1

Critical success factors for HT-ATES in Europe

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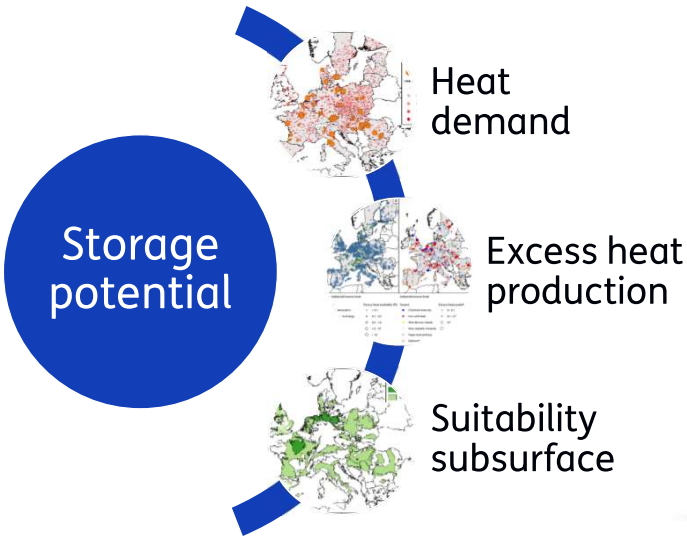
Screening for EU potential – first order estimate



Based on thesis by J.M. van der Stoel (2022) and HEATSTORE results

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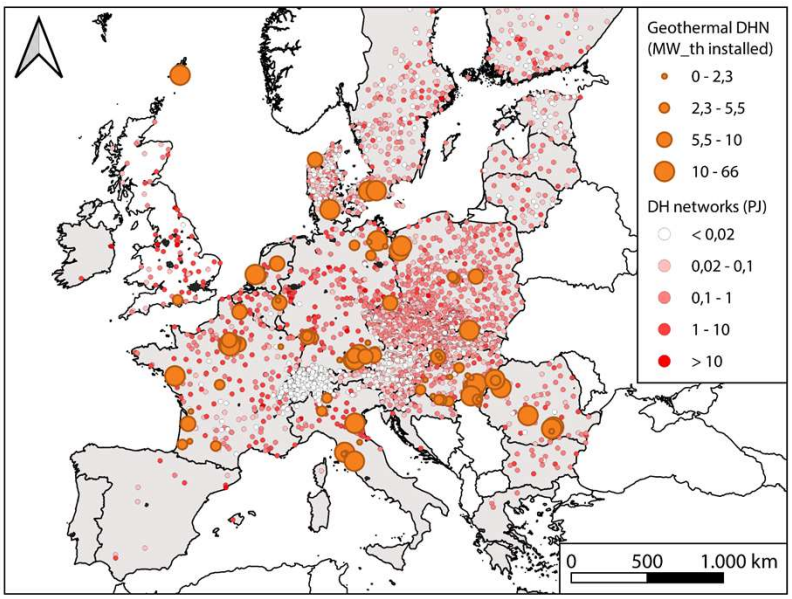
Heating demand

- Where is demand for heat located?
- Map shows district heating networks (DHN) in Europe
- To be included: potential for future/planned heating networks
  - Heat Roadmap Europe: 50% of heat demand through district heating networks



sEEnergies D5.1 DH networks
GeoDH geothermal DH networks

Van der Stoel (2022)

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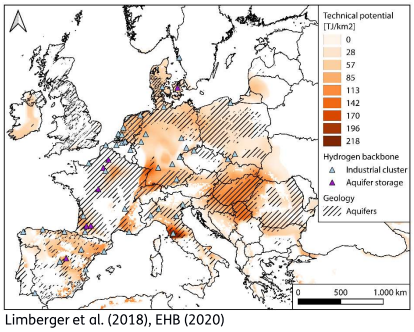
3

