HEATSTORE WEBINAR SERIES

HOW TO DEVELOP UNDERGROUND THERMAL ENERGY STORAGE (UTES) PROJECTS?

Learnings from the European HEATSTORE project

Host: TNO, The Netherlands

heatstore
High Temperature Underground Thermal Energy Storage

GEOTHERMICA

7, 14, 21, 28 Sept. and 5, 12 Oct. 2021 | all 15-16 h (CEST)

Register on www.heatstore.eu

HEATSTORE WEBINAR SERIES 2021

All webinars are at 15 – 16 h CEST

Tuesday 7 Sept. (Holger Cremer, TNO): Challenges in Underground Thermal Energy Storage (UTES)

Tuesday 14 Sept. (Thomas Driesner, ETH Zurich): Advances in subsurface characterization and simulation

Tuesday 21 Sept. (Koen Allaerts, VITO): Integrating UTES and DSM in geothermal district heating networks

Tuesday 28 Sept. (Florian Hahn, Fraunhofer IEG): Abandoned coal mines – promising sites to store heat in the underground

Tuesday 5 Oct. (Bas Godschalk, IF Technology): The ECW Energy HT-ATES project in the Netherlands

Tuesday 12 Oct. (Joris Koornneef, TNO): The role of UTES in the future EU energy system – a moderated table discussion.

heatstore High Temperature Underground Thermal Energy Storage

GEOTHERMICA

Register on www.heatstore.eu

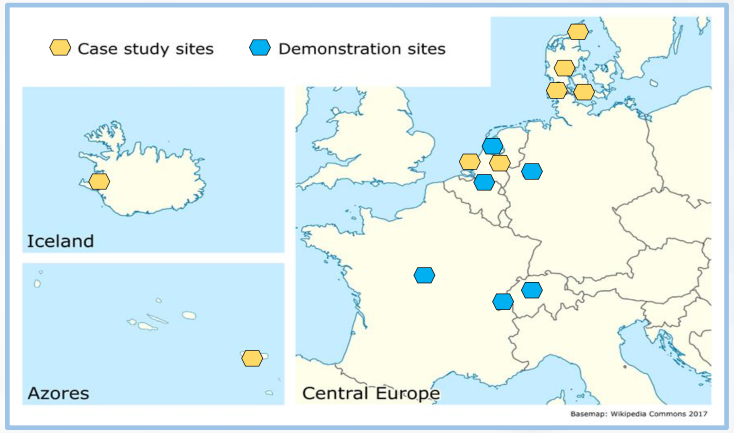
HEATSTORE

- HEATSTORE = GEOTHERMICA ERA-NET co-fund project
- 16.3 M€ | 23 partners in 9 EU countries
- 6 demonstration sites, 8 case studies.
- Coordination: TNO Netherlands Organization for Applied Scientific Research)

TNO innovation for life · GEUS · Université de Genève · vito · KWR · ECW · NIOO · unine Université de Neuchâtel · Fraunhofer IEG · storengy · ETH zürich · SIG · ewb · u^b · PlanEnergi · OR Reykjavik Energy · IVAR · UPC · if · brgm Géosciences pour une Terre durable · delta h Ingenieurgesellschaft · Kempens Warmtebedrijf groene warmte uit de regio · SPIE

heatstore High Temperature Underground Thermal Energy Storage · GEOTHERMICA

www.heatstore.eu

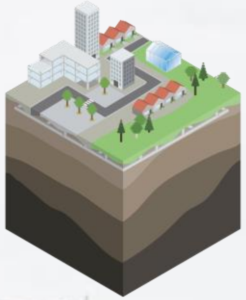


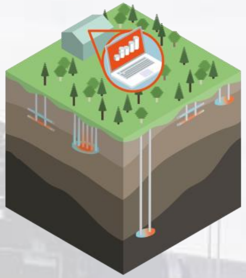
- **Best practice guidelines:** Design & System integration | Business models | Regulatory framework | Stakeholder perception & engagement | Monitoring technical, economic and environmental performance

- Proof and operation of UTES and DSM technologies

Fast track market uptake

Model & design validation





Demonstration

System performance monitoring

- **Roadmap Europe**: Technical future potential UTES and DSM in Europe | New business models | Stakeholder engagement | Roadmap for fast track uptake

Characterization of UTES

Modelling sub-surface dynamics

Heating system integration & design optimisation

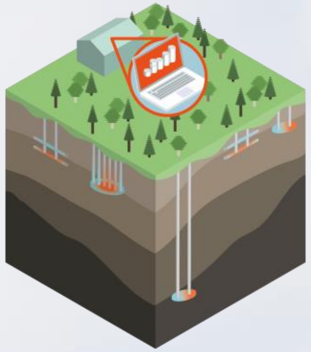
Design → **Demonstration** → **Replication and scale-up**

heatstore High Temperature Underground Thermal Energy Storage

GEOTHERMICA

www.heatstore.eu

HEATSTORE – 14 Sept. 2021 Advances in subsurface characterization and simulation



- Thomas Driesner (ETHZ): Convenor & Opening
- Thomas Driesner (ETHZ): Simulating subsurface dynamics – approaches, workflows, suitable tools
- Luca Guglielmetti, Alex Daniilidis (Univ. Geneva): Integration of subsurface and energy system data for HT-ATES modelling in Geneva

heatstore High Temperature Underground Thermal Energy Storage

GEOTHERMICA

INTEGRATION OF SUBSURFACE AND ENERGY SYSTEM DATA FOR HT-ATES MODELLING IN GENEVA

LUCA GUGLIELMETTI (UNIGE), ALEXANDROS DANIILIDIS (UNIGE)

WITH THE CONTRIBUTION OF:

- OVIE ERUTEYA, ANDREA MOSCARIELLO, YASIN MAKLHOUFI, HONG YING LO, LORENZO PEROZZI, FLEURY DE OLIVEIRA FILHO, PIERRE HOLLMULLER (UNIGE)
- JULIAN MINDEL, THOMAS DRIESNER, DANIEL BIRDSELL, MARTIN SAAR (ETHZ)
- DANIELA VAN DEN HEUVEL, CHRISTOPH WANNER, PETER ALT EPPING, LARRYN DIAMOND (UNIBE)
- BENOIT VALLEY, REZA SOHRABI, MORGANE KOUMROUYAN (UNINE)
- CAROLE NAWRATIL DE BONO, MICHEL MEYER (SERVICES INDUSTRIELS DE GENEVE)

HT-ATES CASE STUDY IN GENEVA

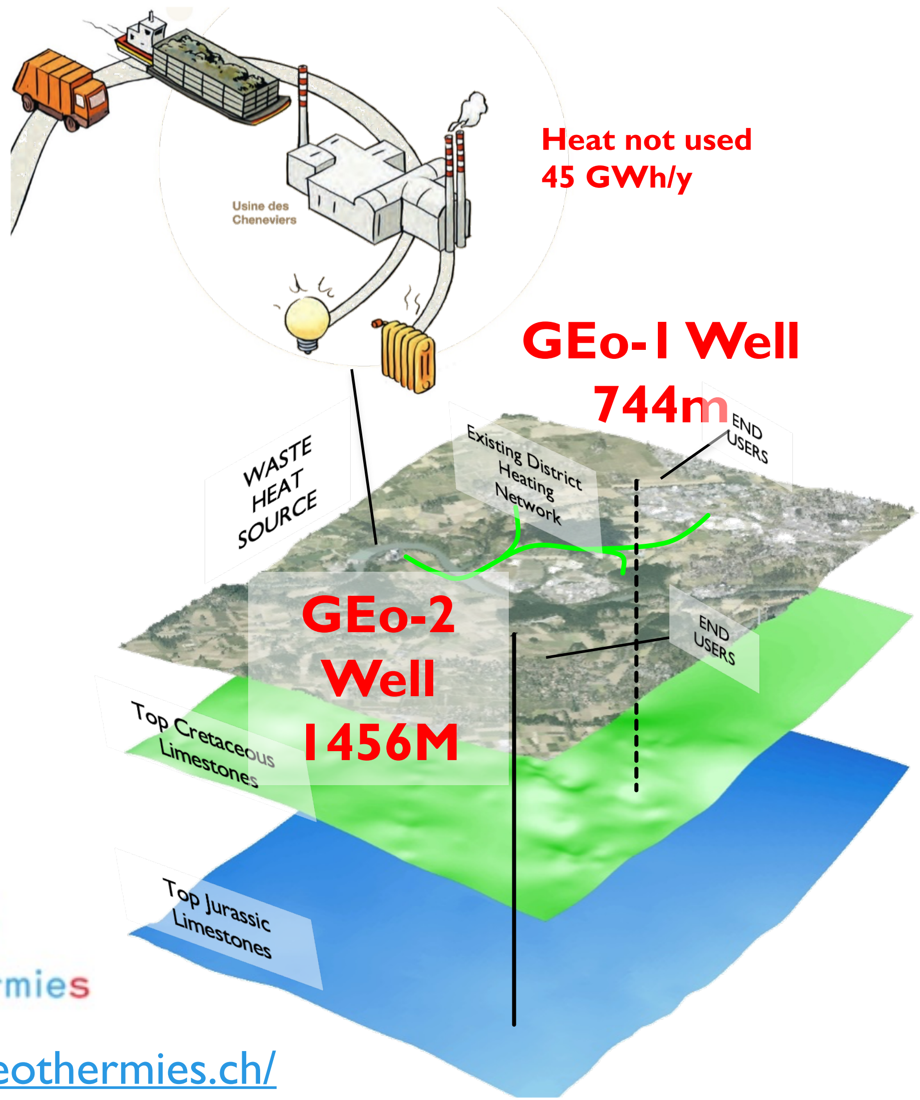
Drilling, data collection, business case modelling, regulatory framework

Subsurface characterization and static modelling, fluid geochemistry
Energy system scenarios
Economics and business models
Multi-criteria Play analysis

