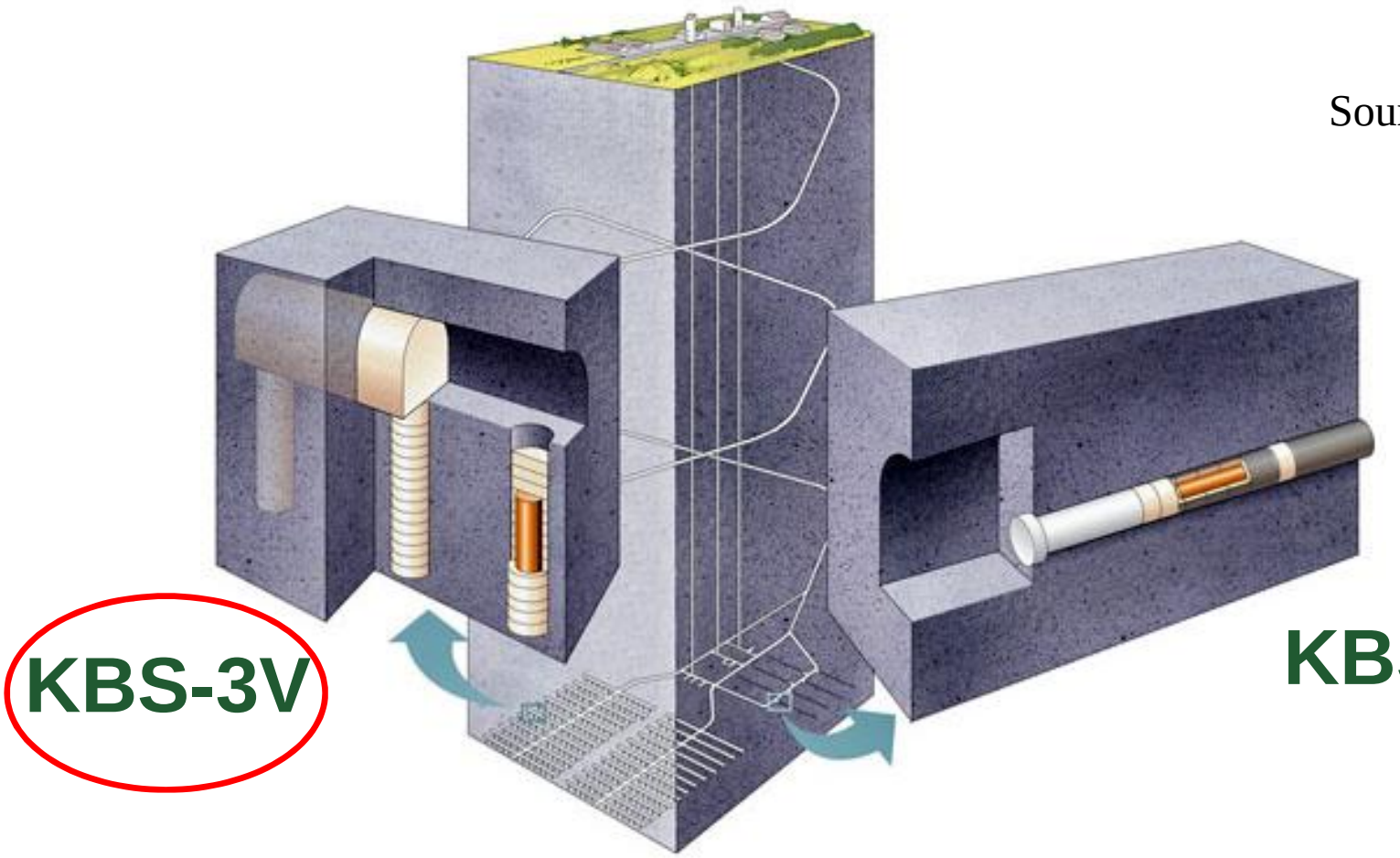
High Level Waste (HLW)

The Swedish RWM*-system (SKB's mission)