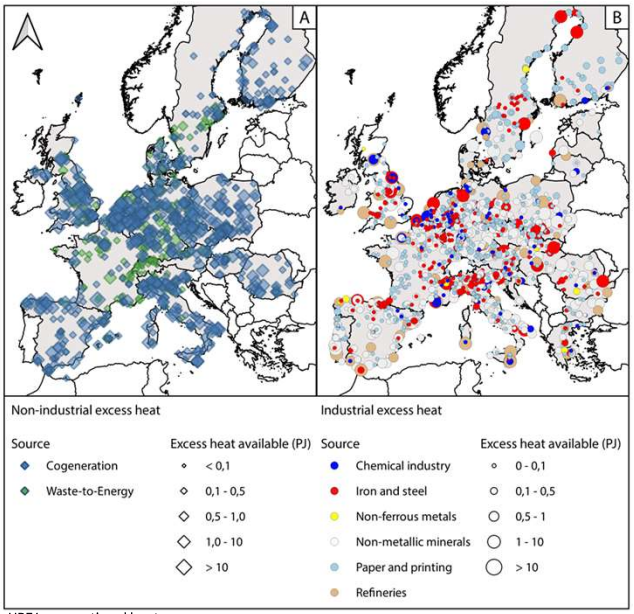
Excess heat

- Maps show locations with excess heat available from industrial and non-industrial sources
- To be included: combining sources to support district heating:
  - Geothermal energy, aquathermal energy, solar energy, datacentres, electrolysers.

Geothermal energy and hydrogen backbone



Limberger et al. (2018), EHB (2020)



HRE4 conventional heat sources
sEEnergies D5.1 industrial heat sources

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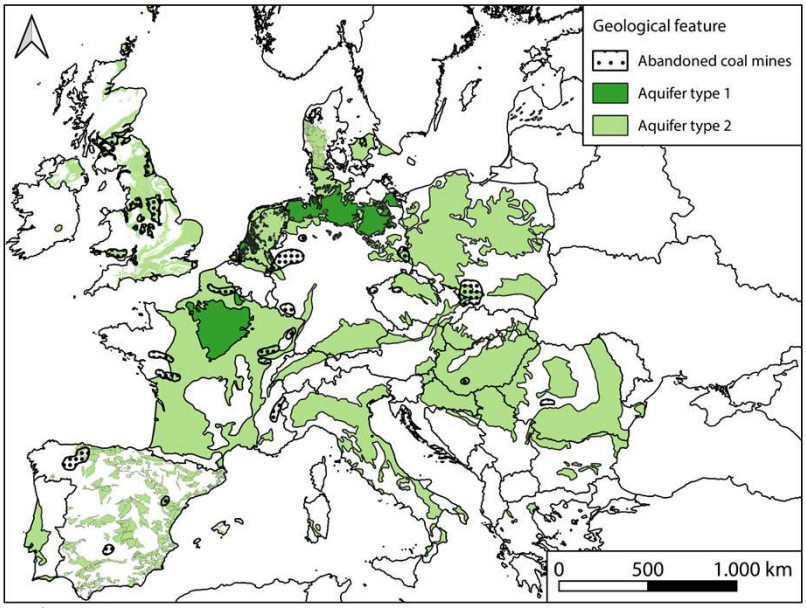
Suitability of the subsurface

- Aquifer Type 1:
  - Well known properties that make it suitable for ATES
  - I.e., depth, thickness, transmissivity
  - E.g. WNB, North German Basin, Paris Basin
- Aquifer Type 2:
  - Other aquifers with less information on suitability



Aquifer Europe (GeoEERA)
Coal mines Europe (literature)

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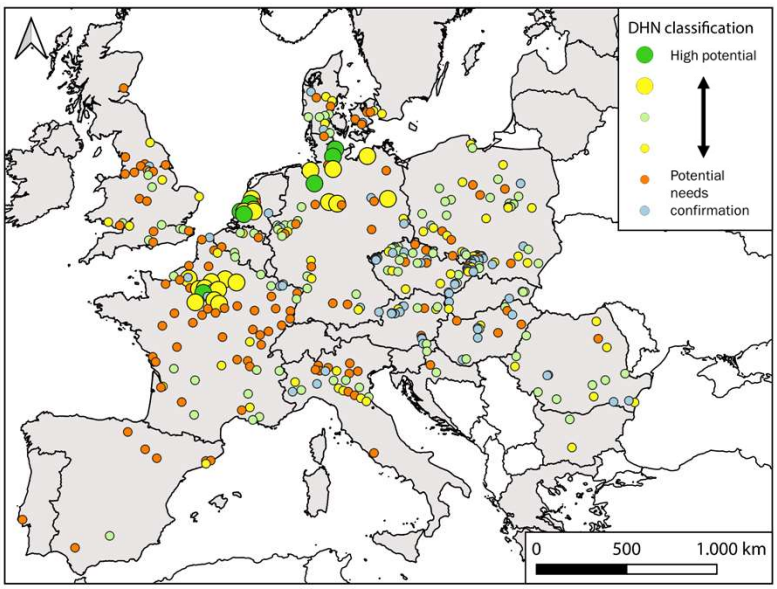
Potential ATES and MTES

