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

GEOTHERMAL TRENCHES FOR UTILISATION OF SHALLOW GROUND RESOURCES

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Geothermal Trenches

Technology

- Closed-loop vertical collectors
- Inserted in trenches or holes of a few m depth

Urban potentials

- SUHI effects raise ground temperature
- Capture surplus heat from infrastructures

Advantages & disadvantages

- Compact, linear solution
- Rarely applied, often overlooked

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Van den Ven et al., 2024: **Analytical solution for the simulation of ground thermal conditions around planar trench collectors**. *Geothermics* 124, 103123.
Hemmerle et al., 2022: **The evolution of the geothermal potential of a subsurface urban heat island**. *Environ. Res. Lett.* 17 (8), 84018.

Design Aspects

Collector geometry

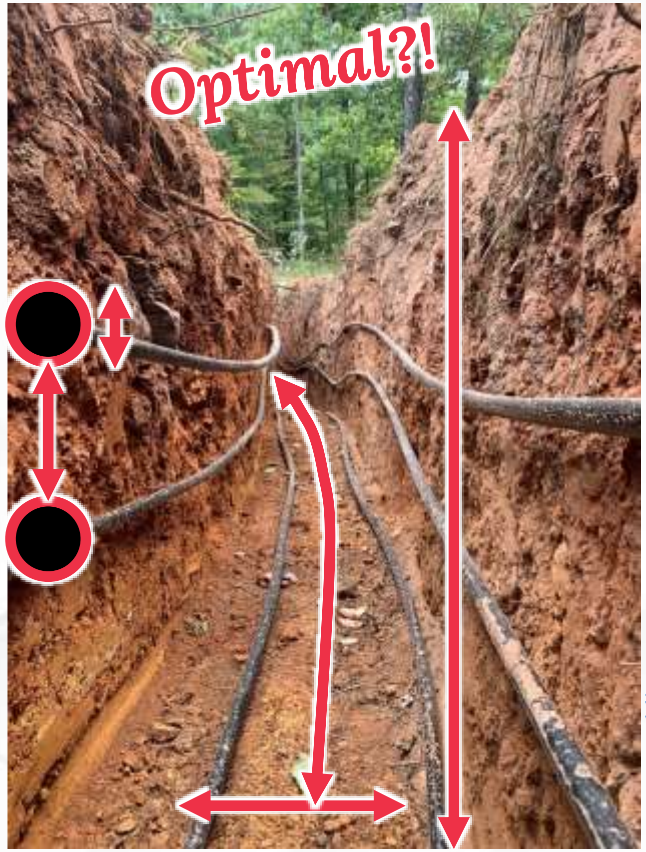
- Linear loops, coils, vertical flat-plates

Installation parameters

- Depth, orientation
- Spacings, distances from infrastructures

Subsurface & climate conditions

- Seasonal temperature variation
- Subsurface thermal properties
- Soil moisture, groundwater …



Source: Reddit.com

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Reddit.com, 2020: „**View from the trenches. Horizontal Geothermal loop**", posted by peaeyeparker – https://www.reddit.com/r/HVAC/comments/ita49q/view_from_the_trenches_horizontal_geothermal_loop

Research Gaps & Contributions

Innovations & awareness

- Heat recycling largely unexplored

Tools & processes

- Lack of versatile models
- Oversimplified processes
- Soil freezing often neglected

