



# Energy From Rocks™

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29th February 2024



*“Sustainable and Cost-Effective Energy Storage Solutions for Europe from Mechanical and Geothermal Energy Technologies”*



SAGE GEOSYSTEMS  
Geothermal everywhere.

**GeoTHERM**  
expo & congress



# *The Challenge & The Opportunity*

- How can we safely and cost-effectively store energy in the subsurface?
- How do we generate electricity from the Earth's heat when we can't rely on interconnected water in the subsurface?
- Can we do this in a sustainable and cost-effective way by utilizing existing oil and gas technology?





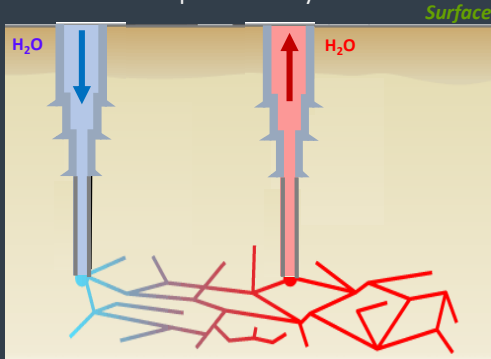
# Hot Dry Rock Technologies

## Enhanced Geothermal Systems

### Open-Loop EGS

fracturing creates an artificial reservoir  
(Fervo / XGS)

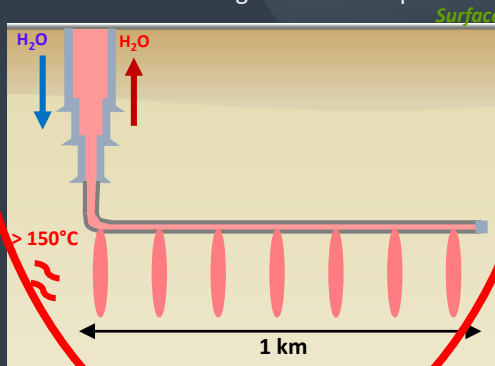
- **Multiple wells:** higher CAPEX/MW
- Fractures must connect across multiple wells
- Requires continuous injection of large volumes of water at high pressure (10'000 to 15'000 PSI)
- Fluid must disperse evenly across fractures



## Geopressed Geothermal Systems

### Sage Geosystems GGS Mechanical Energy Storage Geothermal Energy Production

- **Single well:** less CAPEX/MW
- Off-the-shelf oil & gas drilling technology
- Gravity fractures are additive, injection pressures < 1'000 PSI
- Near-zero 'voidage' in managed system
- Fluid dispersion is not material to design
- Scalable from storage to baseload power

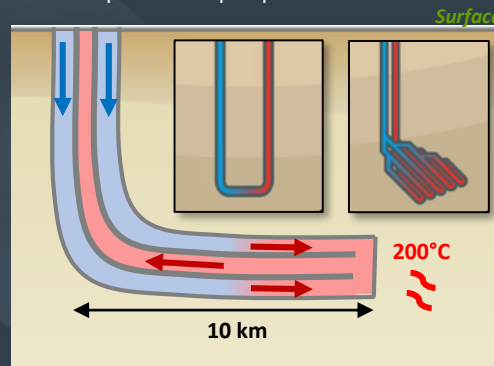


## Advanced Geothermal Systems

### Closed-Loop

wells form a "radiator" shape underground  
(Eavor / GreenFire)

- **Single & Multiple wells:** requires tens of km of well length for sufficient surface area
- New technology for complex directional drilling and well completions
- No connectivity with surrounding rock, conduction heating only
- Lower power output per well than EGS





# Energy Storage

- **Pumped Storage Hydropower** accounts for ~93% of energy storage worldwide

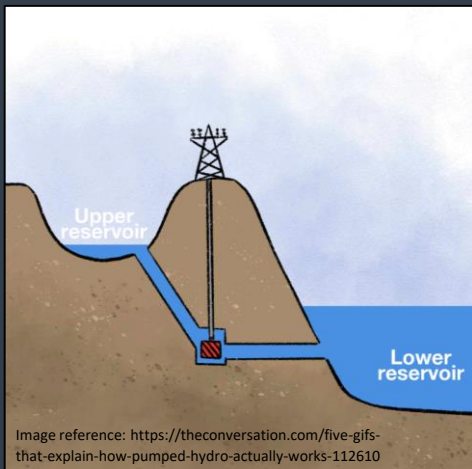


Image reference: <https://theconversation.com/five-gifs-that-explain-how-pumped-hydro-actually-works-112610>



- EarthStore™ = ‘upside down’ Pumped Hydro
  - Pump water into an artificial reservoir created in tight host rock in the subsurface
  - Store it for a period of hours+
  - Reopen the borehole, generating energy from the pressurised water that jettisons to the surface.
- Discharge times of 3 hours and up to 18+
  - Can be used for daily, weekly, or even seasonal storage.
- Can be paired with existing wind and solar project to create 24/7 baseload power
- Uses tested oil and gas technology that’s ready to be scaled now
- Cheaper than PSH

