heatstore High Temperature Underground Thermal Energy Storage

GEOTHERMICA

HEATSTORE
HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE

SWISS CONSORTIUM PROJECT

4 SEPTEMBER 2019, LAUSANNE

SCCER SoE Annual Conference 2019

SWISS NATIONAL PROGRAM

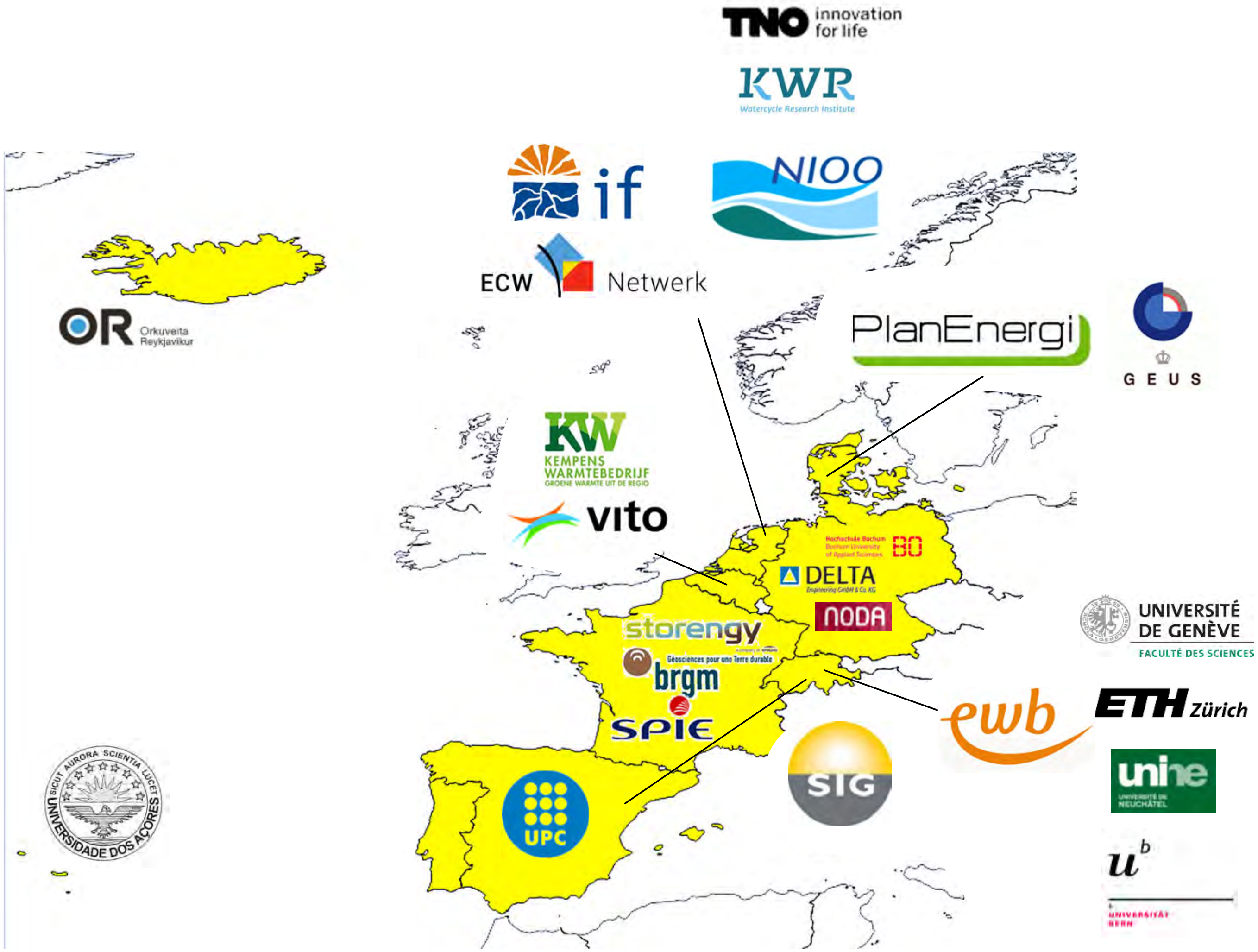
heatstore
High Temperature Underground Thermal Energy Storage

GEOTHERMICA

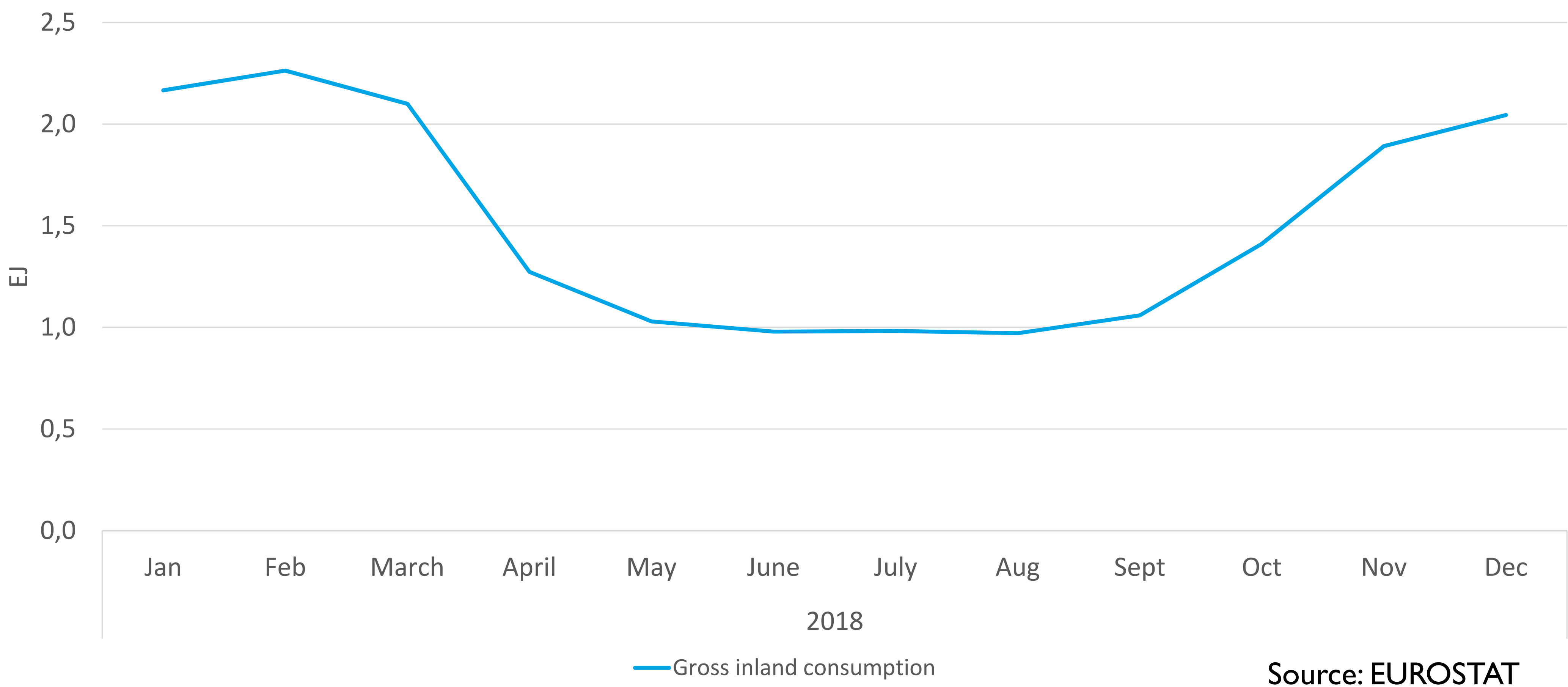
- 24 partners involved
- 9 countries
- 6 Demo sites
- 8 Case studies

NATIONAL LEADS:

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

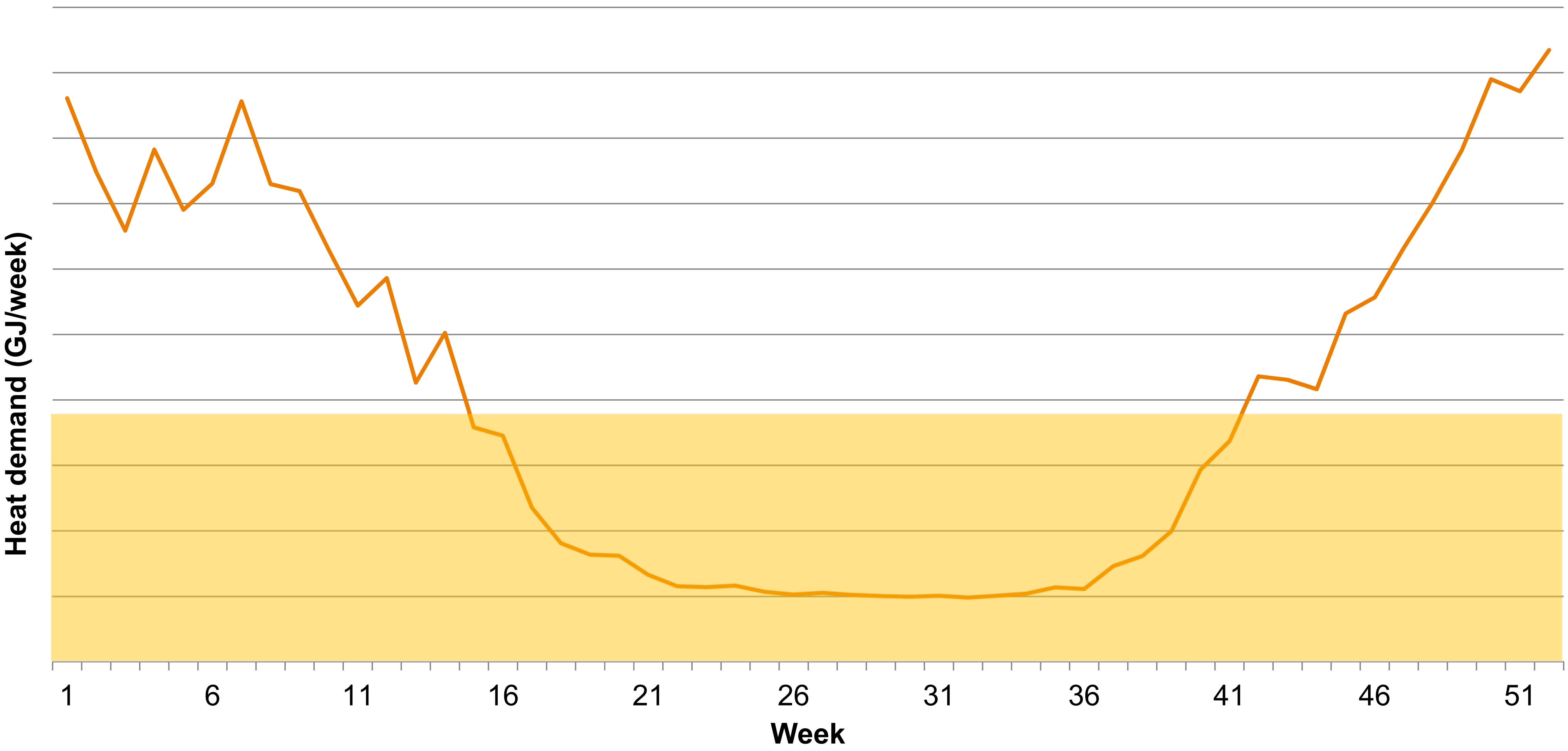


NATURAL GAS CONSUMPTION EU



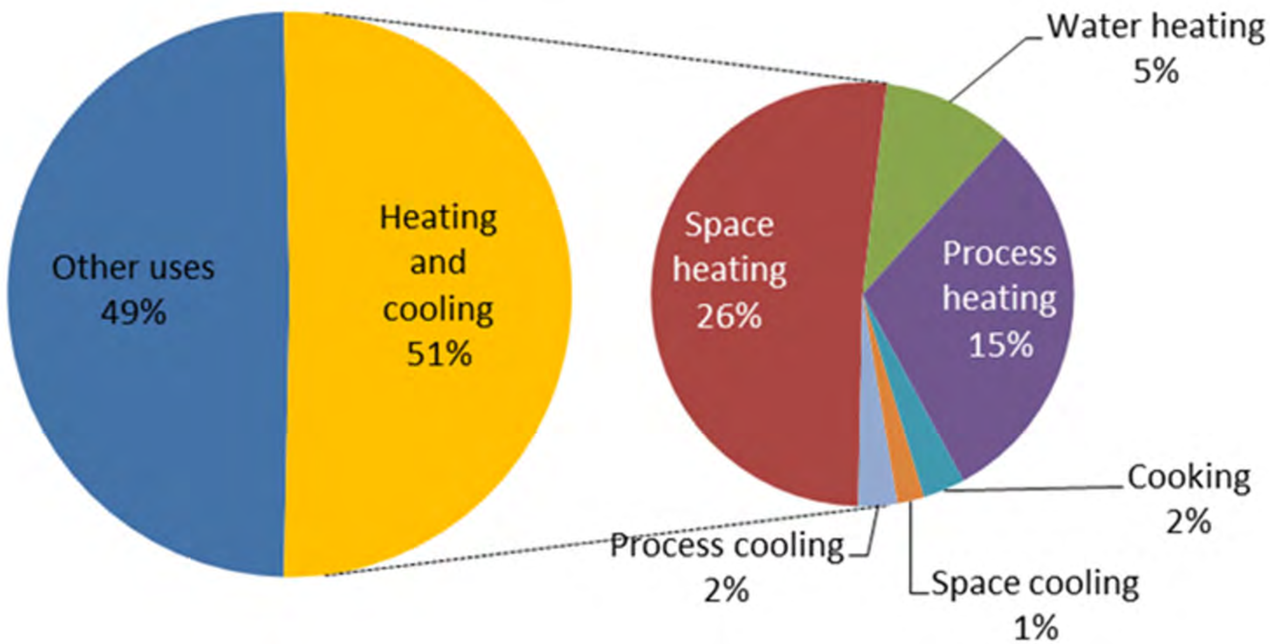
Source: EUROSTAT

TRANSITION MEANS: SOLVE THIS ONE….



TRANSITIONING IN THE HEATING AND COOLING SECTOR

- Heating and cooling is responsible for half of all consumed final energy in Europe.
- The vast majority – 85% - of the demand is fulfilled by fossil fuels, most notably natural gas. 68% of all EU gas imports.
- There thousands of District Heating Networks in Europe, currently supplying more than 10% of total European heat demand.
- In terms of energy, heat storage is by far the largest single energy storage application field in Europe.



MOTIVATION

- Industry uses about 92% of their total energy requirement for generating process heat
- 50% of the total energy consumed in Switzerland is used to supply heat
- 86% of the required heat is generated by the burning of fossil fuel
- Households and services use about 92% of their total energy needs for heating applications
- Waste heat generated is continuously discharged into the environment

Let's convert waste heat into a resource

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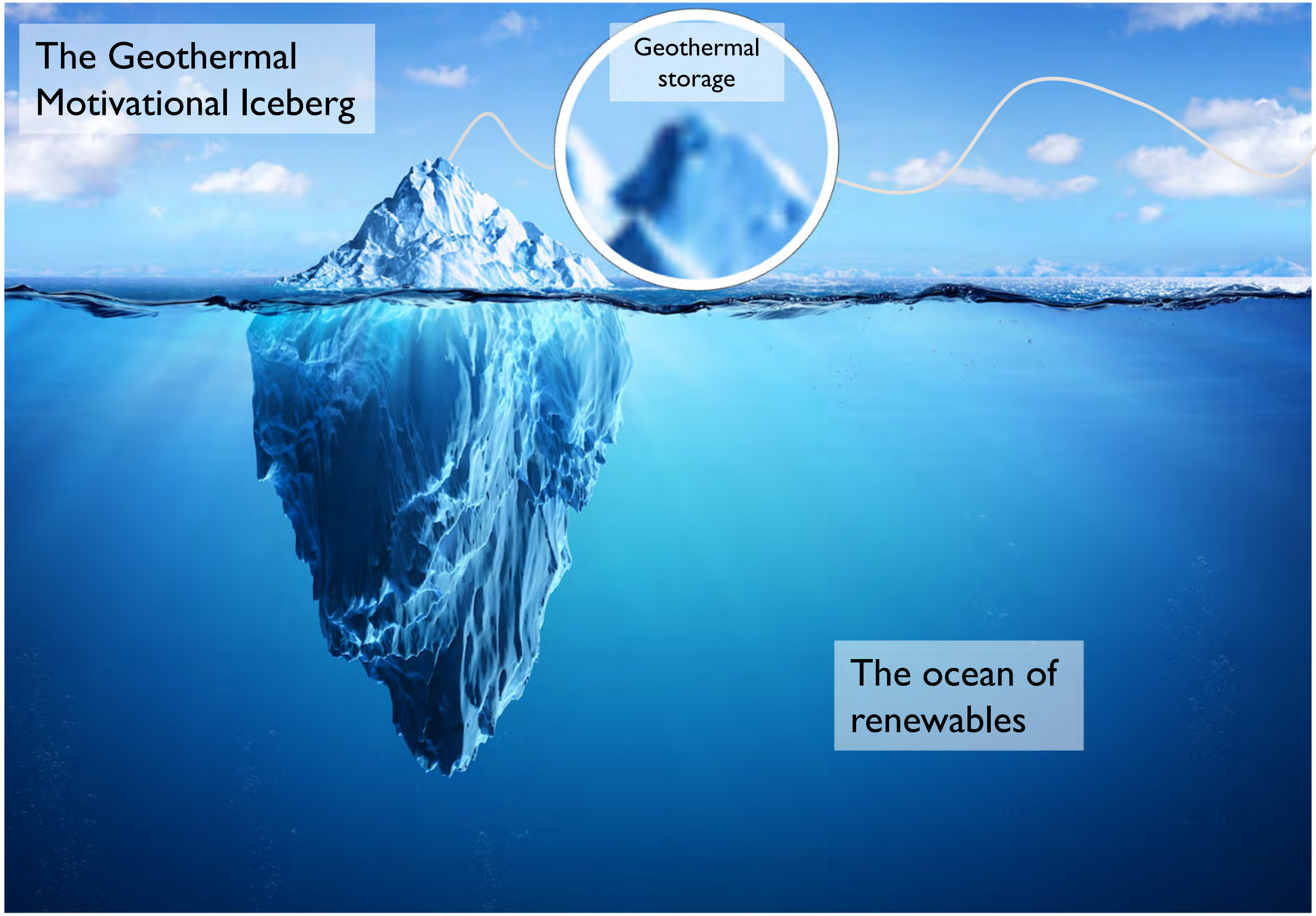
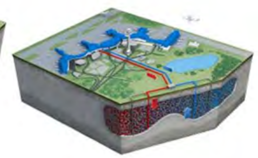
WHAT CAN BE THE CONTRIBUTION OF GEOTHERMAL HEAT (STORAGE)?

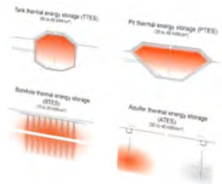


BTES

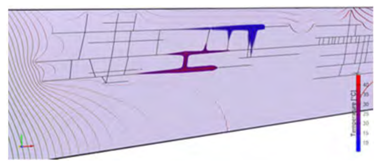
ATES



PTES



MTES



OPEN QUESTIONS

What is the performance of HT injection (i.e. recovery factor)?
How performances can be predicted and managed?

What are the impacts of HT injection in the subsurface and for the surface infrastructures?

What is the energy demand now and in the future?

How HT-ATES could be integrated into complex energy systems?

How to make HT-ATES sustainable

How to make HT-ATES profitable

How to make HT-ATES viable on a regulatory perspective

HEATSTORE IMPACT

Improved performance (target efficiency of 75%) and economics of UTES technologies

Advanced system integration using UTES and smart demand side management

Significantly higher integration of sustainable and surplus heat sources in heating networks (geothermal, solar and industrial surplus heat)

Bringing multiple underground thermal energy storage concepts and demand side management techniques further,

Key advancements in the science related to challenges identified in earlier pilot projects for the demonstrated concepts, including environmental impacts

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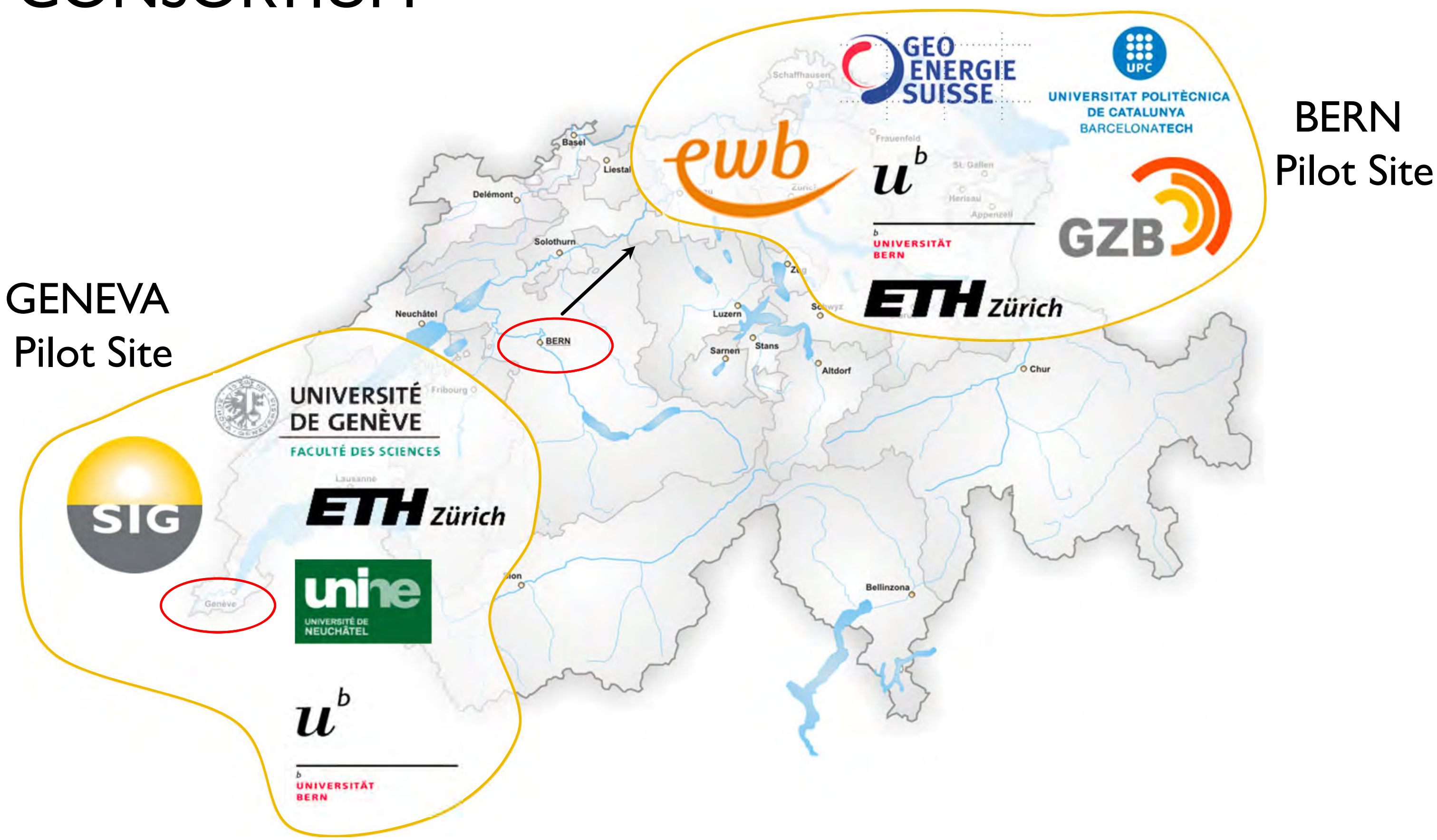
THE SWISS CONSORTIUM