TH, THM reservoir modelling

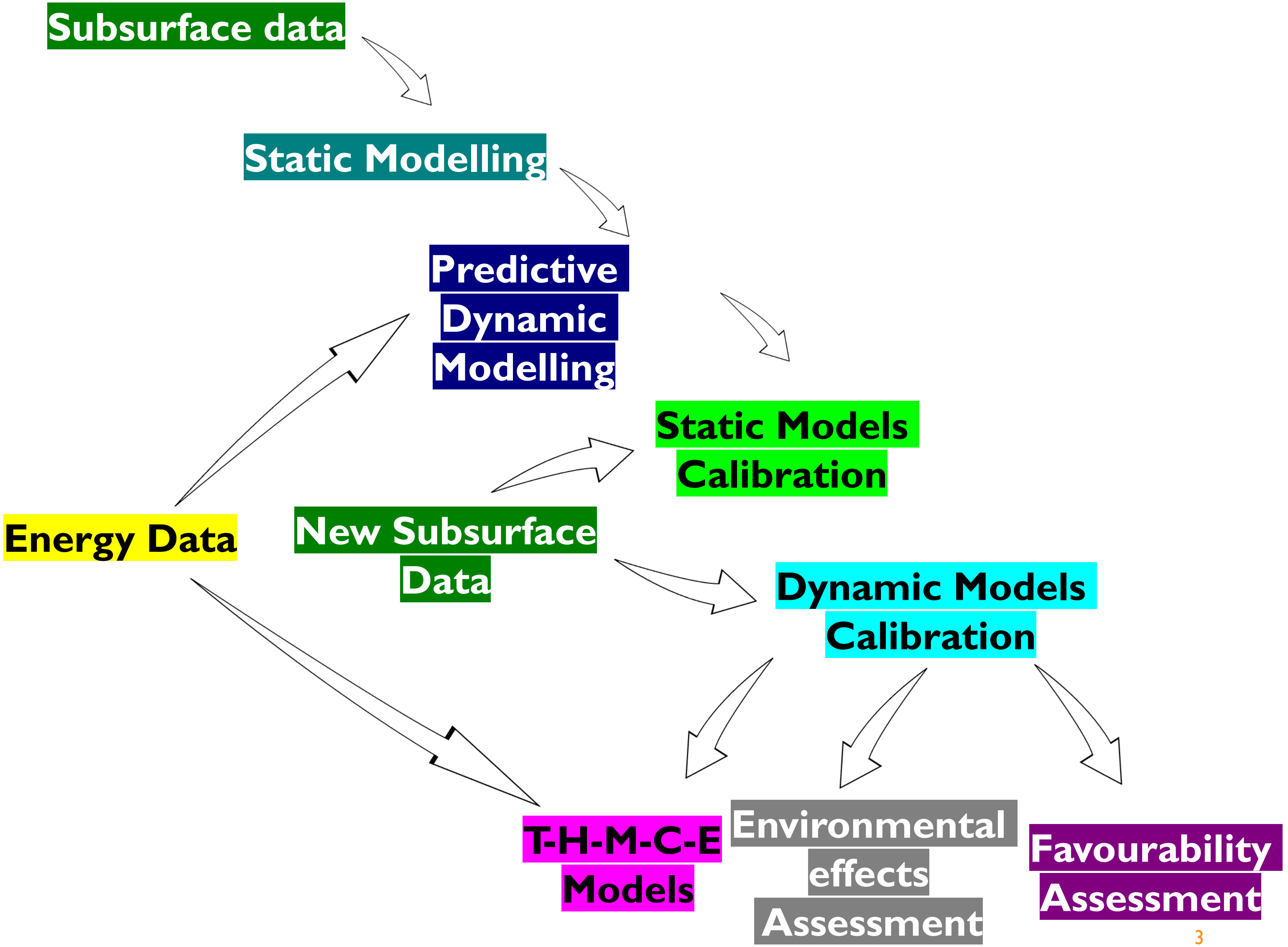
Reservoir geomechanical characterization, Play Analysis

THC modelling,
Water-rock interaction laboratory experiments



https://www.geothermies.ch/

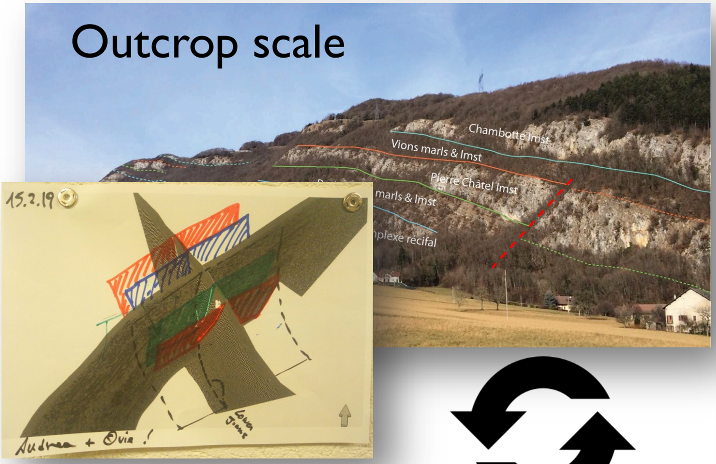
WORKFLOW

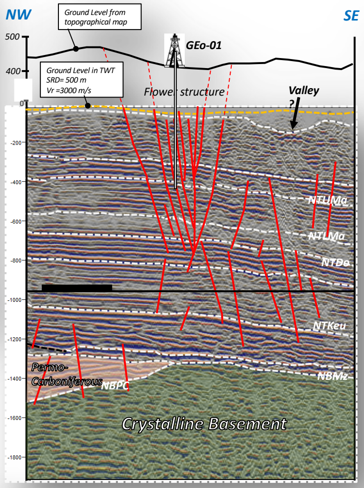

Subsurface data
Static Modelling
Predictive Dynamic Modelling
Static Models Calibration
Energy Data
New Subsurface Data
Dynamic Models Calibration
T-H-M-C-E Models
Environmental effects Assessment
Favourability Assessment

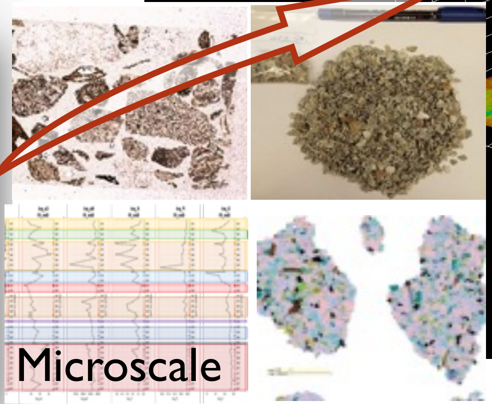
STATIC MODELLING – THE GEO-01 WELL – UNIVERSITY OF GENEVA