* Radioactive Waste Management



The Swedish and Finnish repository concept for Spent Nuclear Fuel

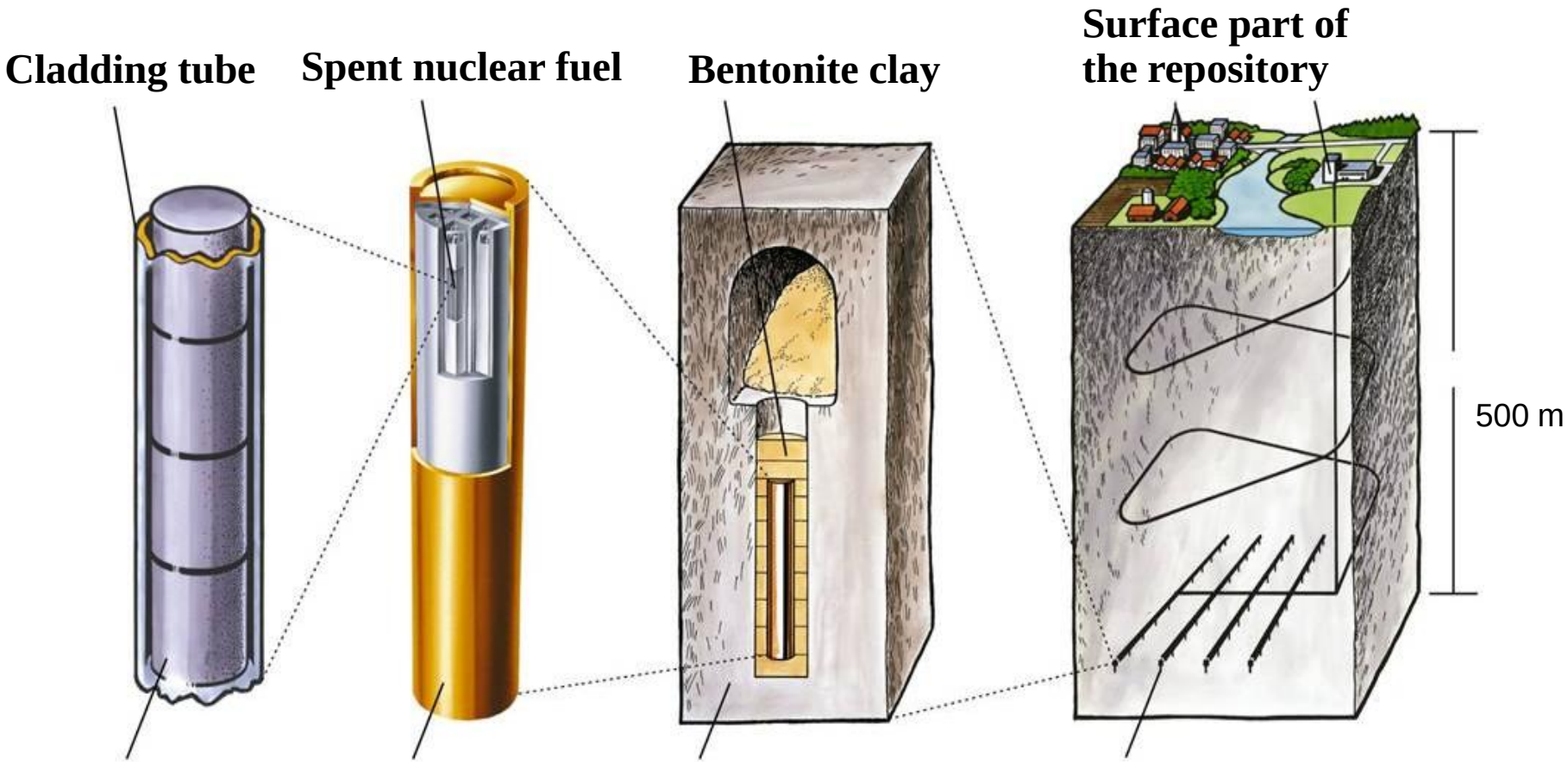


Source: SKB ©

KBS-3V

KBS-3H

KBS-3V - Engineered Barrier Systems

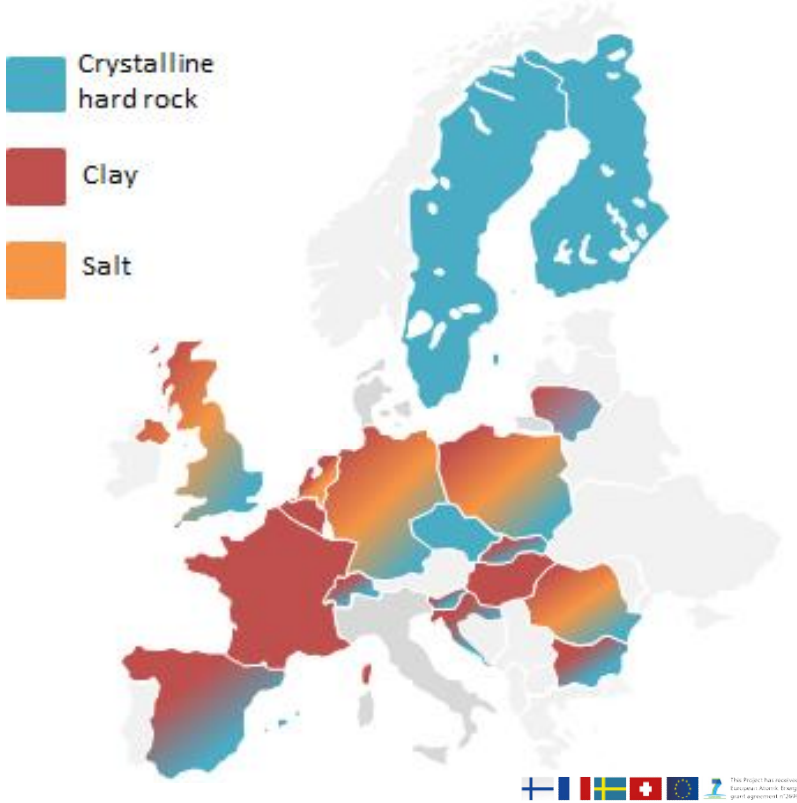


European geology

http://portal.onegeology.org/

https://en.wikipedia.org/wiki/Geology_of_Europe#/media/File:Europe_geological_map-en.jpg

Schematic of suitable host rock in Europe for deep geological repository



Source: LUCOEX

Country	Geological inventory for deep geological repository
Belgium	Clay
Bulgaria	Clay, Crystalline rock
Croatia	
Denmark	
Czech Republic	Crystalline rock
Finland	Crystalline rock
France	Clay
Germany	Clay, Crystalline rock, Salt
Hungary	Clay
Italy	
Lithuania	Clay, Crystalline rock
The Netherlands	Clay, Salt
Poland	Clay, Crystalline rock, Salt
Romania	Clay, Crystalline rock, Salt
Slovakia	Clay, Crystalline rock
Slovenia	Clay, Crystalline rock
Spain	Clay, Crystalline rock
Sweden	Crystalline rock
Switzerland	Clay, Crystalline rock
United Kingdom	Clay, Crystalline rock, Salt

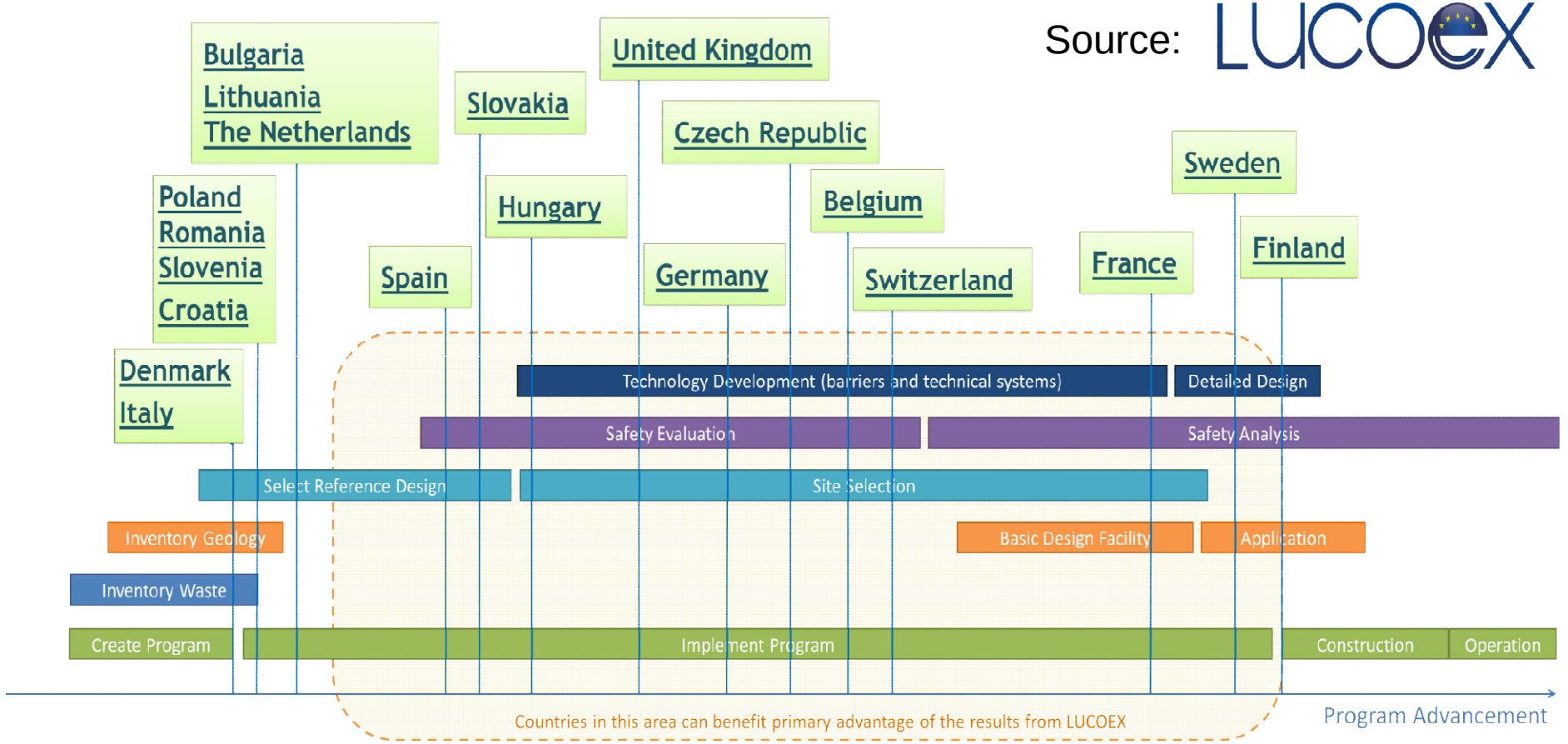
Countries with planned start year for operation

Source: LUCOEX

Country	Year for start of operation of deep geological repository
Belgium	
Bulgaria	
Croatia	
Denmark	
Czech Republic	2065
Finland	2022
France	2025
Germany	2035
Hungary	2064
Italy	
Lithuania	
The Netherlands	
Poland	
Romania	2055
Slovakia	
Slovenia	2065
Spain	
Sweden	2029
Switzerland	2050
United Kingdom	

How far the member states have come in their repository work

Source: LUCOEX



Choice of geology (to be made..)