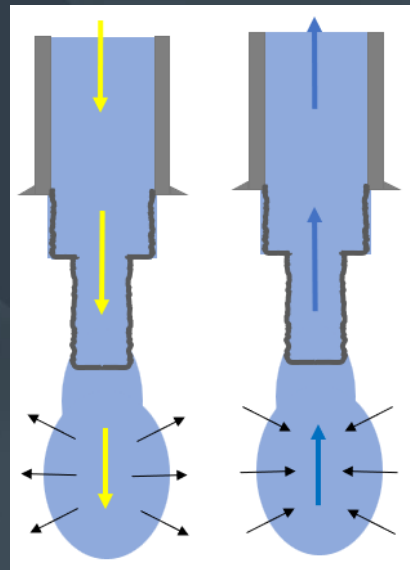
## Single Cased Well

3MW per well

70-75% Efficiency

Step 1

Step 2

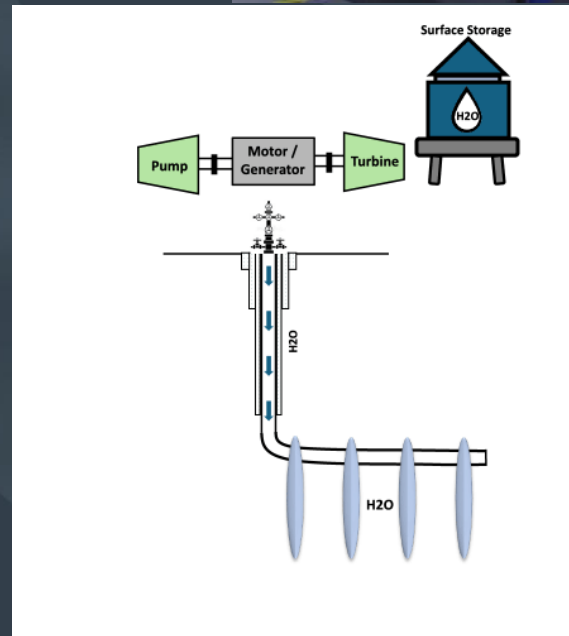
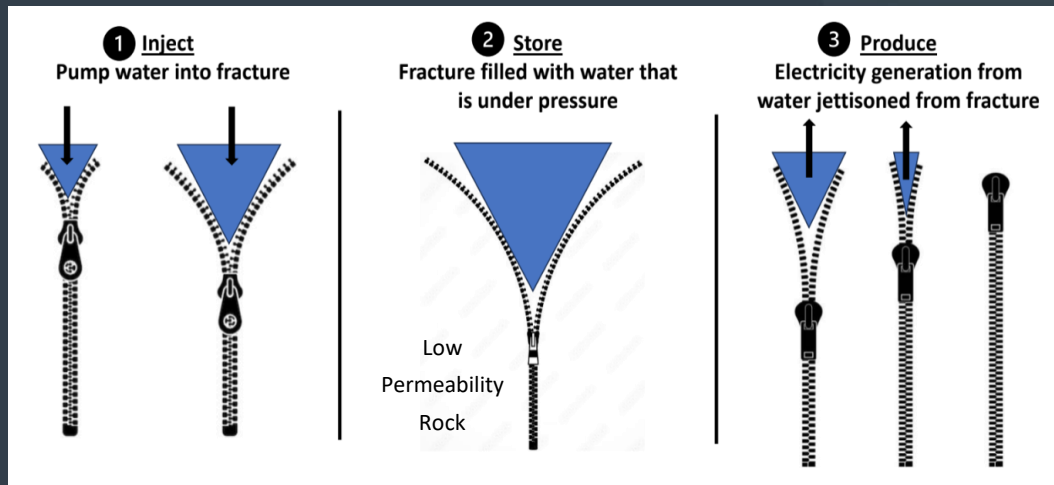


**Storage Energy == Pressure**  
(Pelton turbine generates electricity)



# Downward-Oriented Fractures

Fractures open from the top down and close from the bottom up (like a zipper) and with depth comes more force/energy



HeatRoot™ is a patented, proprietary gravity fracturing technology which orients fractures downward toward hotter rock

