INTER STORES

International Innovation Network for the Development of
Cost- and Environmentally Efficient Seasonal Thermal Energy Storages

PLANNING AND DESIGN OF WORLD'S LARGEST CAVERN THERMAL ENERGY STORAGE

Optimization of VECTES Varanto

interstores.eu

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#INTERSTORES

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ISEC 2026 - 4th International Sustainable Energy Conference, Graz (AT) Apr 14-16, 2026

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- Call: *Demonstration of innovative, large-scale, seasonal heat and/or cooling storage technologies for decarbonisation and security of supply*
  - HORIZON-CL5-2023-D3-01-14

- Start date:
  January 2024
- Duration
  48 months
- Budget
  > 11 million €

2 demo sites

8 countries

14 partners

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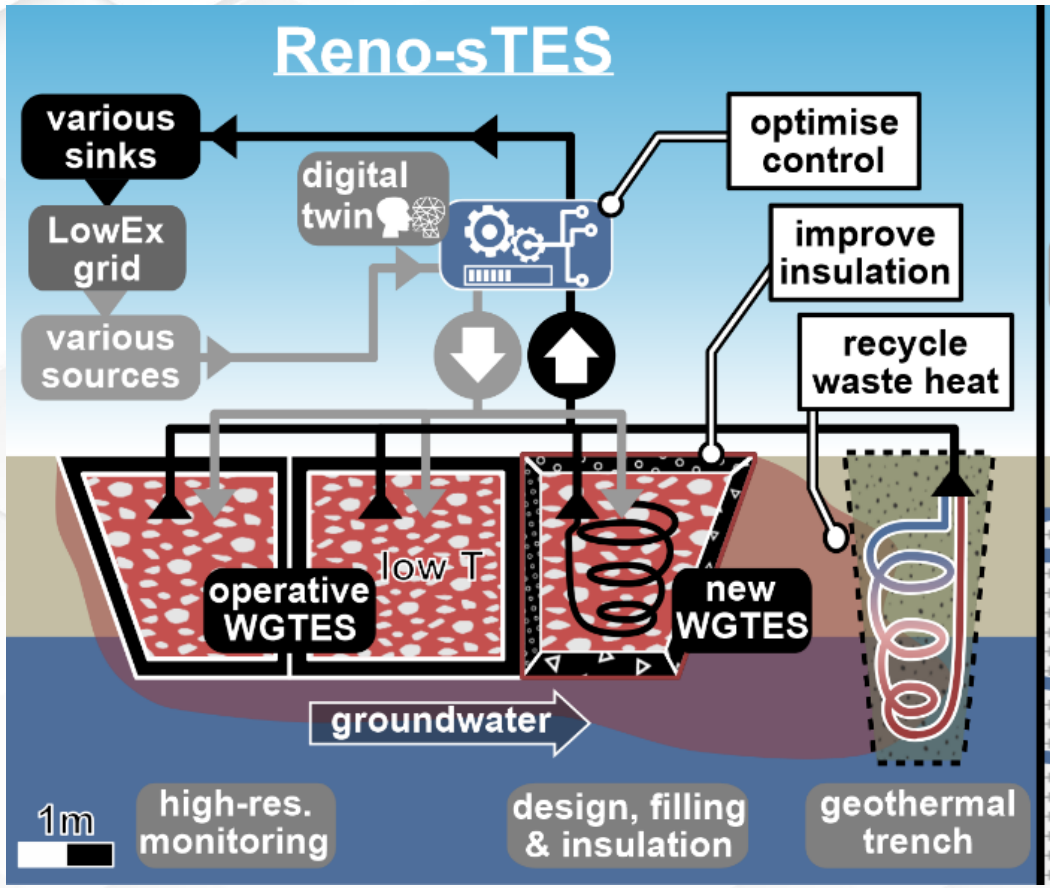
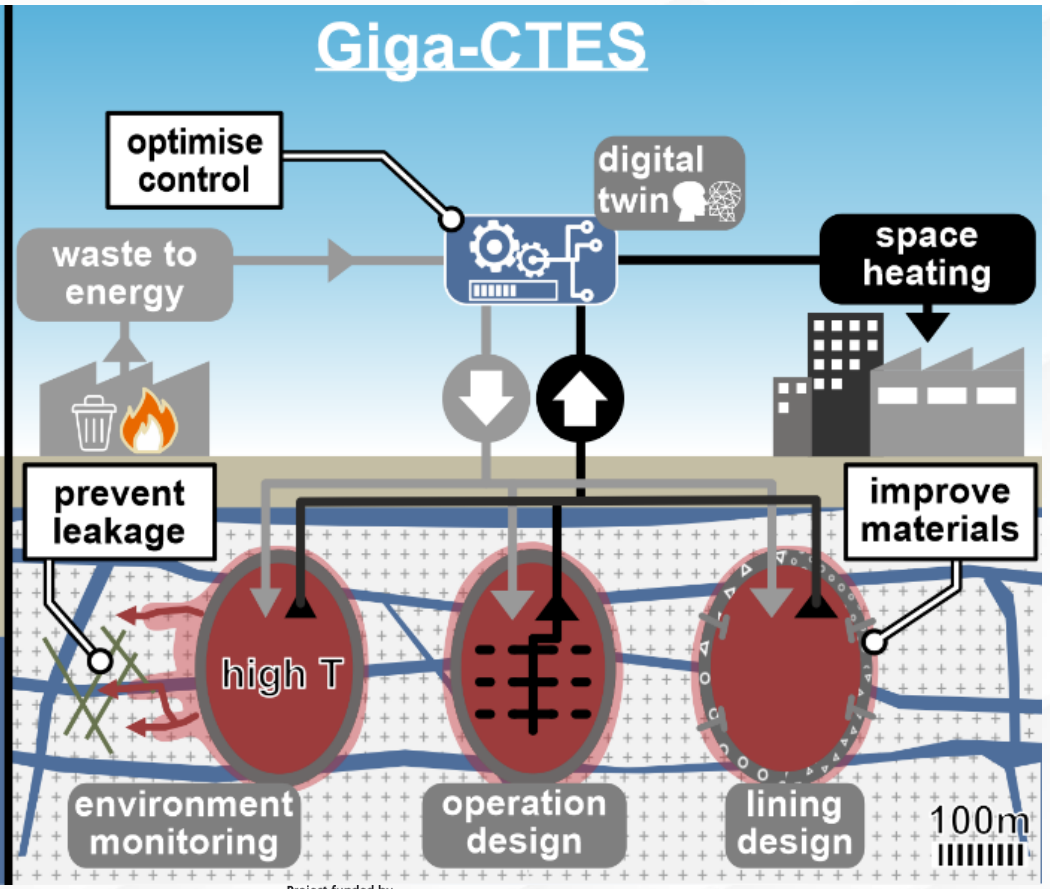
Demo-sites and innovations