- **Belgium, Bulgaria, France, Germany, Hungary, Lithuania, the Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland and United Kingdom consider clay as an option for host rock.**

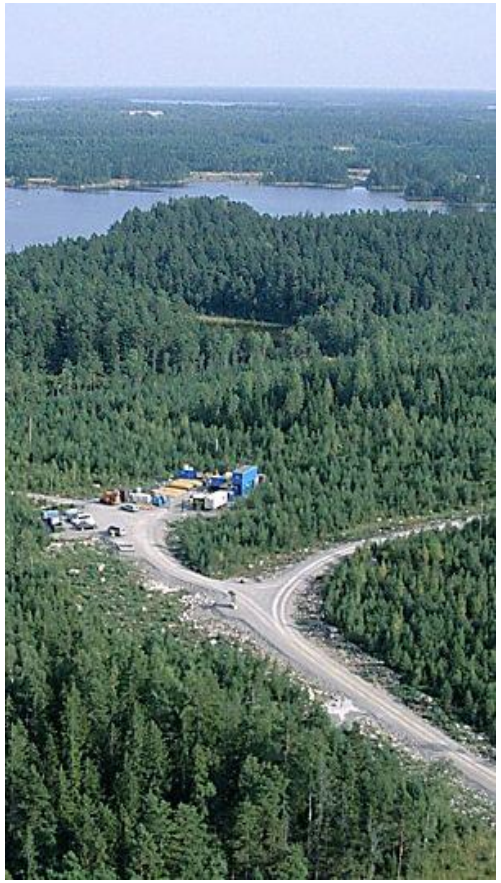
- **Bulgaria, Czech Republic, Finland, Germany, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland and United Kingdom consider crystalline rock as an option for host rock.**

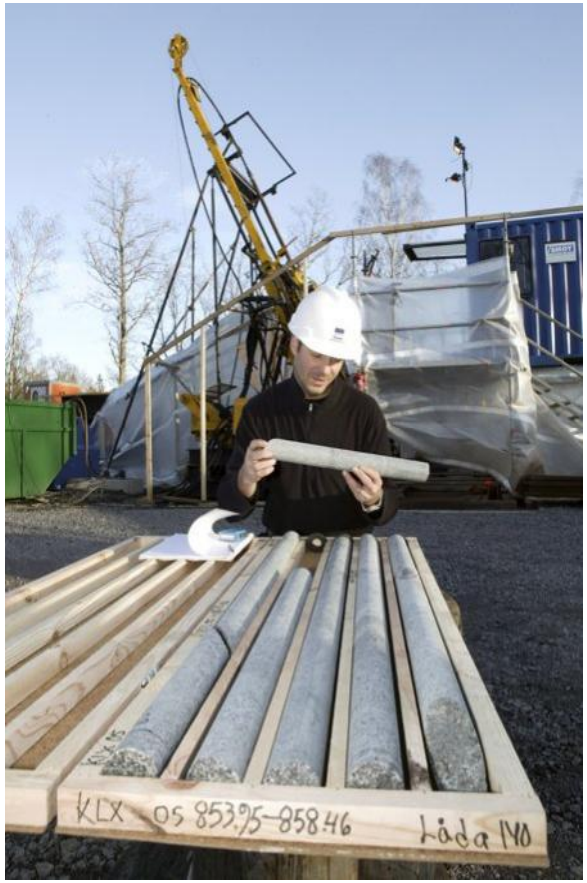
Source: LUCOEX

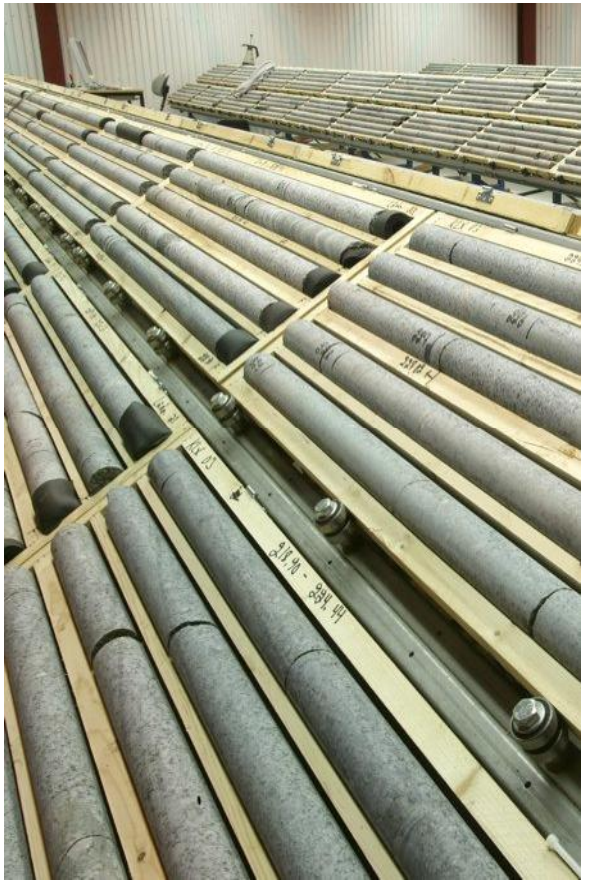
Crystalline rock

Photos by SKB

- **Site investigations - Rock type and fracture zones are studied from drill cores**

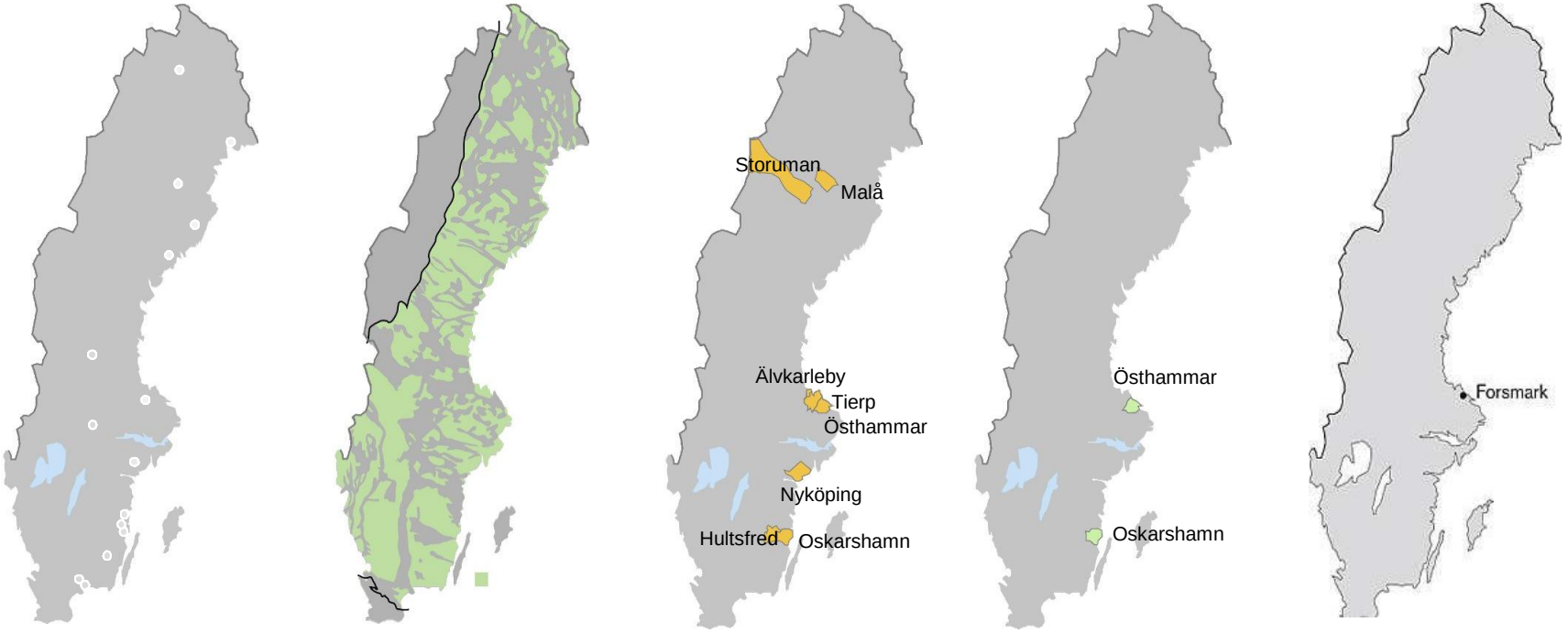






Finding a site in Sweden…

Source: SKB



Type areas	Overview studies	Pilot studies	Site Investigations	Choice
1977-1985	**1990s**	**1993-2002**	**2002-2008**	**2009**