- Classes with excess heat ratio: excess heat available / heat demand.
- The assumption is: higher the excess heat the larger the opportunity for heat storage
- Result: 690 PJ of excess heat within 5 km of a DH network and located above an aquifer or mine, spread over 387 areas



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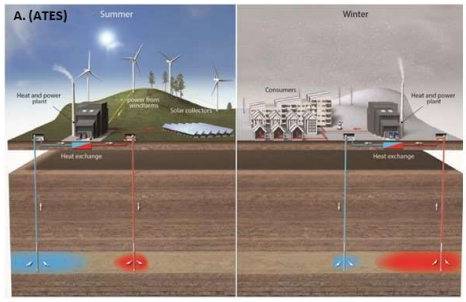
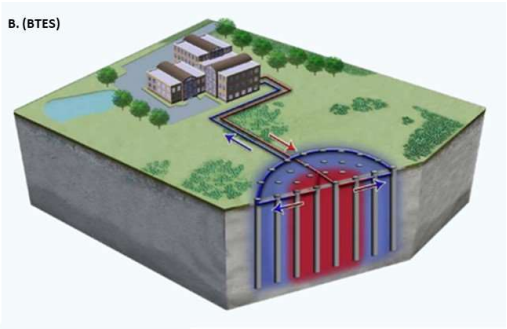
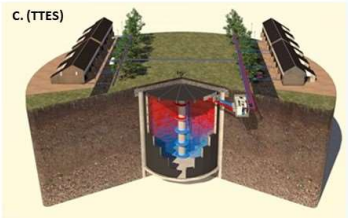
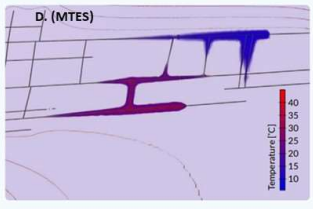
Underground Thermal Energy Storage



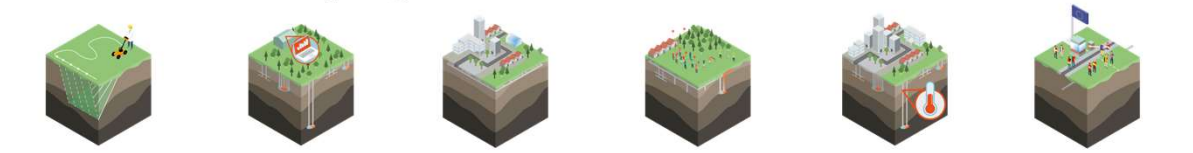






Sources: see HEATSTORE Roadmap (2021)

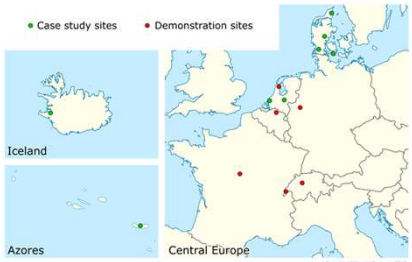
HEATSTORE project and consortium



Characterization of UTES	Modeling subsurface dynamics	System integration & UTES design optimisation	Demonstration	System performance monitoring	Fast track market uptake

- 23 partners in 9 European countries

- 6 demonstration sites, 8 case studies



heatstore
High Temperature Underground Thermal Energy Storage

- EU Geothermica Era-Net co-fund
- 16.3 MEUR total project budget

Fast track market uptake, what actions are needed?

Vision 2050

Technology & innovation

Market & Economics

Society & Environment

Policy & regulation

Including the latest results from recent national projects and project proposals on HT-ATES in NL