IN-Campus, DE (18,000 m³)



VECTES-Varanto, FI (1,100,000 m³)



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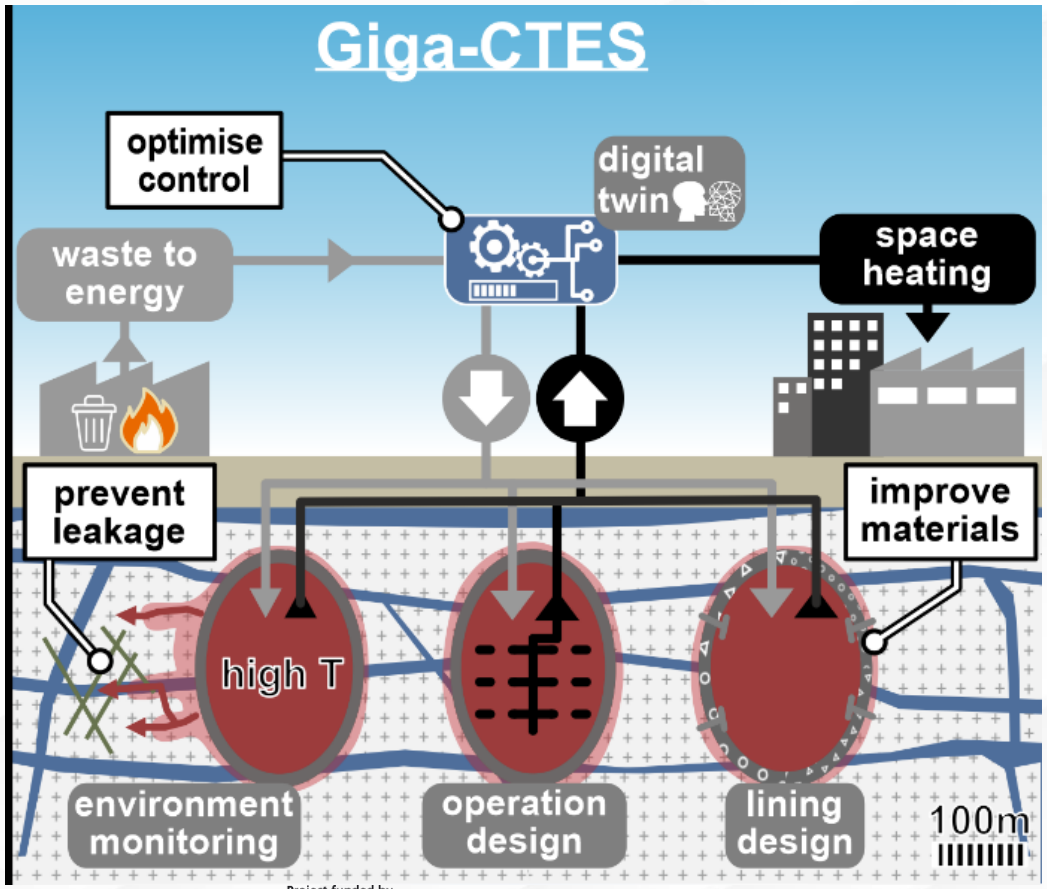
Demo-sites: VECTES-Varanto

- World's largest (**C**)TES
- Storage medium
  - **Pressurized** water – temperature > **140°C**
- Material improvements
  - Sealing and liners
  - Construction materials (shotcrete/grouting, novel rock bolts)
- Environment
  - **THMC** modeling for the ambient rock
- **Reduced** land (space) **footprint** by 90%

VECTES-Varanto, FI (1,100,000 m³)