Validation & standardisation

- Field data is crucial
- No common design optimization methods

Proposed Solutions

Complementary Modeling Approaches

A) **Analytical**

B) **Numerical**

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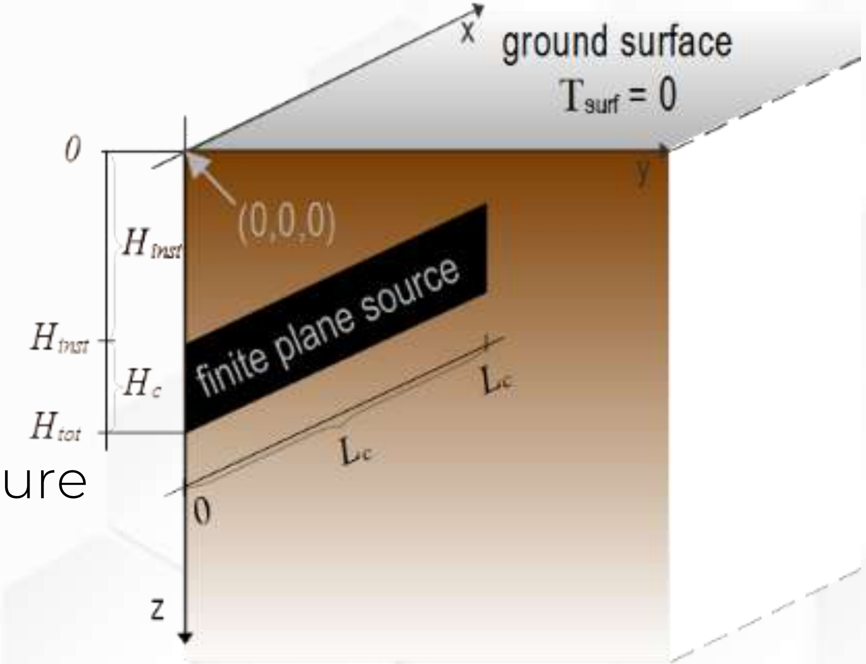
A) Analytical Approach – Model

Analytical models for design

- Fast, sufficient accuracy for first design
- Practical and easy to handle for small systems

Main components

- Heat conduction via finite plane source (FPS)
- Thermal resistance network for fluid temperature
- Seasonal subsurface temperature variation



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A) Analytical Approach – Model

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Heat conduction representation

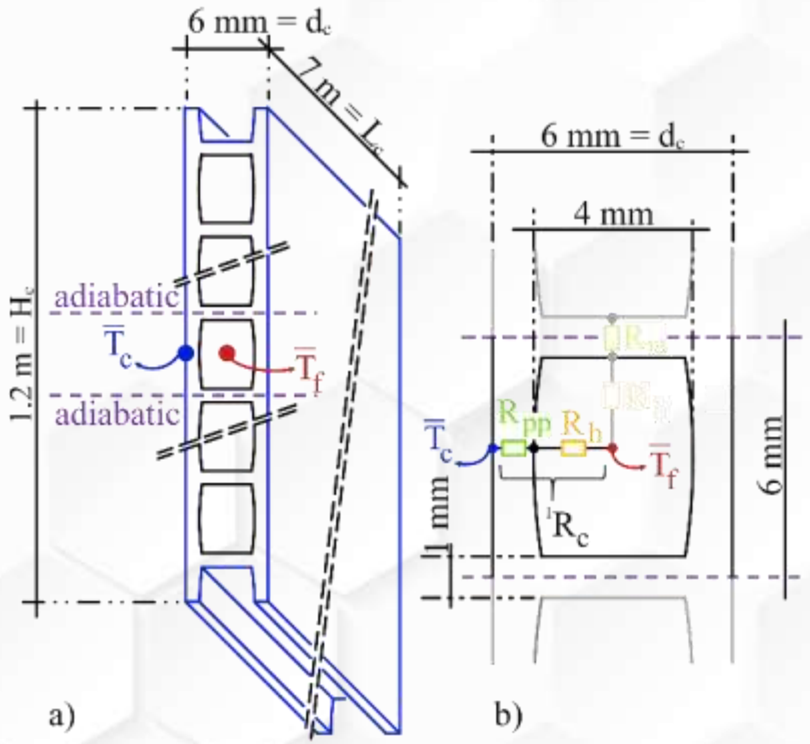
- FPS solution
- Soil thermal conductivity, diffusivity

Collector resistance

- Overall resistance R_c → 0.00429 (m²·K)/W

Boundary assumptions

- Ideal soil contact, uniform flow
- Spatial averaging of subsurface temperature
- Seasonal temperature variation



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Van de Ven et al., submitted 2024: **Behaviour of the subsurface as a reaction on an operating planar trench collector**. *Scientific Data*.