SKB has chosen Forsmark

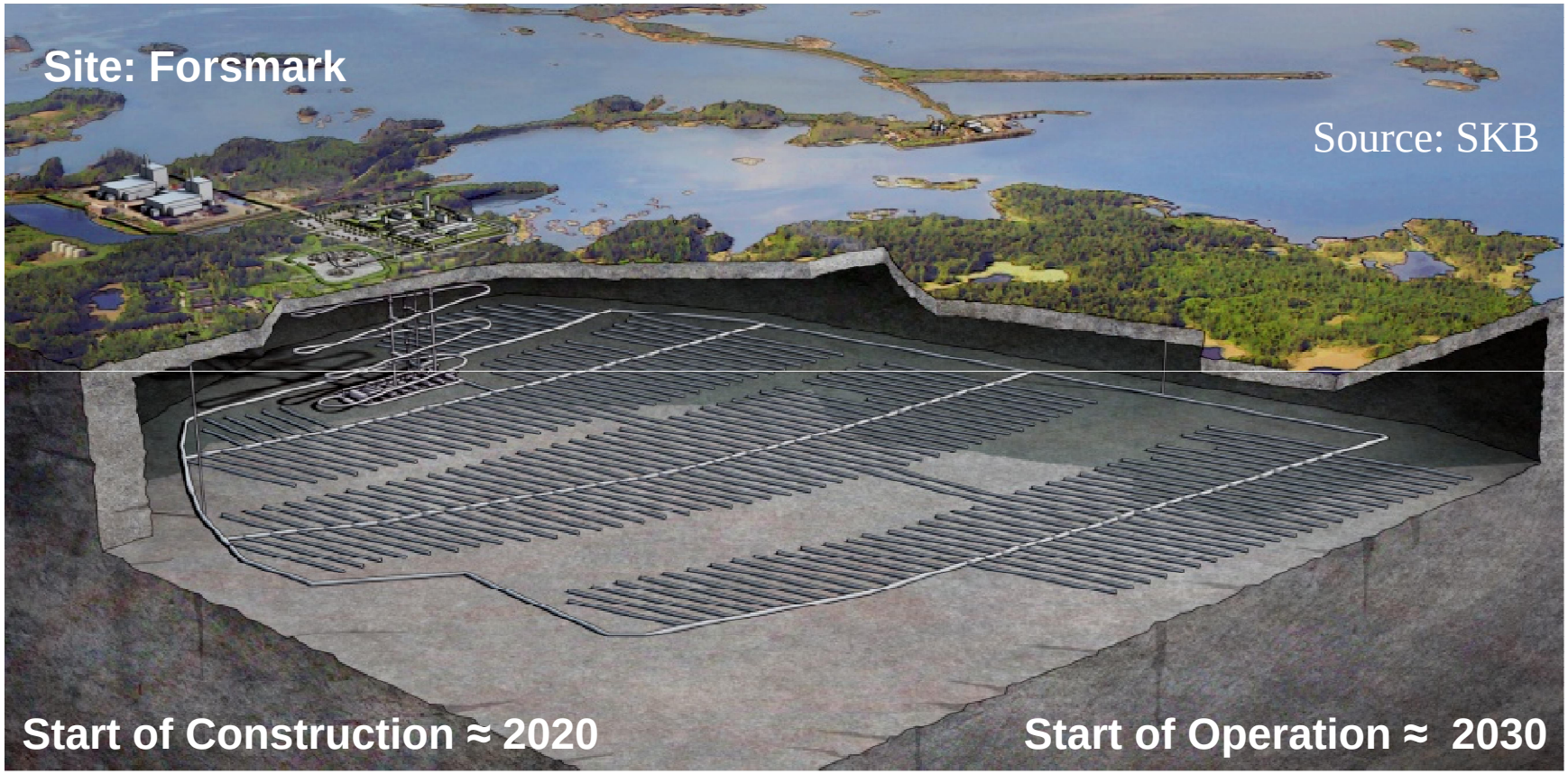
- **The rock in Forsmark offers much better prerequisites for long-term safe disposal and facilitates implementation**
  - **The rock is homogenous and has only sparsely fractured water-carrying fractures at repository depth**
  - **Good thermal conductivity allows the repository to take up less space**
  - **Less rock mass and material for backfill**

- **Buildings above ground can be built within the existing industrial area**
  - **Access to infrastructure**
  - **Limits environmental impact**

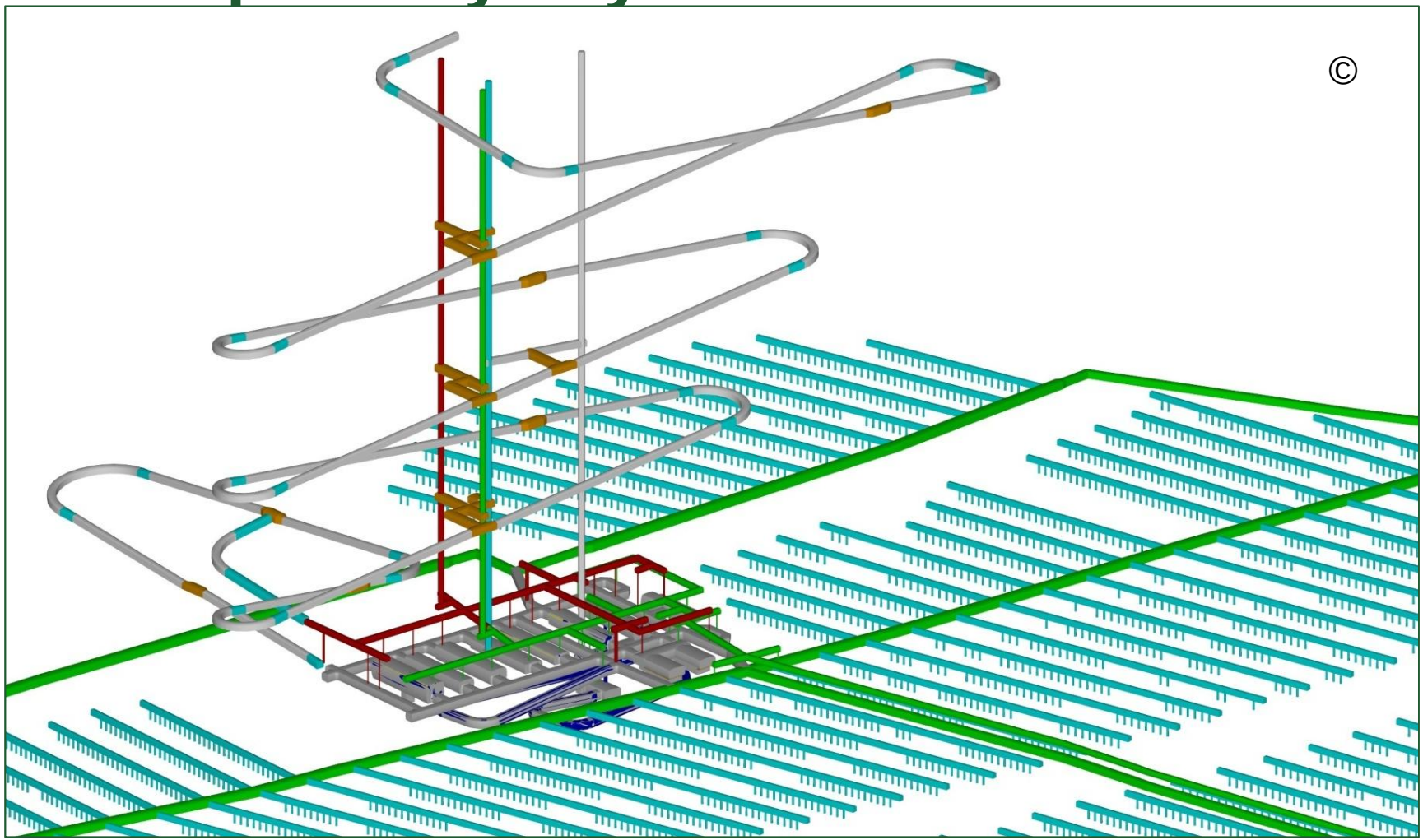
Source: SKB

The Spent Fuel Repository

- **Principle outline of the deposition area -470 m (licensing ongoing)**
- **Each deposition tunnel will be sealed by an end plug**