UTES as part of Europe's energy storage portfolio

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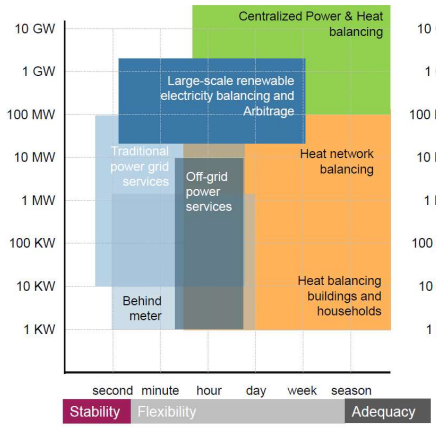
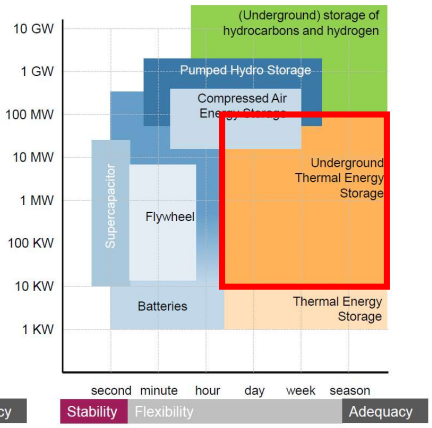
Society & Environment

Policy & regulation





Infrastructure:
- Electricity grid
- Gas infrastructure
- Heat networks

Towards UTES as largest (heat) storage option in Europe

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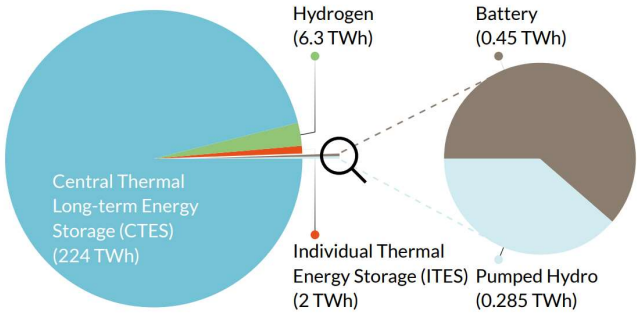

Storage requirements in a future decarbonized European energy system scenario with 95% emission reduction

Source: Victoria et al. (2019)

- The heating and cooling sector is projected to remain the largest energy sector even in the long-term under both business-as-usual and decarbonisation scenarios by 2030 and 2050.
- Overall, the integration of low carbon heat sources in the energy system implies that ***hundreds to even thousands of large scale UTES systems need to become operational in Europe in the next thirty years*** in order for the European heating and cooling sector to contribute to the sustainability goals of the Paris agreement and EUs Green Deal.

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TECHNOLOGY & INNOVATION

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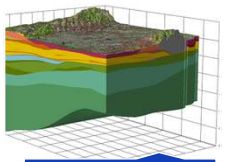
What has been done, or is going to happen in the Netherlands for HT-ATES?

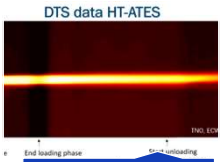
Scale-up: 5+ planned demonstrators



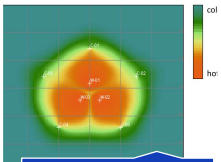
Detailed (regional) subsurface characterization of two most promising aquifers

Optimization of system integration (Design Toolkit) Multi-source (solar, CHP, HP) strategies

Experimental HT-ATES well, performance testing in controlled environment
Sand production experiments



Improve models by history matching with monitoring data from first pilot site



Advanced subsurface de-risking method, subsurface and operational optimization (digital twin)

Equipment and material innovation (flexible pumps, well isolation)

General UTES actions: Reduce subsurface uncertainty by data acquisition and mapping, gain skills and experience, integration of UTES in heat grids, improve (initial) efficiency of UTES, reduce operational risks

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MARKET & ECONOMICS

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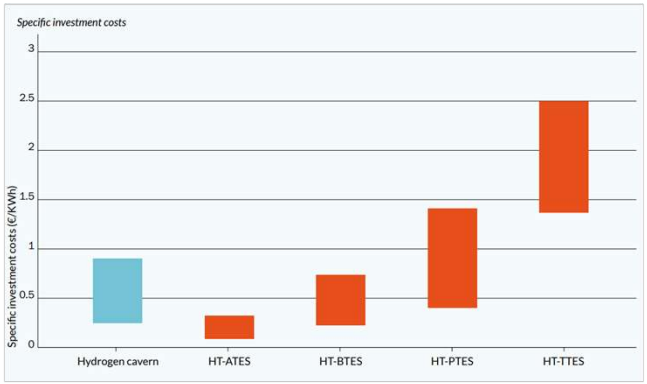

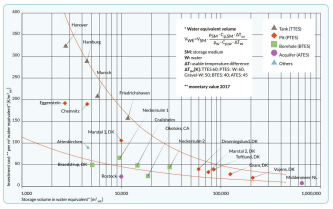

Source: HEATSTORE Roadmap (2021)