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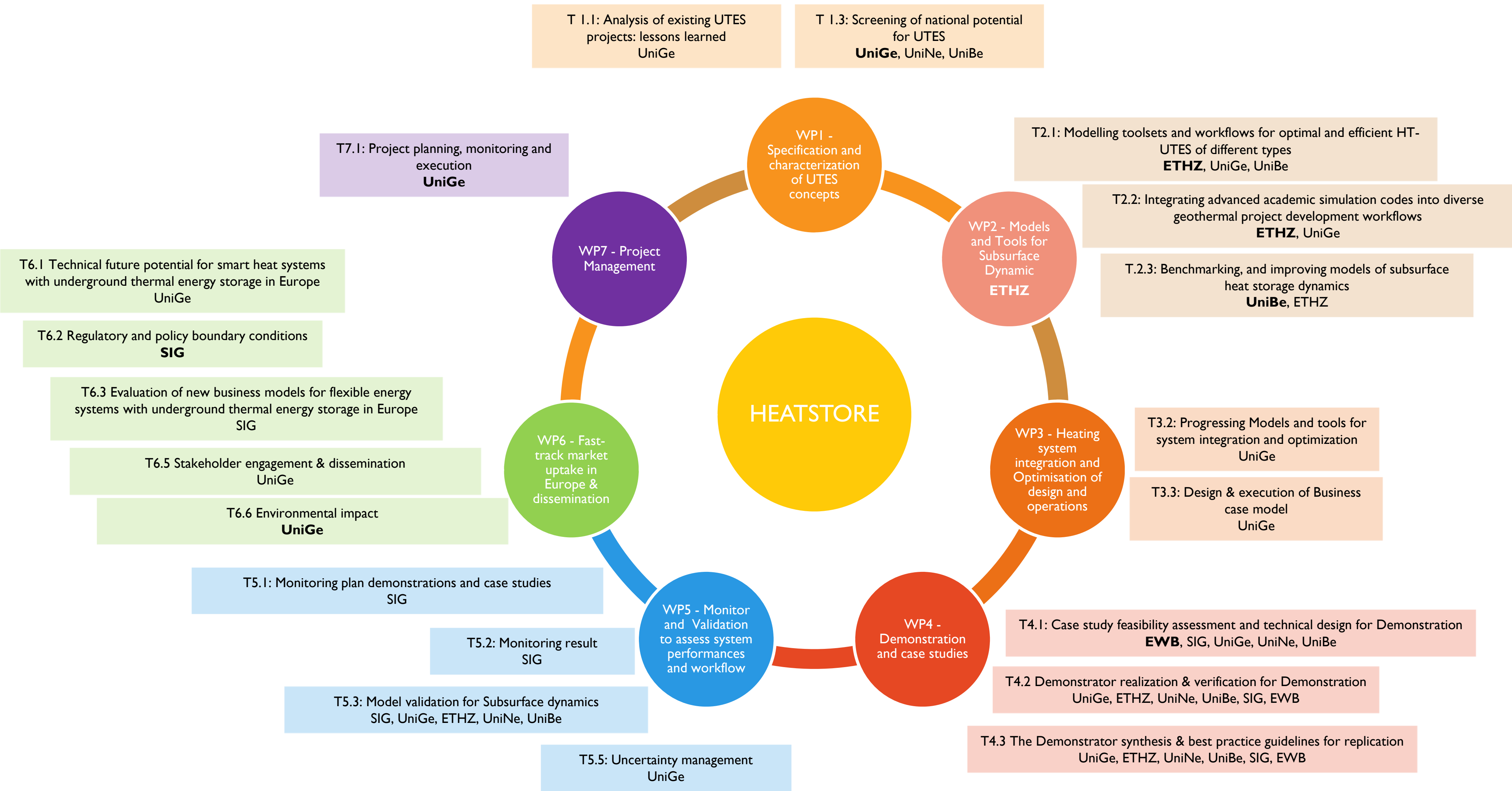
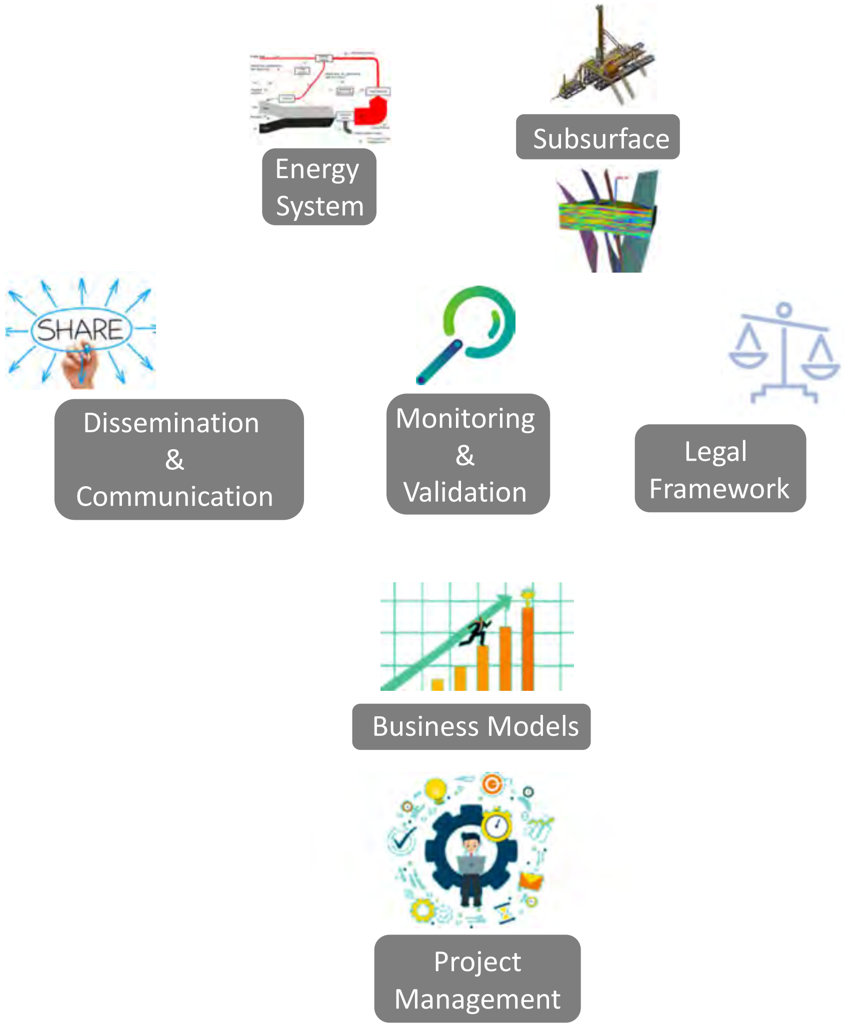


WORKFLOW


Energy System
Subsurface
Dissemination & Communication
Monitoring & Validation
Legal Framework
Business Models
Project Management

THE GENEVA PILOT PROJECT

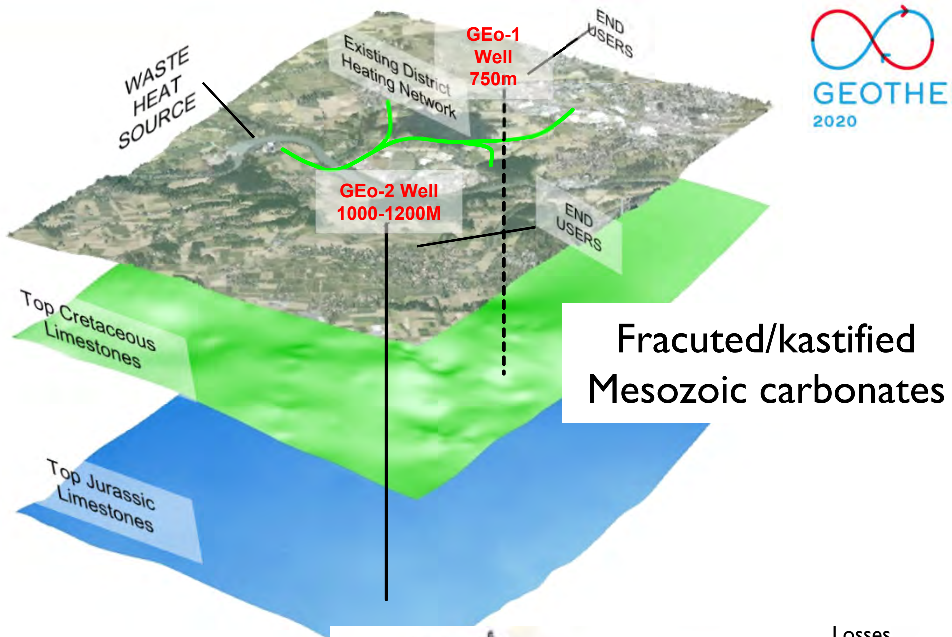
Drilling, data collection, business case modelling, regulatory framework

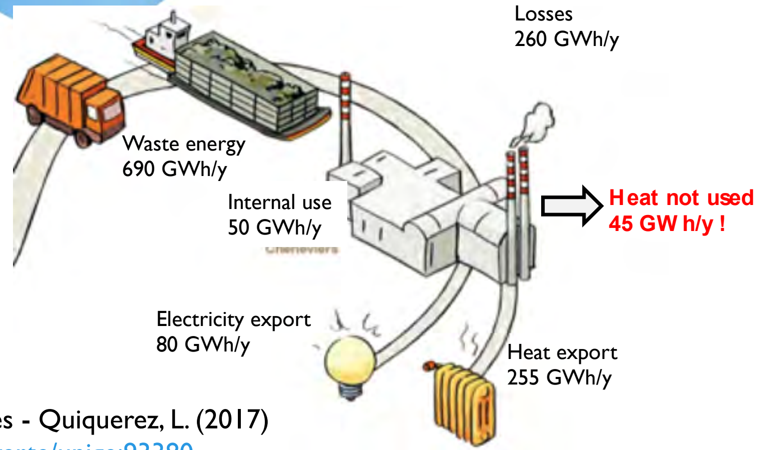
Subsurface data integration and characterization, energy system scenarios, national coordination

TH, THM reservoir modelling

Reservoir geomechanical characterization

THC modelling, Water-rock interaction laboratory experiments





Ref : 2013-2014 values - Quiquerez, L. (2017)
10.13097/archive-ouverte/unige:93380

