HEATSTORE

HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE

7^{TH} GEOTHERMAL GET-TOGETHER TU DELFT

4 NOVEMBER 2020

heatstore

High Temperature Underground Thermal Energy Storage

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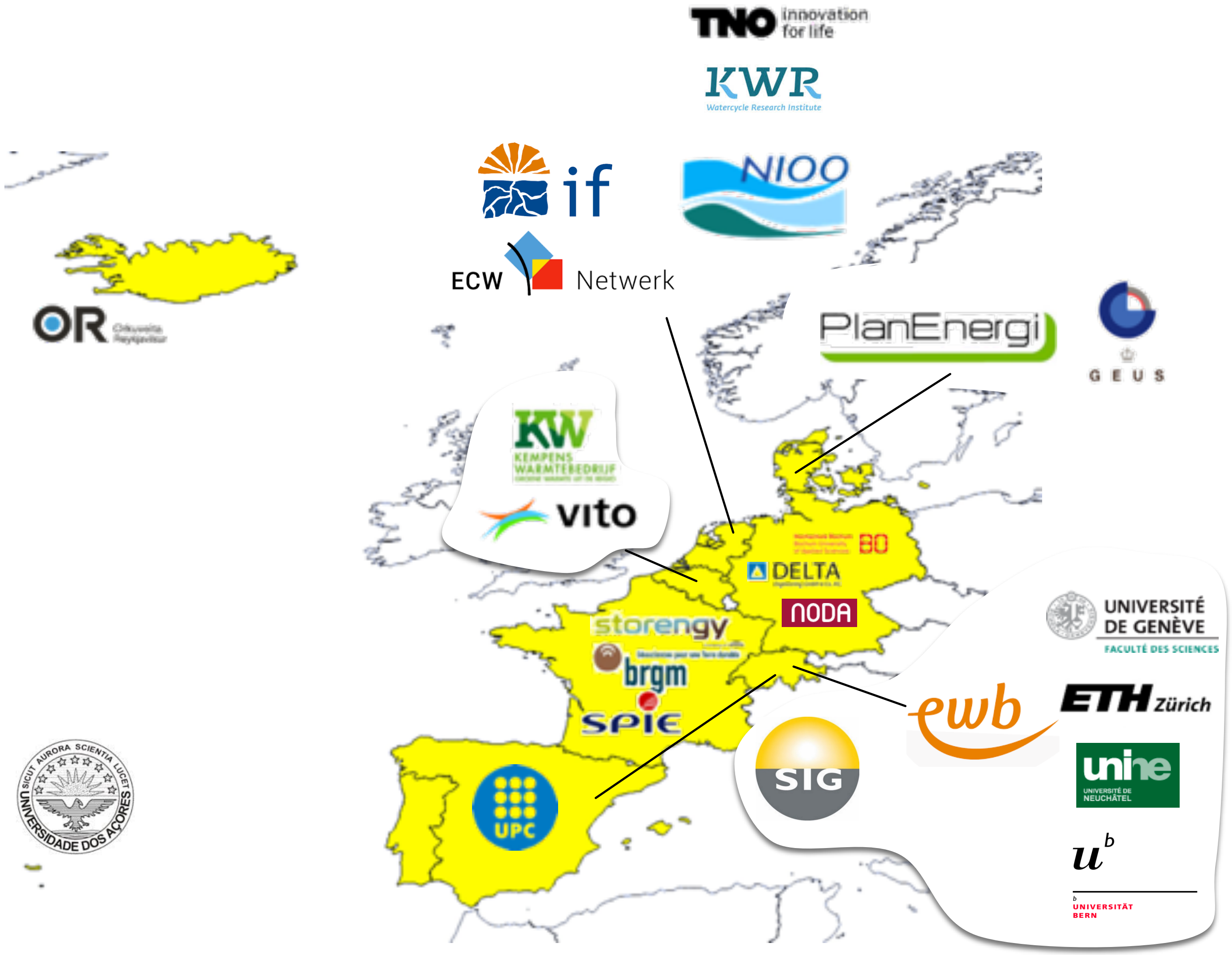
UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES

GEOTHERMICA

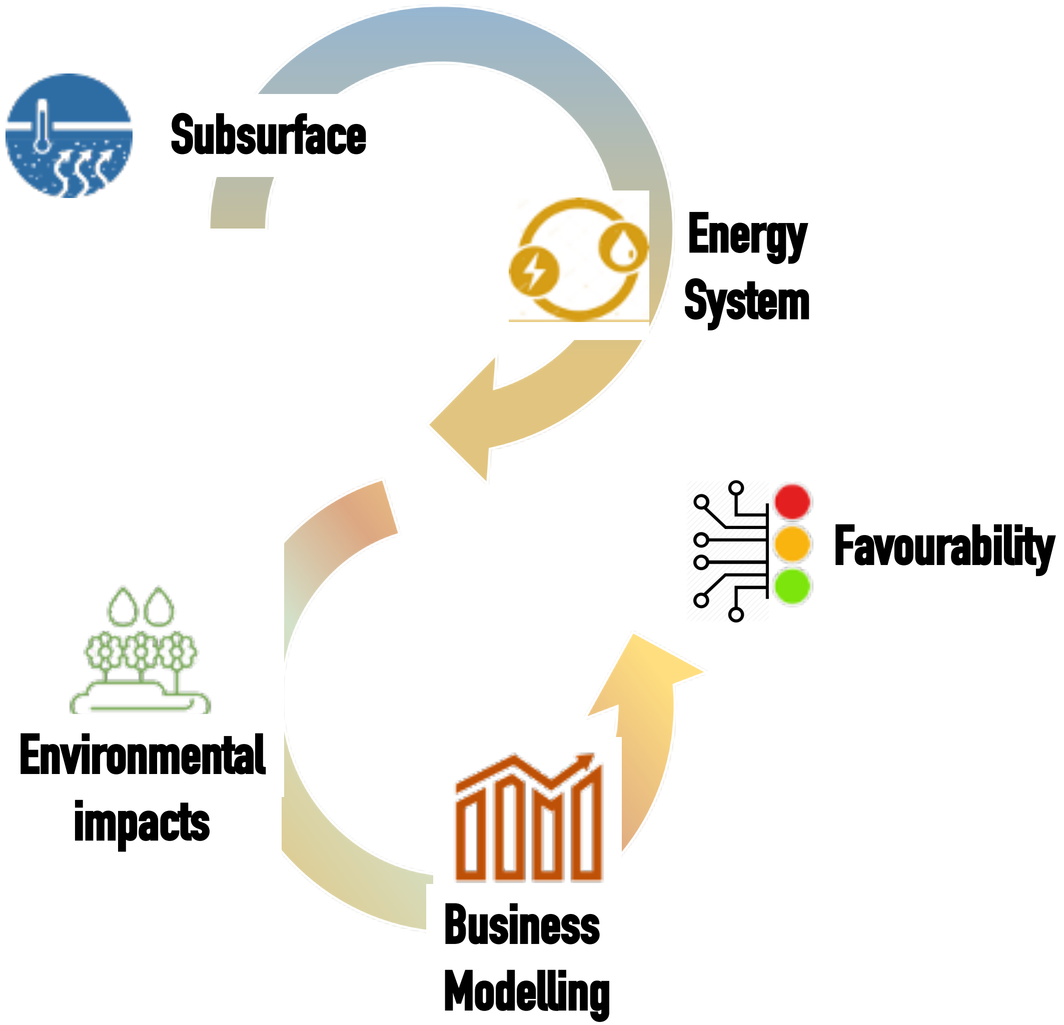
- 24 partners involved
- 9 different countries (and funding agencies)
- 6 P&D sites

4 UTES Types
PTES
MTES
BTES
ATES

NATIONAL LEADS
- NL: TNO
- CH: University of Geneva
- DK: GEUS
- FR: Storengy
- PT: UAC/IVAR
- BE: VITO
- ES: UPC
- GE: GZB
- IS: Reykjavik Energy



HEATSTORE – The approach



The EU highlighted the strategic importance addressing heating energy demand[1].