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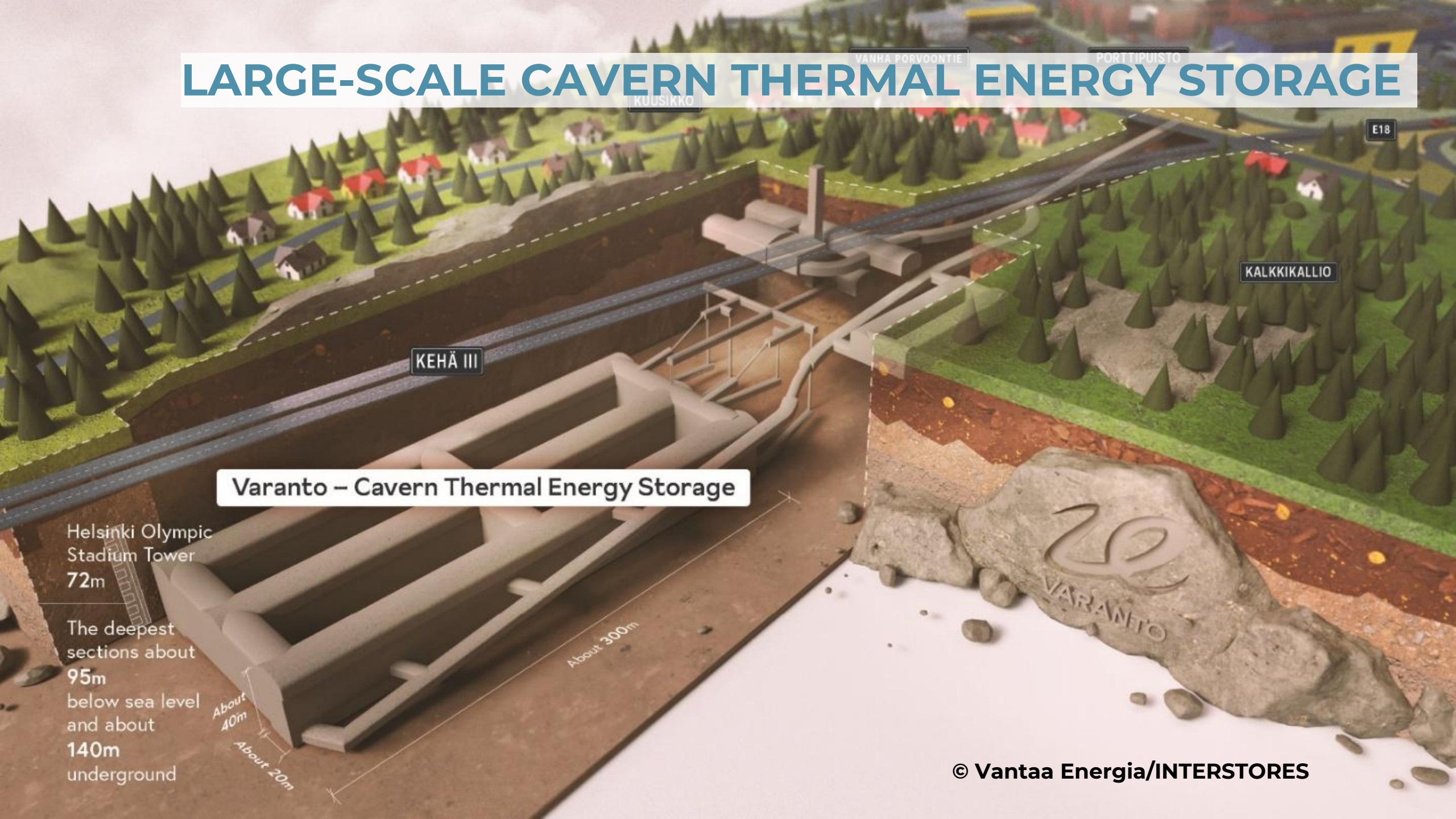
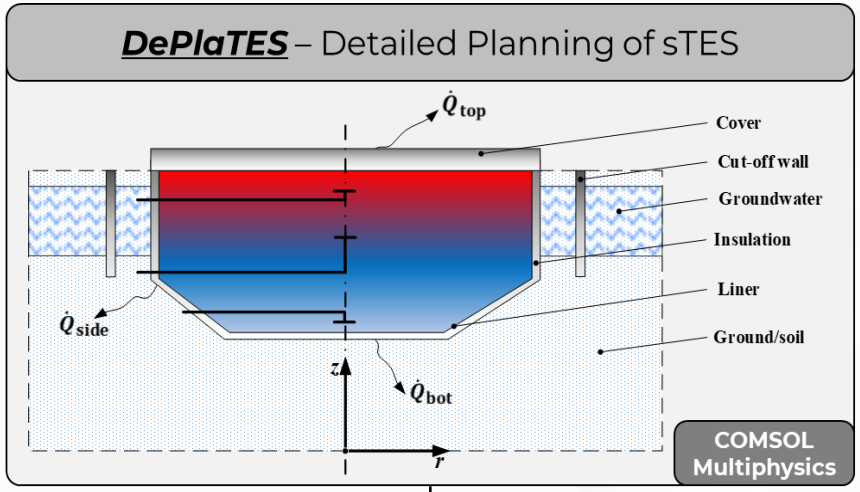
LARGE-SCALE CAVERN THERMAL ENERGY STORAGE

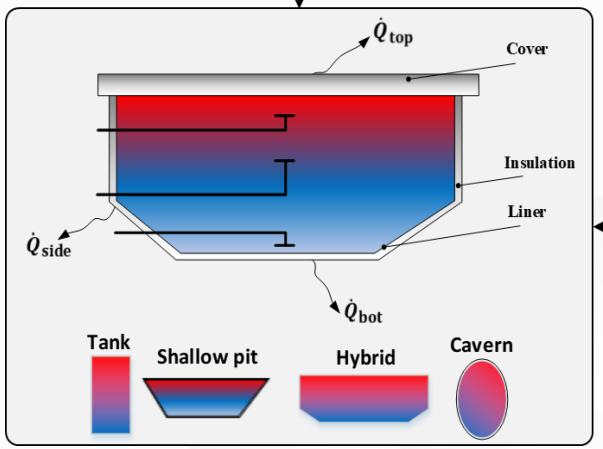


METHODOLOGY
DePlaTES



Thermal energy storage model

Discretization into *n* number of equivolume segments along the height of sTES



Inputs

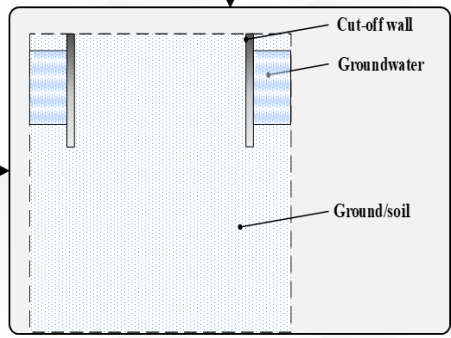
Construction type
Geometry
Dimensions
Storage medium
Number of diffusors
Insulation material properties (ρ, λ, c_p)
Insulation distribution

Inputs

Type of subsurface
Soil thermophysical properties (ρ, λ, c_p)
Cut-off walls

Subsurface model

Physics-controlled or optimized user-controlled FEM meshing



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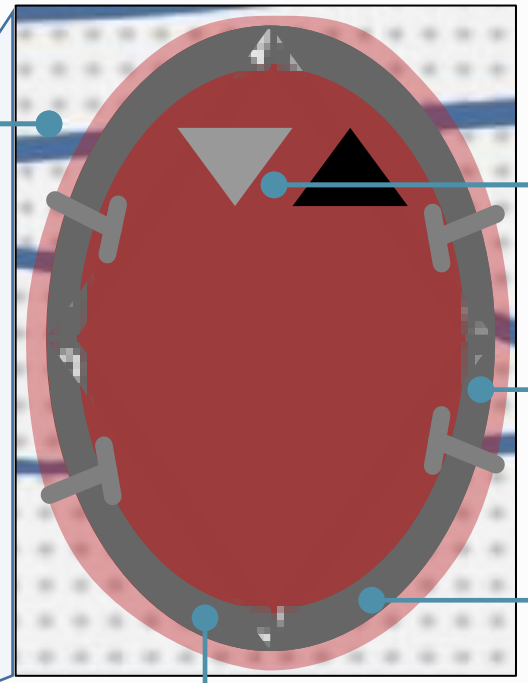
METHODOLOGY
VECTES Varanto in DePlaTES