A) Analytical Approach – Demo Site

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Location

- Biberach University of Applied Sciences

Trench collector parameters

- Length 7 m, height 1.2 m, thickness 6 mm

Construction challenges

- Collector plate and steel mats not fully centered

Measurement equipment

- Pt100, fibre-optics, soil moisture
- Initial data published on Zenodo

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Van de Ven et al., 2024: **Data set of a thermal response test on a planar trench collector**. https://zenodo.org/.

A) Analytical Approach – Results

Experimental setup

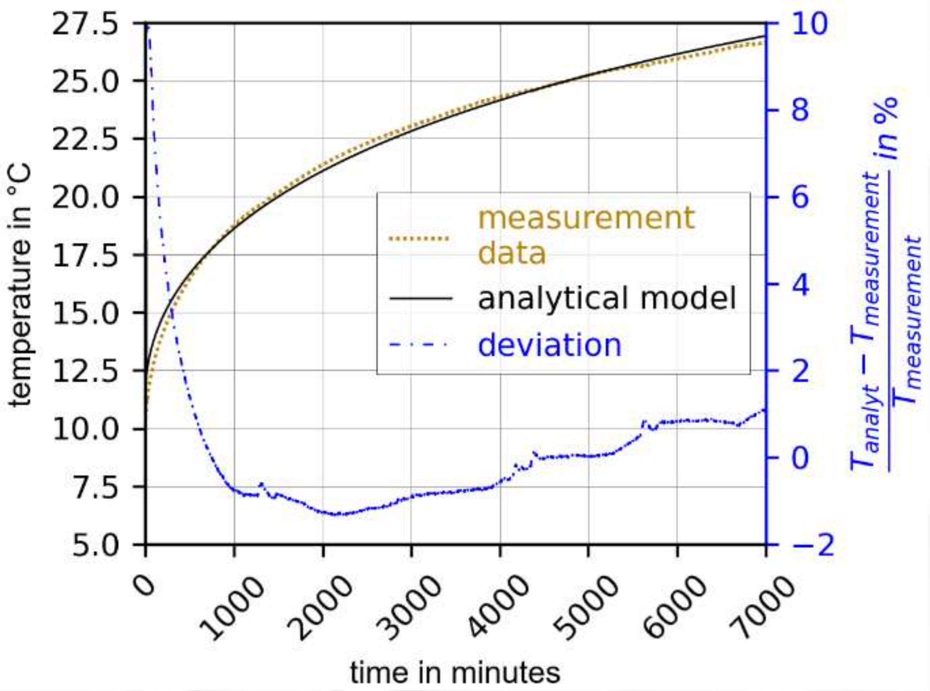
- Flow: 1.0 m³/h, const.
- Heat input: 0.88 kW (105 W/m²), const.