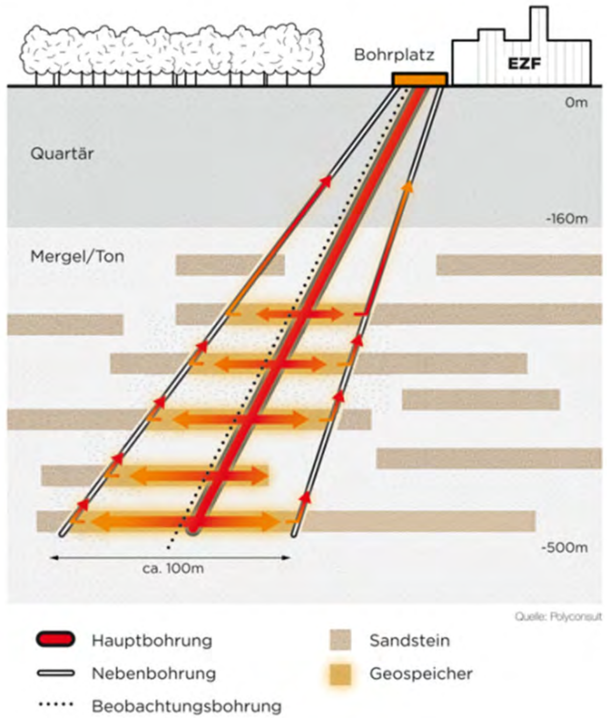
THE BERN PILOT PROJECT

Project owner

Project engineering partner

Water-rock interaction laboratory experiments and modelling

THMC reservoir modelling

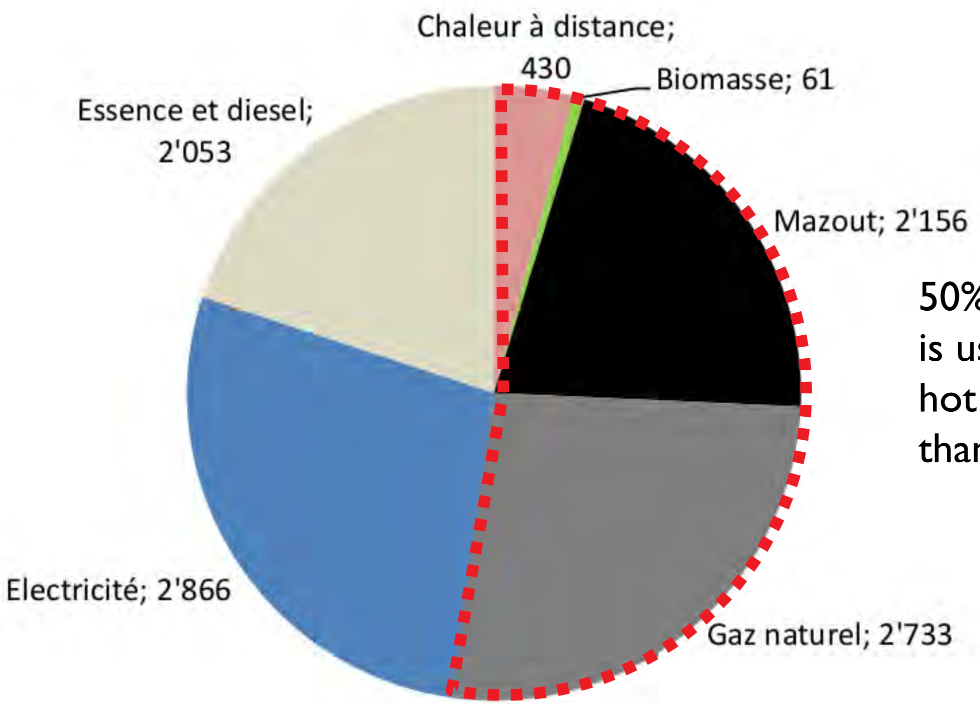


- Underground heat storage (P_{th} 3-12 MW of excess industrial heat) in sandstones of the Lower Freshwater Molasse (USM)
- Loading cycle during summer; un-loading during winter into the existing and expanding district heating network

GEOTHERMICA

ATES INTEGRATION INTO EXISTING ENERGY SYSTEMS

- SCENARIOS CONSTRUCTION FOR GENEVA -



GWh/y

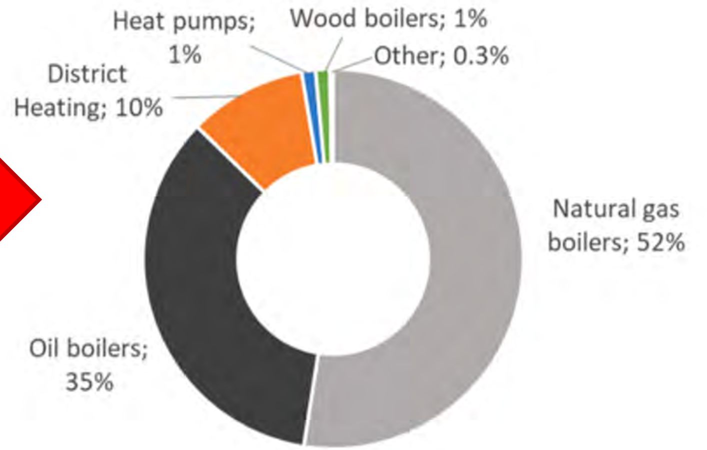
data: OCSTAT, SIG, OCEN, SITG

With heating climatic correction.

Aviation fuels and CERN consumption not included

Heat requirements

50% of the total final energy is used for space heating and hot water production, yet less than 10% covered by DH

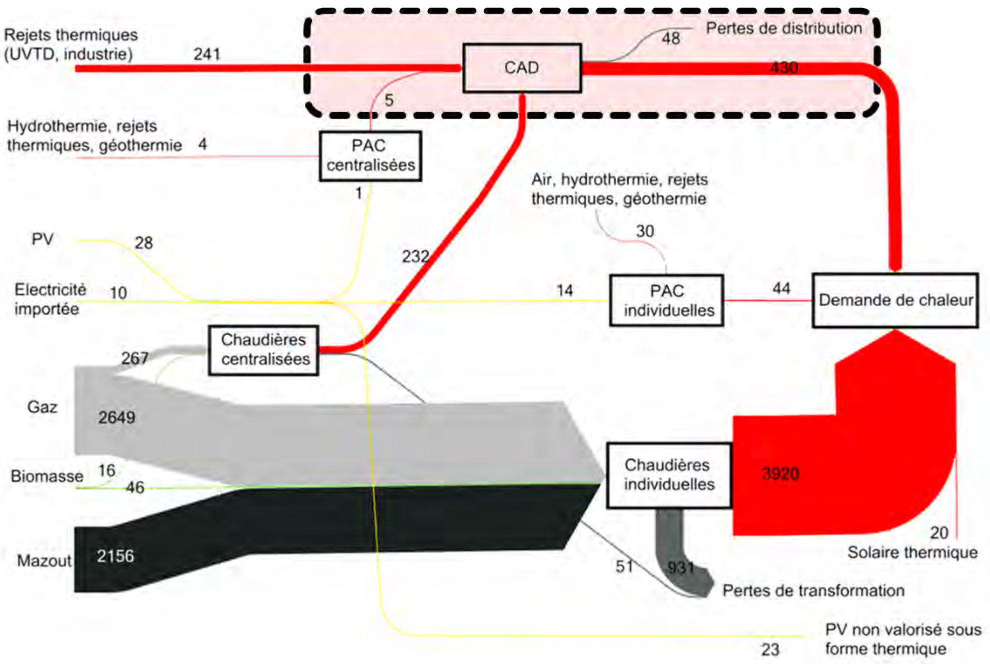


Heat delivery to buildings by technology, Geneva 2017. Total = 5.3 TWh.
Source: Statistical Office of Geneva.

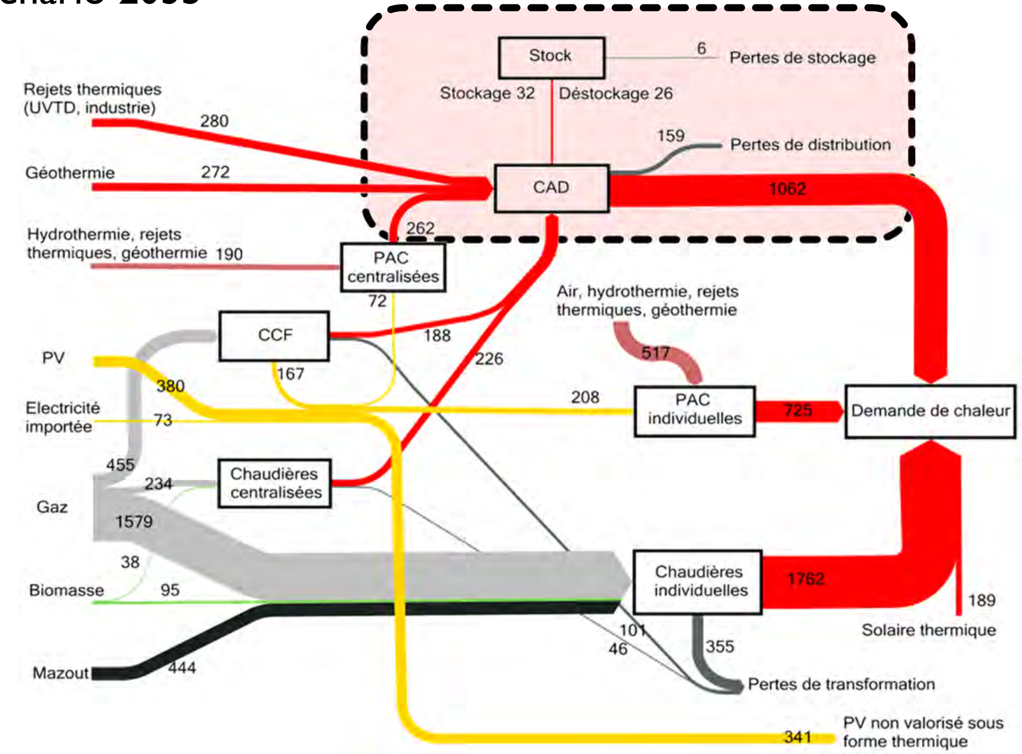
Tripling the penetration rate of DH by 2035 !

Prospective scenario for DH at GE

2014



Scenario 2035

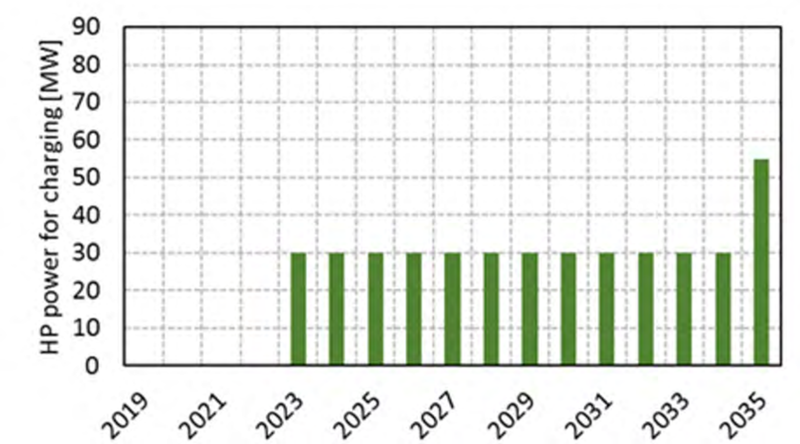


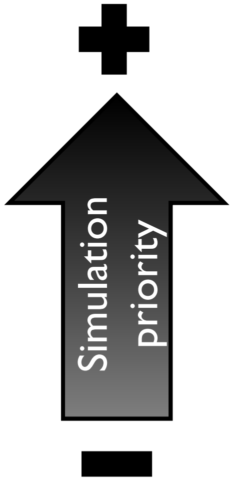
Ref : http://archive-ouverte.unige.ch/unige:93380

GWh/y

6 chosen scenarios

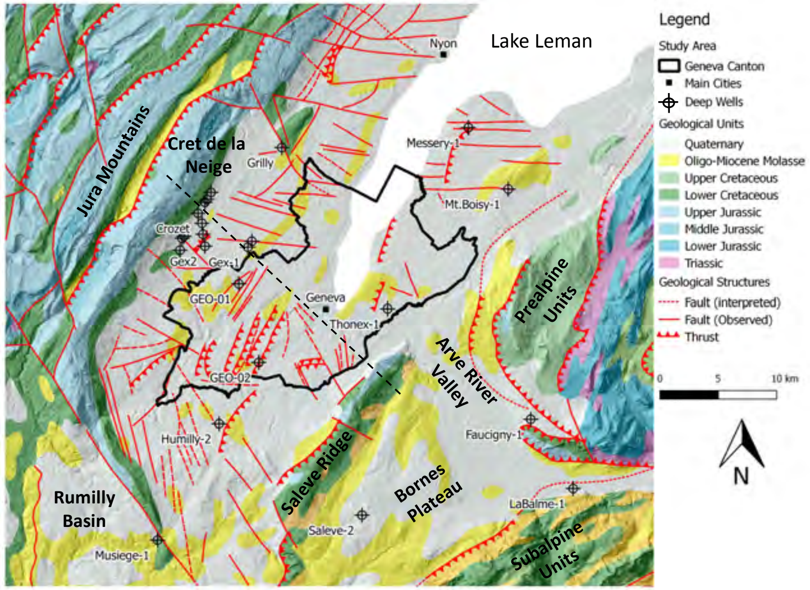
- 17 years at daily basis
- Merit order fixed to **Cheneviers – CHP – Storage – HP – Wood**
- 3 charging temperatures : 50, 75 and 90°C
- 2 charging strategies