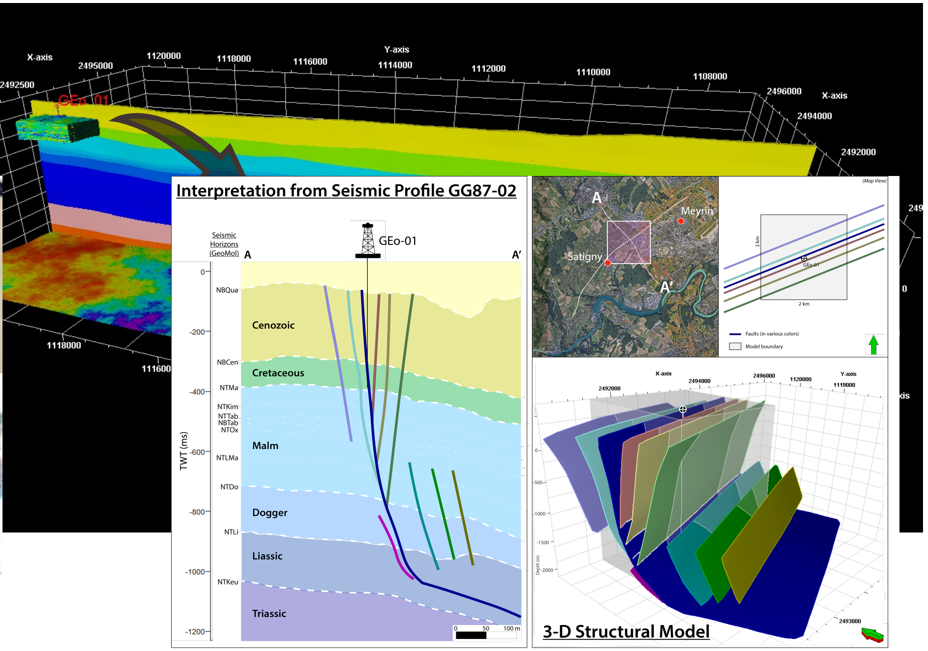
Seismic data interpretation

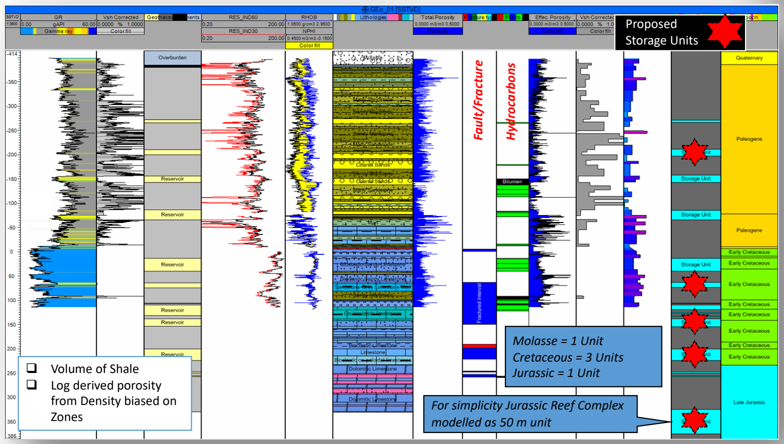
Outcrop scale



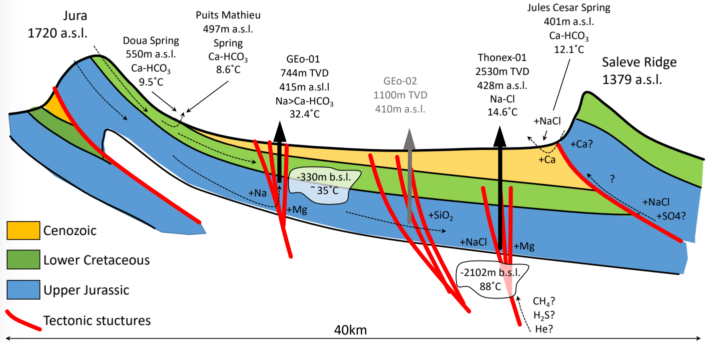




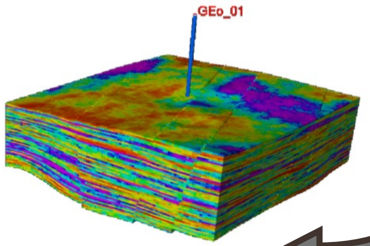




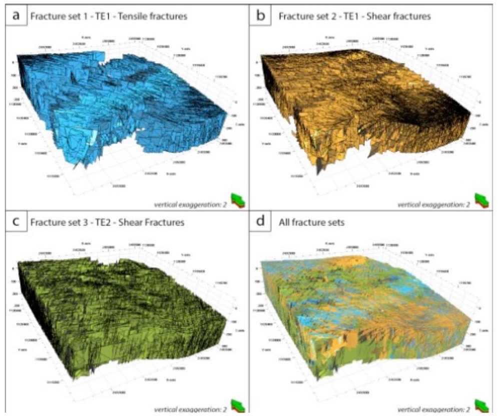
Borehole data interpretation



Fluid chemistry

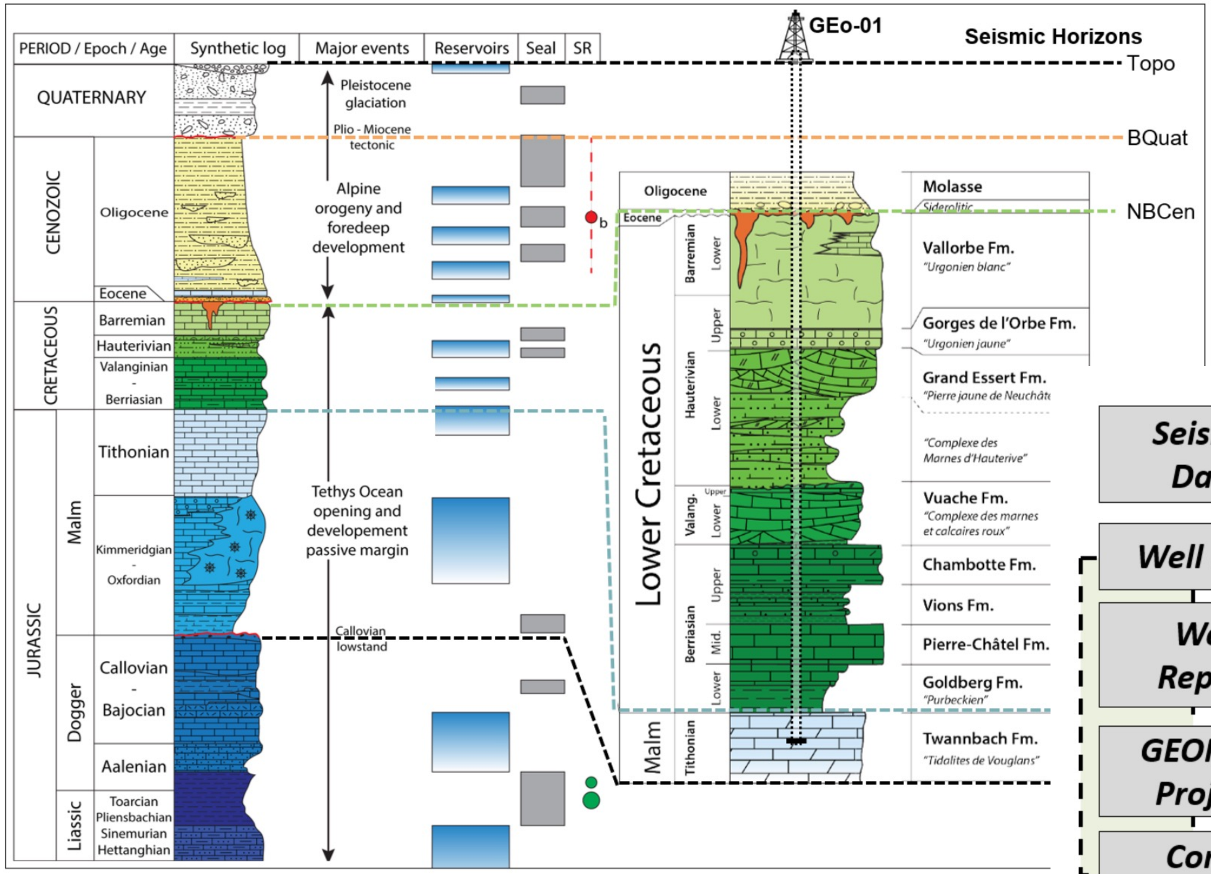


Petrophysical Model

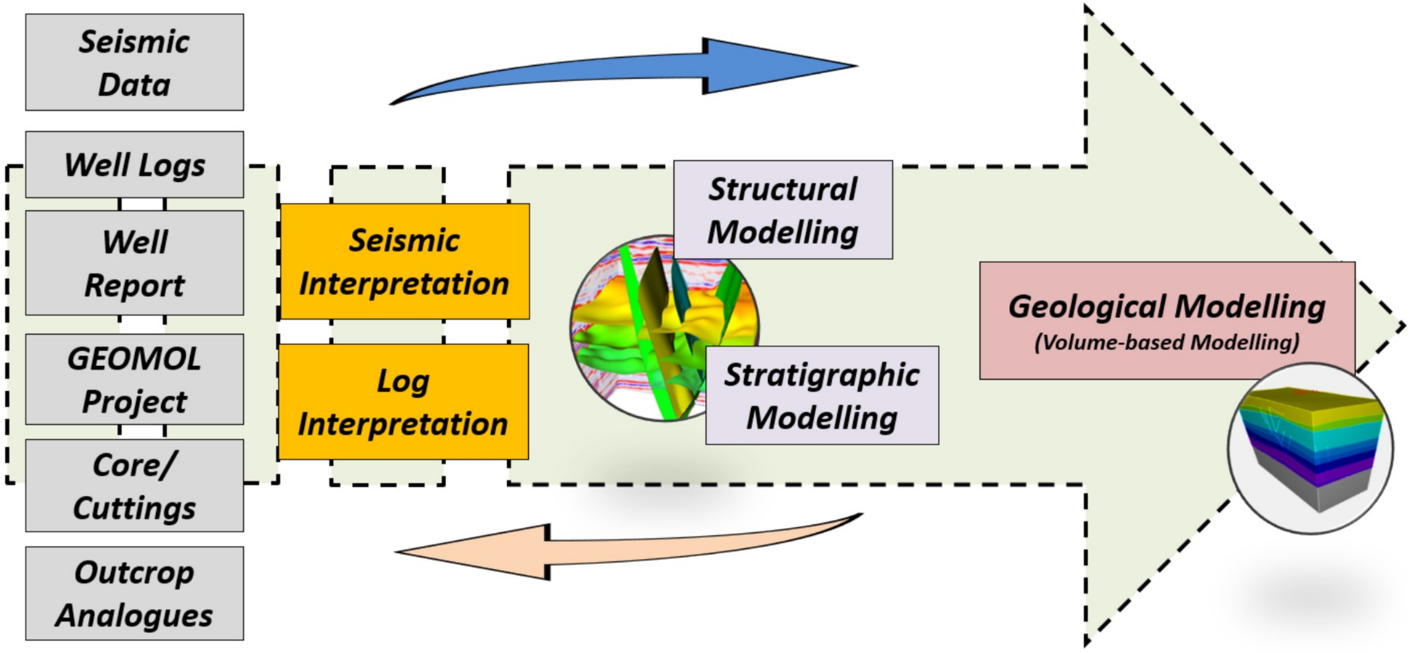


DFN Modelling

STATIC MODELLING – THE GEO-01 WELL – UNIVERSITY OF GENEVA



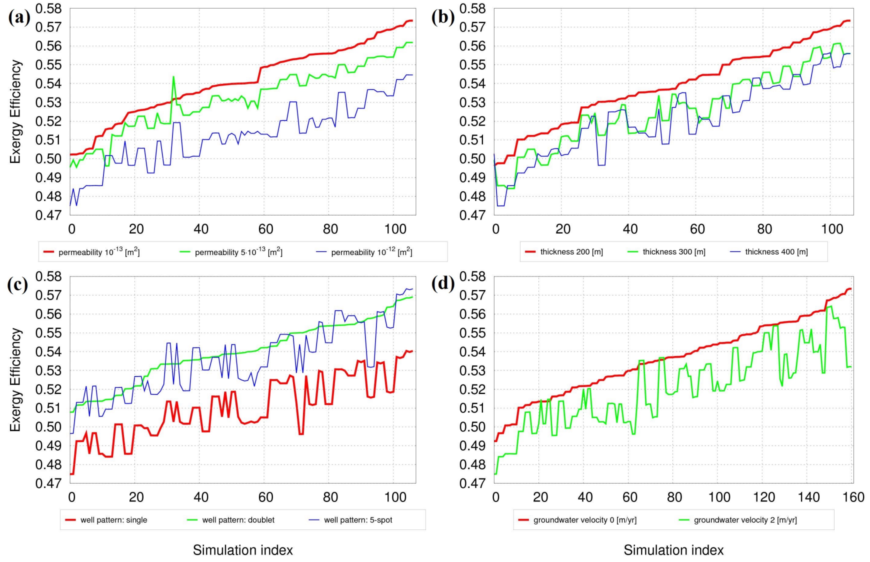
From Borehole, seismic data integration to 3D Geologic Model



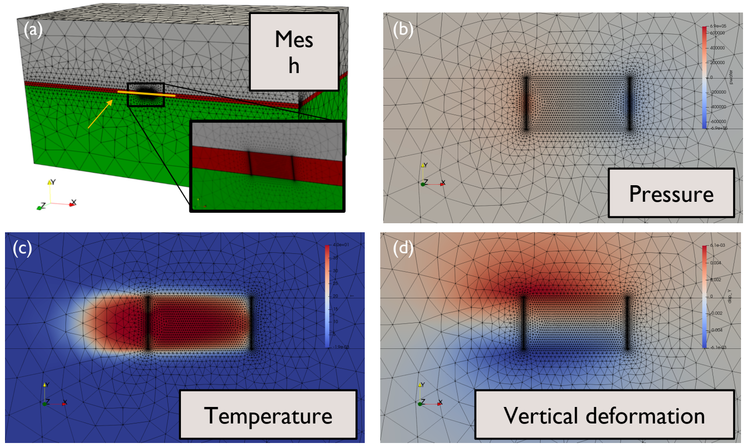
DYNAMIC SCENARIO MODELLING

- Use high-end academic modelling tools to predictively assess the impact of geologic complexity on feasibility, sustainability, and efficiency
- We developed a set of "what if" scenarios based on the geologic models from the exploration and characterization activities
- Two-step approach:
  - Thermo-hydraulic modelling to identify most promising geologic volumes and identify risky ones. Measured dynamic effects of: **permeability, porosity, aquifer thickness, well patterns, groundwater flow, fracture configurations, reef structures, aquifer depth, multiple aquifers, auxiliary well injection temperature**. (>1200 simulations)
  - Thermo-hydro-mechanical modelling to assess possible risks resulting from poro- and thermo-elastic responses (heave and subsidence, differential stresses, …)
- Interfacing with system integration modelling

3D TH modeling



3D HM modeling of ATES



MOOSE

ETHZ RESULTS – HM MODELING

We explored two aspects of ground surface deformation at the Geneva wells using a hydro-mechanical (HM) model.