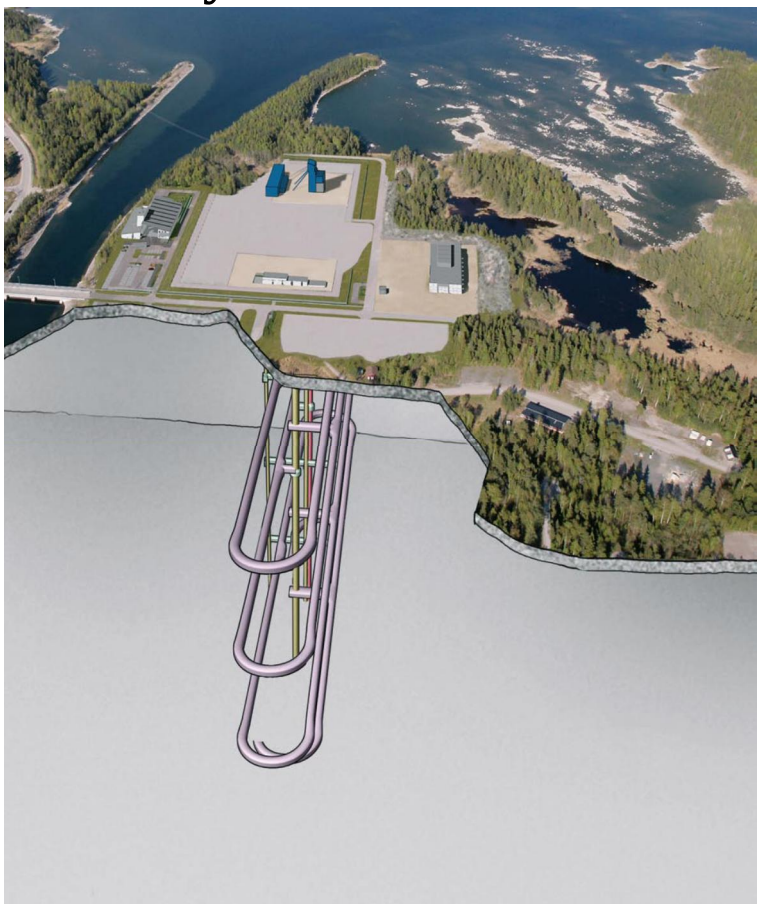


Repository Layout

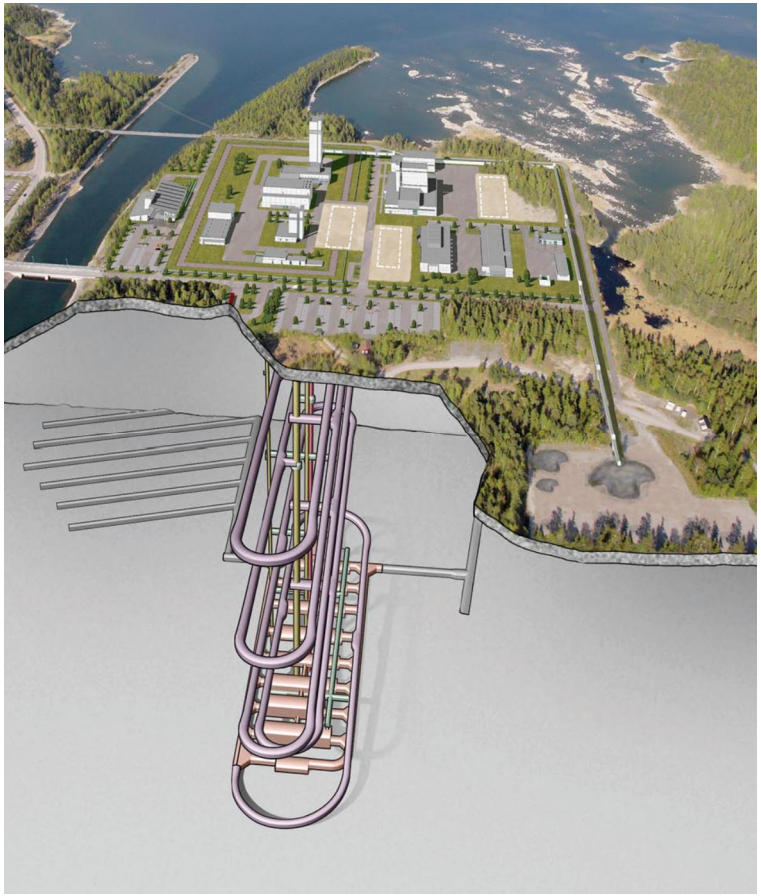


Spent Fuel Repository – Construction phase

- **After 3 years**



- **After 6 years**



Spent Fuel Repository in the future

Construction around 10 years

Operation around 40 years

Site after closure

Finland: ONKALO layout and technical spec.

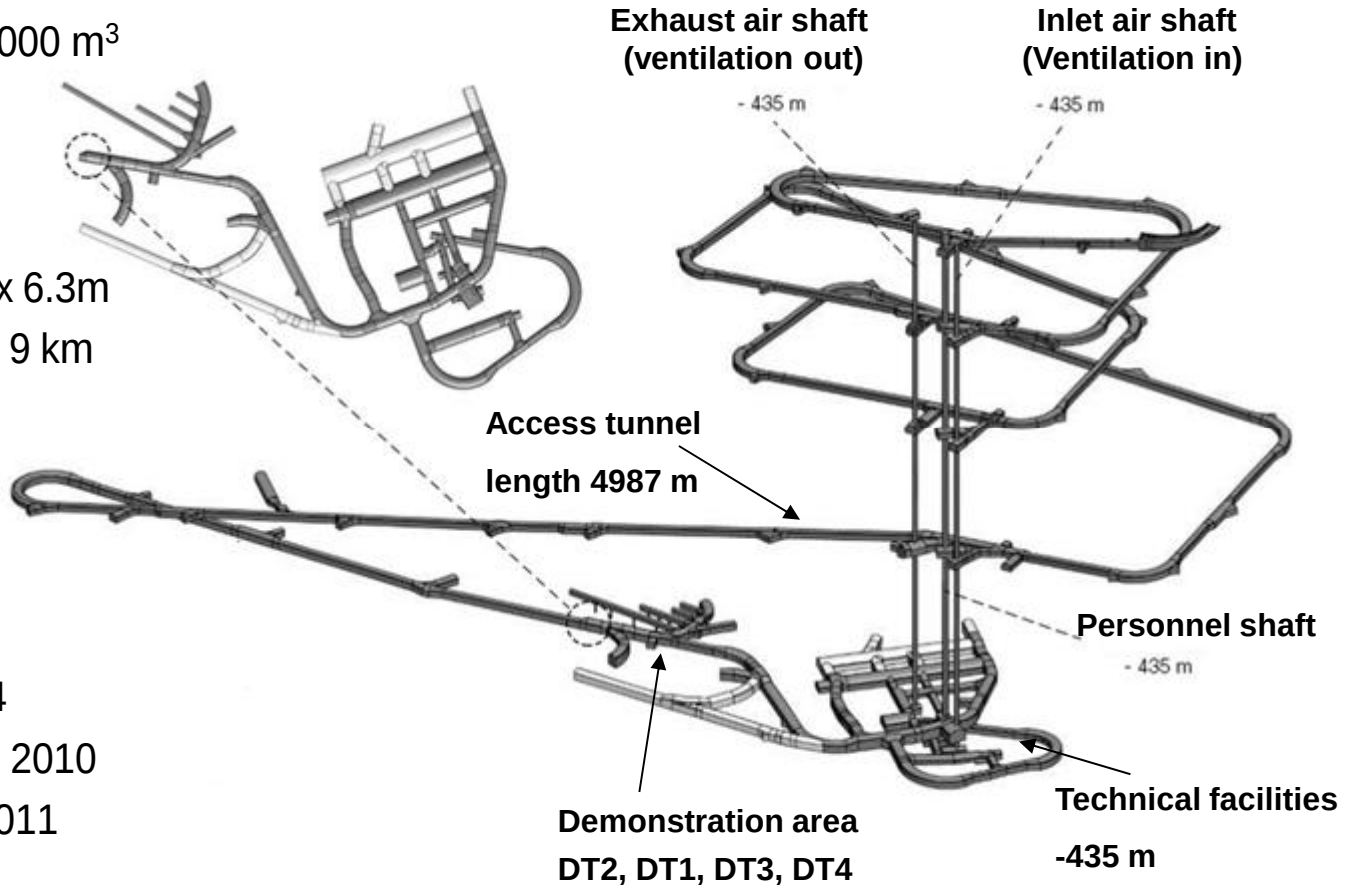
Status: 3 July 2015
Source: Posiva Oy ©

Technical specifications

- Excavation volume 365 000 m^3
- Access tunnel
  - Length 5 km
  - Inclination 1:10
  - Dimensions 5.5m x 6.3m
- Total tunnels and shafts 9 km
- Shaft diameters 3.5m and 4.5 m
- Shaft depths -435m