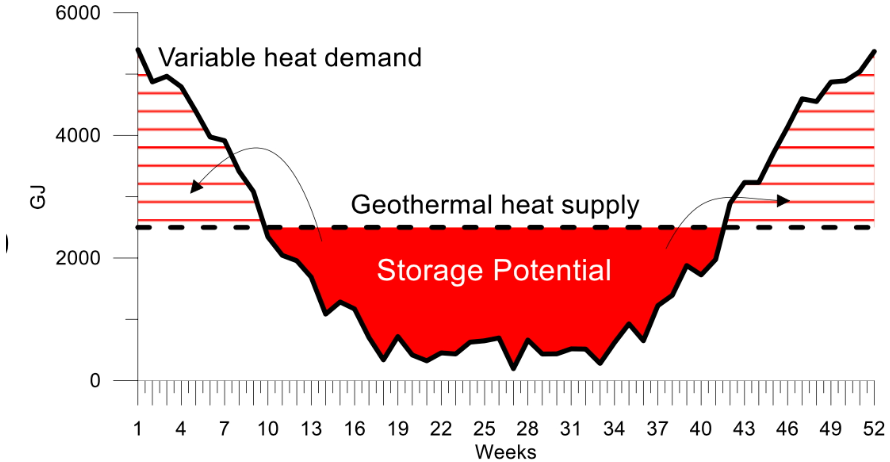
The EU, as well as the IRENA, have underlined the role of district heat networks (DHN) to meet that demand efficiently and with low-emissions[2].

Households and Industry accounts from more that 50% of the total energy uses (source: EUROSTAT)

80% of the heat delivered is produced by fossil fuels (source: EUROSTAT)

Industrial processes and Urban can produce large amount of WASTE HEAT that is commonly discharged into the environment

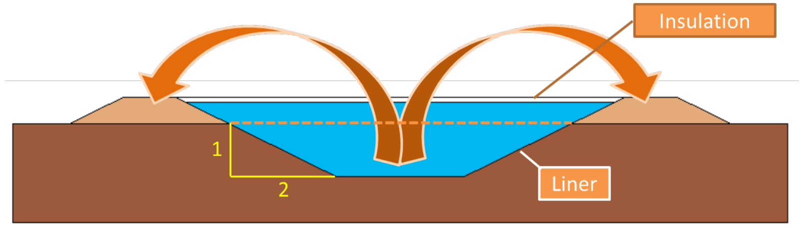
Let's convert waste heat into a resource



Improve the flexibility of a DHN

Reduce fossil fuels consumption

Pit TES



The principle of PTES is simple and works by storing hot water in very large excavated basins with an insulated lid.
Sides and bottom are typically covered by a polymer-liner, but can also be made of concrete.
Temperatures up to approx. 90°C can be stored and PTES and delivered with large flexibility

The main advantages of the PTES concept are

- ✓ the possibility for quick charging or discharging.
- ✓ short heat storage periods
- ✓ water is ideal as storage medium due to high thermal capacity.

Some of the disadvantages are

- ✗ the system is space demanding.
- ✗ the lifetime of liners and the lid construction is still partly unknown.
- ✗ high groundwater levels and poor soil conditions directly affects the construction costs.

Photos: GEUS

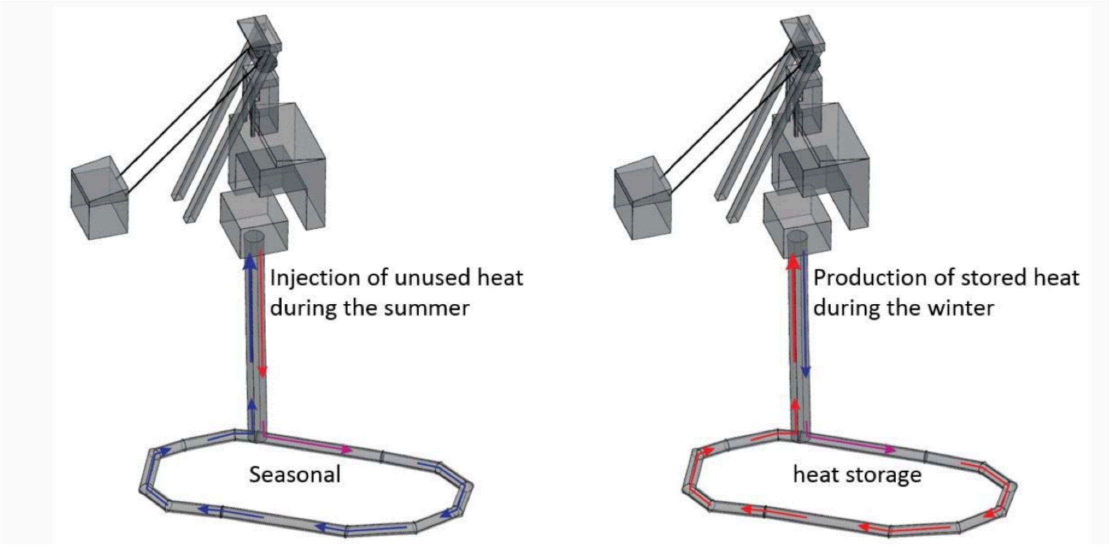
PTES in Denmark

- DH heat demand: 32,000 MWh/a
- 33,300 m^2 solar collectors
- 75,000 m^3 pit heat storage
- 2,100 m^3 buffer tank
- 18 MW bio-oil boiler
- 4 MW biomass boiler
- 750 kW_{el} biomass CHP Organic Rankine Cycle
- 1.5 MW_{th} CO_2 heat pump

- Storage capacity: 6,960 MWh (T_{max} 90°C, T_{min} 10°C)
- Efficiency: 67% (2016)
- Investment/capacity: 0.374 €/kWh (without transmission pipe)
- Max charge/discharge capacity: 10.5 MW
- Investment/max charge capacity: 252 €/kW

Mine TES in Germany

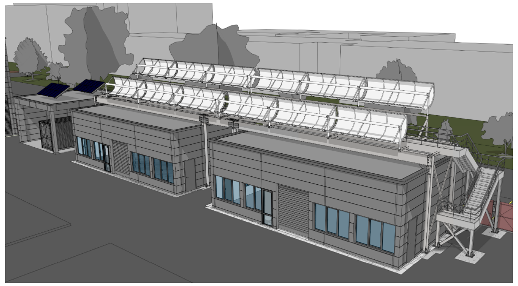
Mine water from abandoned and flooded former coal mines can be used as a low-temperature geothermal energy source for heating buildings and industrial complexes.



Conceptual model of seasonal underground heat storage in an abandoned coal mine (Source: HEATSTORE Reprt D1.1)

This pilot plant in Germany aims at utilizing the abandoned coal mine located under the premises of the International Geothermal Centre (GZB) in Bochum

Heat source: 60 kW CSP plant



Seasonal heat storage

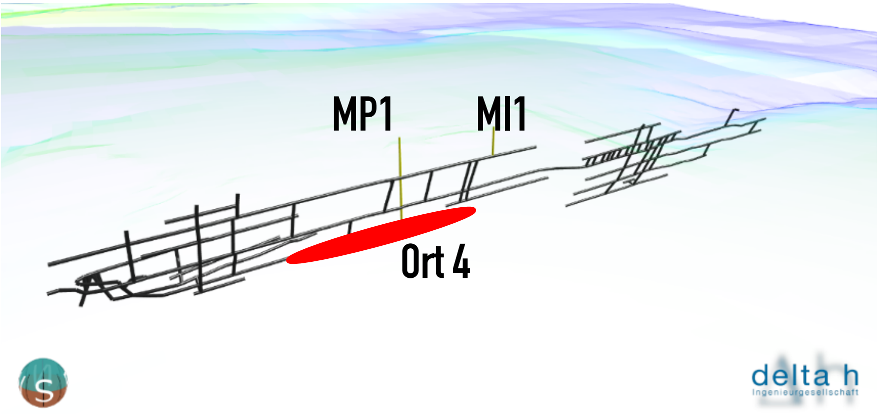
in Ort 4 at a depth of 62 m bgl

Drilling of 3 wells completed in Q3/2020

- All wells reached their target within the stone drifts of the mine!
- 2 out 3 wells showed high hydraulic conductivities during pump test