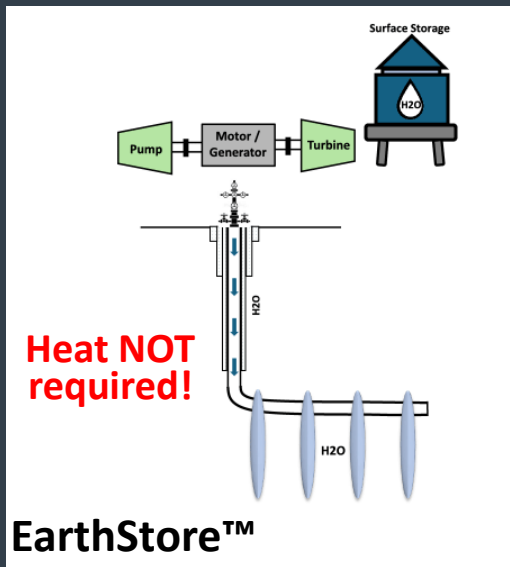




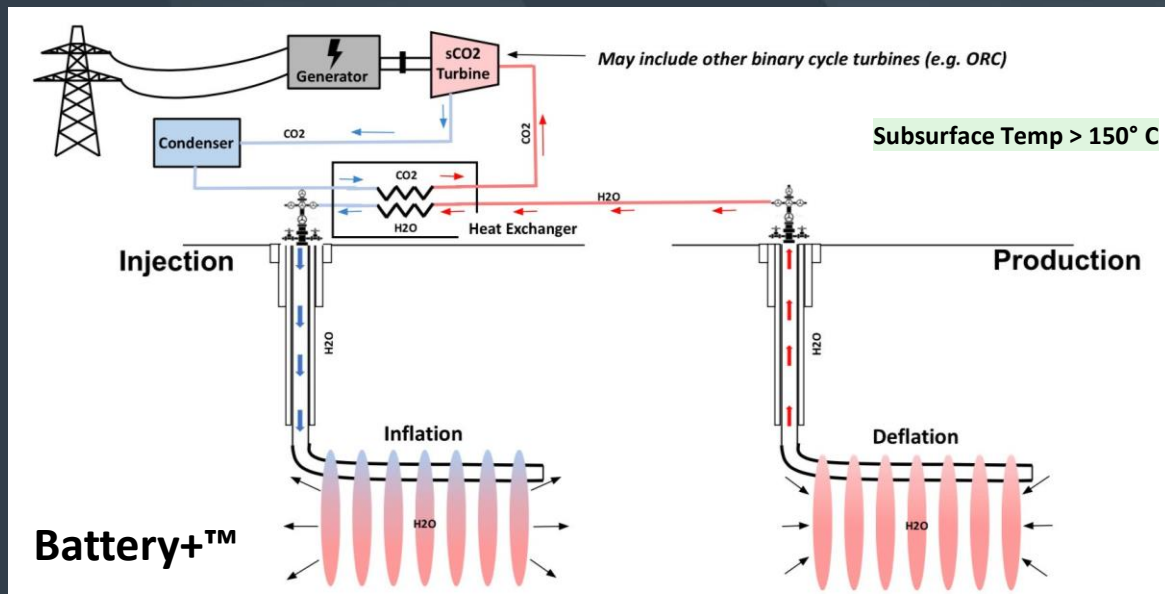
# One Technology, Two Solutions

## Mechanical Storage

Energy = Pressure



## Geothermal Power Generation = Heat + Pressure

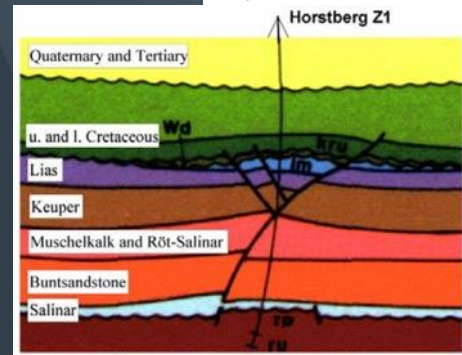


Zero carbon: By utilizing renewables to power the system, you can make solar baseload

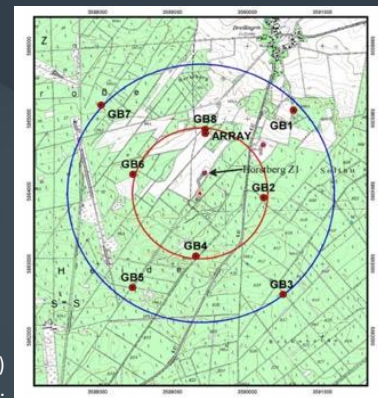


# Comparable Geopressured Tests

- **GeneSys Project (2005/2006) – Lower Saxony Basin**
  - **Horstberg-Z1: Abandoned natural gas well in Lower Saxony**
  - Used a **single borehole** to recover hot water for direct use from tight sedimentary rock
  - Injected water in a sandstone layer of the Bunter formation at a **depth of 3'800m** by **injecting more than 20'000 m<sup>3</sup> of water at flow rates up to 50 litre/sec** and at a wellhead pressure of about 330 bar
  - A comprehensive geophysical programme detected only 11 micro seismic events, none of which could be reliably isolated to the borehole operations
- **This research is directly comparable to EarthStore™ and Battery+™**
  - GeneSys verified the HeatCycle™ inflation/deflation process to generate baseload power and supports the results from Sage Geosystem's Starr County well tests



Schematic cross-section of the Fassberg inversion-structure and the relative location of the well (from Baldschuhn et al., 1991).