Comparison with measurements

- High initial deviation decreases rapidly
- < 10 % after short runtime

Conclusions on model performance

- Good agreement with field data
- Practical, robust, efficient tool



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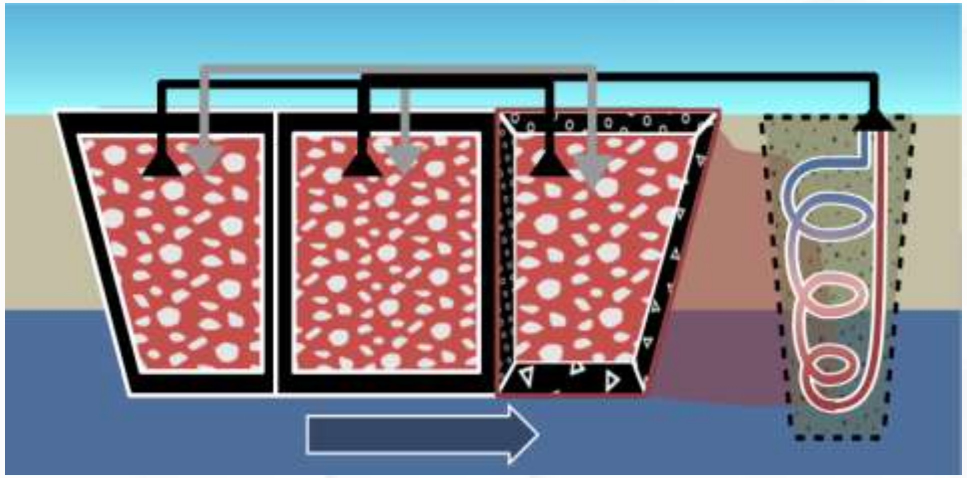
B) Numerical Approach – Model

Focus

- Waste heat recycling of Water Gravel Thermal Energy Storage (WGTES)
- Techno-economic feasibility
- Parameter studies for optimum design



Components

- Water-Gravel Thermal Energy Storage
- Groundwater → waste heat plume
- Downstream geothermal trench

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B) Numerical Approach – Model

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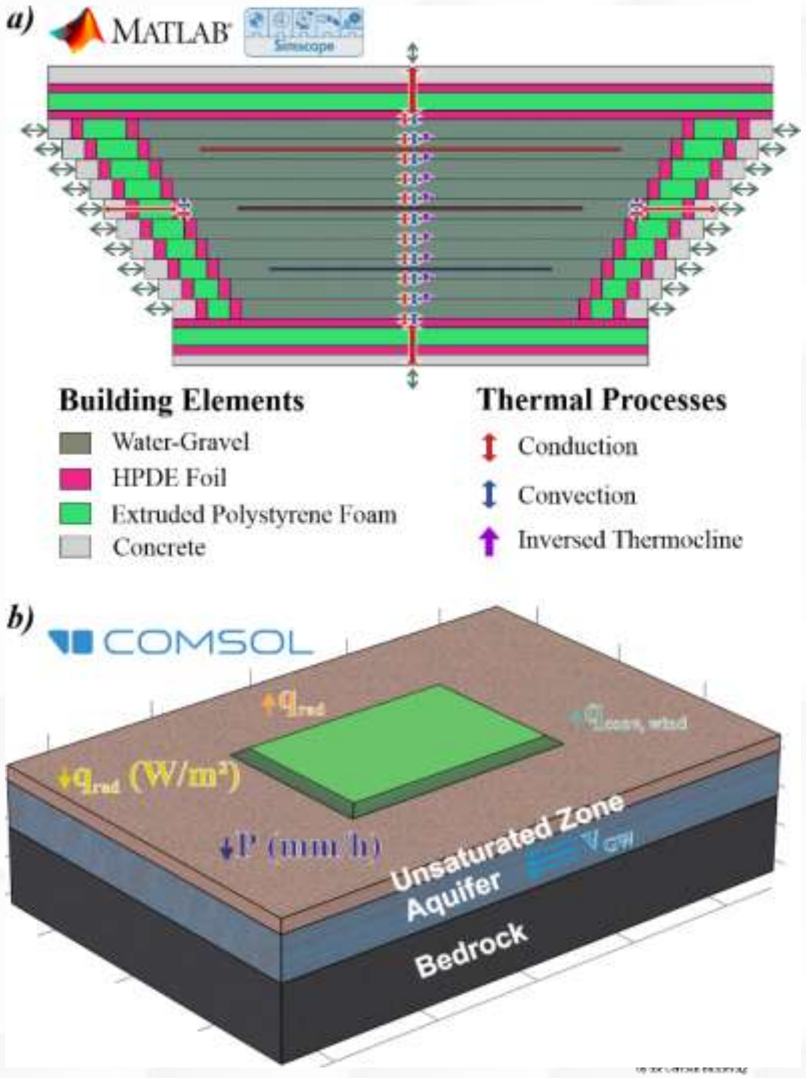
Framework
- a) STORE: 2.5D, WGTES, component-based
- b) COMSOL: 3D, multiphysics, subsurface