- Follow a structural approach to establish a robust business case model
- **Improve storage economic project fundamentals – further CAPEX and OPEX reduction**
- Create and stack business model revenue opportunities
- Transparent ownership and market player relationships

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SOCIETY & ENVIRONMENT

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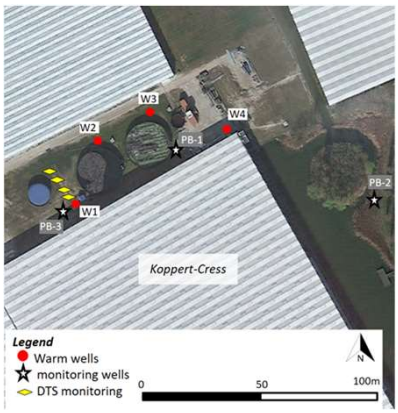

Source: Guglielmetti et al. (2021) Environmental effects of UTES technologies in Europe

- **Evaluate, mitigate and <u>monitor</u> environmental impacts**
- Solid spatial planning for subsurface
- Create social awareness and support

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POLICY & REGULATION

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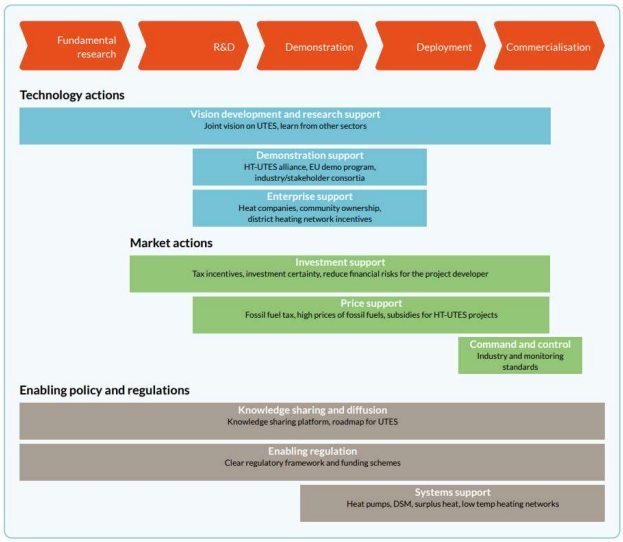
- Create a joint vision on UTES
- Provide clear regulatory framework
- **Adapt policy to UTES: support programme to lower financial risks**



Source: HEATSTORE Roadmap (2021)

KEY RECOMMENDATIONS FOR THE SHORT TERM

Momentum for UTES is now, large potential

Strong need for awareness and strategy on local, national and European level

Help early movers with financial de-risking and support scheme for early commercialisation

Launch the European Underground Thermal Energy Storage Alliance

What's next in Europe?
Research topics

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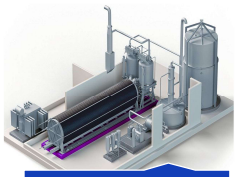
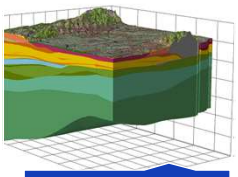
Large demonstration portfolio needed

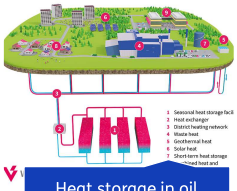


Power-to-heat (HP, e-boiler, electrolysers)



HT-ATES in rock/deeper than 500 m

Growth DHN share



Heat storage in oil reservoirs or caverns

Flexible HT-ATES pumps, material innovation

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Thank you!

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HT-ATES projects in NL and EU

GENOVATIVE TKITOE-Gas 2020-2022	TKI HTO-PEN 2022-2025	WarmingUP GOO MOOI 2023-2026	Com2Heat MOOI 2023-2026	WGoBES MOOI 2023-2026	PUSH-IT (EU) 2023-2027	Warmtestad Groningen 2021-2024	ACCEL-UTES (proposal)
Realization first experimental HT-ATES well	3 year monitoring program	Scale up of HT-ATES	Use composite instead of steel in low & middle temperature heat systems	High temperature closed loop systems	HT-ATES demonstrator in Delft coupled to geothermal source	Solar heat, waste heat datacentres	P2H: solar power coupled with heat pumps and HT-ATES
First time drilling with RCSG's 160t rig; hybrid between water well & deep drilling equipment and requirements	Unique data set of first operational HT-ATES Middenmeer	Screening 4 locations	System integration RCSG*	Thermal properties of subsurface (also useful for open systems)	Improving & monitoring efficiency	Commercial project	Advanced subsurface de-risking method
ECI's automated Rotary Steerable System	Thermal, geochemical, microbiological, geomechanical monitoring	Detailed (regional) subsurface characterization of two most promising aquifers	Solar thermal with heat pump	Insulation materials	Optimizing system integration	Digital twin	Technology innovations (well insulation, flexible pumps)
Composite casing	History matching and optimization	Sand production experiments			Social embedding		Optimization of HT-ATES design based on multi-source (solar, CHP) strategy
Full well-length Glass fibre monitoring system		HT-ATES optimization					
		Realisation of 2nd HT-ATES well in Rijswijk					