1. We model ground deformation during the pumping test at GEO-01 and compare to deformation measurements from INSAR, tilt-meter and GPS data (report in preparation). → **NO DEFORMATION IS OBSERVED AND MODELLED** according to production test data
2. Secondly, we performed predictive simulations of the potential ground deformation resulting from HT-ATES to explore the question: ***what HM ground deformation could we expect if GEO-01 was used as one well in an HT-ATES doublet?***

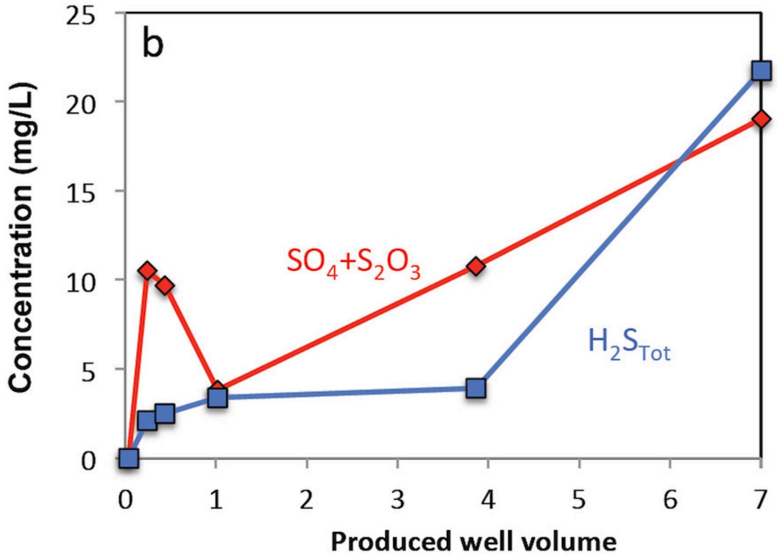
Predictive Simulation Scenarios and Results

Well and Scenario	Targeted Reservoir and Depth [m]	Reservoir Permeability [m²]	Reservoir Thickness [m]	Flow Rate [kg/s]	Young modulus [GPa]	Years simulated	Maximum ground deformation [cm]
GEO-01	LC-UJ (400 – 750)	$3*10^{-13}$	350	60	35	15	<0.01
					2	1	0.10
					0.35	15	0.49
GEO-02 Scen. 1	LC-UJ (750-1450)	$7*10^{-16}$	700	3.9	35	15	0.015
					2	1	0.053
					0.35	1	0.055
GEO-02 Scen. 2	Siderolitic (600-750)	$7*10^{-16}$	150	0.7	35	1	<0.01
					2	1	0.015
					0.35	1	0.016
GEO-02 Scen. 3	Siderolitic (600-750)	$3*10^{-13}$	150	60	35	1	<0.01
					2	1	0.097
					0.35	1	0.40

HYDRO-CHEMICAL MODELLING AT GEO-01

HM modelling was performed using water analysis results and energy inputs to predict the potential effects of operating an HT-ATES.

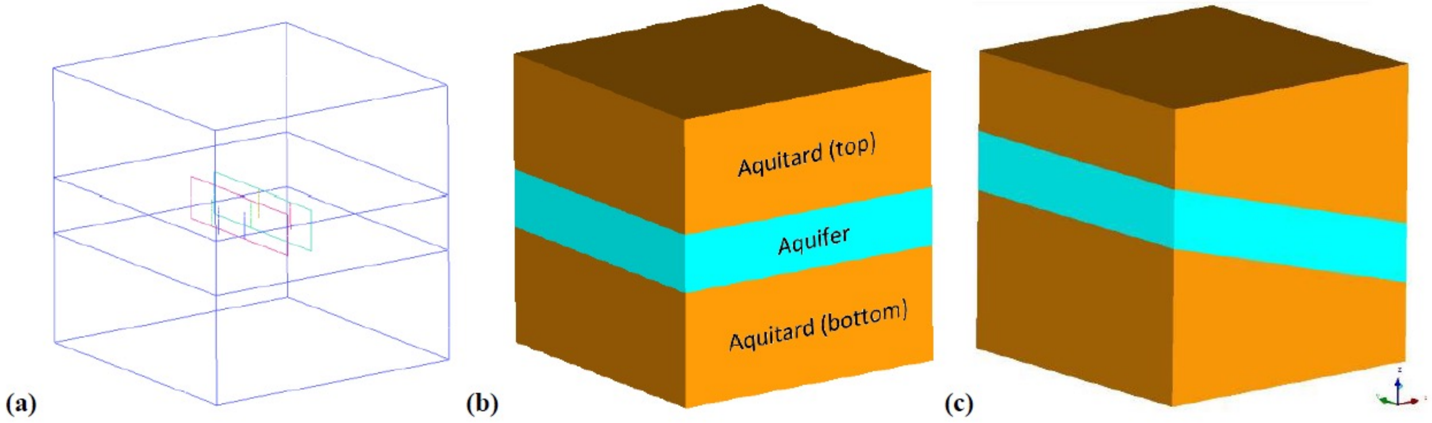
- **Carbonate precipitation when the waters are heated to 90°C during storage cycles.** This could impede flow and heat exchange in the surface installations.
- In case of the water produced from GEO-01, corrosion of technical installations such as pumps, casings, and heat exchangers may occur due to the high sulfide concentration

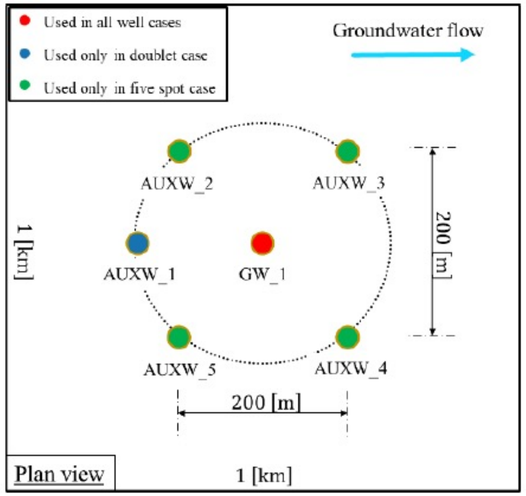


ENVIRONMENTAL EFFECTS RISK MATRIX (TASK 6.6)

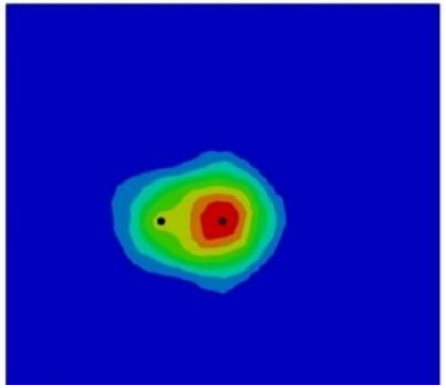
GEo-01												
Phase / Effect	Drilling						Operations (predicted)					
	P	A	M	Probability	Consequences	Risk	P	A	M	Probability	Consequences	Risk
Air quality				H	L	M				L	L	L
Noise and vibration				H	L	M				M	L	L
Formation water quality				L	L	L				H	M	H
Formation water temperature										H	L	M
Surface clear water				H	L	M				L	L	L
Soil occupation				H	L	M				H	L	M
Wastes and dangerous substances				H	L	M				M	L	L
Environment				M	L	L				L	L	L
Nature				M	L	L				L	L	L
Soil mechanics										L	L	L
Seismicity				L	H	M				L	H	M
CO2 intensity redyction										H	M	H