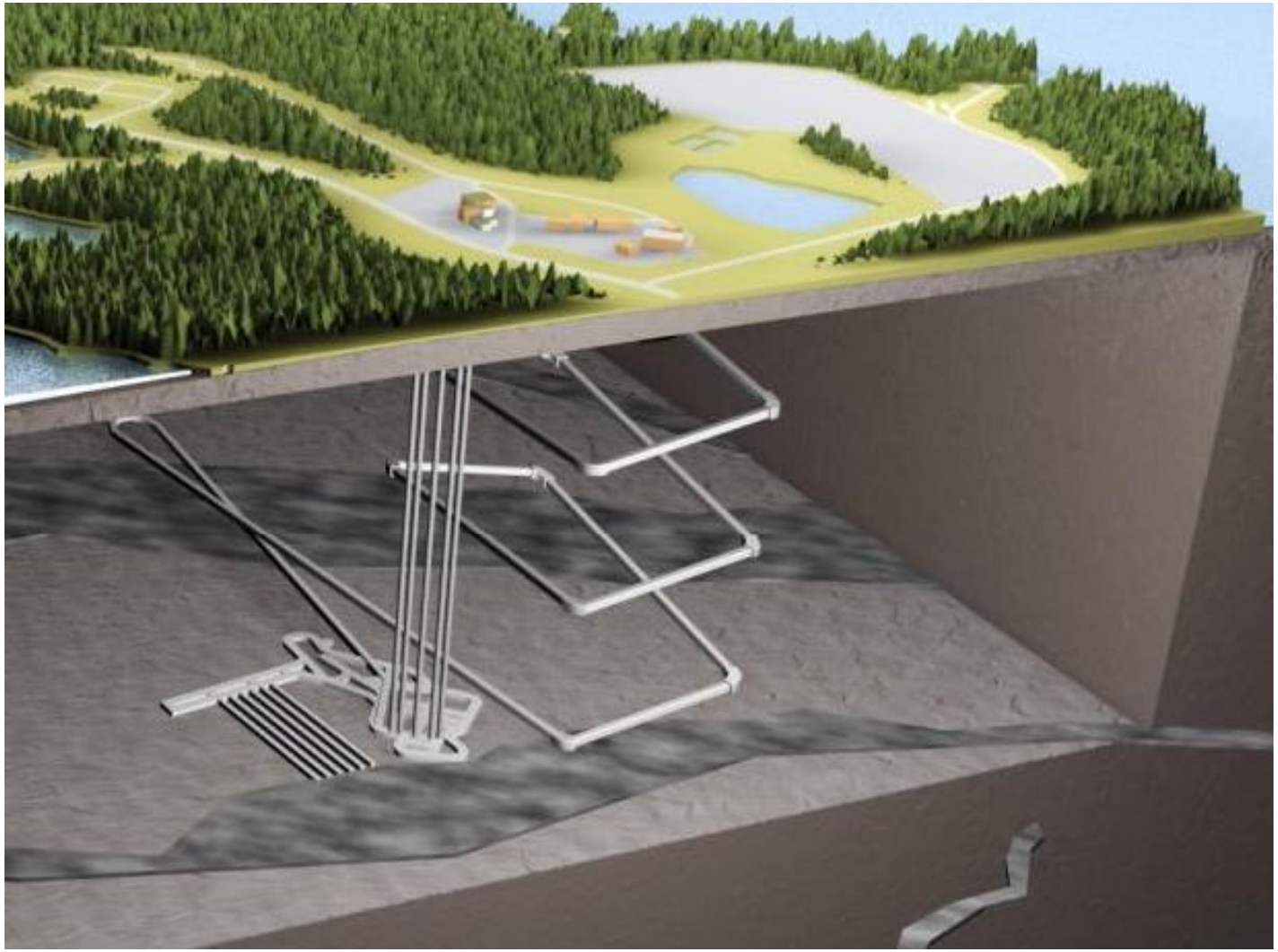
Schedule

- Start of excavation 2004
- Research level -420m in 2010
- Excavation finished in 2011



Layout for the first years of operation in 2020's

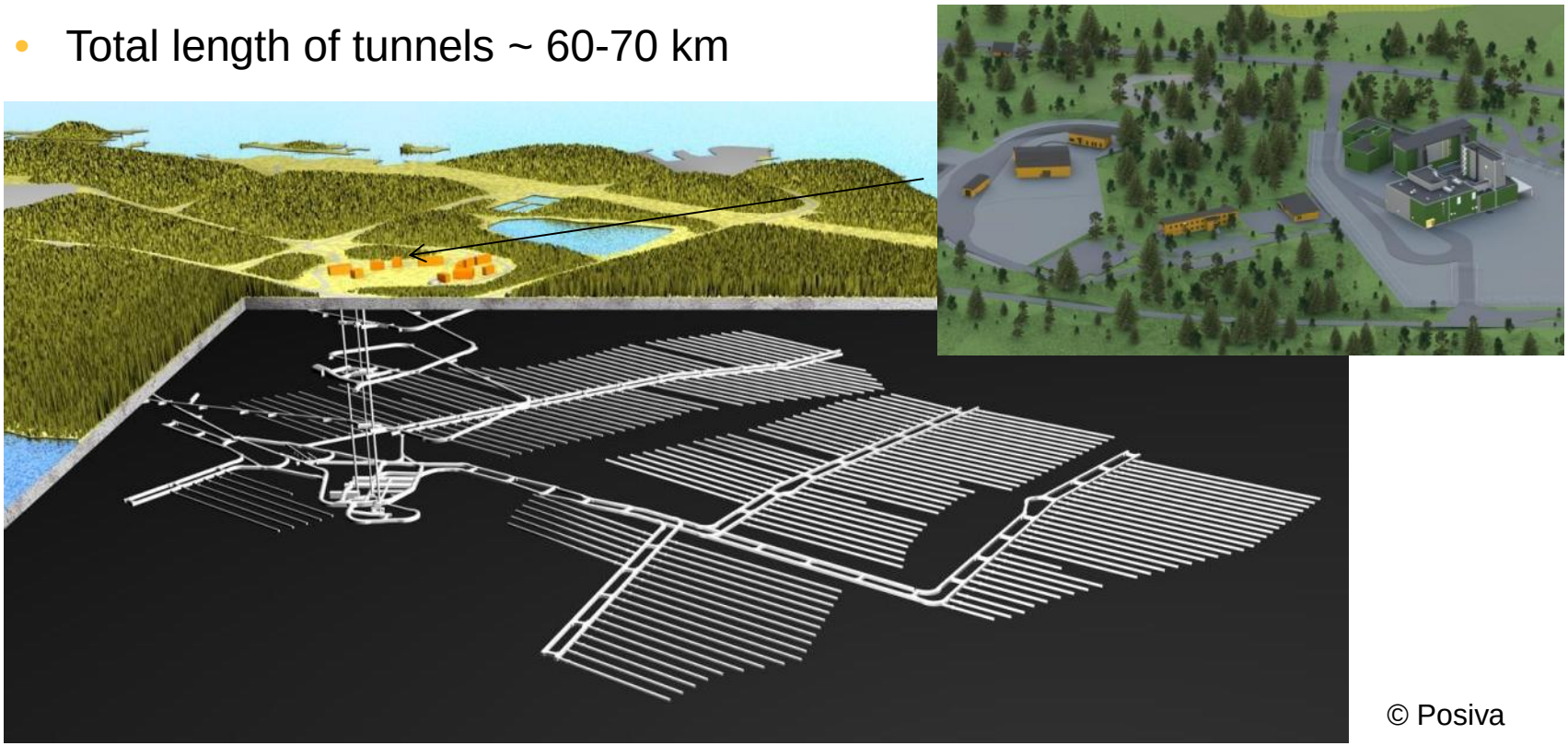
Source: Posiva Oy



© Posiva

Extended disposal facility around 2120's

- Repository capacity is 6500 tU*) (about 3325 canisters)
- Depth of the tunnel system -420-455 m and the footprint is about 2 km²
- Construction and operating time approximately 100 years
- The total excavation volume about 2 million m³
- Total length of tunnels ~ 60-70 km