→ Co-Simulation

Trench representation
- Vertically stacked loops, DTS for monitoring
- Uniform extraction

Boundary conditions, datasets
- Ambient conditions and parameters
- sTES operation, geometry, materials



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Bott et al., 2022: **Component-based modeling of ground-coupled seasonal thermal energy storages**. *Applied Thermal Engineering*, 118810.
Bott et al., 2024: **Influence of thermal energy storage basins on the subsurface and shallow groundwater.** *Journal of Energy Storage* 92, 112222..

B) Numerical Approach – Demo Site

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Location

- INTERSTORES Reno-sTES site, Ingolstadt

Site context

- Reuse of firewater basins
- Conversion into buried WGTES
- Multifunctional (seasonal + short-term)

Trench innovation & integration

- Installed in groundwater downstream
- Connected to local DHN

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INTERSTORES, 2025: **INTERSTORES - International Innovation Network for the Development of Cost- and Environmentally Efficient Seasonal Thermal Energy Storages**. https://interstores.eu/.

B) Numerical Approach – Results

Storage energy balance

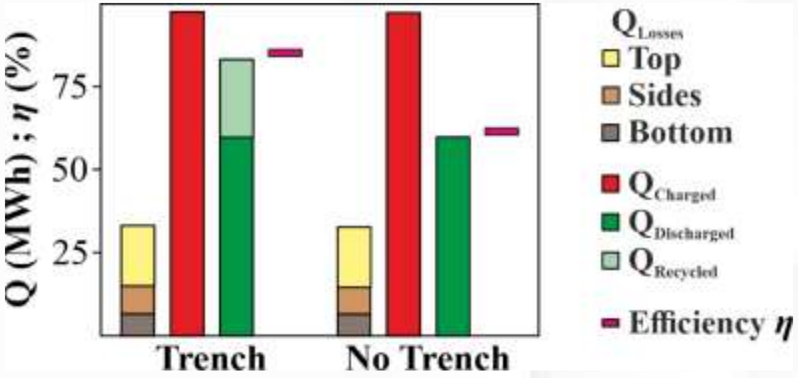
- Trench: 97.6 MWh in / 59.7 MWh out,
- No trench: 97.4 MWh in / 59.9 MWh out
- sTES operation not negatively affected

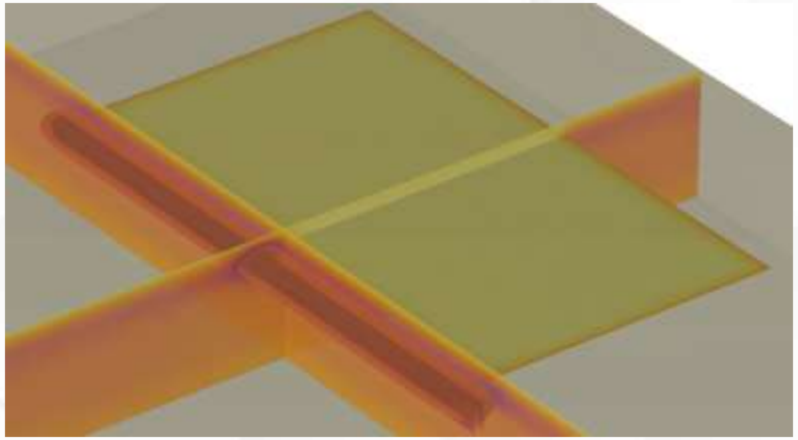
System efficiency

- Trench: 85.3% vs. no trench: 61.5%

Environmental benefit

- Waste heat plume effectively contained
- 20°C thermocline within a safe distance