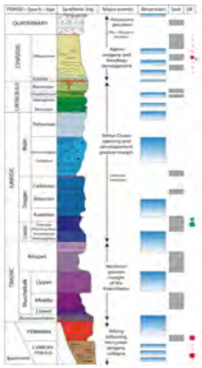


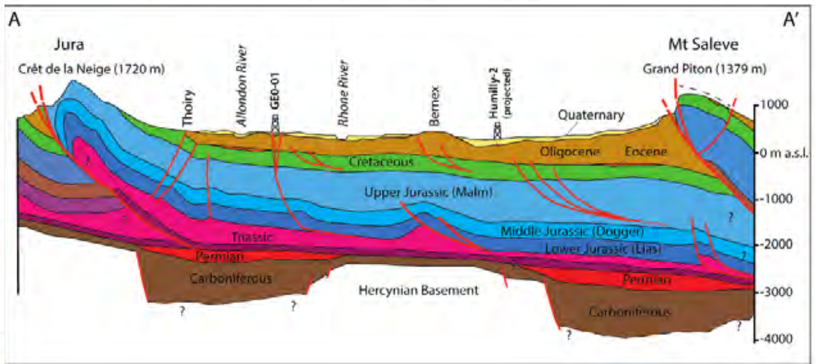
1. T.charging = 90°C, non-stop renewable production;
2. T.charging = 75°C, non-stop renewable production;
3. T.charging = 90°C, renewable production driven by demand;
4. T.charging = 75°C, renewable production driven by demand;
5. T.charging = 50°C, non-stop renewable production;
6. T.charging = 50°C, renewable production driven by demand.

GEOLOGY

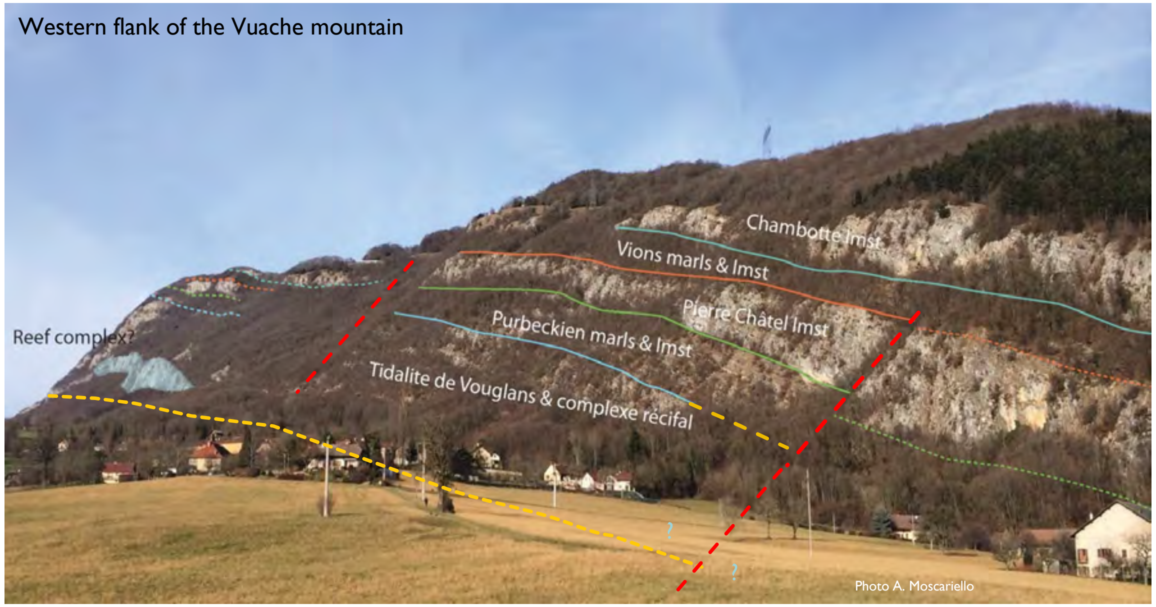


Lake Leman
Nyon
Jura Mountains
Cret de la Neige
Grilly
Messery-1
Mt.Boisy-1
Crozet
Gex2
Gex-1
GEO-01
Geneva
Thonex-1
Prealpine Units
Arve River Valley
GEO-02
Humilly-2
Faucigny-1
Saleve Ridge
Bornes Plateau
Rumilly Basin
Saleve-2
LaBalme-1
Musiege-1
Subalpine Units
Legend
Study Area
Geneva Canton
Main Cities
Deep Wells
Geological Units
Quaternary
Oligo-Miocene Molasse
Upper Cretaceous
Lower Cretaceous
Upper Jurassic
Middle Jurassic
Lower Jurassic
Triassic
Geological Structures
Fault (interpreted)
Fault (Observed)
Thrust
0
5
10 km
N





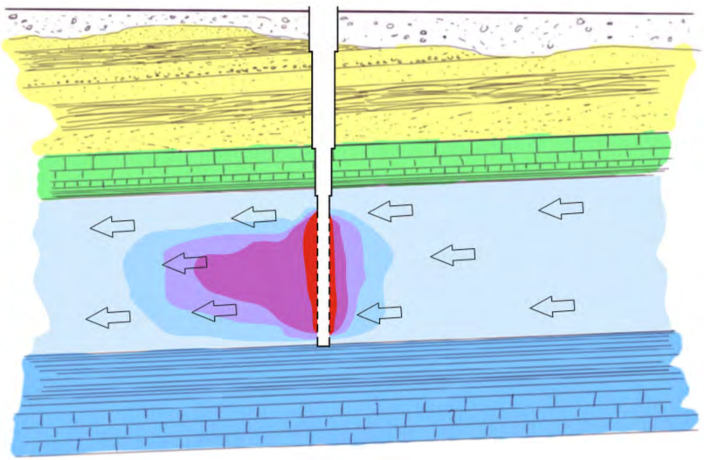
A
A'
Jura
Crêt de la Neige (1720 m)
Thoiry
Allondon River
GEO-01
Rhone River
Bernex
Humilly-2 (projected)
Mt Saleve
Grand Piton (1379 m)
Quaternary
Oligocene
Eocene
Cretaceous
Upper Jurassic (Malm)
Middle Jurassic (Dogger)
Lower Jurassic (Lias)
Triassic
Permian
Carboniferous
Hercynian Basement
1000
0 m a.s.l.
-1000
-2000
-3000
-4000



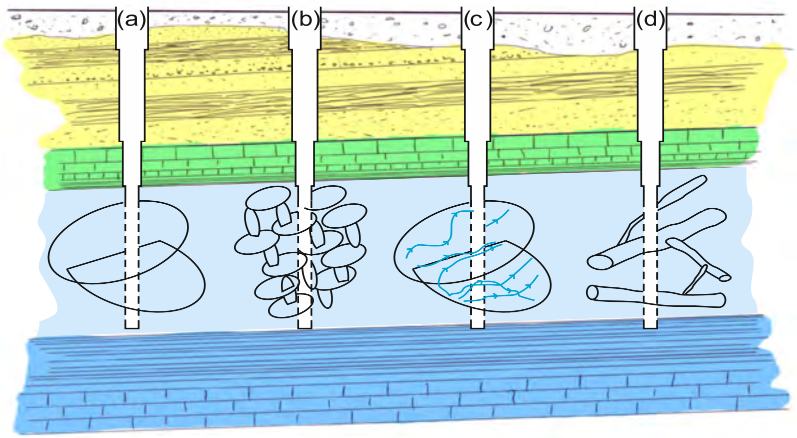
Western flank of the Vuache mountain
Chambotte lmst
Vions marls & lmst
Pierre Châtel lmst
Purbeckien marls & lmst
Tidalite de Vouglans & complexe récifal
Reef complex?
Photo A. Moscariello

RELEVANT PROCESSES FOR ATES IN SWITZERLAND

Regional hydrogeological gradients



Heterogeneous heat exchanger characteristics



The most important properties are:

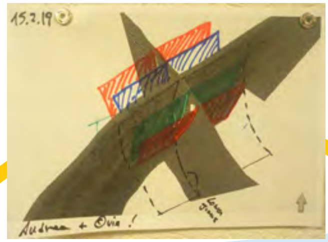
- Geometry (surface area and thickness)
- Stratigraphy (different layers of strata)
- Static heat (groundwater or pressure level)
- Groundwater table gradient (natural flow direction)

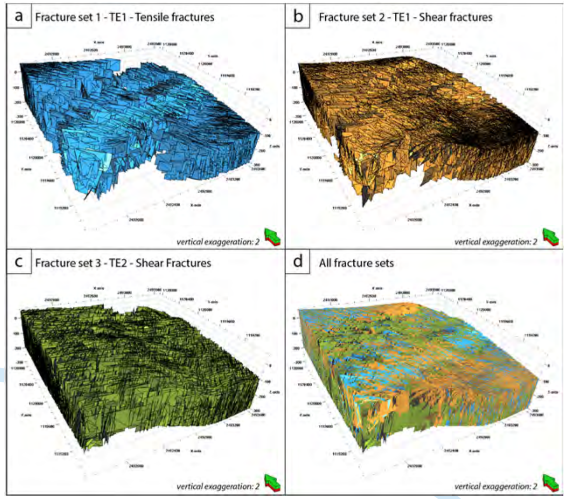
Topographical, geological and hydrogeological descriptions

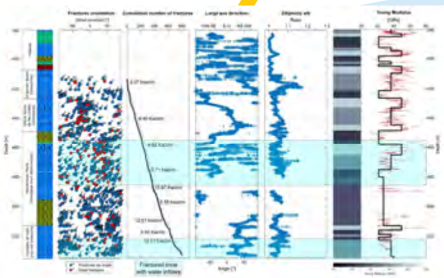
- Hydraulic conductivity (permeability)
- Transmissivity (hydraulic conductivity x thickness)
- Storage coefficient (yield as a function of volume)
- Leakage factor (vertical leakage to the aquifer)
- Boundary conditions (surrounding limits)

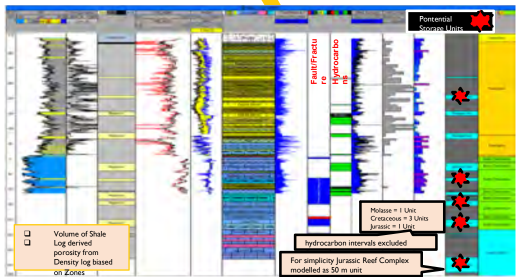
Geomechanical and geophyiscal data, well test characterization, pumping test