Heat Transfer in Porous Media

Porous Media Flow



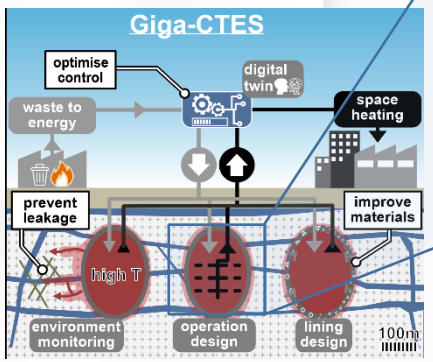
Heat Transfer in Fluids

Turbulent Flow

Thermal Stress, Solids

Heat Transfer in Solids

Electrochemistry, Corrosion



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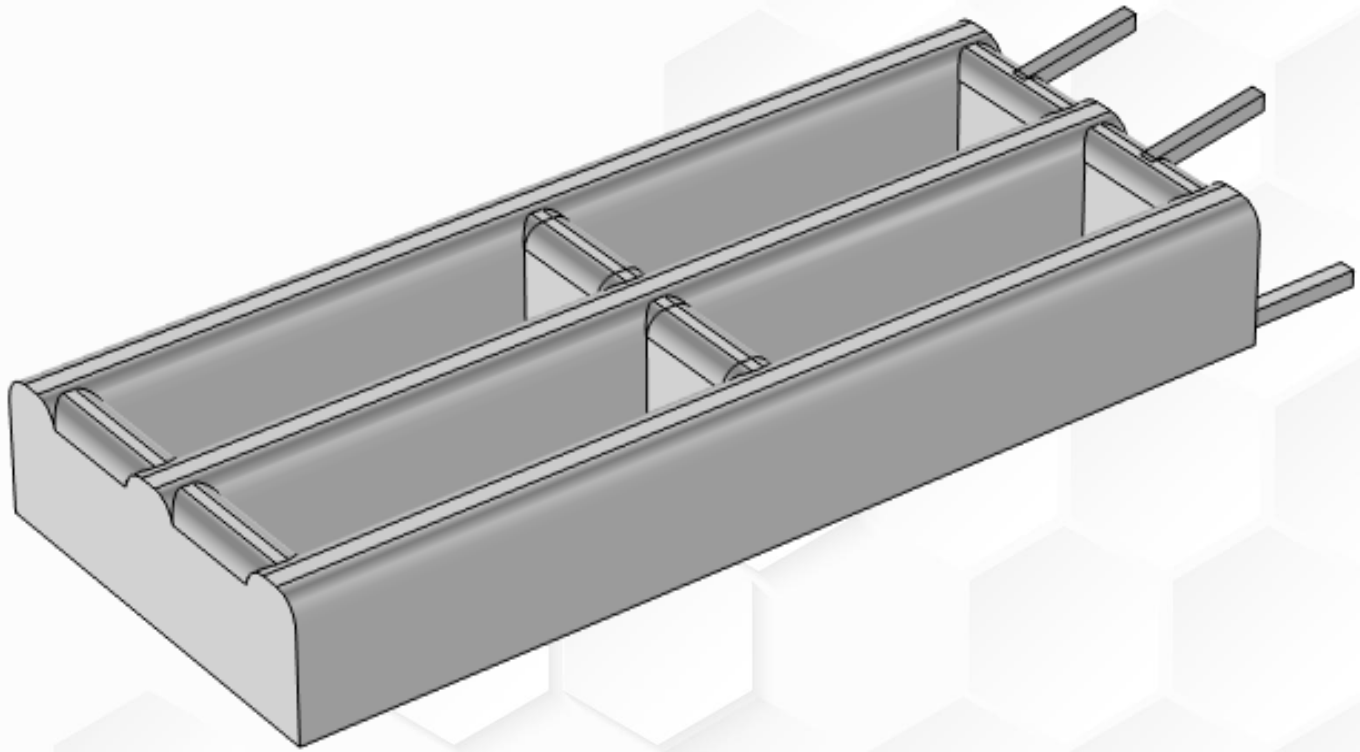
METHODOLOGY
Boundary conditions

- **Dimensions:**
  - Volume: V_{CTES} = 1,100,000 m^3,
  - Cavern length: L_{CTES} = 310 m,
  - Cavern width: W_{CTES} = 22 m,
  - Cavern height: H_{CTES} = 41.6 m,
  - Total width: W_{tot} = 130 m,

- **Materials:**
  - No insulation,
  - Shotcrete and reinforcement,

- **Charging/Discharging:**
  - 3 levels each with 2 channels,



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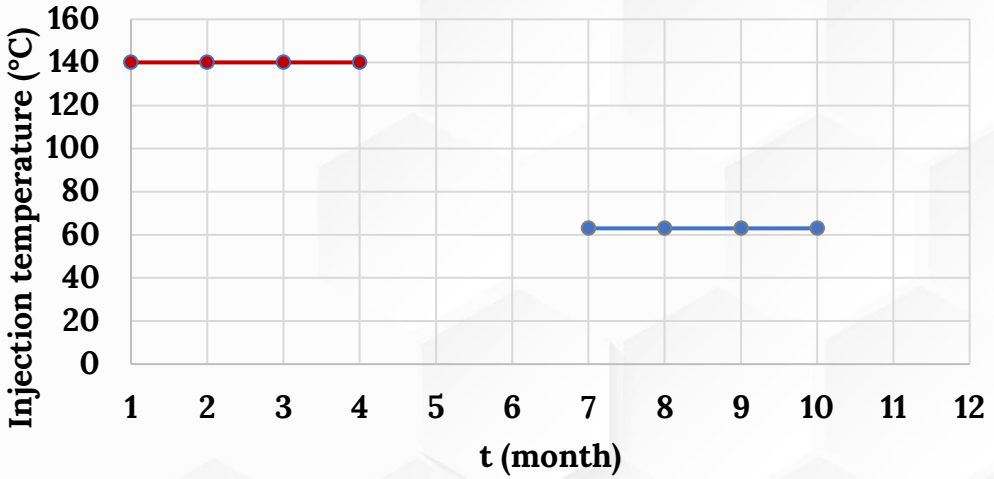