Locations of the seismic stations (red symbols) and the array relative to the well Horstberg-Z1.



# Induced Seismicity?

There is a low risk of induced seismicity with these gravity fracturing technologies

- **Low-rates** - Use low pump rates to allow heavy frac fluid to work through gravity fracturing.
- **Zero voidage** – Once the frac network is created, very little fluid is added or subtracted during operations.
- **Avoid natural faults/fractures** – Operate in low permeability rock and avoid the high permeability of natural faults/fractures, a source of induced seismicity.
- **Small lateral reach** - Single well EGS fracture network has a smaller lateral extent as compared to 2-well EGS.
- **Utilize small rig pumps** - Rig pumps are used for fracturing operations versus a traditional frac fleet.

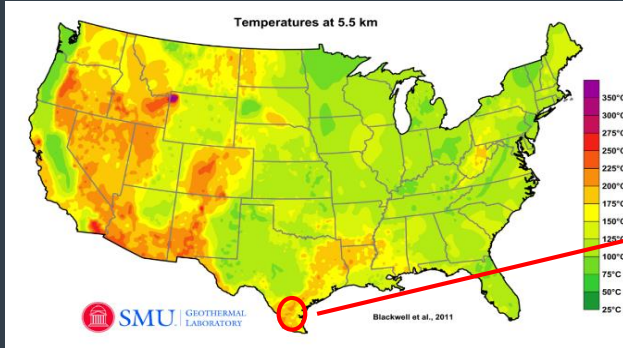
## Initial Pilot project test well

- Since Sept. 2021 four seismicity monitoring stations installed near Sage's Starr County test well (led University of Texas / Bureau of Economic Geology)
- We do not expect any induced seismicity from operations, but measure it on all projects to demonstrate that they are not causing earthquakes or tremors
- **Monitoring sites installed 2 months prior to commencement of testing**
- In the 4 months of testing, **no seismic events were recorded** related to either HeatRoot™ stimulation operations or subsequent pump-in/flowback operations





# Field Testing: Starr County



Re-enter gas exploration well



Create fracture



Testing performed in Starr County, TX well from November '21 to April '23

Testing in 2022 and 2023



Water Storage 2023

M. Carter 728209  
+DRC 1207-308

P&Ad MECHANICAL WELL SKETCH  
JFB Heard #1  
Exploration

Lat 28° 34' 34.8040"  
Long 98° 34' 01.8664"  
P&Ad 12/09

CASING DETAIL:

GRD	DEPTH	SIZE	WYPT	GRADE	BURST	CON	LAB	CON	LAB	DRIFT	IS	WELLET	CEMENT	HOUL	REV	BY	DATE
Surface	0-2500	10	6 1/2	250	5045	1410	87C	14.822	15.010				1700 sa	25	13.0pg	WBM	TOC = surface
Production	0-7500	10-34	65	P-10	6700	6480	97D2M-A	10.028	10.682	1100			1400 sa	14.54	16.0pg	TOC = 100%	Ramp plug, 11 3/8 CBM
liner	7500-11504	9-58	83 S	P-10			Hydr 8103		8.535				303 sa	10-40	16.0pg	TOC = 100%	16.5 CBM cell TOC = TOL

**Abandoned**

RECEIVED  
RRC OF TEXAS  
JAN 06 2010

O&G  
CORPUS CHRISTI TX

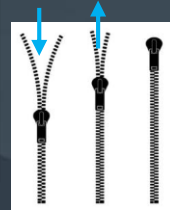
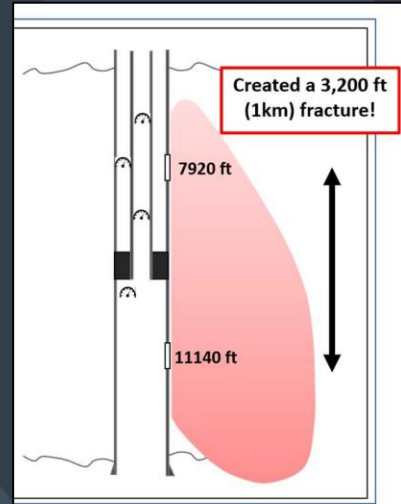
Comments:  
Dry hole  
Left hole full of 9.5 ppg WBM from 2540' to surface