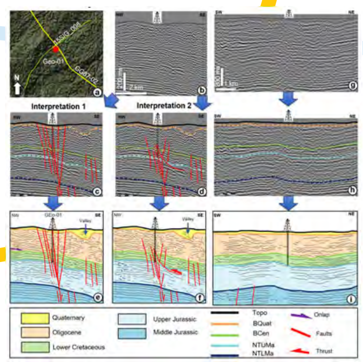
3D STATIC MODELLING

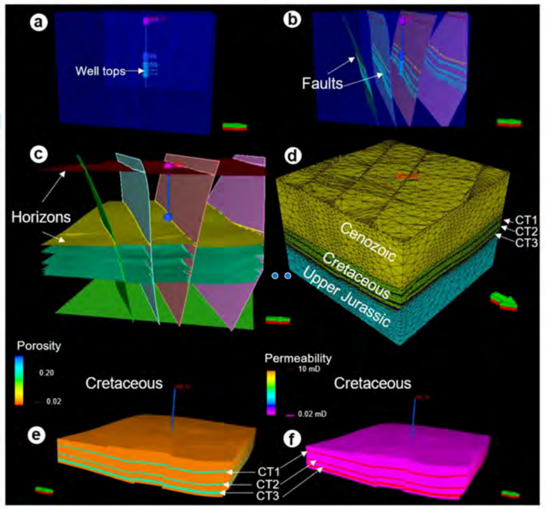






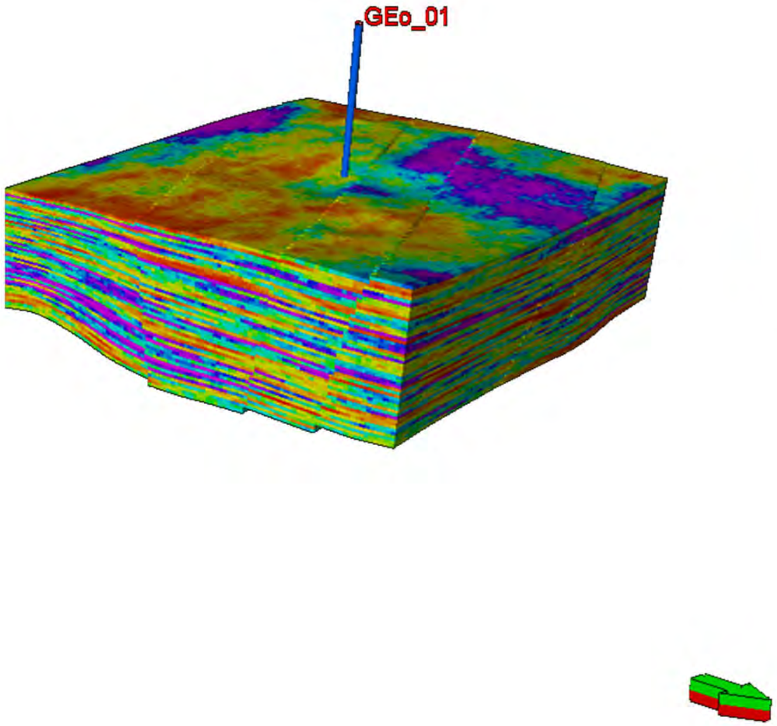


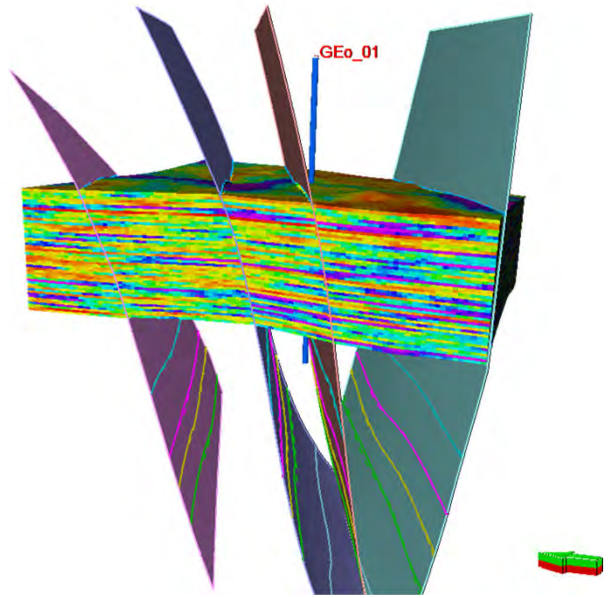




3D STATIC MODELLING

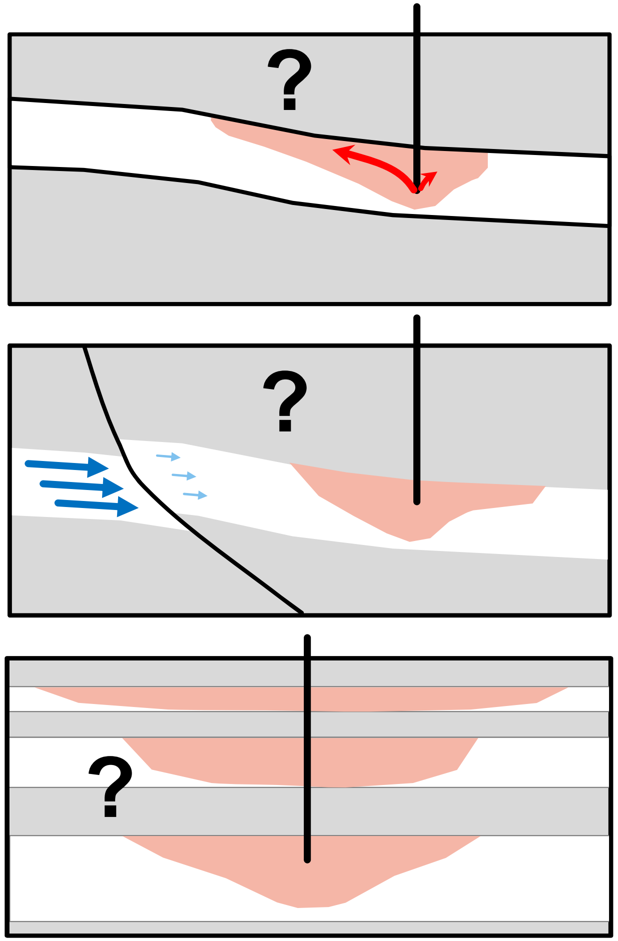
Porosity and Permeability



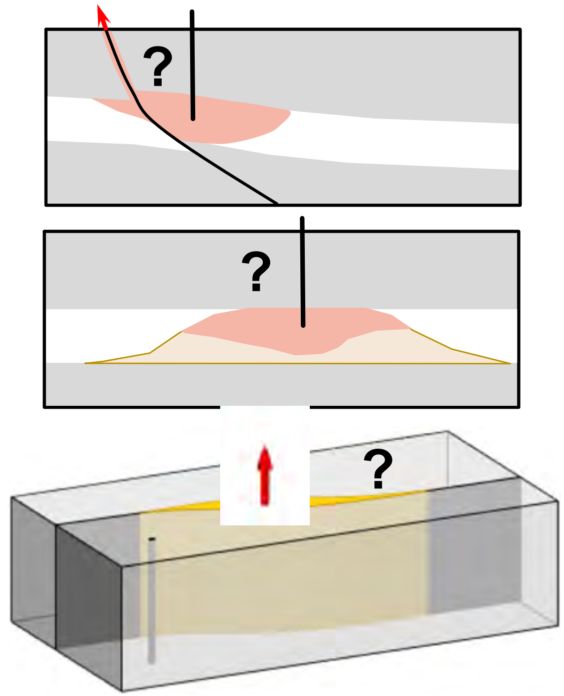


TH MODELLING QUESTIONS

- We are looking for insights into the following main topics via a scenario-based approach:
  - Buoyancy:
    - Given permeability values and inclination of layers, as well as the operational timeframes, will it have significant effects?
  - Groundwater flow:
    - How does it affect the heat storage signature over time?
    - Can faults/fractures play a role in redirecting it?
    - Given more data, could we predict a location "shielded" from it?
  - Multiple Aquifer Storage
    - How does thickness-dependent spreading affect efficiency?
    - What is the role of completion length?
    - Is there a significant impact from the temperature dependency of viscosity?

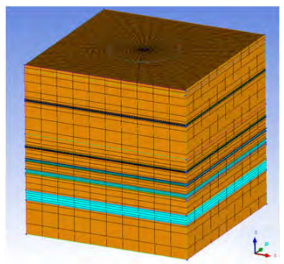


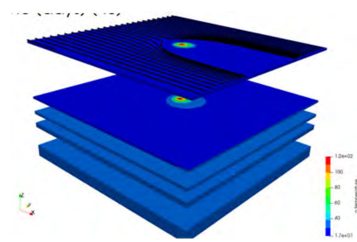
TH MODELLING QUESTIONS



- (continued)
  - Faults/Fractures/Reef structures:
    - How will efficiency be affected by the proximity of a particular feature to the injection location?
    - Sensitivity to feature's hydraulic parameters and shape.
    - Effects of through-going (large) vs. model-contained faults/fractures.
    - Can we predict/confirm a particular type of feature by simulating its effects?
    - Strike-slip faults: effect of dilational stepovers.

Preliminary predictive models





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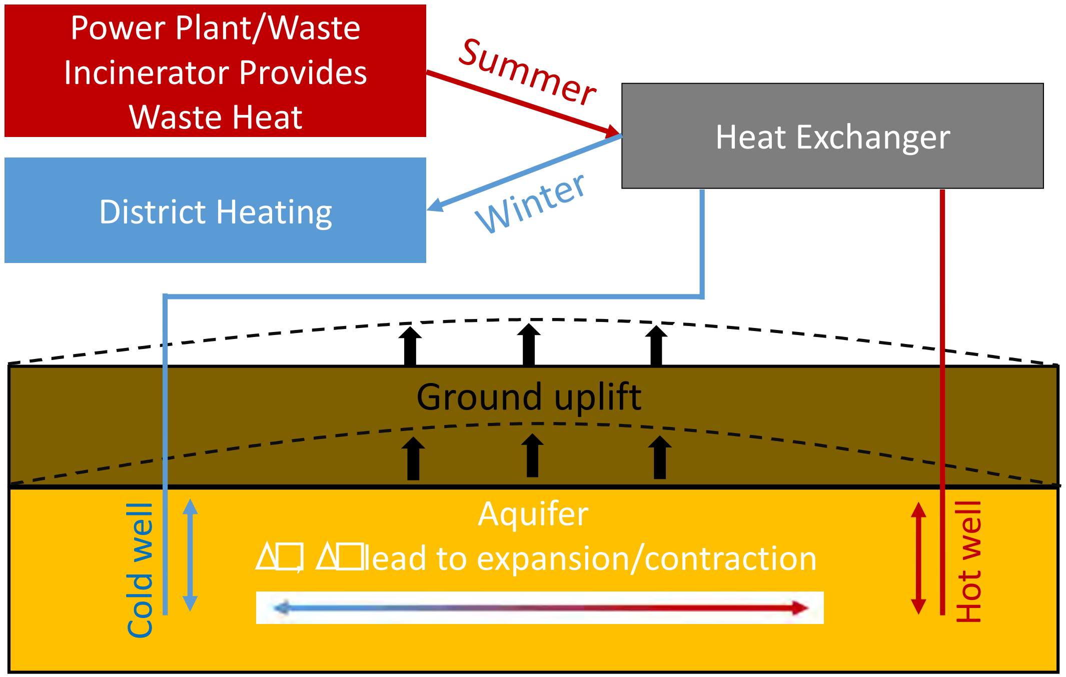
THM & HM MODELING QUESTIONS

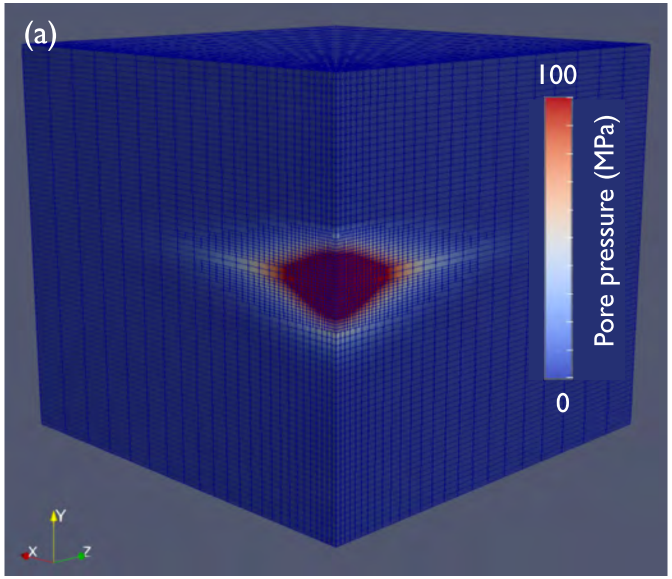
- Investigate how surface uplift is affected by
  - Aquifer depth
  - Rock properties
  - Operational decisions
- Poro-elastic and Thermo-poro-elastic modeling
- Model includes simplified incorporation of subsurface characterization and energy system scenarios