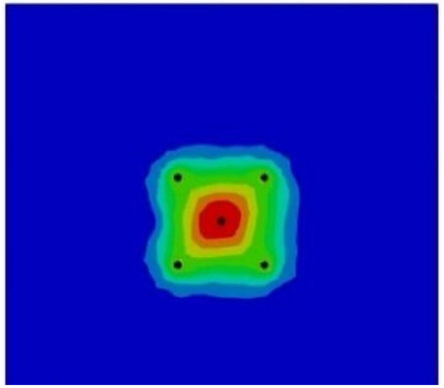
ATES SIMULATIONS





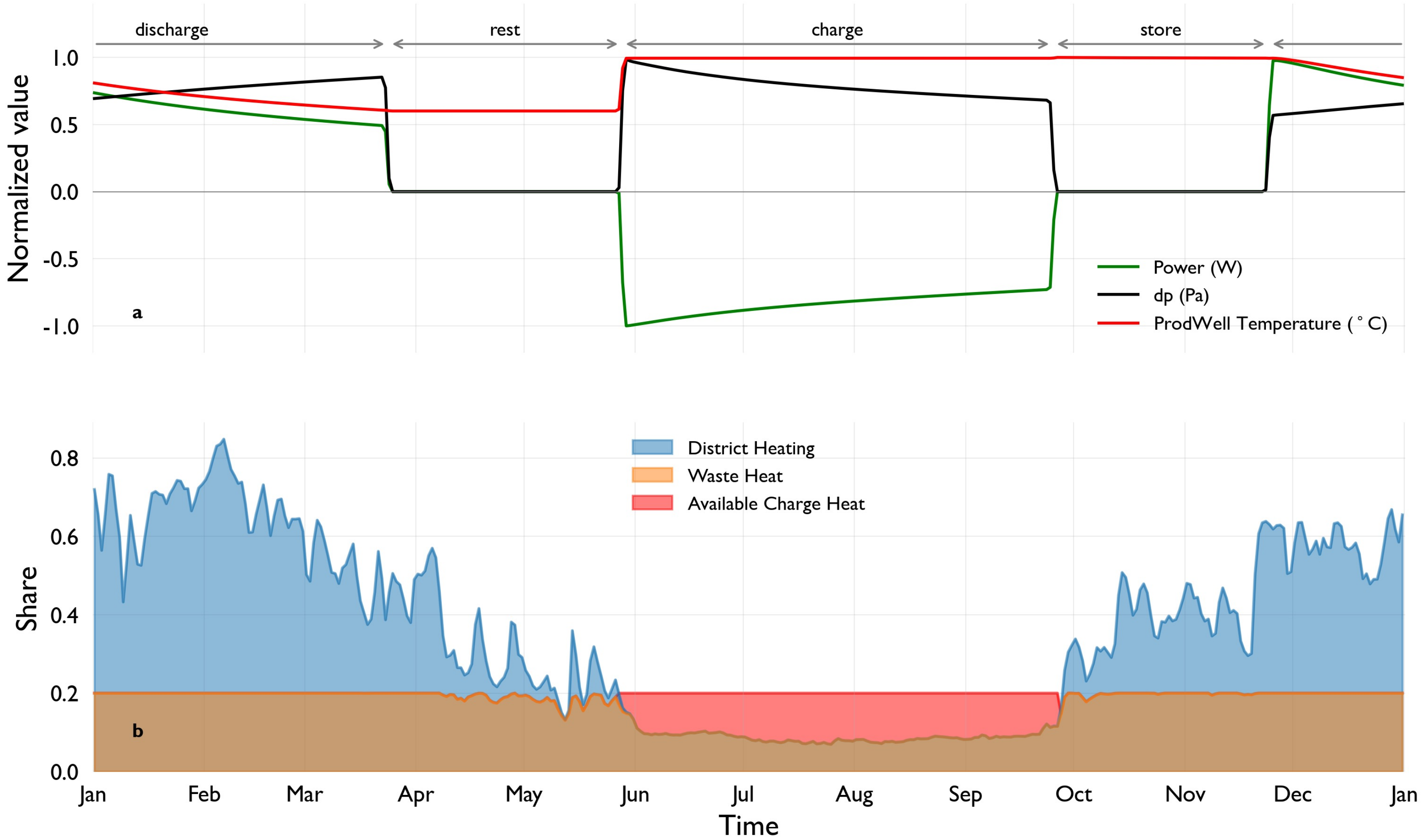
Aquifer thickness (m)	Permeability (m²)	Porosity (%)	Wells	Tcutoff (°C)	Depth (m)	Dip (°)	Groundwater hydraulic gradient (%)	Artesian conditions (Mpa)
50	1×10^{-14}	10	Doublet	20	500	0	0	0
100	5×10^{-14}	20	5-spot	50	1000	15	51.7	1
150	1×10^{-13}							