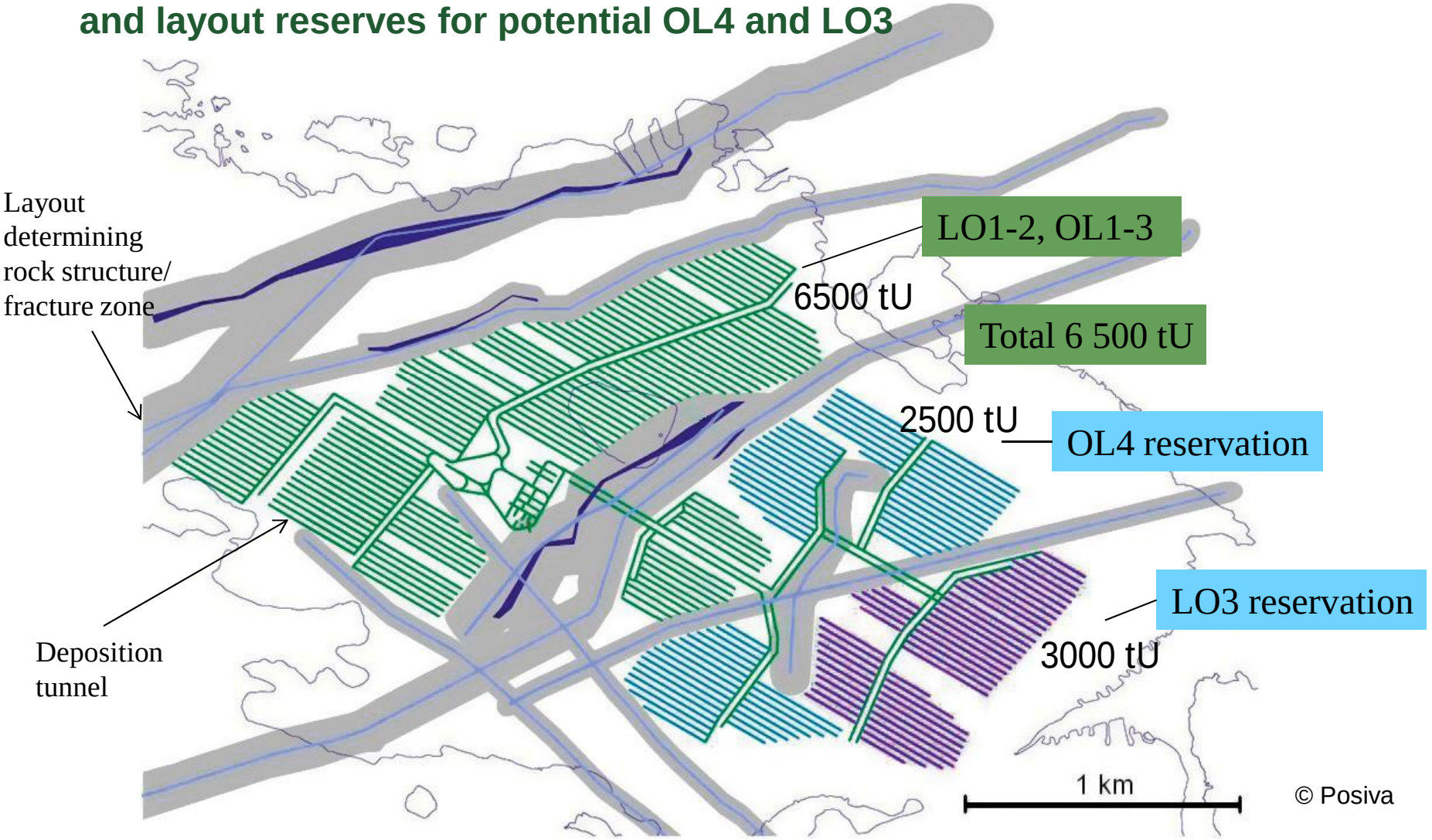


*) This presented layout includes reserve for OL4, too

adapted from Posiva 2013. WR 2012-66, p. 51, 53)

Scope of Posiva's construction license application for 6500 tU (LO1-2 & OL1-3)

and layout reserves for potential OL4 and LO3



Source: adapted from Posiva 2008. EIA08, p.52

Backfilling of deposition tunnels

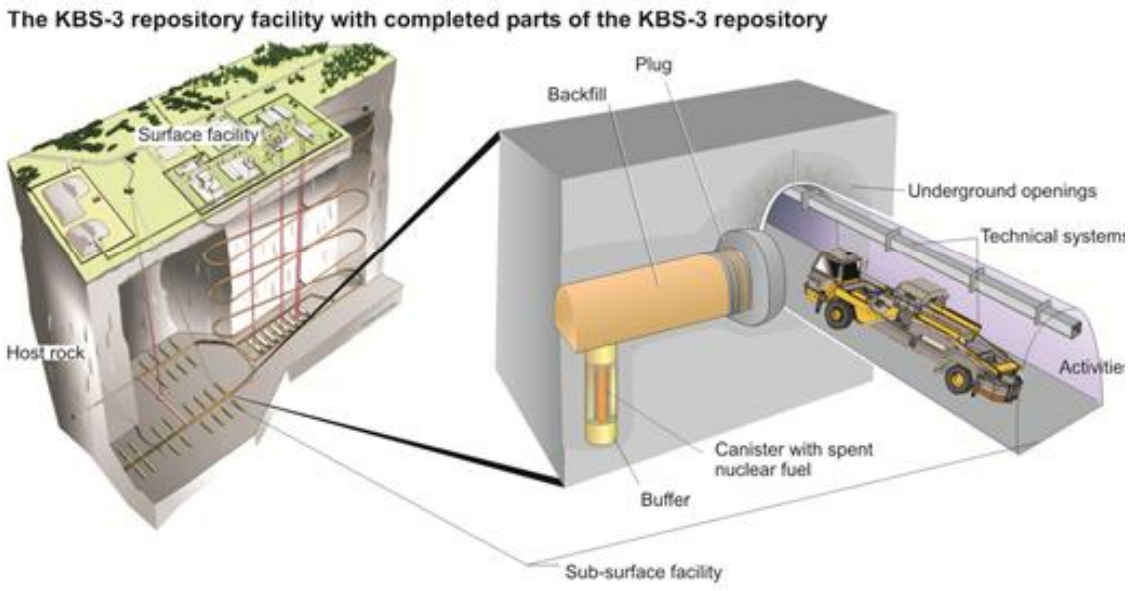
©

Source: SKB

Deposition tunnel end plugs

Plugs are secondary barriers during the operational phase of the repository (≈ 100 years) with following functions:

- **Confine the backfill**
- **Support saturation of the backfill**
- **Provide a barrier against water flow that may cause harmful erosion of the bentonite in buffer and backfill**



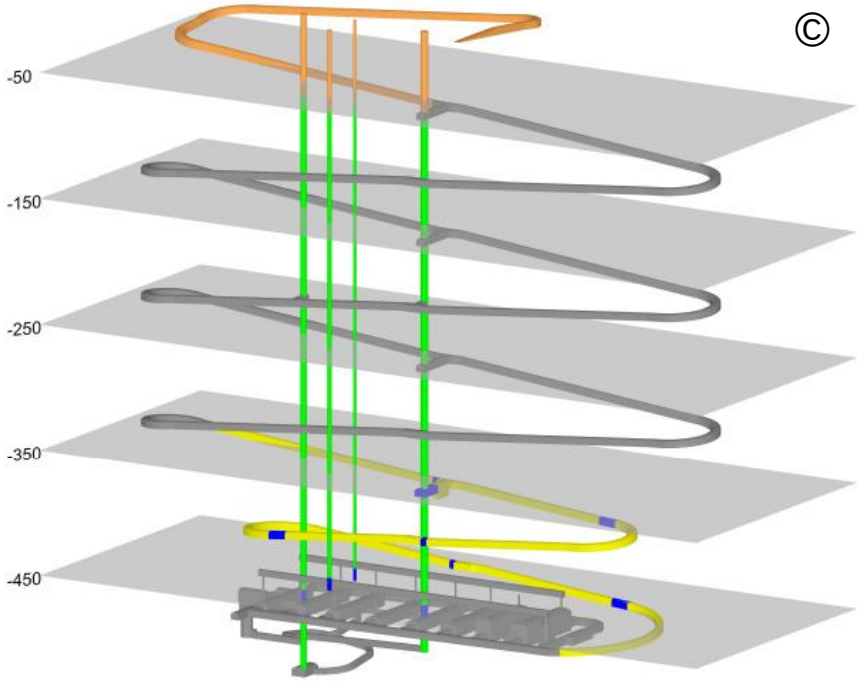
© Source: SKB TR-10-12

Closure of a repository

Source: SKB TR-12-08 (Fig. 2-5)