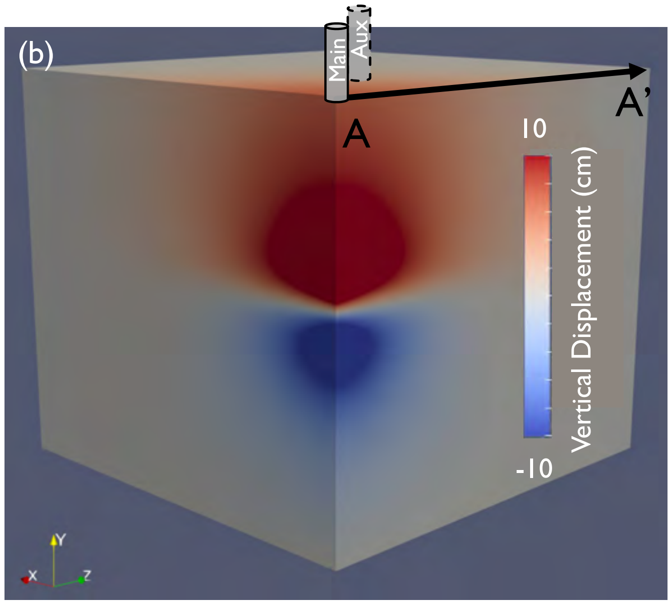
Adapted and expanded from Lu et al. (2019)

GROUND SURFACE UPLIFT DEFORMATION PRELIMINARY RESULTS

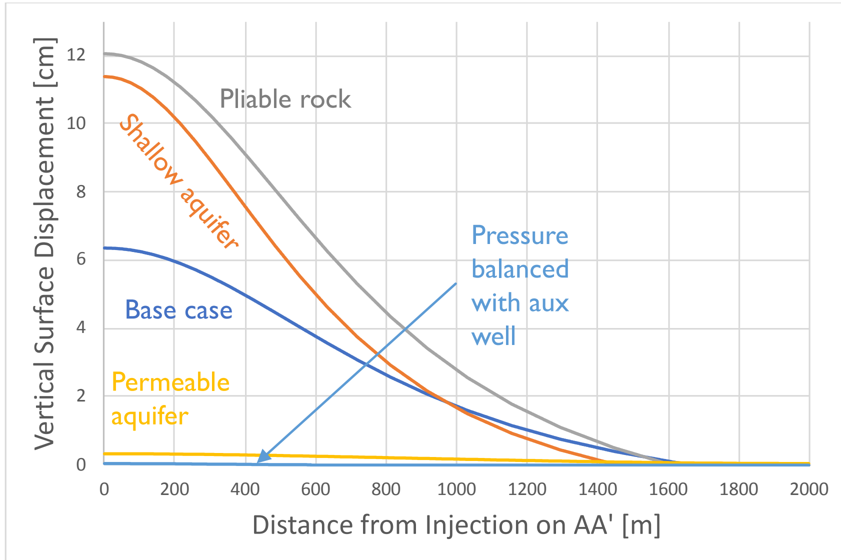
Base Case Pressure



Base Case Deformation



Sensitivity Analysis

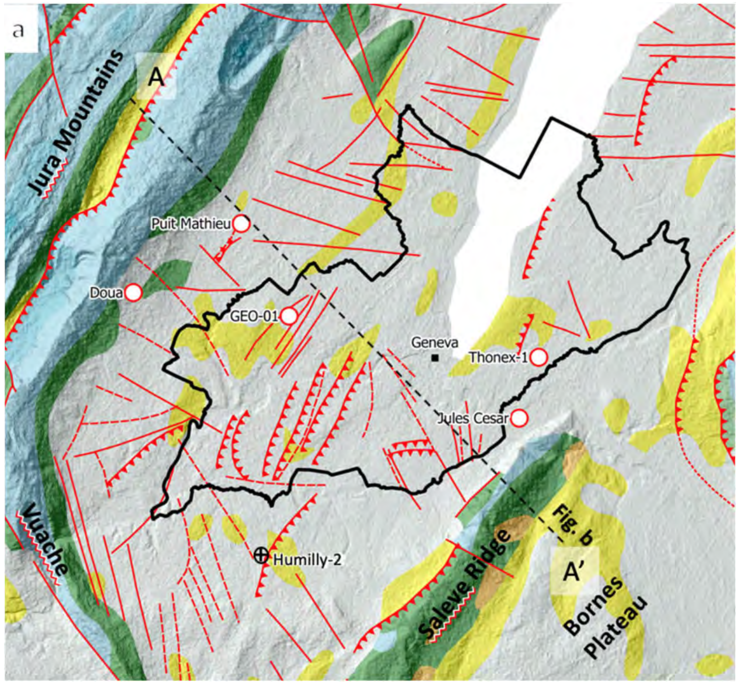


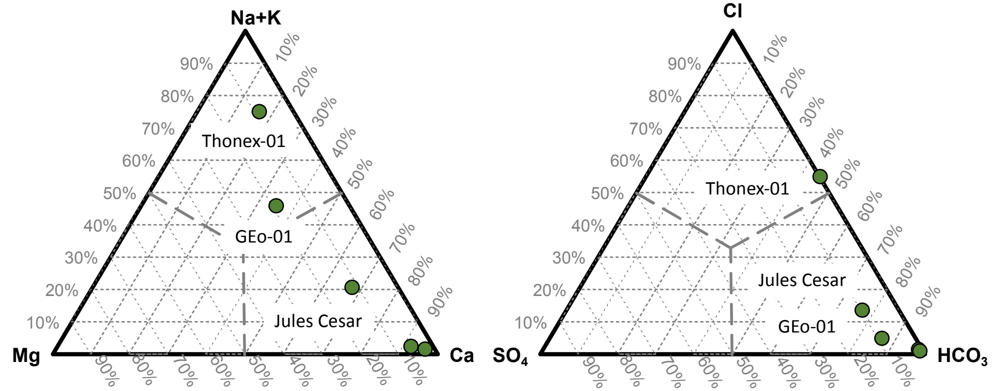
HM simulations. THM in future.

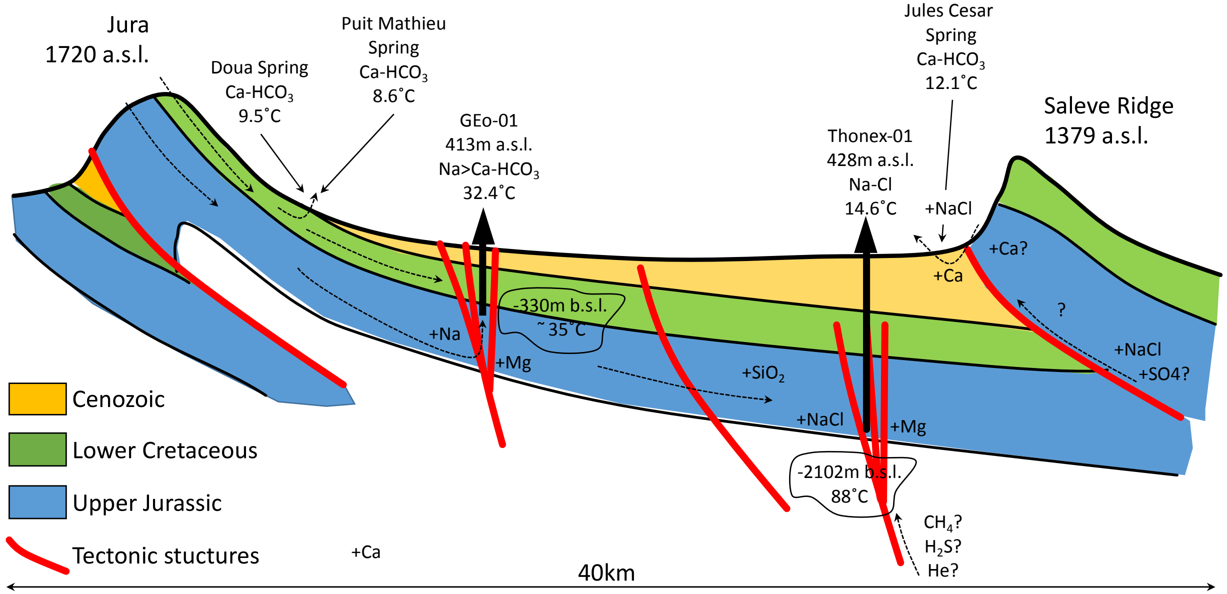
Important:

- Aquifer permeability
- Pressure balance with multiple wells

WATER GEOCHEMISTRY







CARBONATE SYSTEM

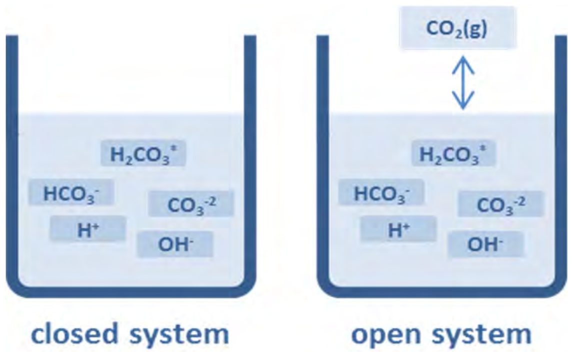
$$CaCO_3\ \text{(calcite)}\ \boxed{+\ CO_{2(g)}}\ +\ H_2O \Leftrightarrow Ca^{2+} + 2\ HCO_3^-$$

$$CaMg(CO_3)_2\ \text{(dolomite)}\ +\ \boxed{2\ CO_{2(g)}}\ +\ 2\ H_2O \Leftrightarrow Ca^{2+} + Mg^{2+} + 4\ HCO_3^-$$

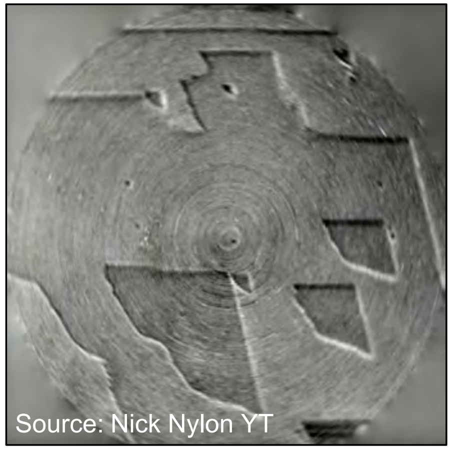
Enhances precipitation ← ↑TDS, ↑Temperature