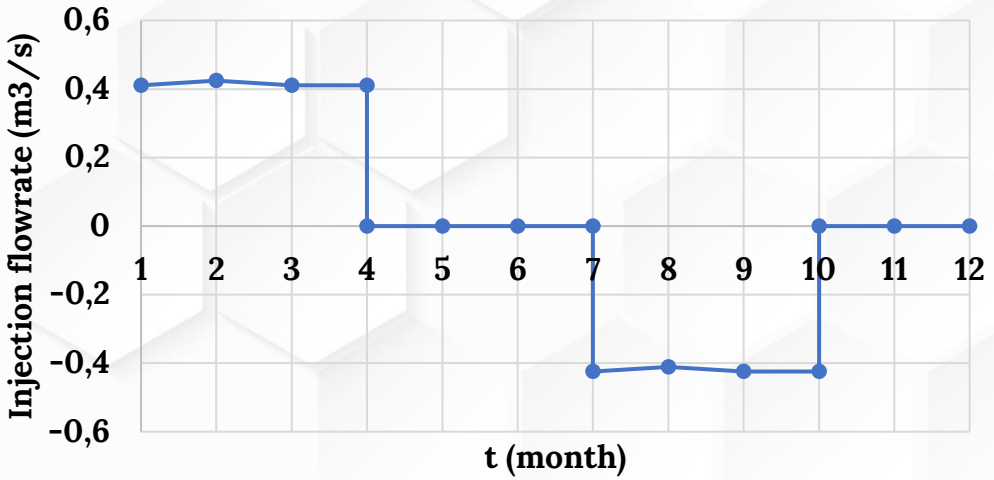

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RESULTS

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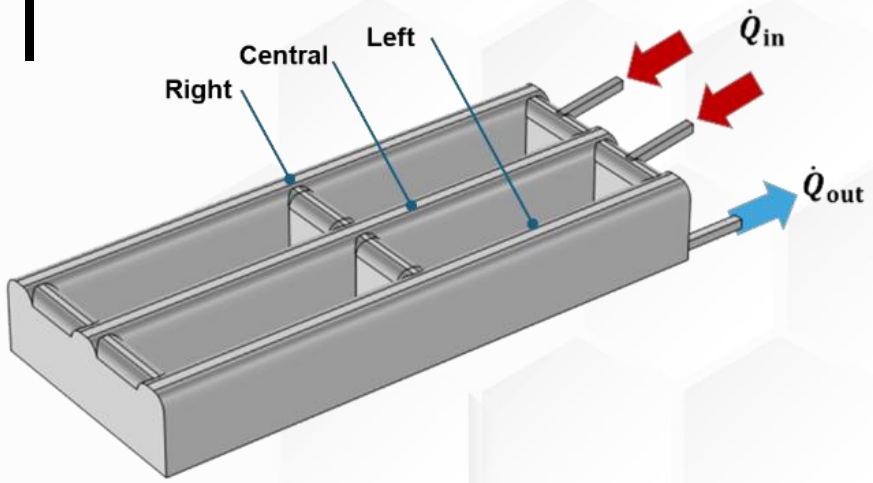
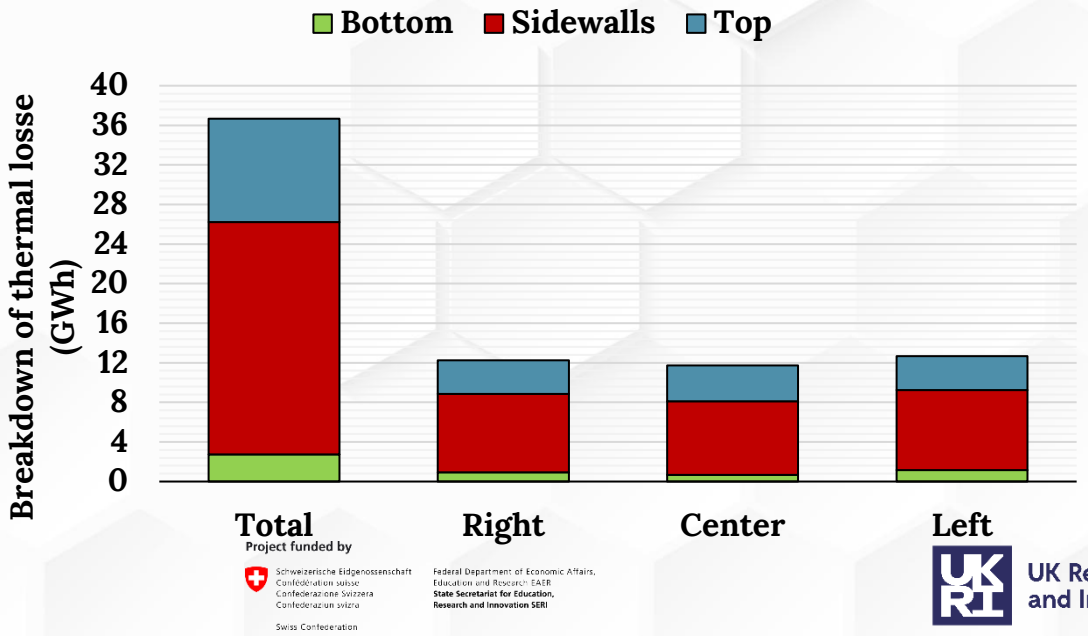
RESULTS
Initial design – VARANTO I

VECTES		
Storage capacity	90	GWh
Total thermal losses	36.7	GWh
Useful storage capacity	53.3	GWh
Storage efficiency	59	%
Breakdown of thermal losses		
Top	10.5	GWh
Sidewalls	23.5	GWh
Bottom	2.7	GWh
Share of thermal losses		
Right	33	%
Central	32	%
Left	35	%