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* Rijswijk Centre for Sustainable Geo-Energy

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WarmingUP

WARMINGUP

3 HT-ATES pilots

- Rotterdam Nesselande
  - Test drilling (feb 2022) results below expectation (subsurface and system integration)
- Delft
  - Test drilling complete
  - Concept selection for HT-ATES design (system integration, heat pump?)
- Leeuwarden
  - Test drilling completed in March 2023 → analysis now

- Extensive knowledge base on: HT-ATES screening an potential in NL, well technology, thermal effects, monitoring, first setup of legal assessment framework, effects on groundwater quality, system concepts and integration

Meerjarige Missiegedreven Innovatie Programma's (MMIP), MMIP-4 – Duurzame warmte en koude in gebouwde omgeving en levert daarmee een bijdrage aan Missie B – Een CO2-vrije gebouwde omgeving in 2050.

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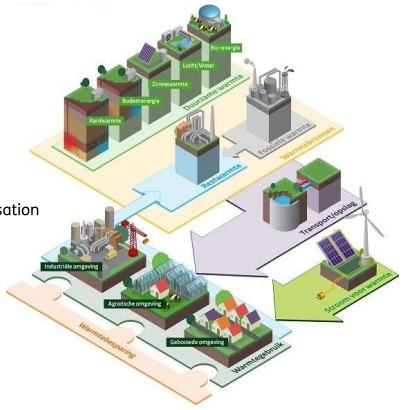
WarmingUP GOO

Warming^{UP}*GOO*
Geothermie & Opslag Opschaling

- Warming^{UP}*GOO*: Geothermie & Opslag Opschaling
- MOOI 2022 (Missiegedreven Onderzoek, Ontwikkeling en Innovatie), Missie B; Gebouwde Omgeving
- Total budget is € 8.550.541, € 5.441.101 subsidy by RVO
- Project duration: 4 year (march 2023 – march 2027)
- 15 partners: 5 research organizations, 6 operators, 1 heat company, 2 municipalities, 1 branche organisation
- Project lead TNO



- Result 1: desrisking middle deep subsurface 100-1500 m
- Result 2: accelarate HT-ATES
- Result 3: improve efficiency geothermal production (digital twin)
- Result 4: Increase societal acceptance

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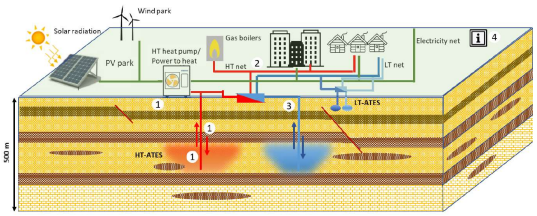
ACCEL-UTES (proposal)

Project proposal, research topics:

- **Subsurface de-risking**
  - Seismic reprocessing and re-interpretation
  - Construct a reference 2D and 3D litho-stratigraphic, hydrologic, geochemical, mechanical and structural model
  - Forward Stratigraphic Modelling (FSM)
  - HT-ATES optimization, multi-criteria performance assessment
- **Technical innovations**
  - Insulation materials of the well pipes
  - Reduce HT-ATES surface footprint from 6 to 2 m2 (integration in urban areas)
  - Flexible pump systems, day-night buffering
  - Sand production, flowrates
  - Monitoring, impact legal framework
- **System integration**
  - Optimization of HT-ATES design based on multi-source (solar, CHP) strategy
    - DesignToolkit coupled to Mixed-Integer Linear Programming
    - Optimization of HT-ATES in DesignToolkit

Towards a CO_2-neutral energy system at the Utrecht Science Park

Solution: P2H, solar power coupled with heat pumps and HT-ATES



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