Preparation of first injection test in Q4/2020 with 60°C

Planned production test in Q1/2021



Borehole TES

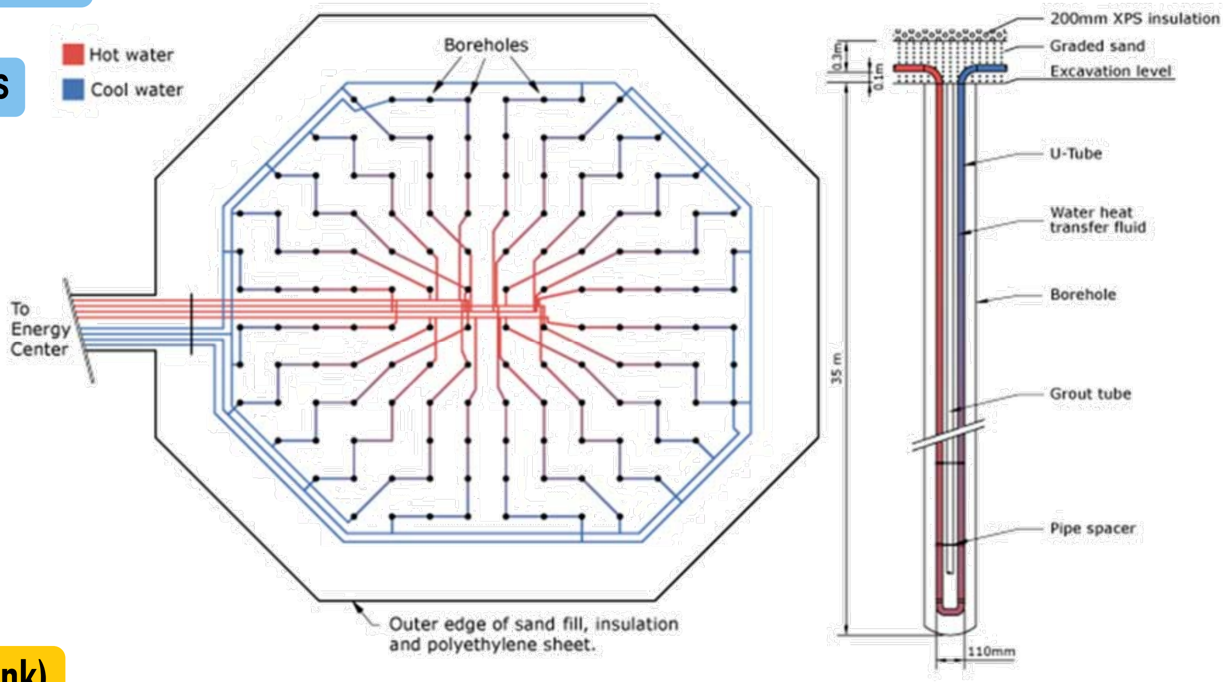
The principle of BTES is to heat up the subsurface and cool it down again by circulating a fluid in Borehole Heat Exchangers (BHE).
The distance between the boreholes is typically in the range of 2-5 m and BTES is normally limited to boreholes of approx. 20-200 m depth.

Temperatures up to approx. 90°C can be stored

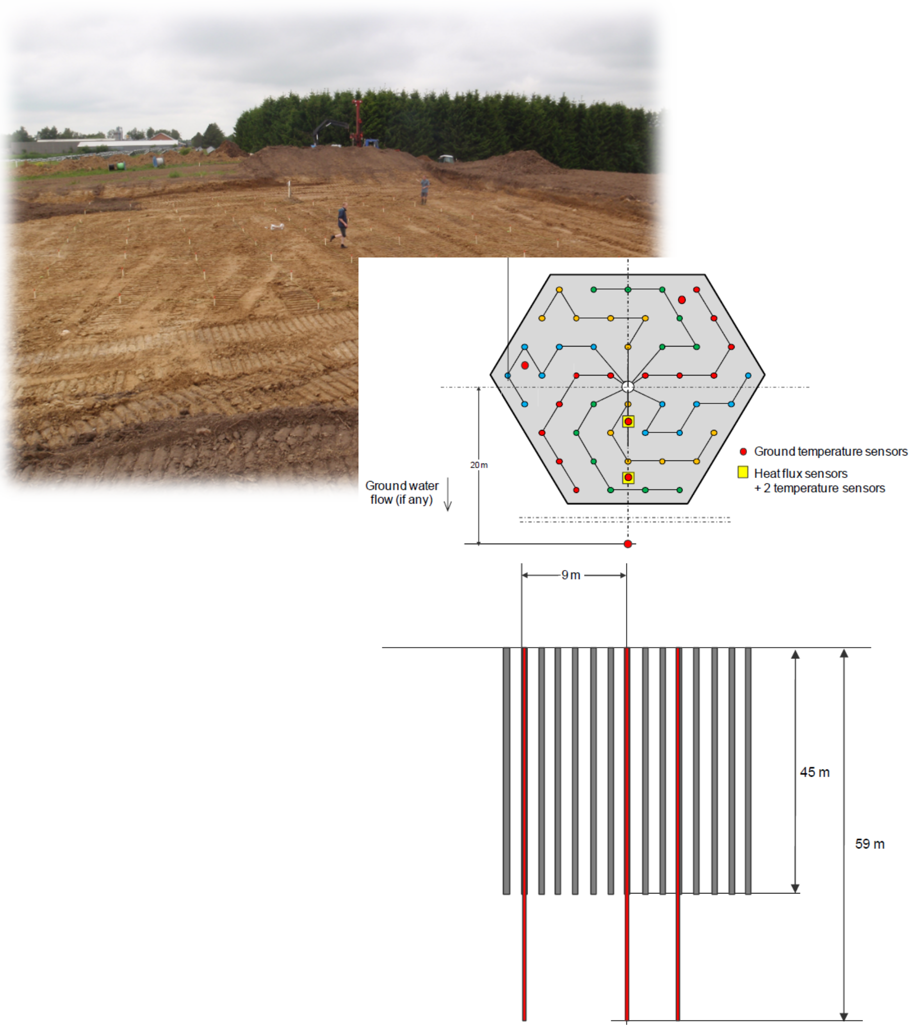
BTES is ideal for integrating heat from various sources

Due to a relatively low heat transfer coefficient, BTES storage does not react very fast.

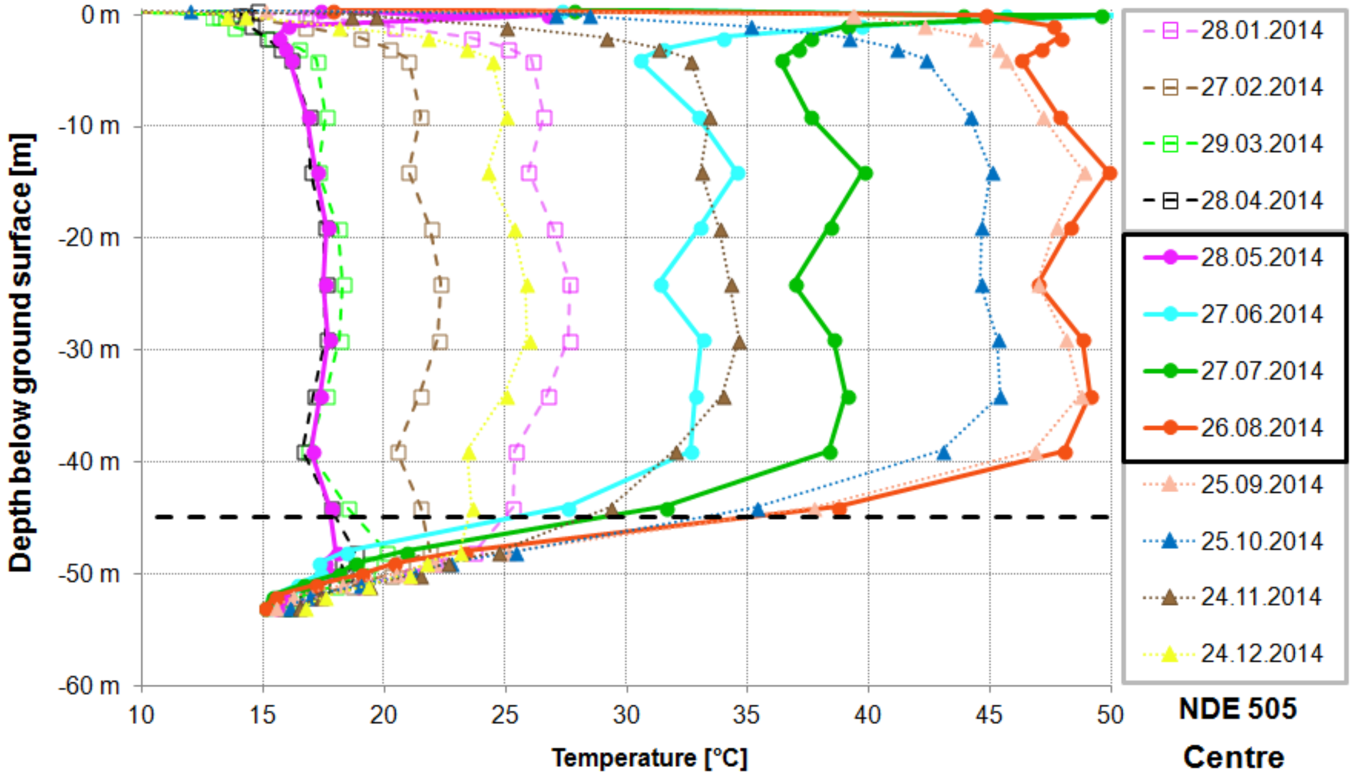
In cases where fast reaction is required a fast reacting buffer storage (e.g. water tank) can be used