↑pCO_2, ↓pH → Enhances dissolution

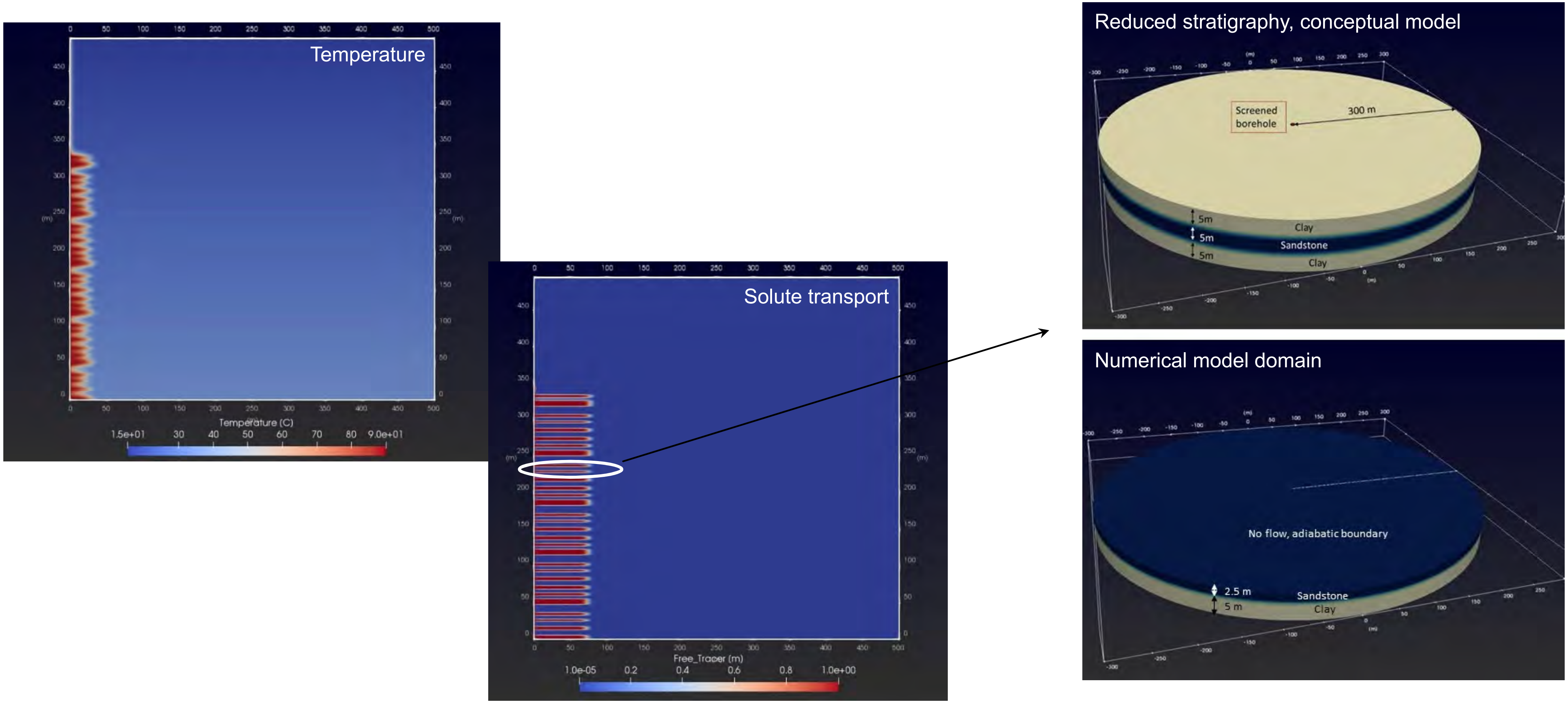

Source: Hydroisotop GmbH



HT-ATES?


Source: Nick Nylon YT

THC MODELLING



LAB EXPERIMENTS

What kind of experiments?

- **Short and Long-term** heating experiments (days to weeks):

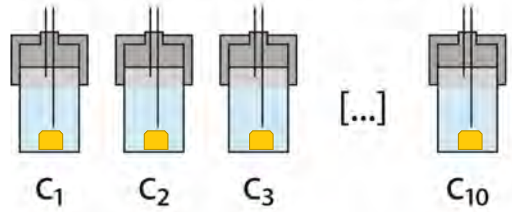
Reservoir waters (saturated with respect to minerals present in the reservoir), synthetic or real **+ rock fragments**

Rapidly heated to $T_{injection}$

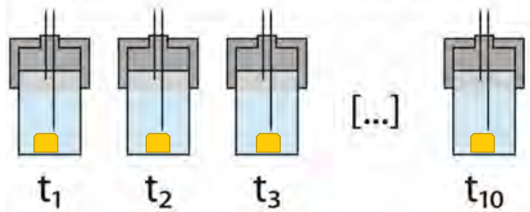
Sample fluid → Changes in fluid chemistry?
(+ minerals precipitated → Identification of polymorphs)

What and how much has precipitated? Any signs of silicate dissolution?

Precipitation experiments:
Different conditions for all vessels, open at the same time

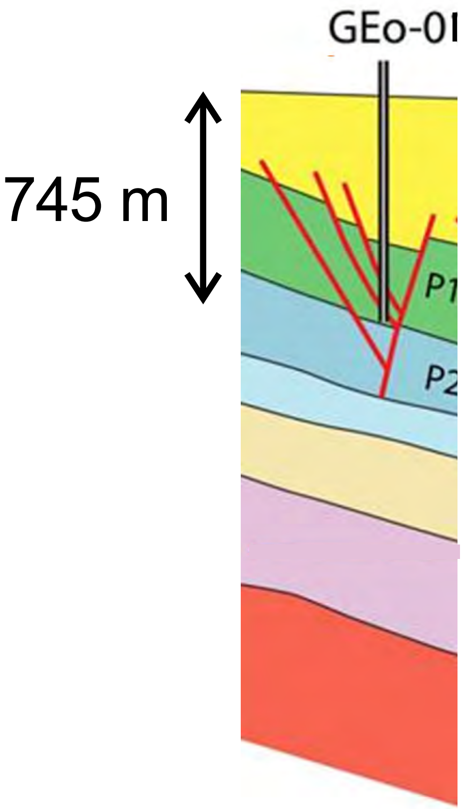


Kinetic experiments:
Same conditions for all vessels, terminate at different times

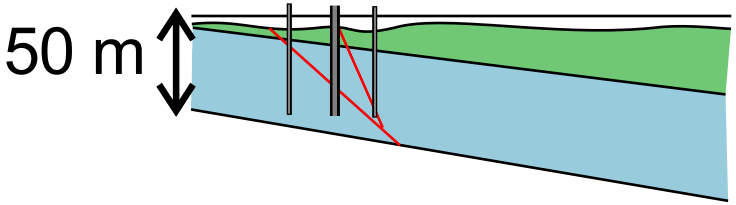


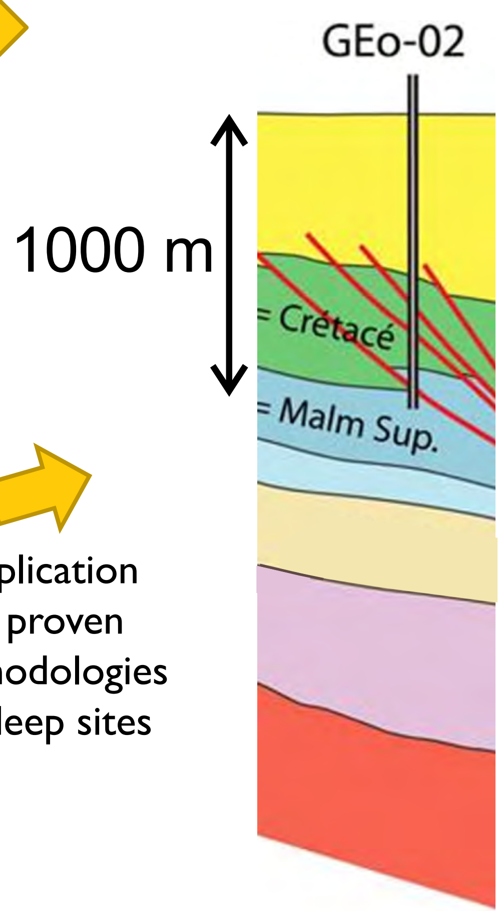
Repeat experiments at different conditions (e.g. $T_{injection}$, fluid composition (TDS, ± Mg, ± SO_4), pCO_2 , ± crystallisation seeds) to cover different hydrochemical conditions which might be encountered at the Geneva and Forsthaus sites

THERMO-HYDRAULIC TESTS IMPLEMENTATION STRATEGY



Shallow analog test site
Concise (VD) – Vaumarcus (NE)





Application of proven methodologies to deep sites

Added value to the project by:

- The possibility to develop and test multiple protocols at low cost (logging and pumping logistic available at CHYN).
- The possibility of validating results with observation holes.

Application of proven methodologies to deep sites

NEXT STEPS

Drilling

Testing

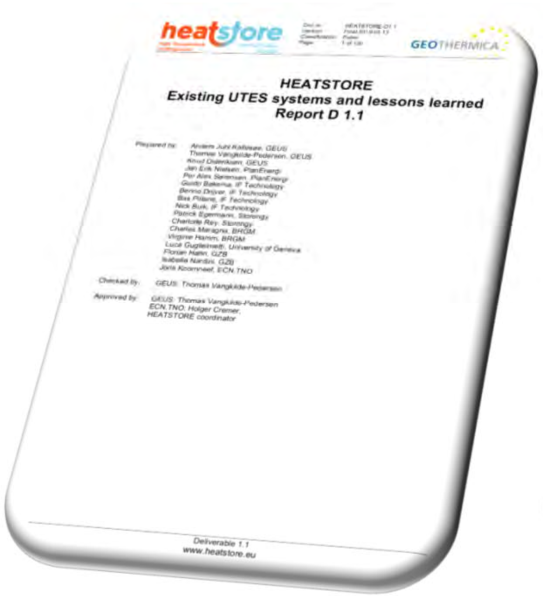
Validating

TAKE HOME MESSAGES:

INTEGRATION

CONTINUITY

[WWW.HEATSTORE.EU](http://www.heatstore.eu)



HEATSTORE
Existing UTES systems and lessons learned
Report D 1.1

Deliverable 1.1
www.heatstore.eu

HEATSTORE
Initial report on tools and workflows for simulating subsurface dynamics of different types of High Temperature Underground Thermal Energy Storage

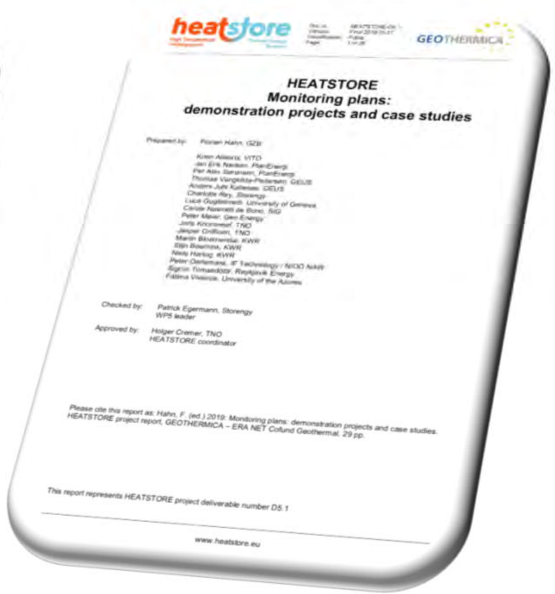
This report represents HEATSTORE project deliverable number D2.1

www.heatstore.eu

HEATSTORE
Technical report on the characteristics of heat demand and supply at the demonstrator sites

This report represents HEATSTORE project deliverable number D3.2

Deliverable 3.2
www.heatstore.eu



HEATSTORE
Monitoring plans: demonstration projects and case studies

This report represents HEATSTORE project deliverable number D5.1

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THANK YOU !

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AND BASIN ANALYSIS GROUP
























… and more to come

HEATSTORE (170153-4401) is one of nine projects under the GEOTHERMICA – ERA NET Cofund aimed at accelerating the uptake of geothermal energy by 1) advancing and integrating different types of underground thermal energy storage (UTES) in the energy system, 2) providing a means to maximise geothermal heat production and optimise the business case of geothermal heat production doublets, 3) addressing technical, economic, environmental, regulatory and policy aspects that are necessary to support efficient and cost-effective deployment of UTES technologies in Europe. The three-year project will stimulate a fast-track market uptake in Europe, promoting development from demonstration phase to commercial deployment within two to five years, and provide an outlook for utilisation potential towards 2030 and 2050.

The GEOTHERMICA project is supported by the European Union's HORIZON 2020 programme for research, technological development and demonstration under grant agreement No 731117.