All figures from: Mindel & Driesner, WGC, 2020

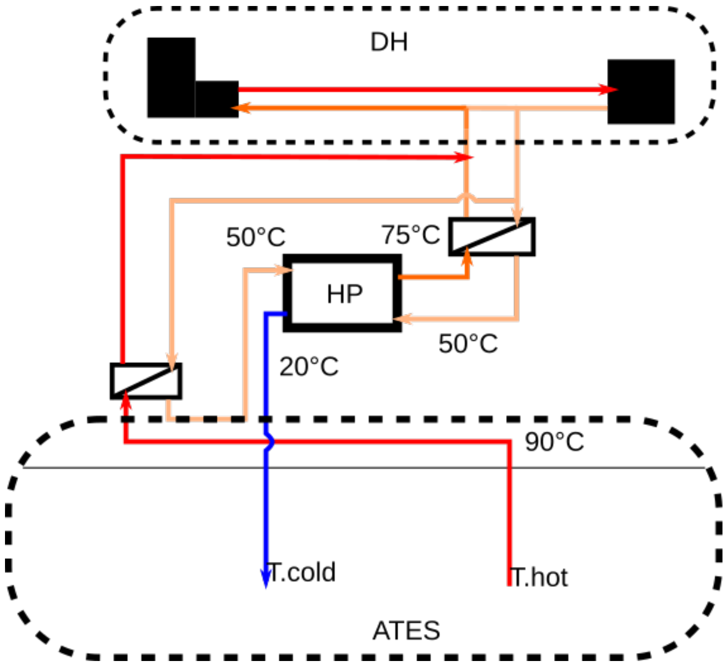
TYPICAL YEARLY CURVE

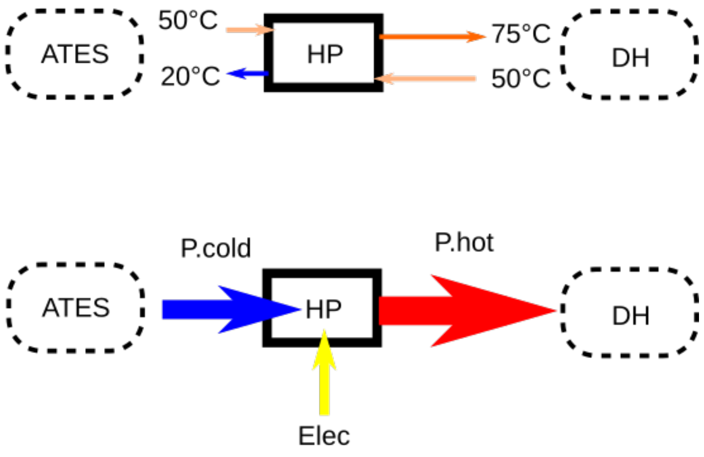


15 years of production

Source: Daniilidis et.al. in Prep

SYSTEM SCHEMATIC

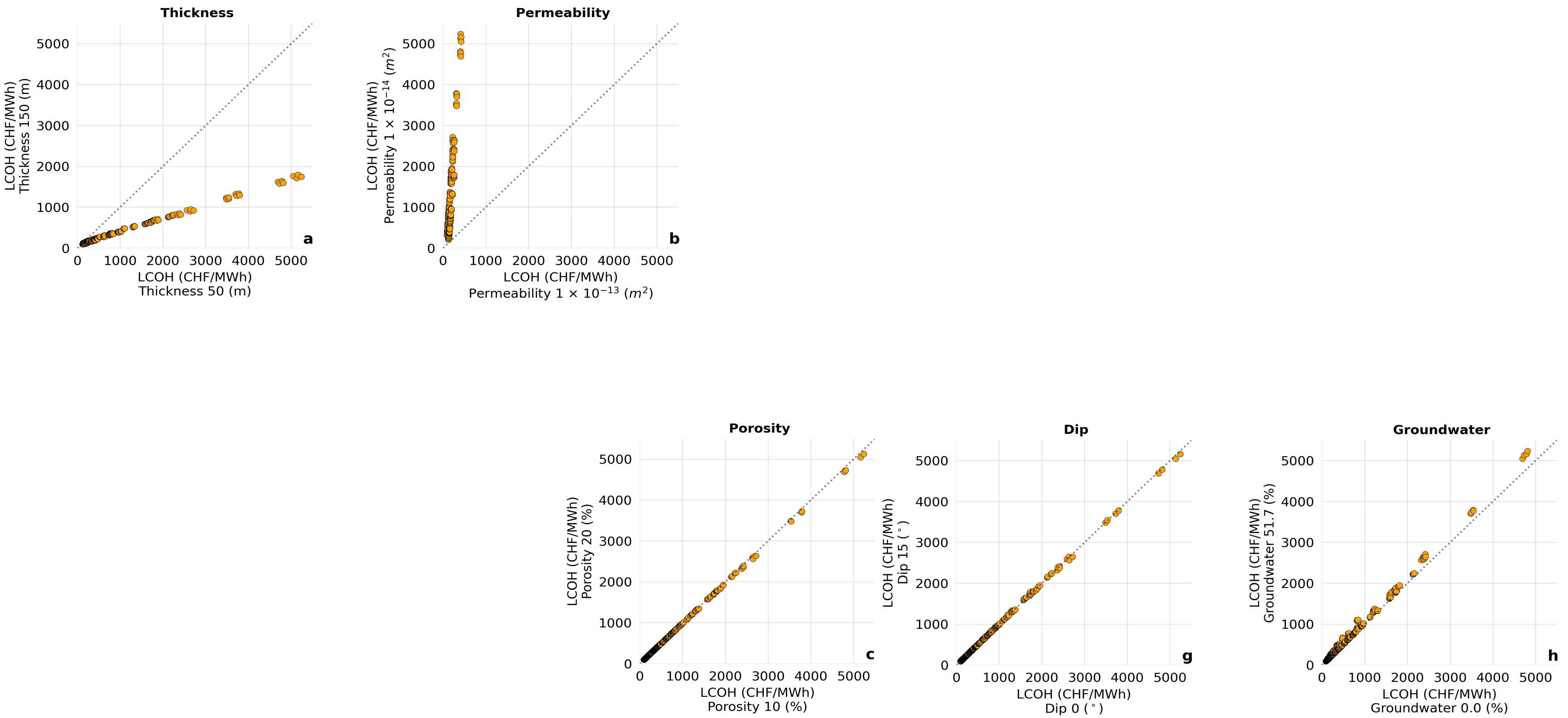




COP = P.hot / Elec
COP -1 = P.cold / Elec

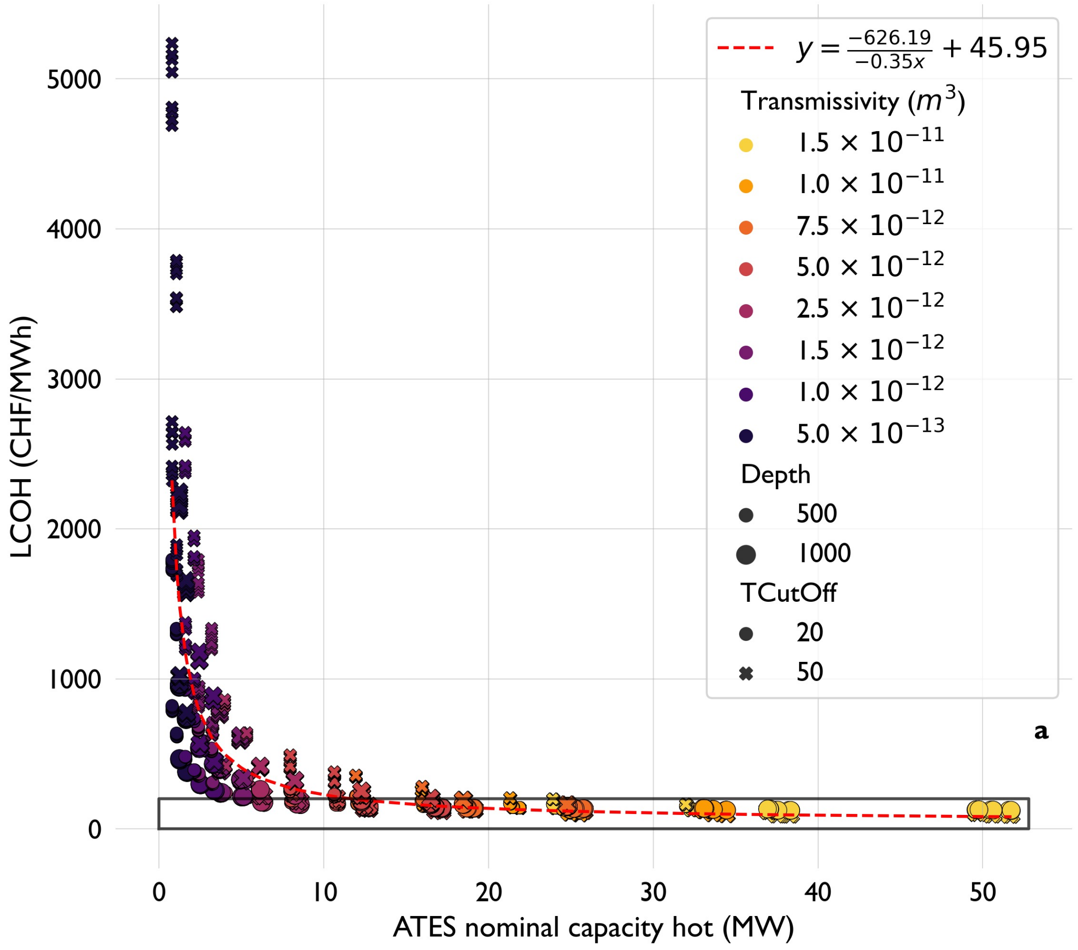
Source: Daniilidis et.al. in Prep

LCOH SENSITIVITY



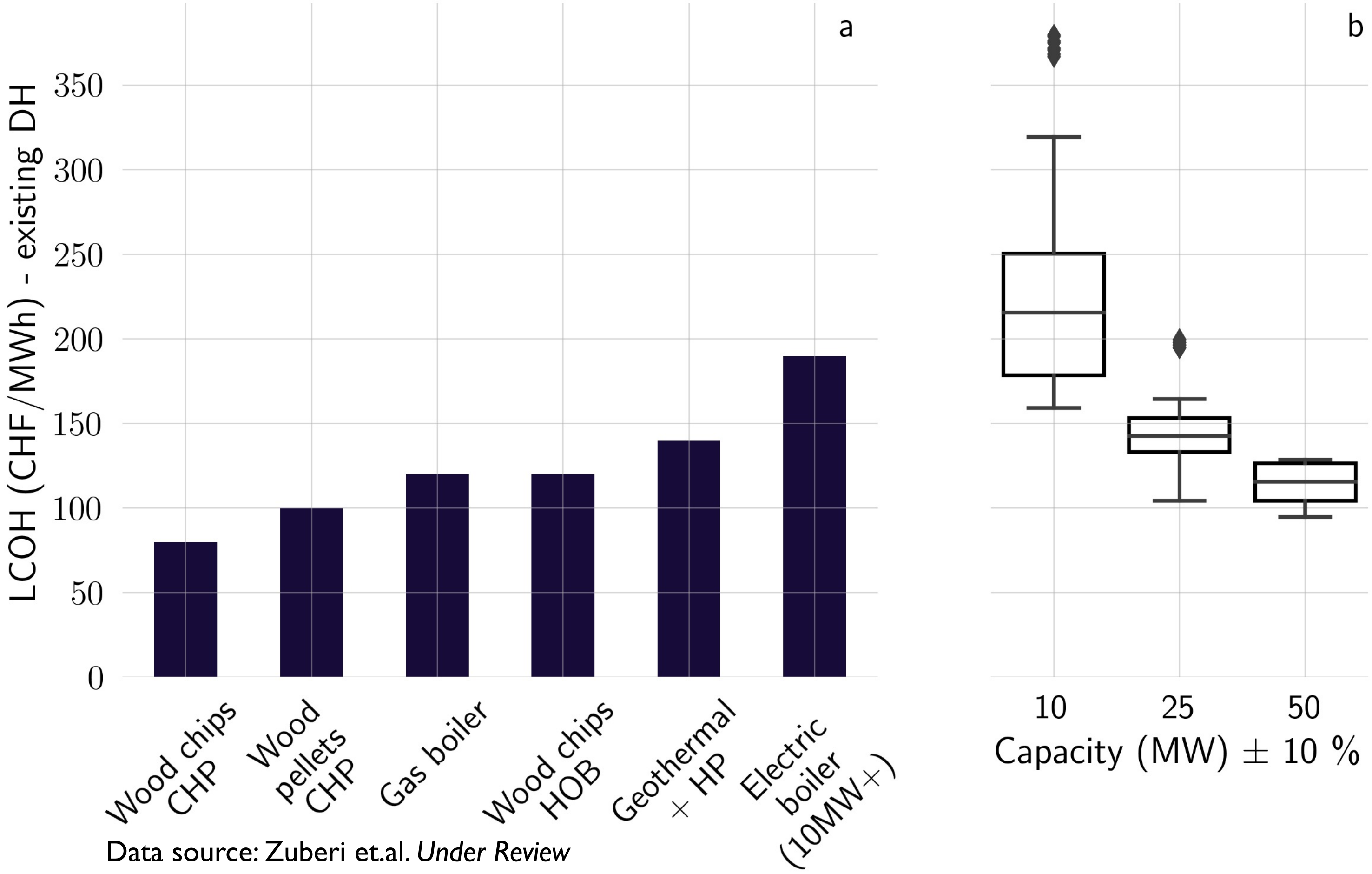
Source: Daniilidis et.al. in Prep

LCOH VS NOMINAL CAPACITY



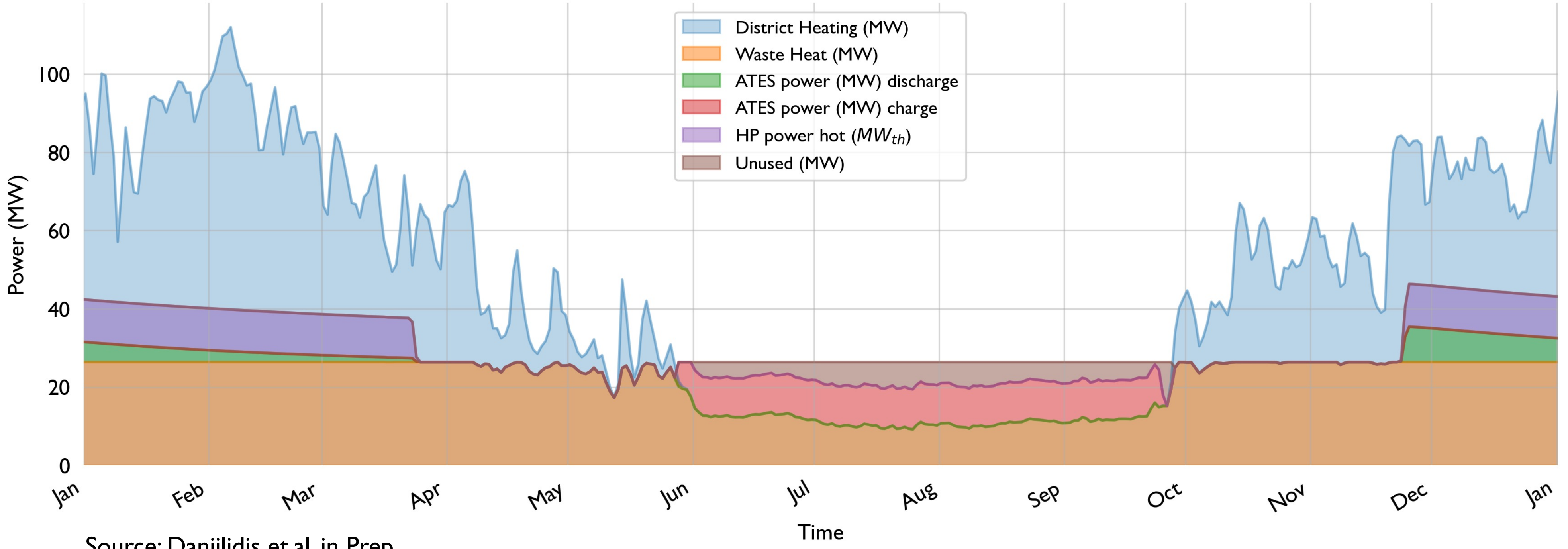
Source: Daniilidis et.al. in Prep

LCOH VS OTHER HEAT SOURCES



Data source: Zuberi et.al. *Under Review*

HT-ATES CONTRIBUTION

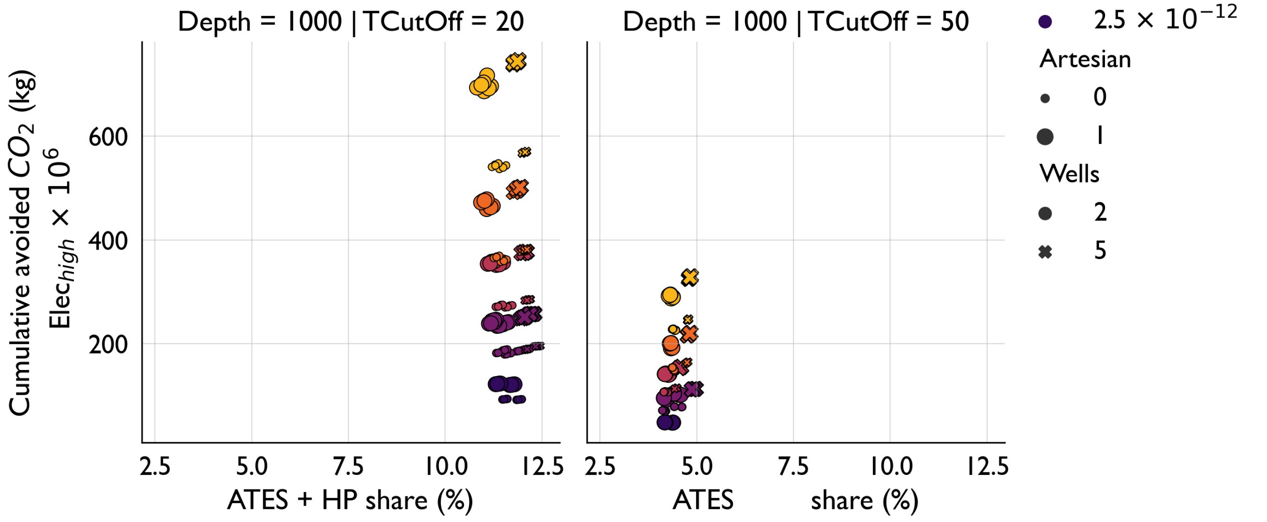


Source: Daniilidis et.al. in Prep

Aquifer thickness of 50 m, a doublet well design, no groundwater, 10% aquifer porosity, 15° dip, cut-off temperature of 20 °C and a depth of 1000 m., well spacing of 141 m.
The unused part of waste heat amounts to 25.6% of the available waste heat during the charging period.