Summary – Benefits

Analytical approach

- Fast, low-complexity design
- Calibrated with <10% deviation from field data

Numerical approach

- Detailed simulation of trench-WGTES interactions
- Total storage efficiency increase from 61% to 85% for example

Both approaches – Highlights

- Support robust planning & design
- Complementary for different planning stages/objectives

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Summary – Challenges & Outlook

Analytical approach

- Limited to idealised conditions
- May not capture complex interactions

Numerical approach

- High computational demand
- Requires detailed site data, calibration

Both approaches – Future work

- Include long-term effects
- Apply to other geometries, environments
- Combine to allow flexible, accurate planning

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Geothermics 124 (2024) 103123

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Analytical solution for the simulation of ground thermal conditions around planar trench collectors

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ARTICLE INFO

Keywords:
Ground heat collector
Trench collector
Thermal response test
Simulation and modelling
g-function

ABSTRACT

Vertical planar installations in … geothermal heat supply. Still, they are of increasing int… …illing of boreholes or the installation of horizontal colle… …heat exchangers that are installed in trenches at a few … …del is presented that accounts for the thermal propert… …d. The model represents the trench collector as a finite … …e the mean temperature of the circulating heat carrier … …ssful comparison to numerical simulation are present… …ated, the model could be validated to the conditions ob… …or installed at Biberach, Germany. The presented analy… …ioning of vertical planar heat collectors in practice, and … …n of advection or latent heat transfer in frozen ground…

Journal of Energy Storage 92 (2024) 112222

Contents lists available at ScienceDirect

Journal of Energy Storage

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Research Papers

Influence of thermal energy storage basins on the subsurface and shallow groundwater

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[b] Center for Energy, AIT Austrian Institute of Technology GmbH, Gießhübelgasse 4, 1210 Vienna, Austria

ARTICLE INFO

Keywords:
Design optimization
Environmental impacts
Modeling and co-simulation
Seasonal thermal energy storage
Subsurface and groundwater
Water-gravel storage

ABSTRACT

Seasonal thermal energy stora… …modern energy systems. Yet, high thermal losses and … …aturity. Especially under challenging conditions, e.g., d… …ons is affected. Moreover, for subsurface installations, i… …d, while operational risks can result when legal environ… …nings, this study presents a new modeling and simulat… …f ground-based, sensible, seasonal thermal energy stora… …mulation approach, both the internal storage (i.e., stor… …the surrounding environment are resolved in detail. I… …aveled allowing in-depth analyses regarding environm… …ns. The study firstly introduces the newly developed … …sequent parameter study, examining impacts under diff… …efficiency range of 13 %, despite thermal insulation. In … …up to 24 %. Introducing a

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Thank You

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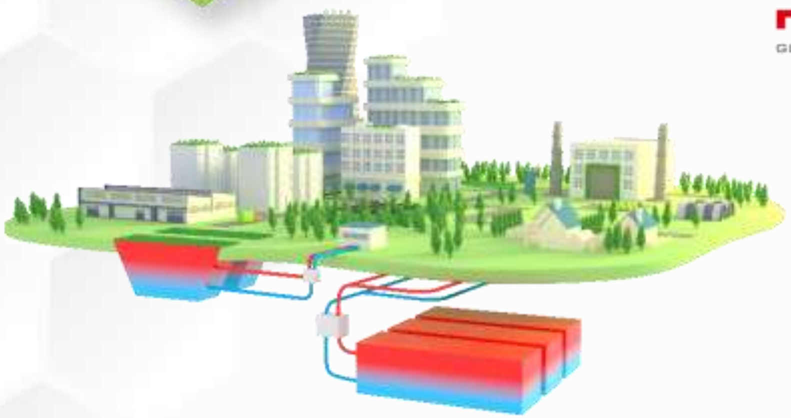

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