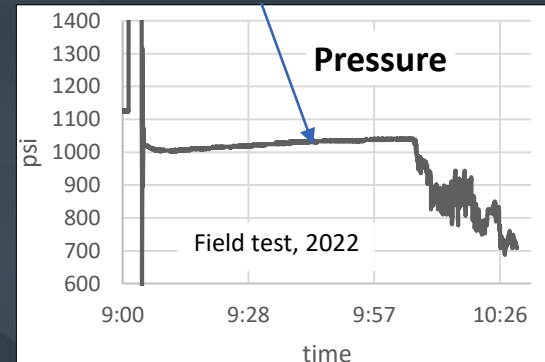
# Field Test #1 - 2022

- Demonstrated Single well EGS
  - Created a HeatRoot™ downward-oriented fracturing
  - Used tight rock with low permeability (target <10 mD)
  - Tested multiple scenarios: Circulated bottom to top; Circulated top to bottom; ‘Huff-and-Puff’ (inflation then deflation) worked best
  - Cycling the fracture network using pump-in/flowback technique decreased short-circuiting and reduced frictional losses
- Carefully managed reservoir pressure is key - The system must stay pressurised and constantly monitored, operating at fracture opening pressure.
- Induced seismicity - There was no induced seismicity detected during fracturing and subsequent pumping operations.

<https://texnet.cpa.Texas.gov/>



No Leak-off in Mudstone





# Field Test #2 - 2023

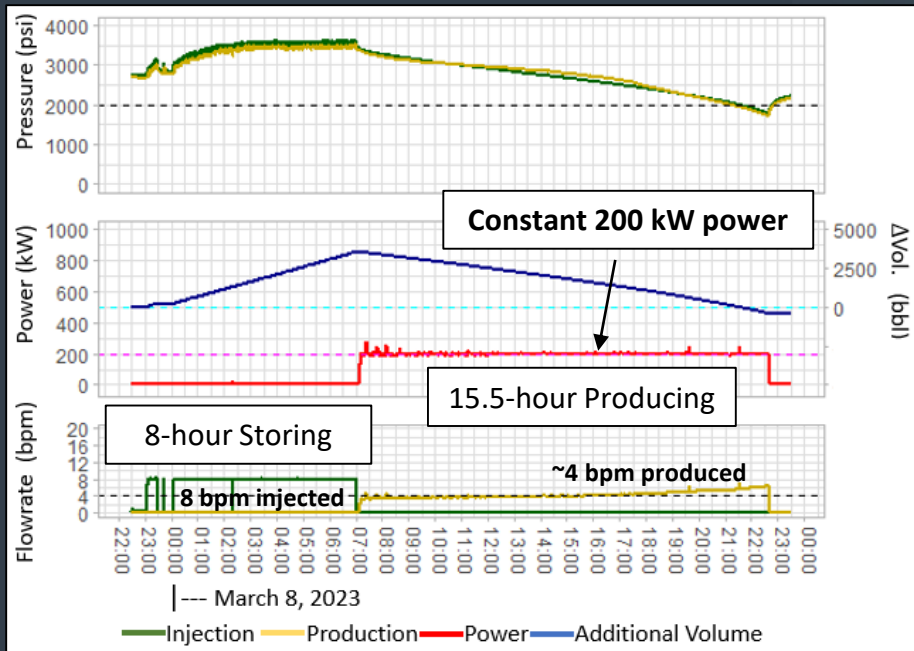
- Initial injection of water to pressurise the reservoir (~30k barrels)
- Energy Storage: Tested water injection for varying lengths of time
- Energy Production: Produced pressurised water
  - Power output == Pressure \* Flow rate
  - Long duration production: 200kW for more than 18 hours
  - Rapid flow rate: peak power production of up to 1 MW [limited by surface piping]
- Stopped production when wellhead pressure reached 2000 psi to maintain reservoir pressure



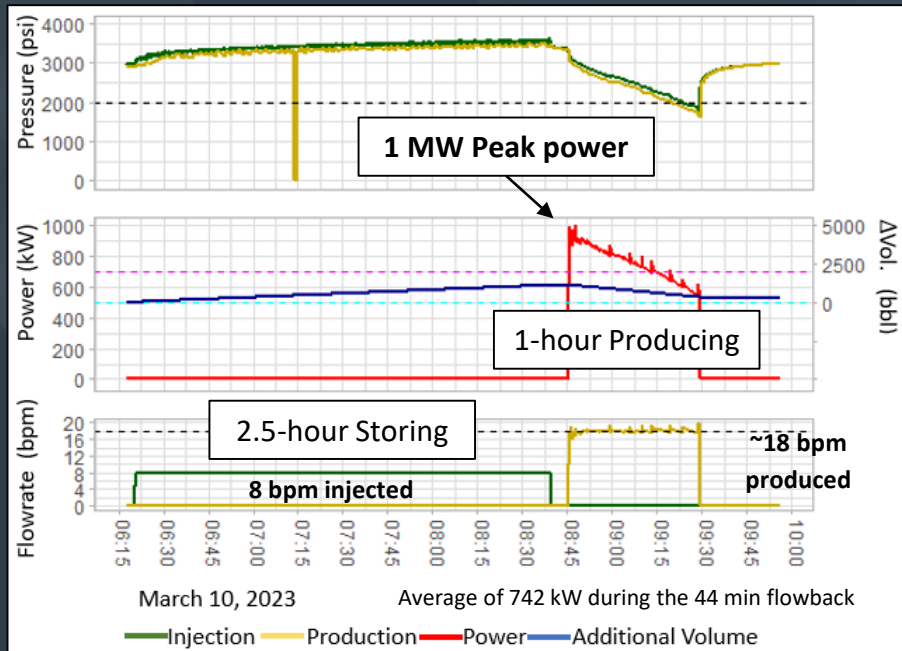


# Long-Duration OR Load-Following Storage

Long-duration  
(16 hours production)