ATES ENERGY SHARE VS AVOIDED CO_2 EMISSIONS

LCOH ≤ 200 CHF/MWh



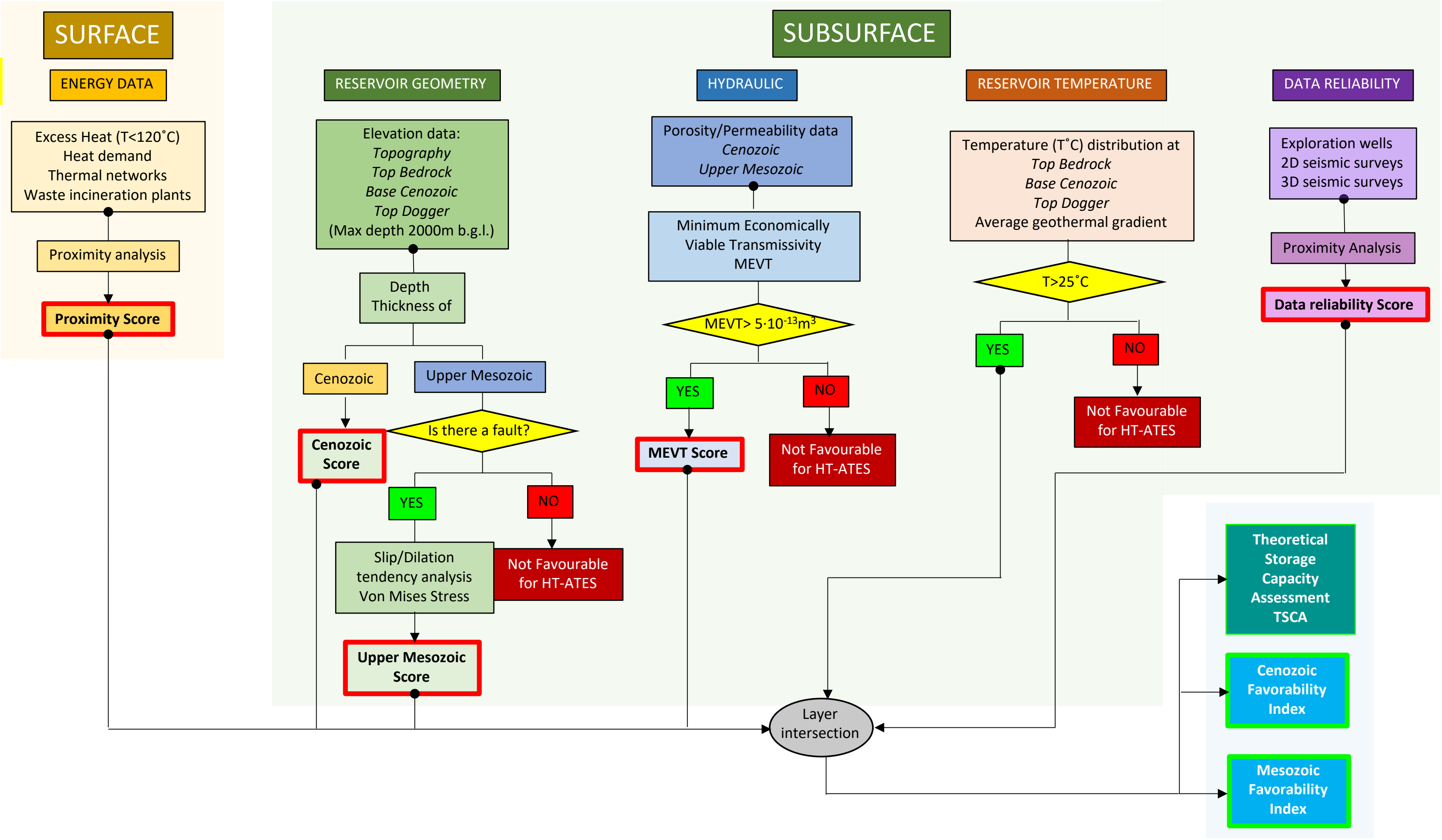
Source: Daniilidis et.al. in Prep

FAVOURABILITY ASSESSMENT FOR HT-ATES IN SWITZERLAND

Based on the concepts of Play Analysis and Spatial Multi-criteria Analysis

Main assumptions:

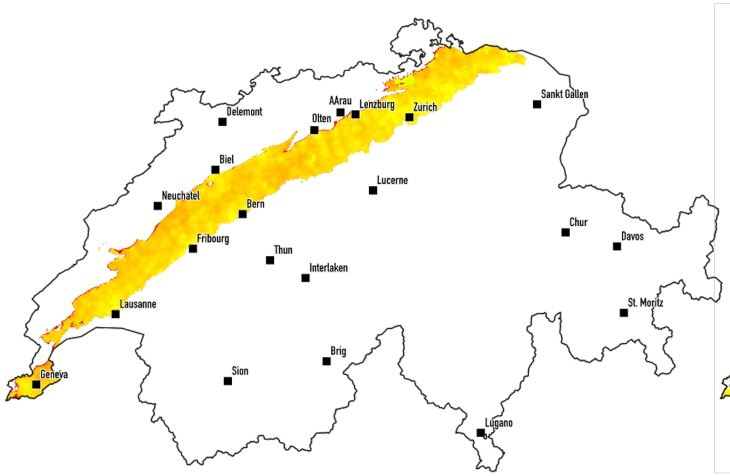
- **2 reservoirs: Cenozoic and Upper Mesozoic**
- **Down to 2000m max**
- **Injection temperature 120°C max**
- **Min temperature reservoir 25°C**
- **Computation of the storage cam**



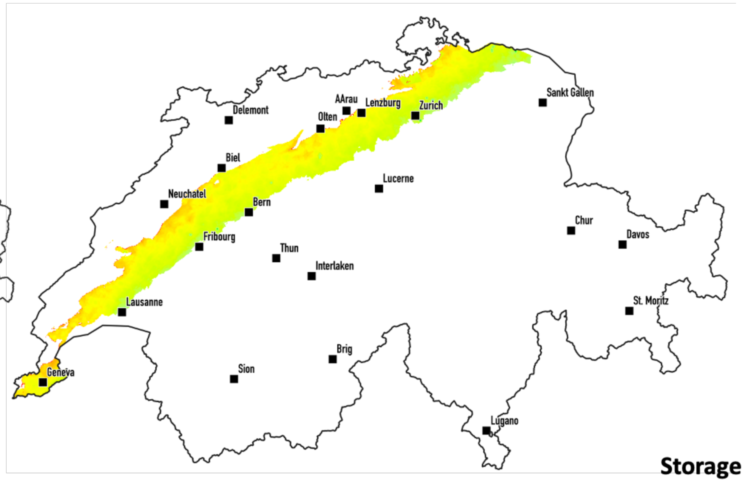
FAVOURABILITY ASSESSMENT FOR HT-ATES IN SWITZERLAND

Favourability Cenozoic

Storage capacity (mean)

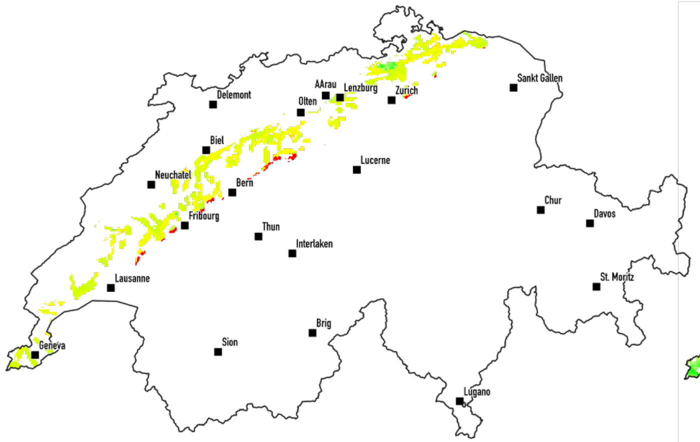


Storage capacity (MAX)

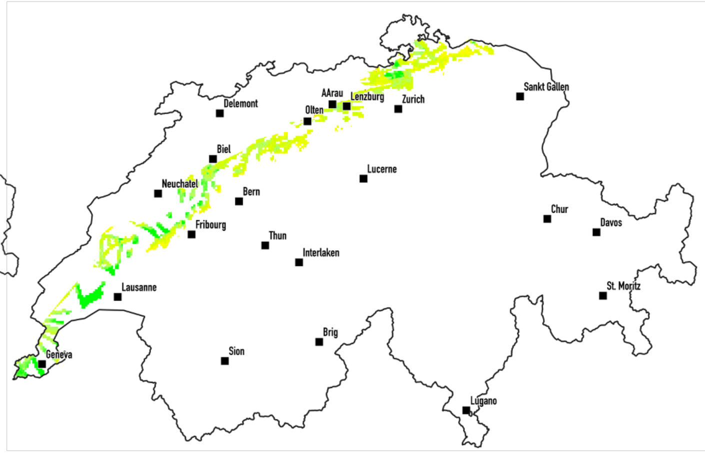


Favourability Mesozoic

Storage capacity (mean)



Storage capacity (MAX)



1 Favourability Score 10

TALKING ABOUT FAVOURABILITY….

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

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

ARE ATES THE BEST SOLUTION?