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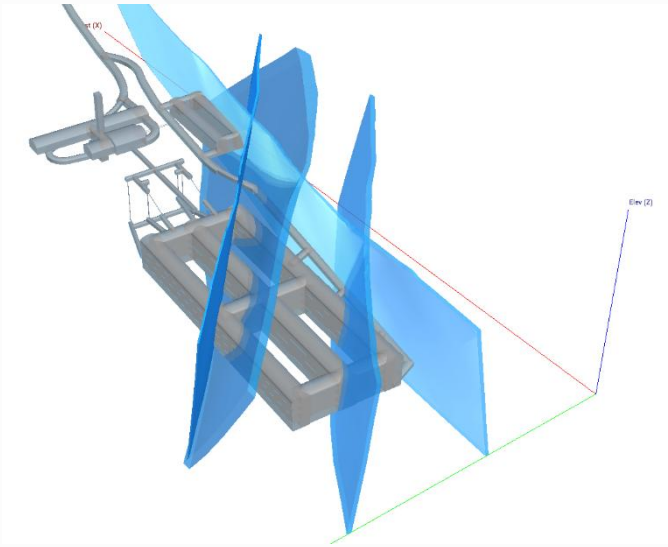
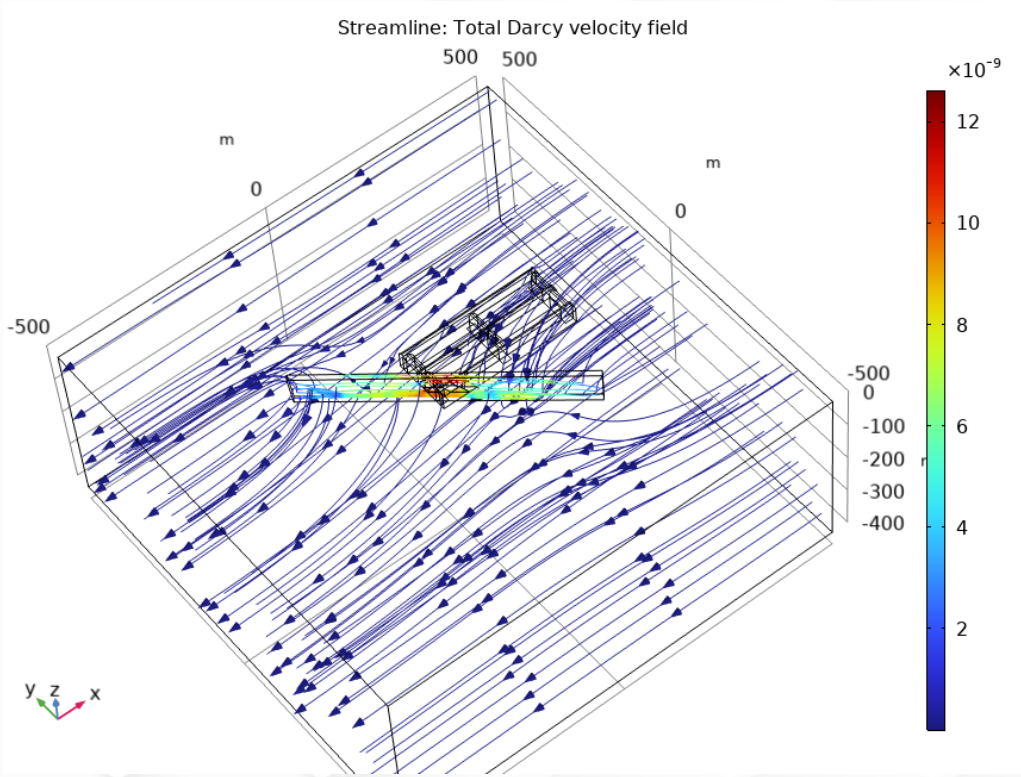
RESULTS
Initial design – VARANTO I

Deformation zones observed in drill cores



Deformation sub-vertical zones implemented



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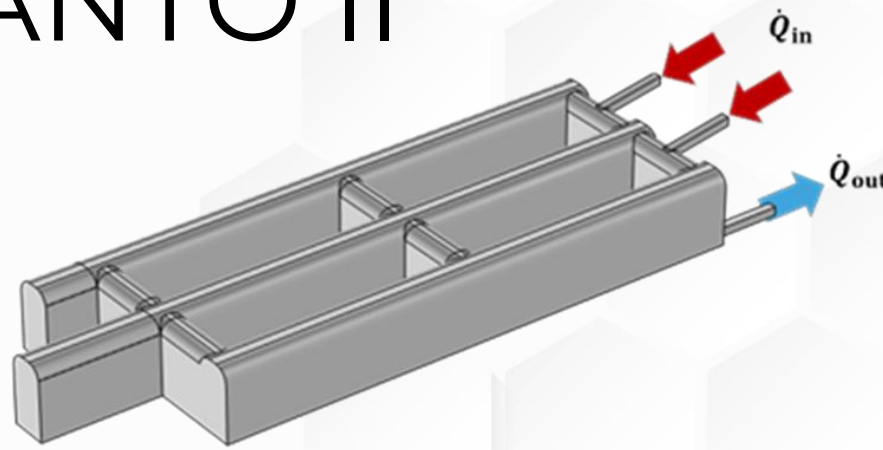
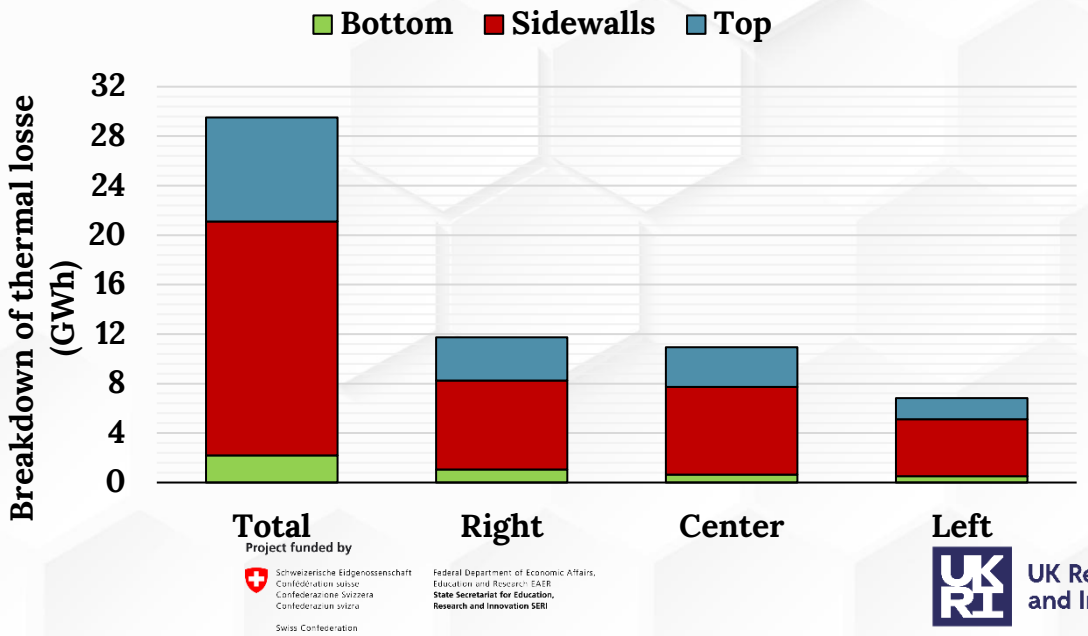
RESULTS
Optimized design – VARANTO II