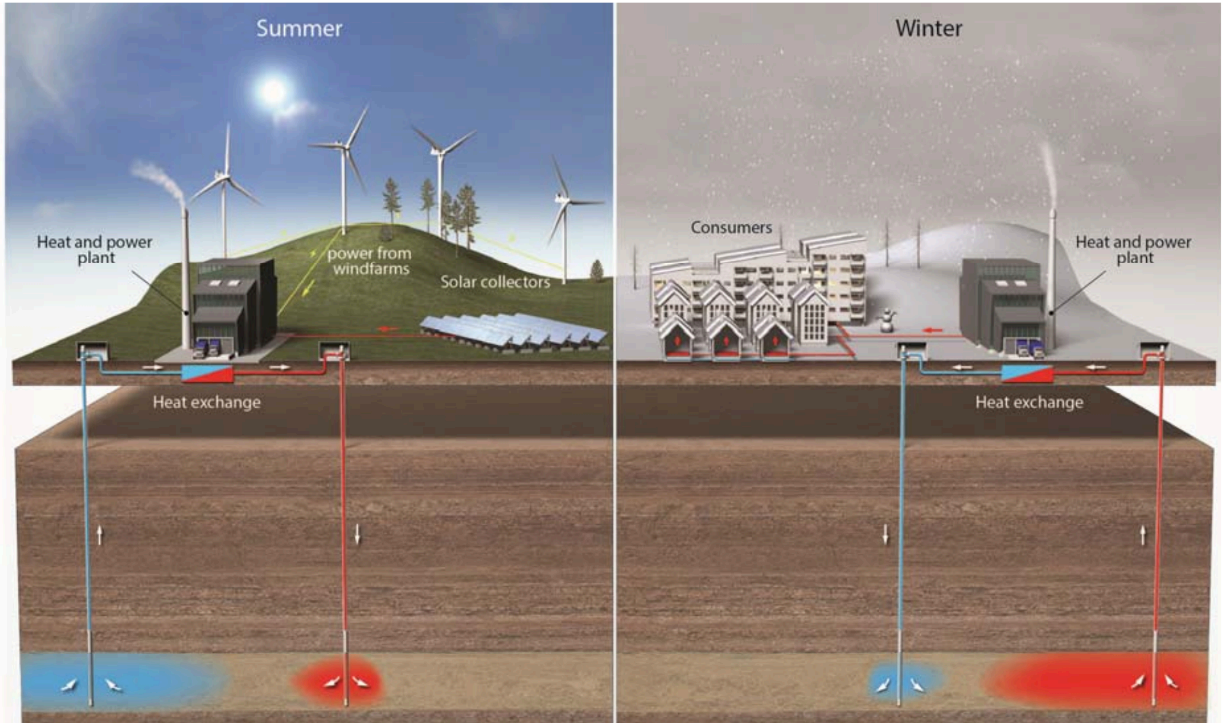
BTES in Denmark



Ground temperature development over a seasonal cycle



Aquifer TES



The principles of seasonal heat storage by the use of ATES in a district heating network (GEUS)

ATES can take place by INJECTION and later EXTRACTION of hot water in aquifers in both shallow and deep geological formations.

The aquifers can be both unconsolidated sand units, porous rocks like sandstones or limestone or e.g. fractured rock formations.

Deep aquifers provide an option for HIGH TEMPERATURE STORAGE (HT), which is defined as systems with injection temperatures > 40-60°C.

Injection temperatures in shallow aquifer units in the upper few hundred meters of the subsurface is, however, in most countries, restricted to a few tens of degrees Celsius (Low Temperature storage).

Medium temperature (MT-ATES) systems are defined as heat storage at temperatures ranging from 20-40°C.

HT-ATES DEMONSTRATION PROJECT AT ECW (NL)

At ECW, geothermal heat (90 °C) is stored in summer and recovered in winter for greenhouse heating

HT-ATES Koppert Cress greenhouse:

Conversion of low-temperature ATES to high temperature ATES integrating HT-ATES to solar heat collectors to imcrease the storage capacity and reduce the use of heat pump.

2018: HT-ATES permit was granted to ECW. Legal 'Go' for project.

2019: Test drilling: Aquifer 4 and 5 were tested. Aquifer 4 was selected for HT-ATES

Well production tests: new insights*

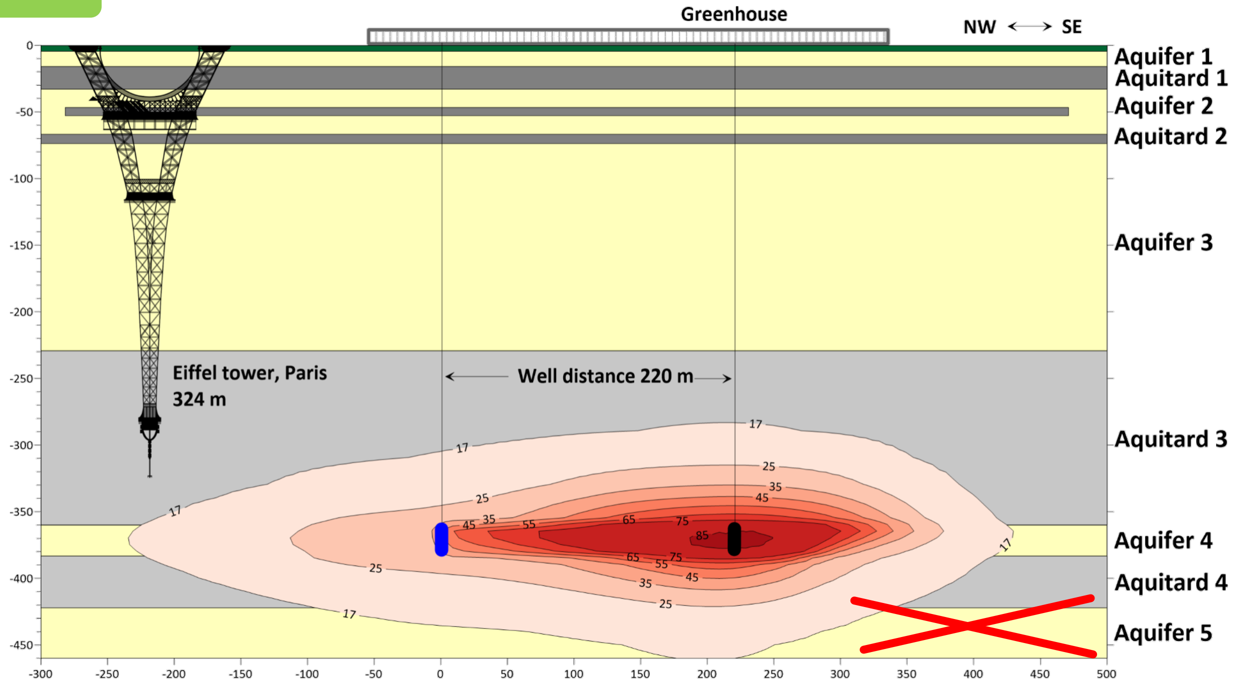
Well design and drilling plan updated

2020: Well realization

HT-ATES permit updated

2021: Additional tests

First Heat storage (spring)