THE PEOPLE…







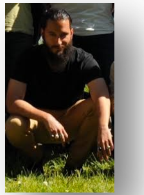




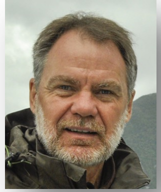










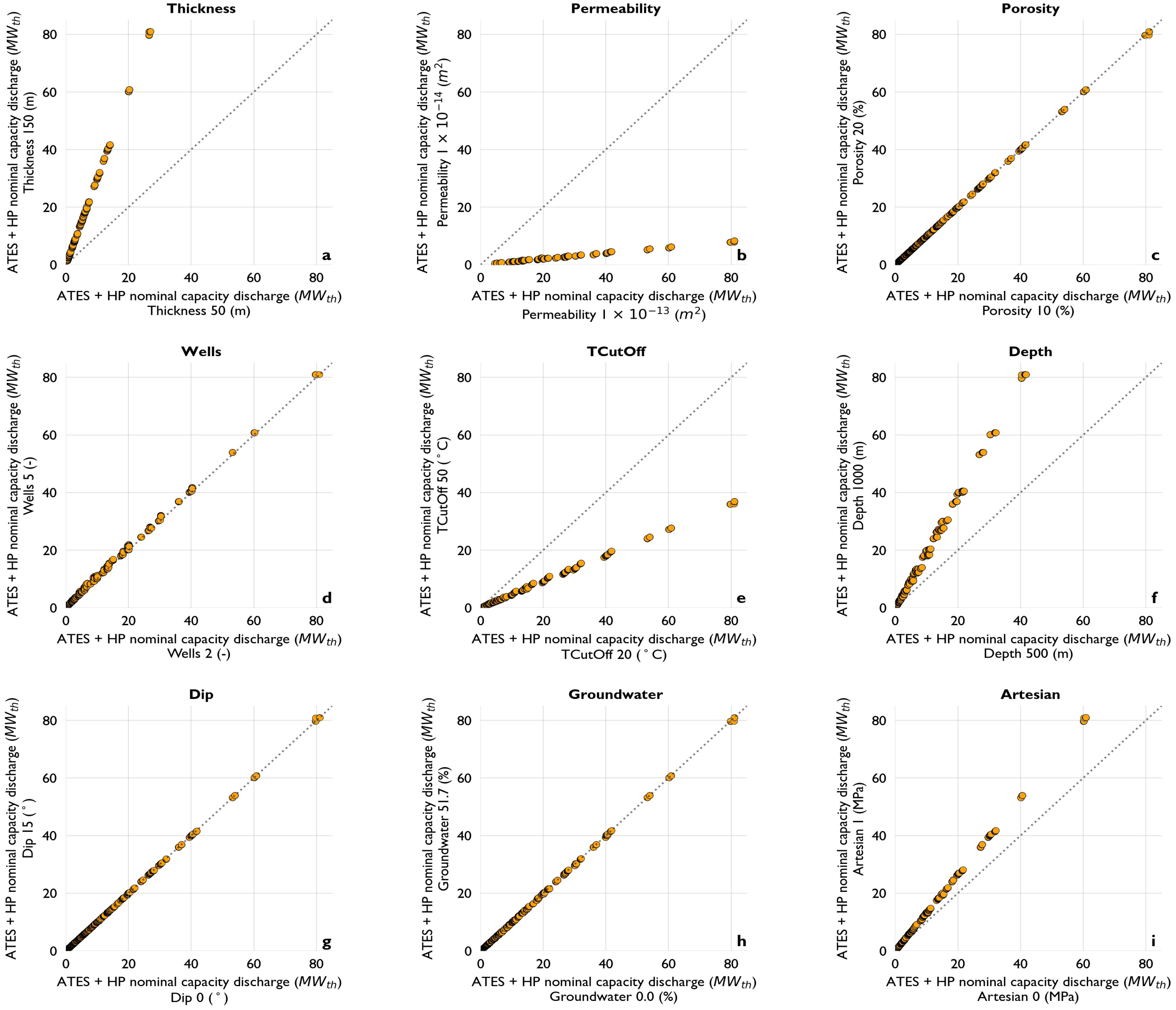
THANK YOU

QUESTIONS?

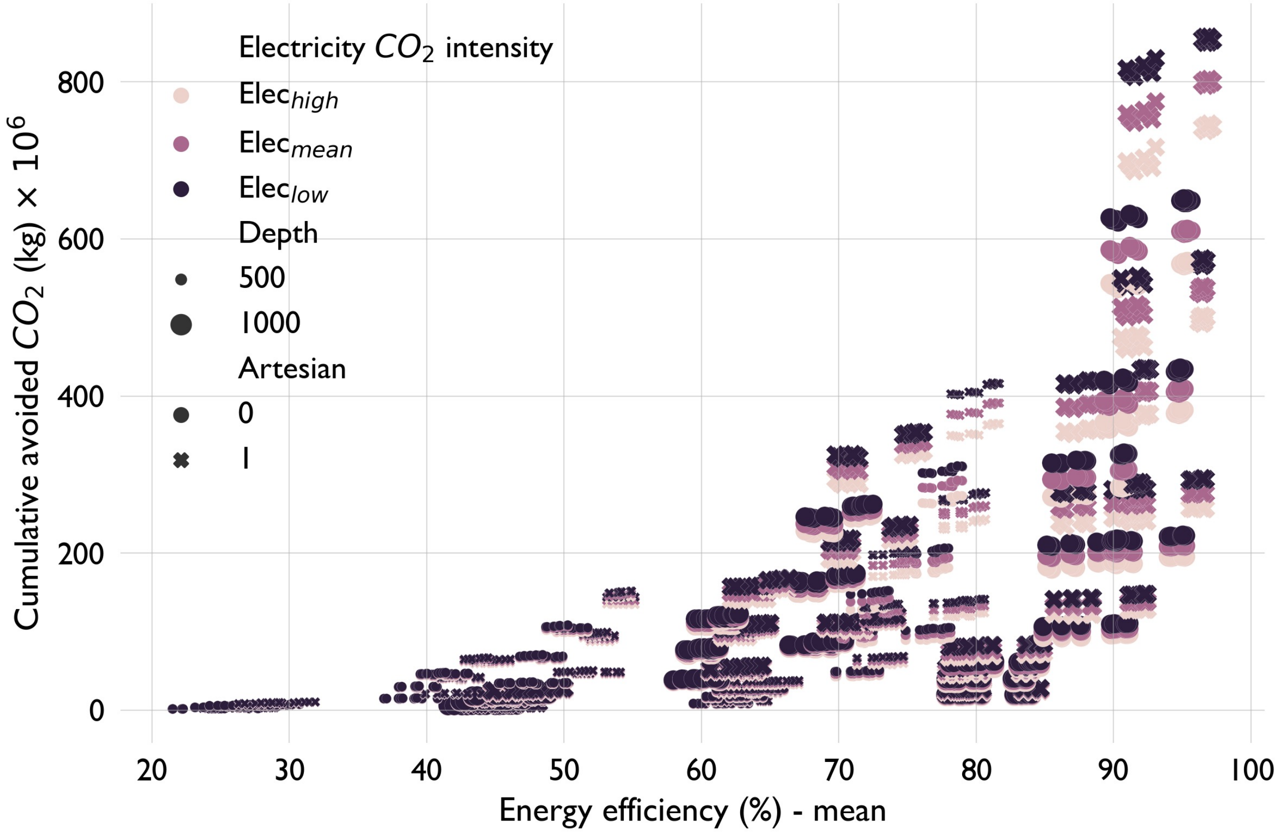
HEATSTORE (170153-4401) is one of nine projects under the GEOTHERMICA – ERA NET Cofund aimed at accelerating the uptake of geothermal energy by 1) advancing and integrating different types of underground thermal energy storage (UTES) in the energy system, 2) providing a means to maximise geothermal heat 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.

This project has been subsidized through the ERANET cofund GEOTHERMICA (Project n. 731117), from the European Commission, RVO (the Netherlands), DETEC (Switzerland), FZJ-PtJ (Germany), ADEME (France), EUDP (Denmark), Rannis (Iceland), VEA (Belgium), FRCT (Portugal), and MINECO (Spain).

CAPACITY SENSITIVITY



AVOIDED CO_2 EMISSIONS



TECHNO-ECONOMIC ANALYSIS

LEVELIZED COST OF HEAT

$$LCOH = \frac{\sum_{n=1}^{n} \frac{CapEx_t + OpEx_t}{(1+r)^t}}{\sum_{n=1}^{n} \frac{E_t}{(1+r)^t}}$$

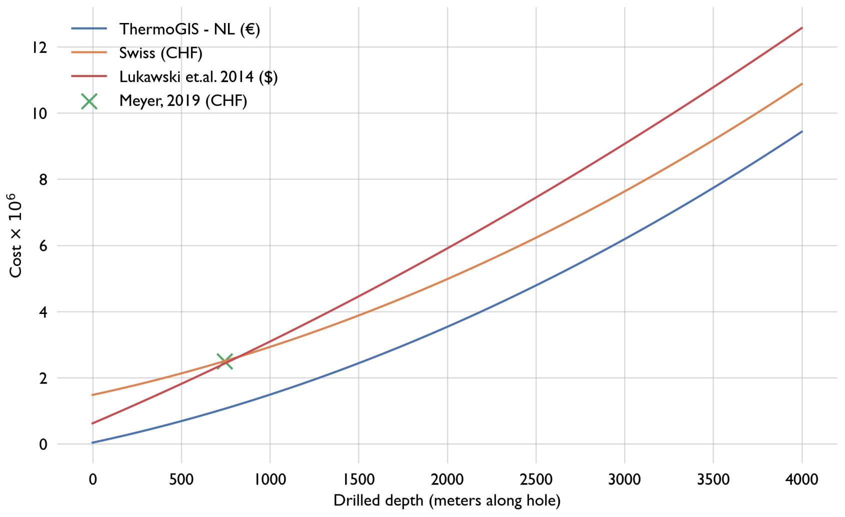
$CapEx_t$: Capital Expenditures at time interval t
$OpEx_t$: Operation Expenditures at time interval t
E_t : Energy generated in time interval t
r : discount rate for period t
t : time interval
n : total number of time intervals

PUMPING POWER

$$P_{pump} = \frac{q\Delta p}{\eta}$$

q : volume flow rate (m^3/s)
Δp : pressure difference (Pa)
η : pump efficiency

DRILLING COSTS



TECHNO-ECONOMIC INPUTS

Variable	Value	Units	Source
Electricity price	120	CHF/MWh	Meyer, 2019
Annual OpEx	3	% of CapEx	Meyer, 2019
Annual discount rate	5	%	
Production pump efficiency	50	%	
Injection pump efficiency	40	%	
Cost of pump	500k	CHF	
Pump replacement	7	years	

HT-ATES SIMULATION INPUTS

Aquifer thickness (m)	Permeability (m²)	Porosity (%)	Wells	Tcutoff (°C)	Depth (m)	Dip (°)	Groundwater hydraulic gradient (%)	Artesian conditions (Mpa)
50	1×10^{-14}	10	Doublet	20	500	0	0	0
100	5×10^{-14}	20	5-spot	50	1000	15	51.7	1
150	1×10^{-13}							