VECTES		
Storage capacity	90	GWh
Total thermal losses	29.5	GWh
Useful storage capacity	60.5	GWh
Storage efficiency	67	%
Breakdown of thermal losses		
Top	8.4	GWh
Sidewalls	18.9	GWh
Bottom	2.2	GWh
Share of thermal losses		
Right	40	%
Central	37	%
Left	23	%





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SUMMARY

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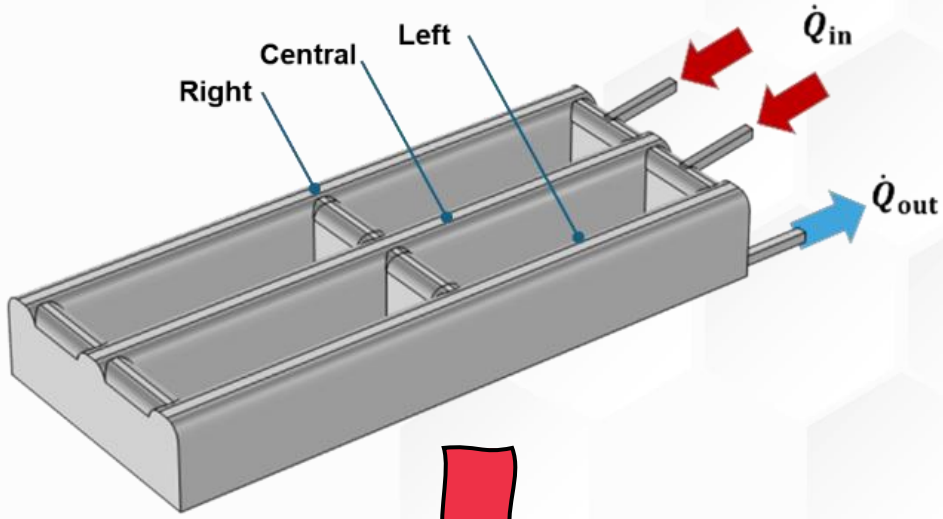
SUMMARY

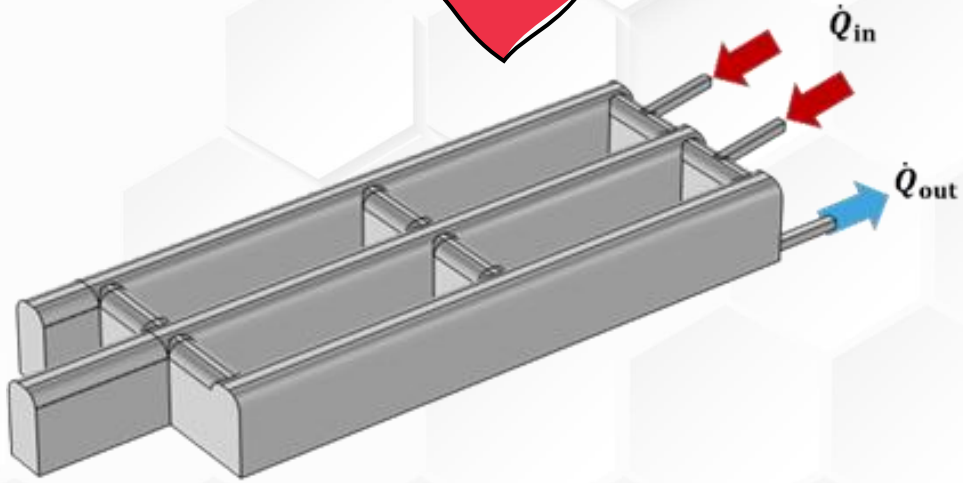
Increase of efficiency by 14% with reduced losses due to improved design

Reduction in operation hours of peak boilers due to higher discharge temperatures