* Well test results are presented on Nov 16th at the GET2020 conference (Geoscience & Engineering in Energy Transition). Drijver, Oerlemans and Bos, 2020. *Full-scale HT-ATES tests demonstrate that current guidelines considerably overestimate sand production risks in deeper unconsolidated aquifers.*

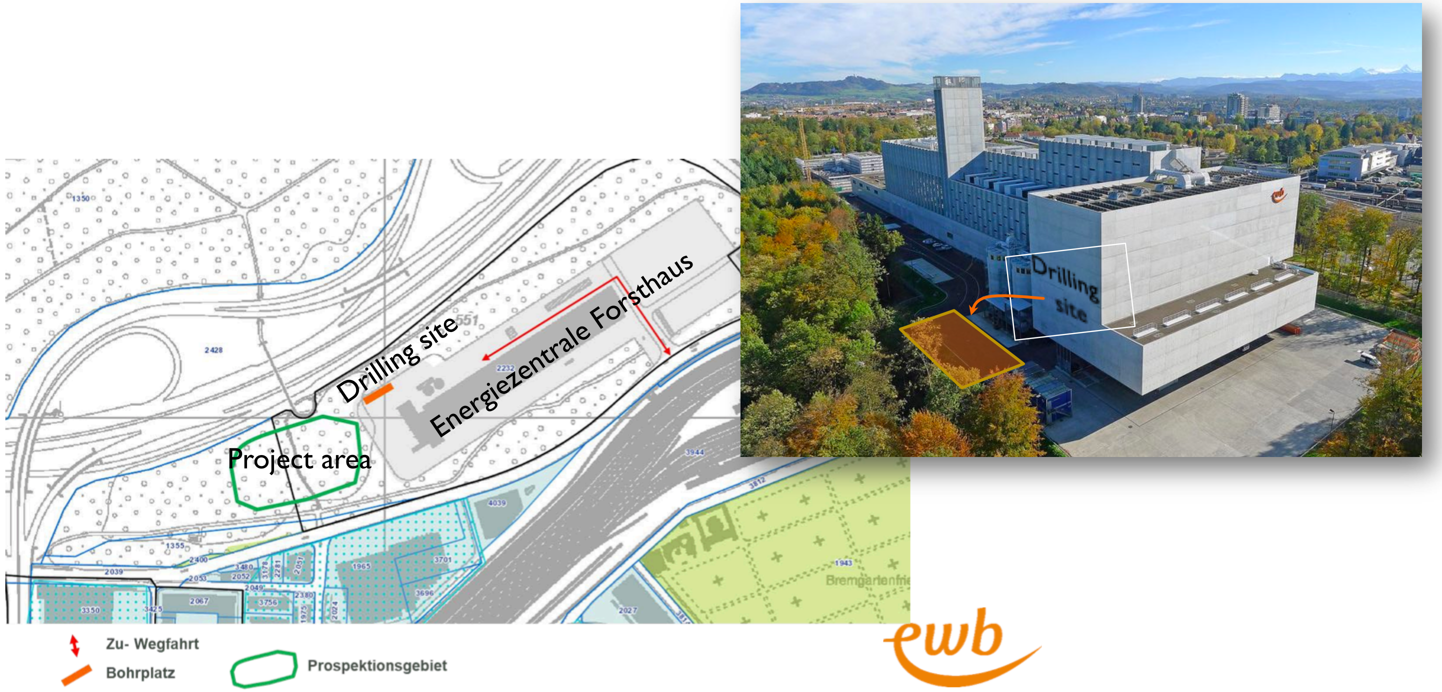
THE BERN PILOT PROJECT

ewb — Project owner

GEO ENERGIE SUISSE — Project engineering partner

UNIVERSITÄT BERN — Water-rock interaction laboratory experiments and modelling

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH — THMC reservoir modelling

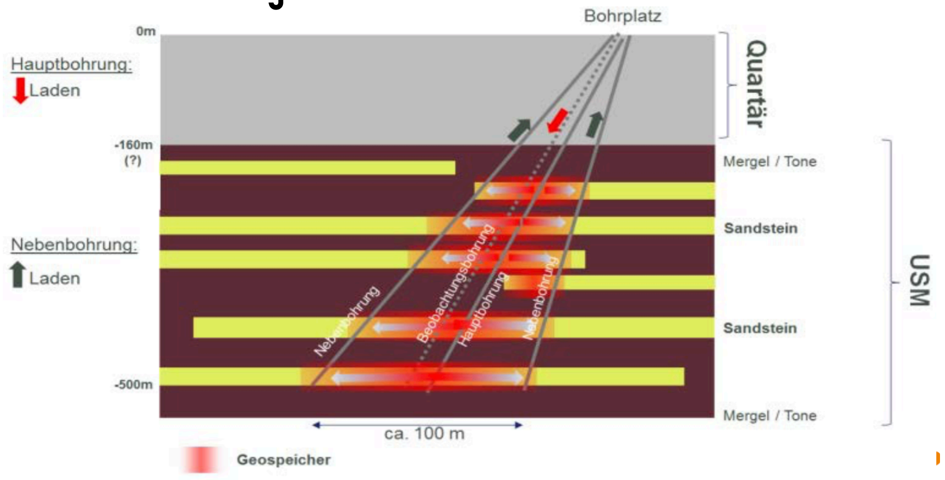


Underground heat storage (P_{th} 3-12 MW of excess industrial heat) in sandstones of the Lower Freshwater Molasse (USM)

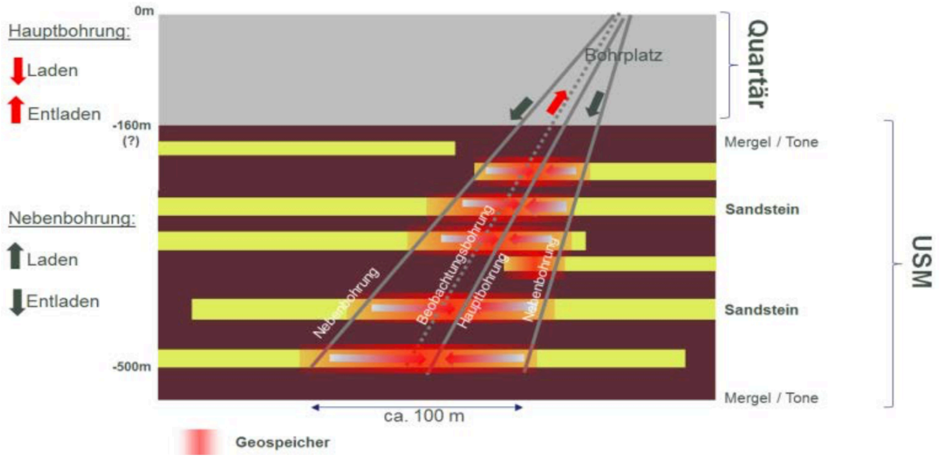
Loading cycle during summer; un-loading during winter into the existing and expanding district heating network