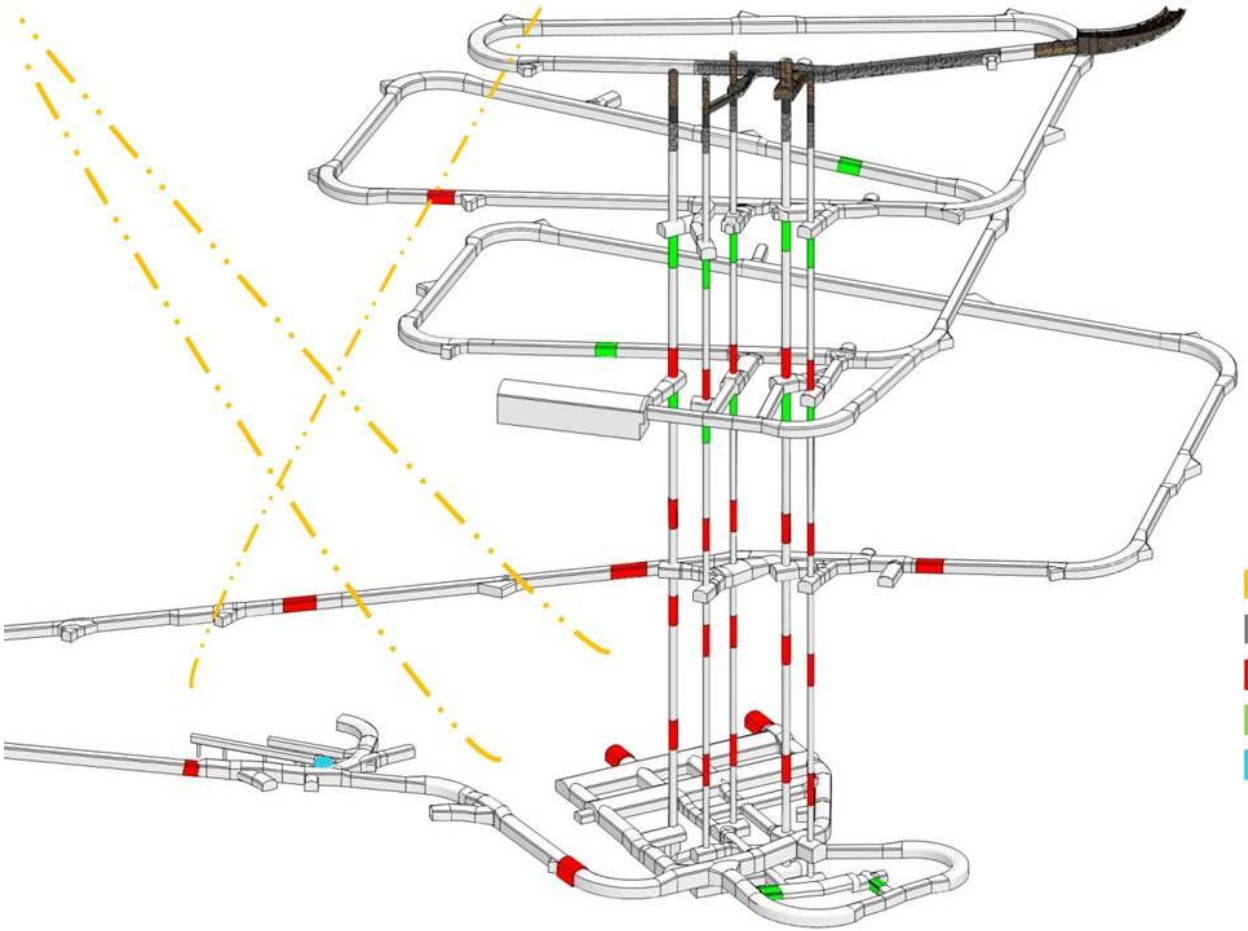
Plugs and Seals are installed at predefined locations to cut off hydraulic paths and/or to give mechanical support to structures.

- **Seal deposition areas**
- **Seal the bottom level ramp (to 100 m above repository level)**
- **Seal shafts**
- **Seal boreholes**
- **Top seal**



Grey colour represents crushed rock, yellow bentonite-filled sections, green crushed rock that has been optimised for low hydraulic conductivity, blue installation plugs of concrete and brown top seal of rock backfill with injected concrete.

Closure of a repository



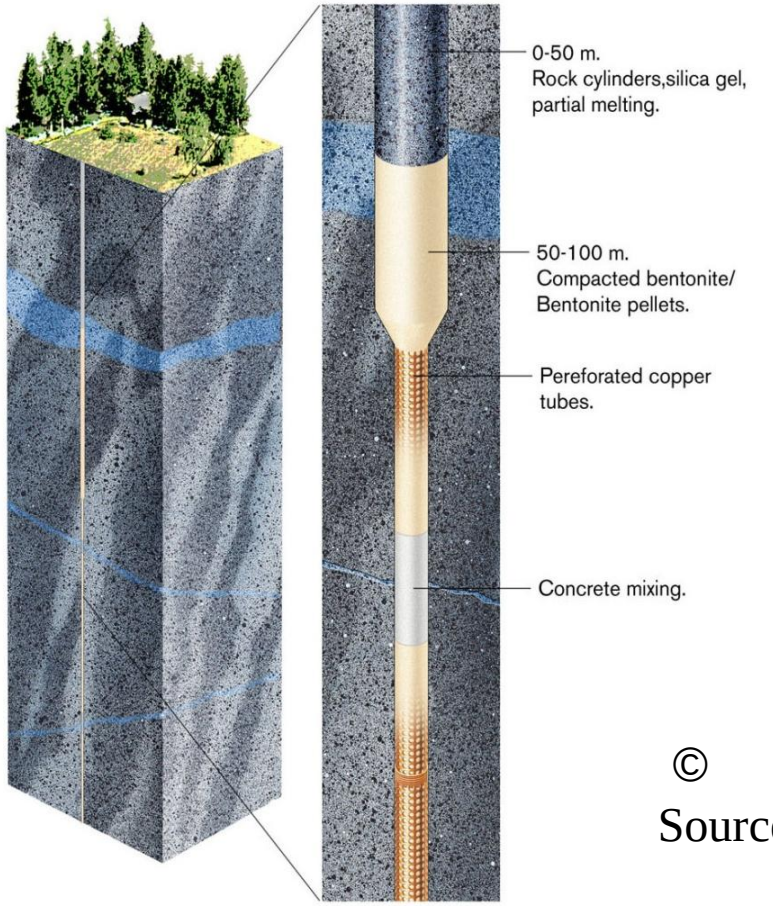
Generic Closure Design (c)
Posiva Oy
by Saanio&Riekkola
(not in scale)

©

Legend:

- BOREHOLE PLUG
- INTRUSION OBSTRUCTING PLUG
- HYDRAULIC PLUG
- MECHANICAL PLUG
- DEPOSITION TUNNEL END PLUG (HYDRO-MECHANICAL PLUG)

Sealing of investigation boreholes



©

Source: SKB TR-12-08 (Fig. 4-1)

The road ahead – Building a repository for spent nuclear fuel

- **Detailed design of EBS; Canister, buffer, backfill and plugs**
- **Detailed design of installation process and quality control**
- **Development of installation equipment**
- **Manufacturing of EBS components**
- **Integrated testing of installation**

DOPAS

Thanks for listening!

www.posiva.fi/en/dopas

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

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