Reduction in CAPEX by 5% due to optimized design and less subsurface works



Thermo-hydraulic-mechanical-chemical modeling framework



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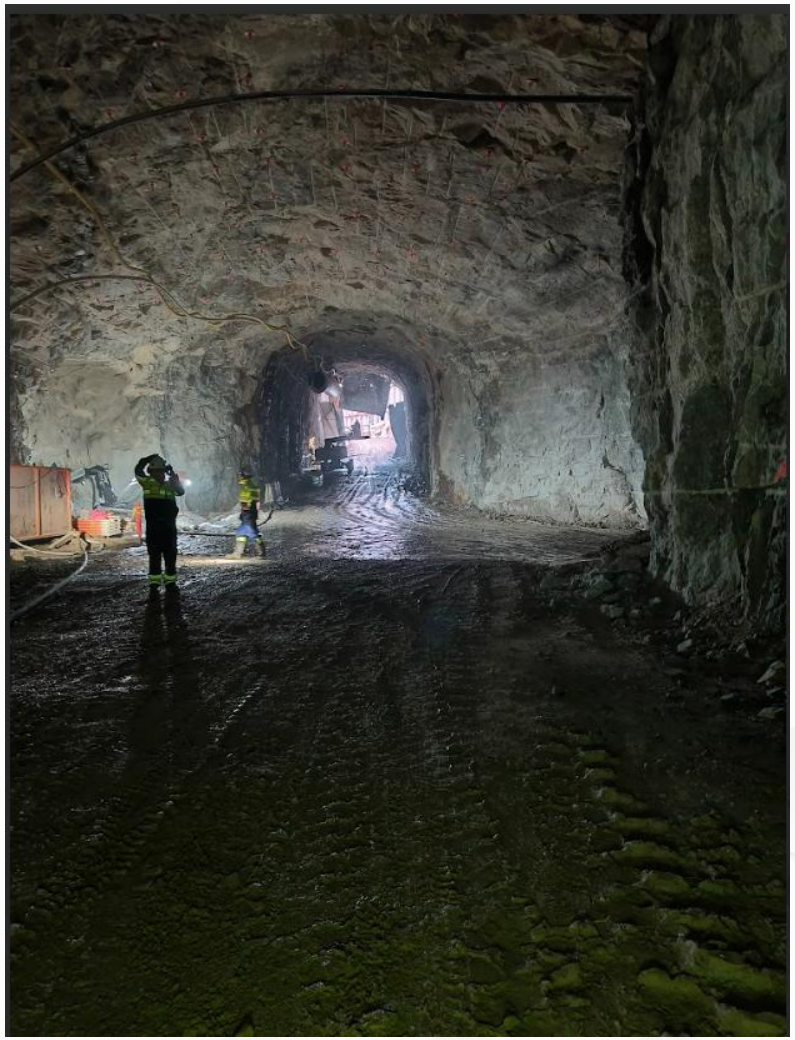
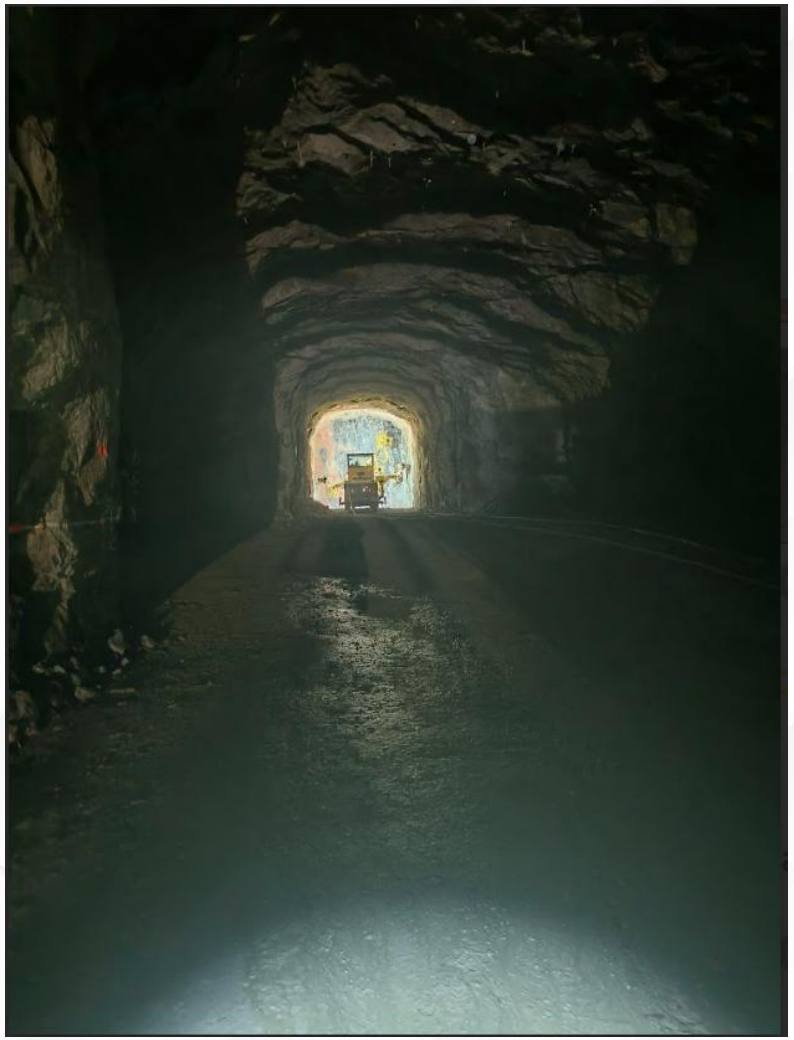
SUMMARY

Construction schedule
excavation work until 2027





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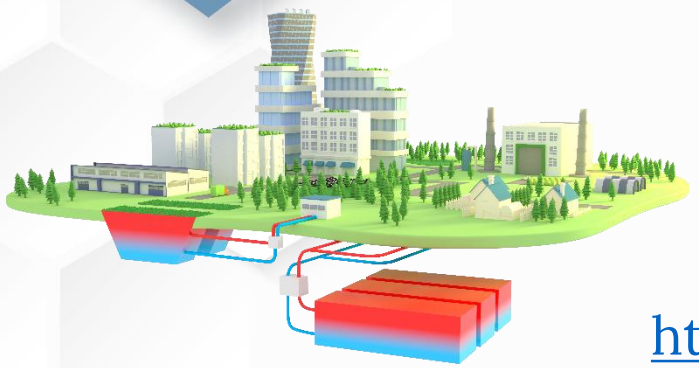

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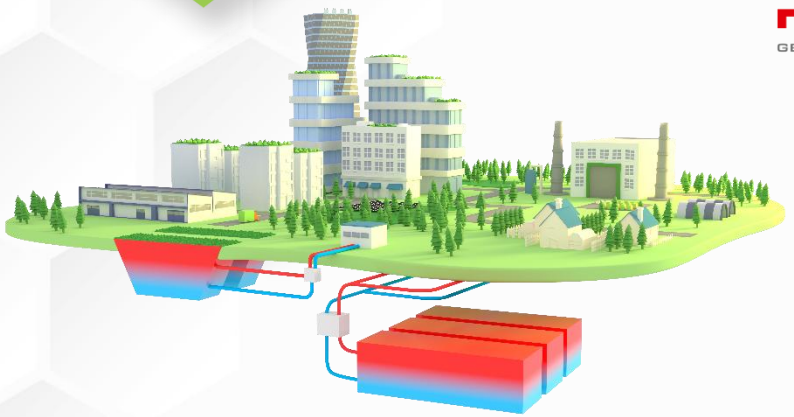

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