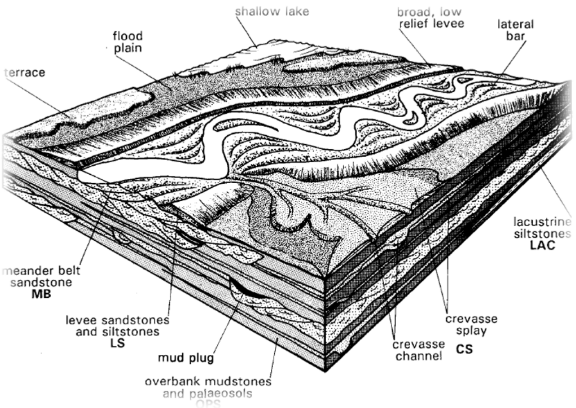
CONCEPT AND GEOLOGY BERN

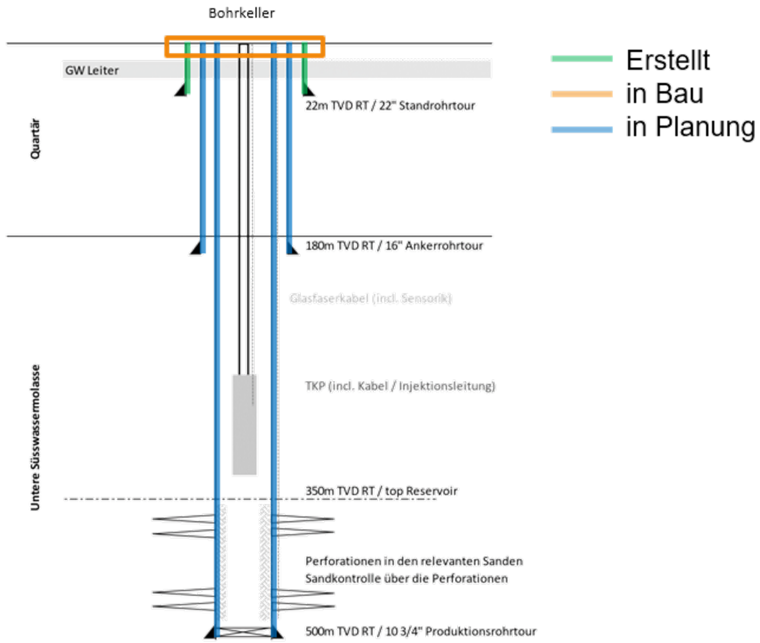
Loading



Unloading







Target: sandstones in former meander systems.
Strong heterogeneity is biggest exploration risk.

ATES CASE STUDY IN GENEVA

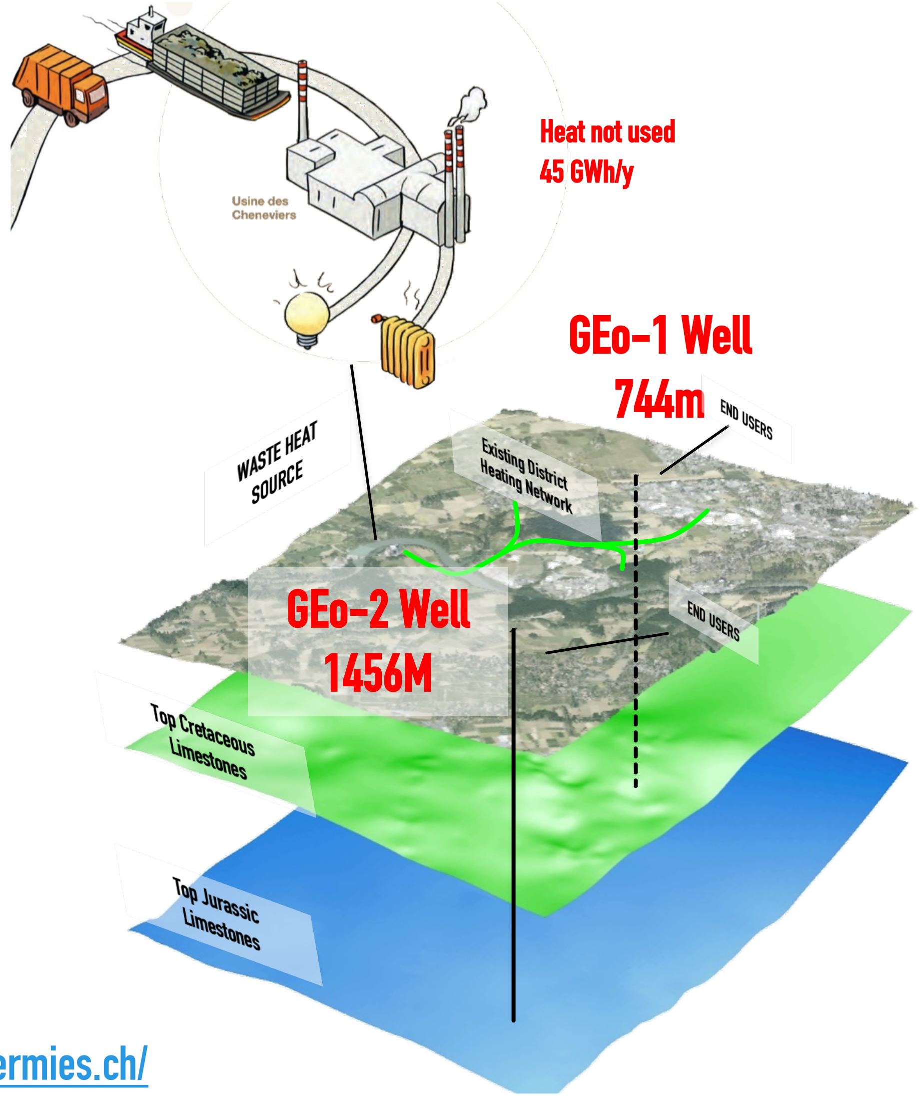
SIG
Drilling, data collection, business case modelling, regulatory framework

UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES
Subsurface characterization and static modelling, fluid geochemistry
Energy system scenarios
Economics and business models
Multi-criteria analysis

ETH Zürich
TH, THM reservoir modelling

unine UNIVERSITÉ DE NEUCHÂTEL
Reservoir geomechanical characterization

UNIVERSITÄT BERN
THC modelling,
Water-rock interaction laboratory experiments



GEothermies
https://www.geothermies.ch/

GENEVA – COMPLEX GEOLOGIC SETTING:

MEANS BOTH CHANCES AND RISK; EXPLORATION & CHARACTERIZATION CRUCIAL

Artesian Flow at GEo-01→Storage in the Mesozoic challenging.
Can the Molasse be an alternative?

But… Definitely great for direct uses

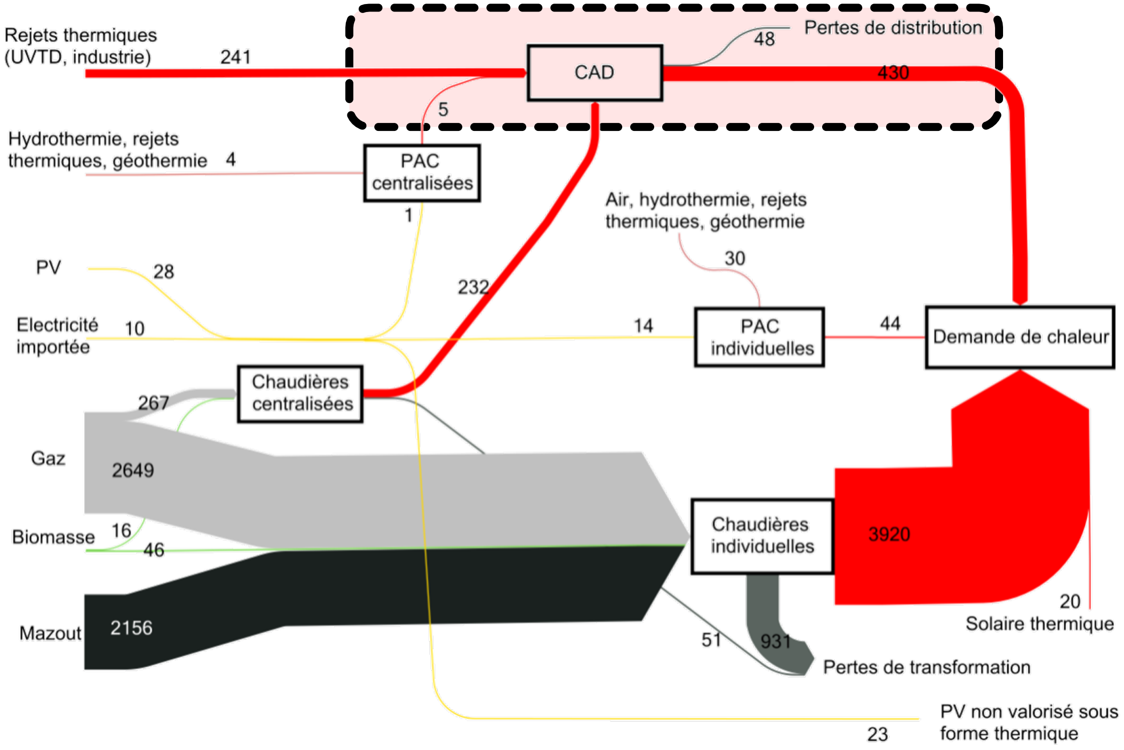
Low Flow at GEo-02 → Storage in the Mesozoic possible?