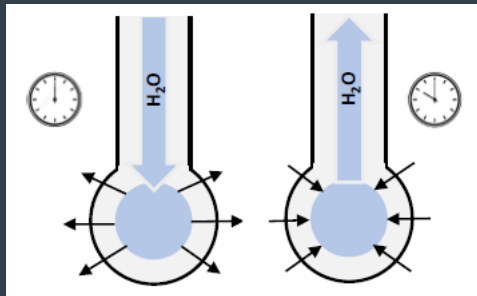


Load-following  
(push the limits - release everything in one hour)

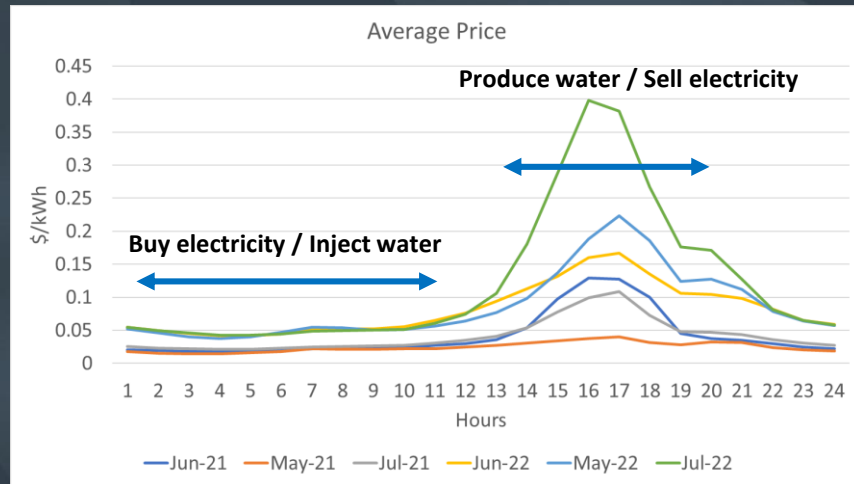




# Energy Storage Paired with Renewables



## Mechanical Storage



+ Solar



+ Wind Farm -> Arbitrage Scenarios

## = 24/7 Baseload Power



# Applicability to geothermal

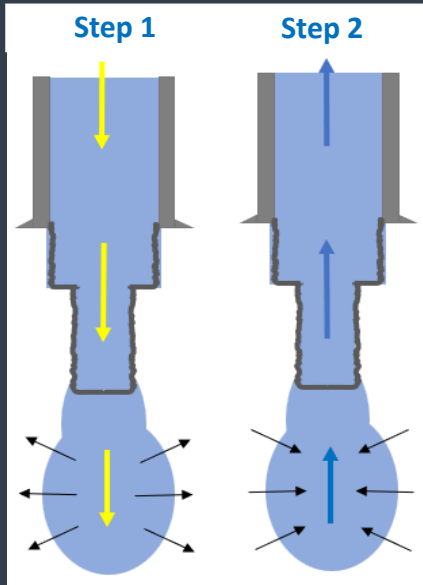
## EarthStore™ = Mechanical Storage

3MW per well  
70-75% Efficiency

Single Cased Well

Storage Energy  
==  
Pressure

(Pelton turbine generates electricity)



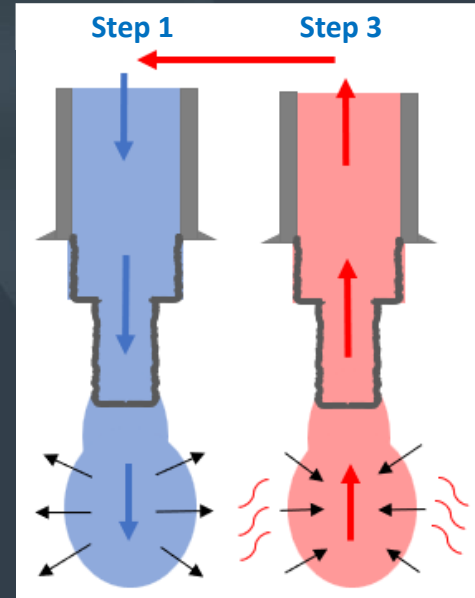
## Battery+™ = Geothermal Power Generation