VSP, minifrac and packer test have been recently performed to evaluate the real geothermal potential of the well

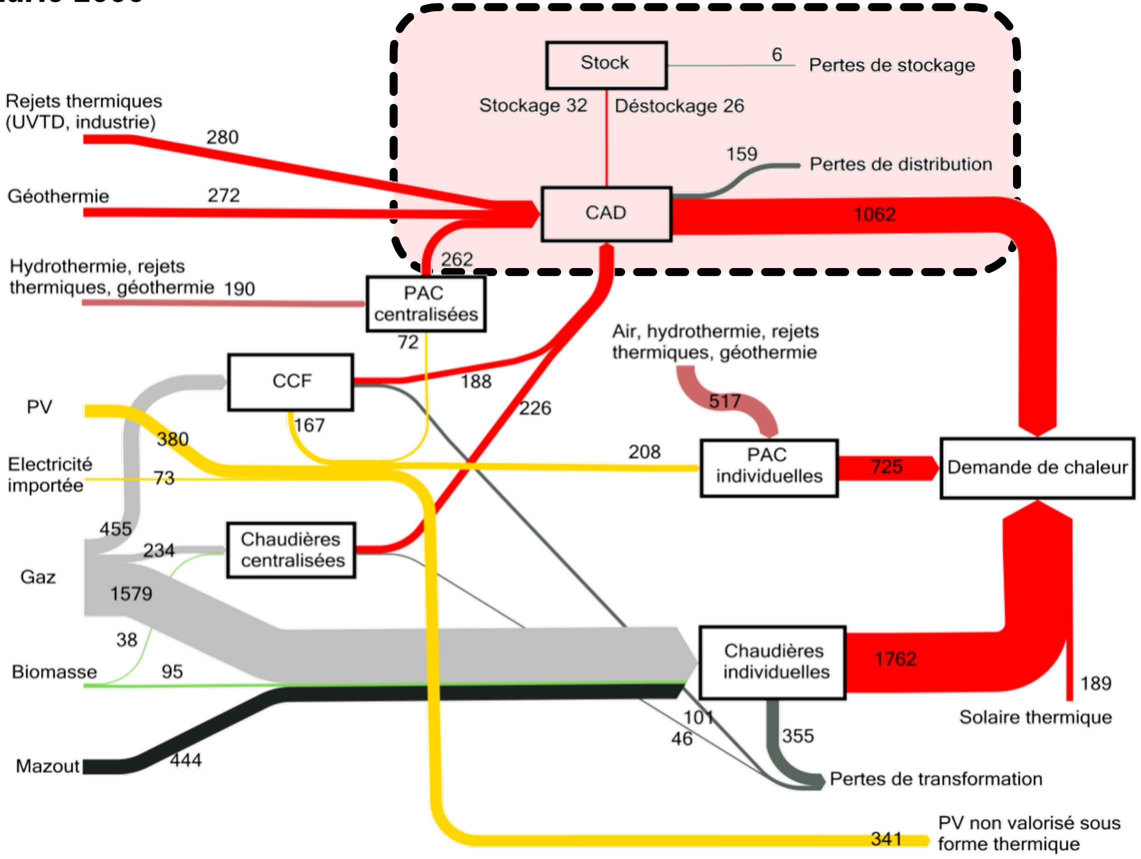
GENEVA – COMPLEX ENERGY SYSTEM SETTING:

MEANS BOTH CHANCES BUT ONLY IF WE CAN FIND THE RIGHT FIT OF ATES IN THE ENERGY MIX

Situation 2014



Scenario 2035

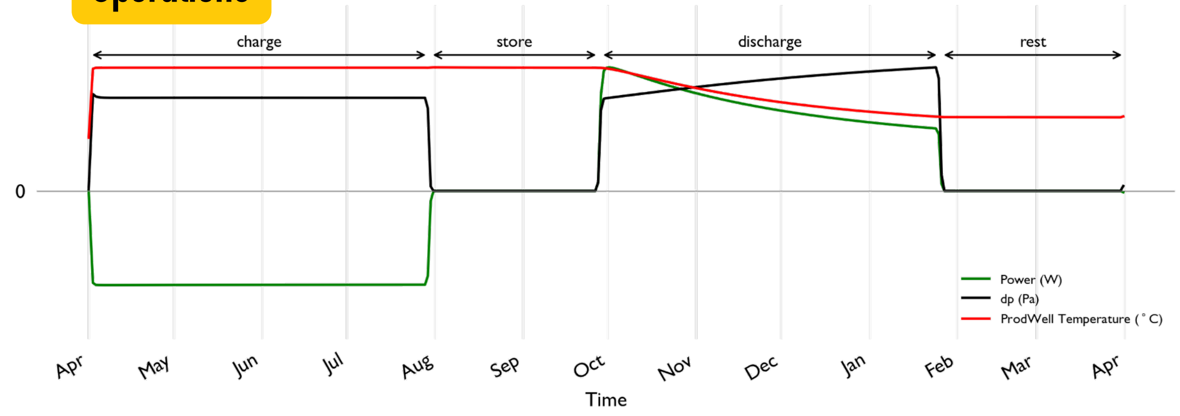


GWh/y

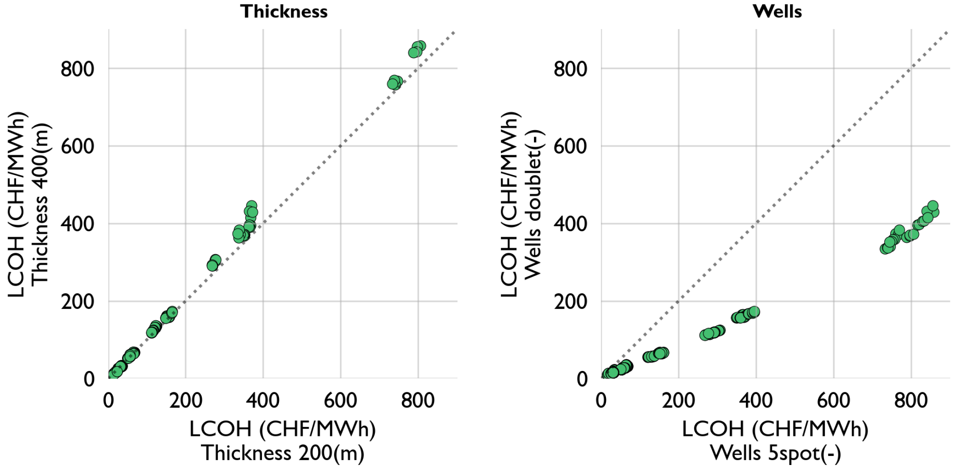
Ref : http://archive-ouverte.unige.ch/unige:93380

COUPLING SURFACE, SUBSURFACE AND ECONOMICS (ONGOING STUDY)