>3MW per well  
2x Power Output

Target Depth > 150° C  
Single Cased Well

Geothermal Energy  
==  
Heat + Pressure

(Baseload Energy)



**Step 2** Fluid is heated from hot dry rock formation



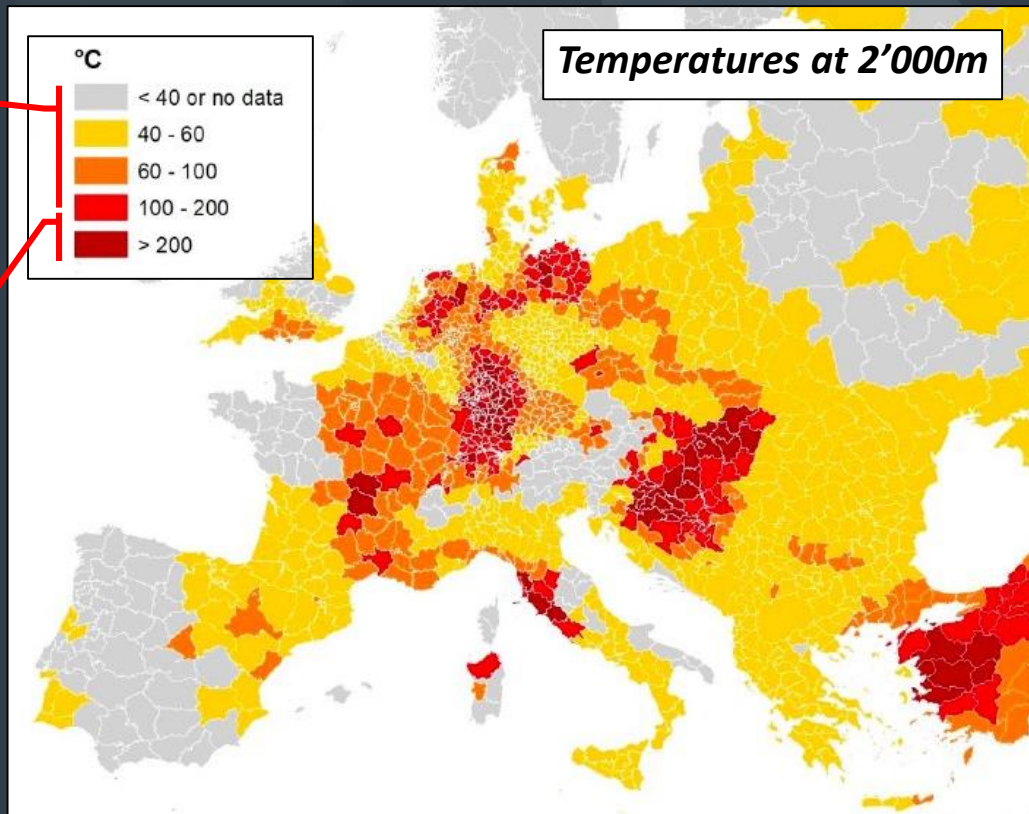
# Deployability

## Mechanical Storage

- Not geographically constrained
- No temperature considerations

## Geothermal Power Generation (>150° C)

- Available in Europe
- 2x the power output



Source: Identified geothermal heat resources by temperature at 2000 m depth by NUTS3 region. Atlas of Geothermal Resources in Europe.

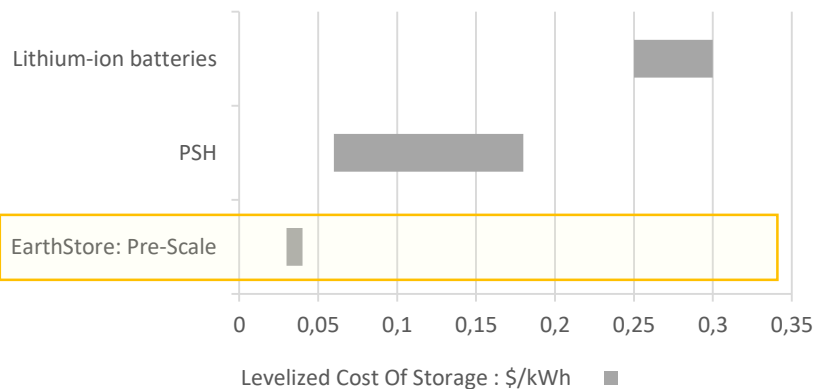


# Scalability

- Utilize existing oil and gas equipment and technologies
- **Not geographically constrained:** Can be adapted to a broad range of subsurface conditions
- Pair with intermittent renewables for 24/7 baseload energy
- Small surface footprint
- Limited environmental impact
- Can potentially re-purpose existing wells
- Long life assets with minimal-to-no degradation
- Able to scale from large to small



## LCOS: Full lifetime cost of ownership / Annual usable kWh

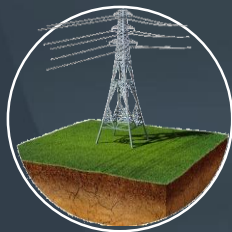




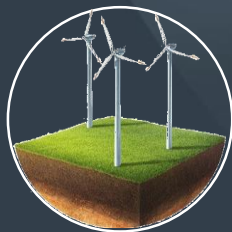
# Applicability

Hot Dry Rock  
GeoStorage for  
the Industrial,  
Renewable,  
Power and  
Energy Sectors

Transmission  
System  
Operators



Wind Farms



Energy Suppliers



Oil & Gas  
Operators



Geothermal  
operators



Ground PV



Energy From Rocks™

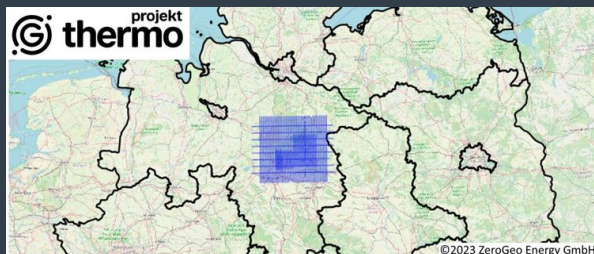


# Our Hot Dry Rock Projects



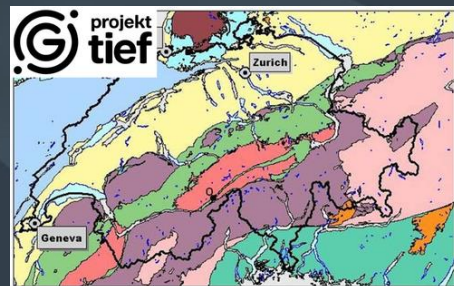
## Energy Storage & Baseload green electricity

- Applications for two geothermal permits in Lower Saxony
- Completed a 5'000 km<sup>2</sup> Air-FTG Survey in Lower Saxony from November 2022 to February 2023
  - The first time Full Tensor Gravity has been acquired in Europe for geothermal exploration
- OMV sponsored the first two phases of Projekt THERMO (FTG and permit applications)



## Energy Storage & Baseload green electricity

- Swiss Kanton for one geothermal permit
- Negotiated access to 3D seismic & geological database over permit area
- Swiss power generator assessing thermodynamic potential of proposed Hot Dry Rock system
- Swiss industrial offtaker to decarbonize their power and heat supply

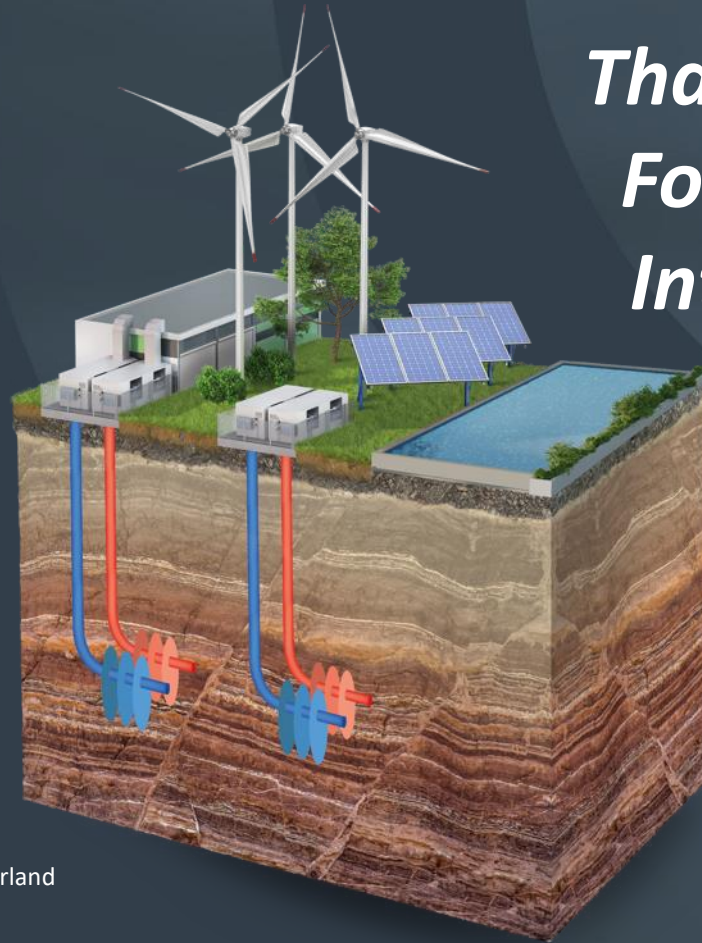




# Energy From Rocks™




*Thank You  
For Your  
Interest*



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