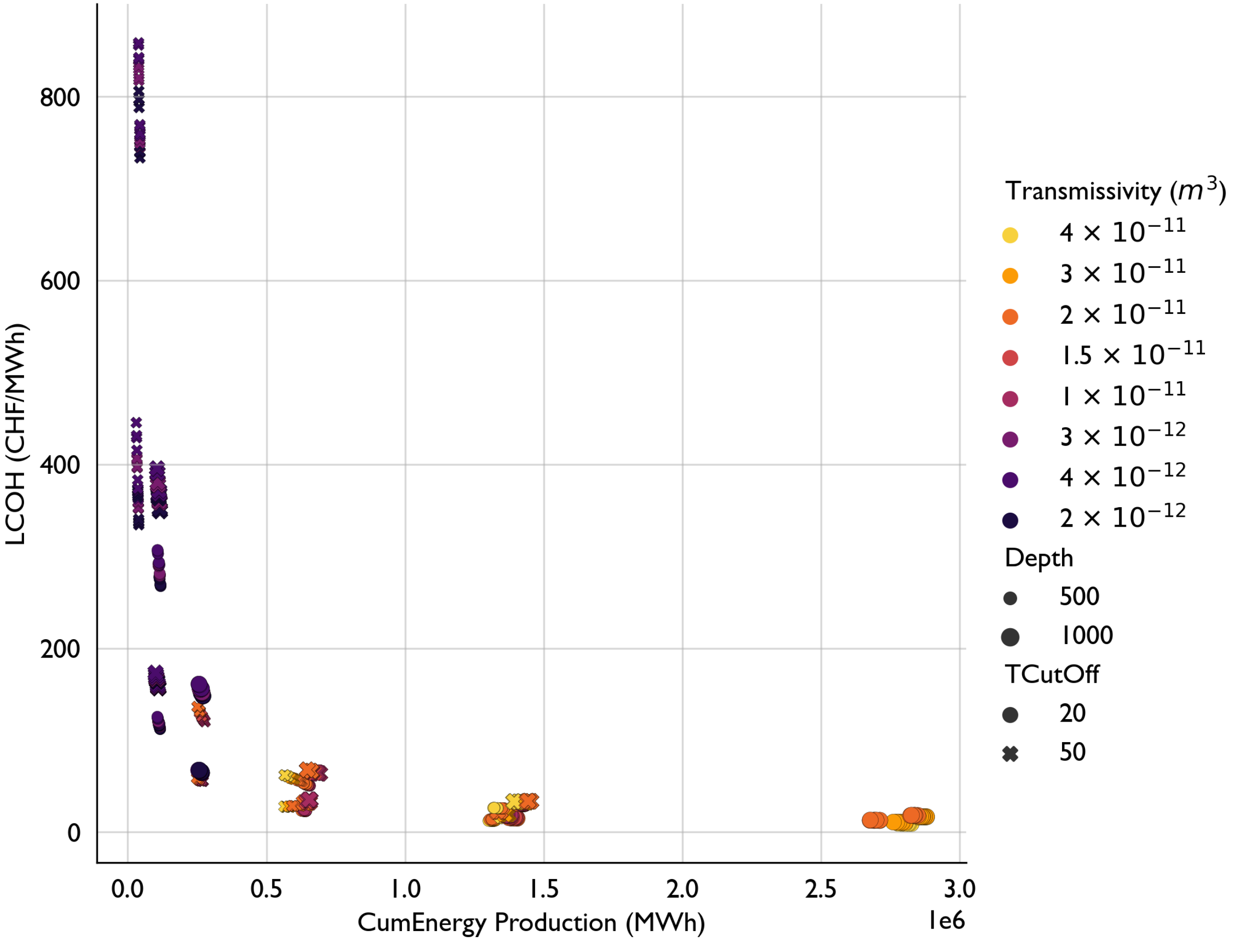
Operations



Correlation between LCOH and subsurface



Energy production vs LCOH vs Subsurface



FAVOURABILITY OF ATES IMPLEMENTATION (WORK IN PROGRESS…)

Parameter — **Weighted sum**

SURFACE

- Excess Heat (EH) • 0.25
  - T° range
  - in Time
  - In space
- Heat Demand (HD) • 0.25
  - in Time
  - In space
- Proximity DHN • 0.5

SURFACE Summary layer — Weight 0.5

SUBSURFACE

- Porosity • 0.1
- Permeability • 0.1
- Transmissivity • 0.1
- Temperature • 0.2
- Geochemistry • 0.1
- Recovery Factor • 0.3
- Env. Impacts • 0.1

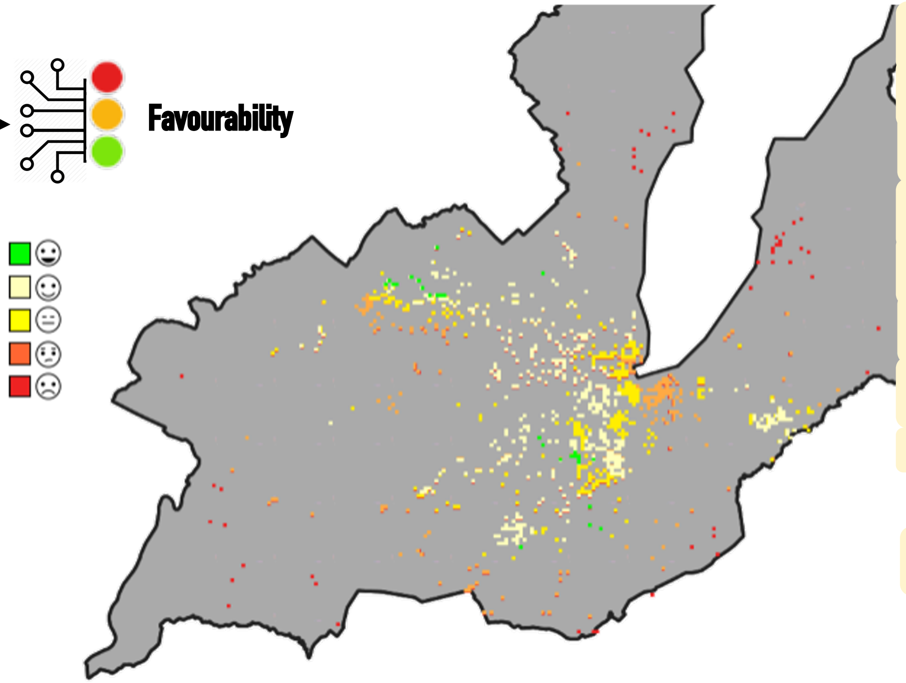
SUBSURFACE Summary layer — Weight 0.25

OPERATION

- Inlet T • 0.2
- Outlet T • 0.2
- Flowrate • 0.2
- Type of install. • 0.2
- Economics • 0.2
- …

OPERATION Summary layer — Weight 0.25

For HEAT STORAGE the PROXIMITY between excess heat source, heat demand and subsurface is of crucial importance.
Therefore, only after having assessed the surface constraints the analysis can then focus on subsurface conditions which are typical of standard PLAY ANALYSIS.
To add complexity to the study ENVIRONMENTAL IMPACTS such as ground deformation, groundwater pollution, seismicity and ECONOMICS can be included



PRELIMINARY FAVOURABILITY of EXCESS HEAT STORAGE in UPPER MESOZOIC UNITS according to the following criteria

1. Proximity of the DHN
2. Presence of permeable faults
3. Temperature distribution

CONCLUSIONS

UTES are for sure an element to be integrated into the European energy system thanks to the large energy storage potential and the low CO_2 footprint in particular in a future perspective with new generation of DHN running at lower temperatures.

The perfect combination of subsurface conditions and surface configuration is hard to identify making the implementation of such systems challenging

HT Thermal Energy Storage	
Opportunities	Challenges
Large amount of EH available Contribute to reduce CO_2 emissions Different and scalable solutions Flexibility Thermal recovery efficiency Integration into existing and new genetations DHCN ...	Proximity to excess heat AND final users AND subsurface Subsurface risks Environmental impacts (groundwater quality, ground deformation, seismicity…) Operational risks (scaling, corrosion, maintenance…) High upfront costs Legal framework not clear ...

Thank you very much

Too early for a Geothermal Beer?

REFERENCES

- [1] EU. Commission. Staff working document on an EU strategy for heating and cooling. 2016. p. 1689e99. https://doi.org/10.1017/CBO9781107415324.004.
- [2] International Renewable Energy Agency, IRENA. Renewable energy in district heating and cooling: a sector roadmap for REmap. 2017.

- https://www.heatstore.eu/