

Thermal Stimulation of Geologic Hydrogen

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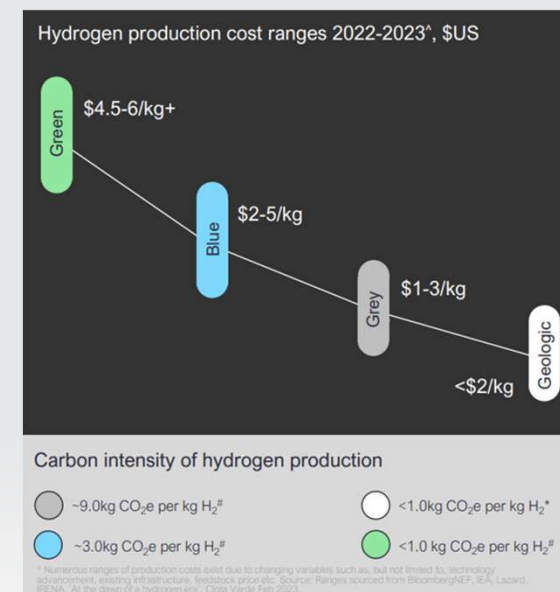


Achieving Cost Parity with Grey Hydrogen at Scale

Win on **cost and energy efficiency**- unlocking a massive market

Only **natural and stimulated hydrogen** are energy positive and therefore suitable for fuel

Method	Feedstock energy (kWhr/kg H ₂)	Electricity (kWh/kg H ₂)	Total Energy (kWh/kg H ₂)	Usable Energy Gain (kWhr/kg H ₂)	CO ₂ Intensity (kg CO ₂ -eq / kg H ₂)	Est. Cost (\$ / kg H ₂)	Key Limitation
Grey H ₂ (SMR)	37.7	~10	~48	-14.4	>10	1-2	CO ₂ emissions unabated
Blue H ₂ (SMR + CCS)	37.7	12-15	~49-53	-16.4	2-4	2-3	Limited CCS capacity & cost
Green H ₂ Electrolysis	N/A	~55	~55	-21.67	0	3-6	High power cost & infrastructure
Natural H ₂ (Geologic)	N/A	N/A	N/A	33.3	0	<1 (est.)	Extremely Rare
MSSH™ (Manufactured)	N/A	6 - 15	6 - 15	18-27*	<< 1	1.5	Reaction optimization & scale up



* Range depends on richness of ferrous iron and reaction exothermicity

Stimulated Hydrogen Demonstrated



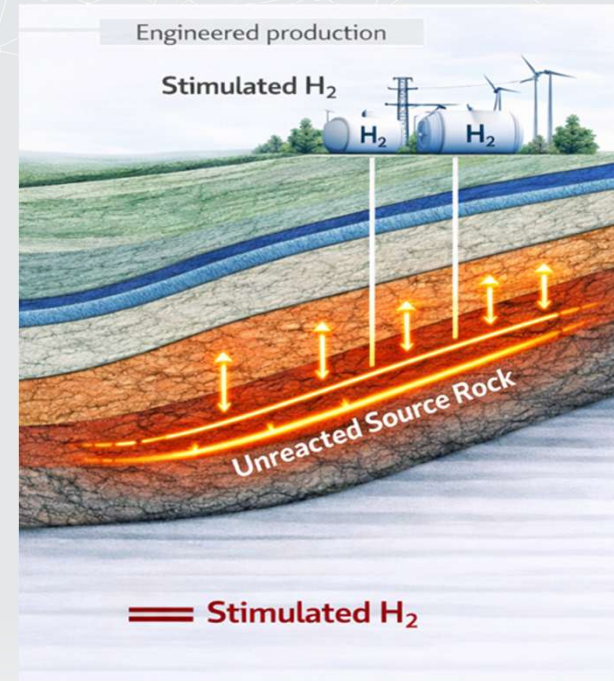
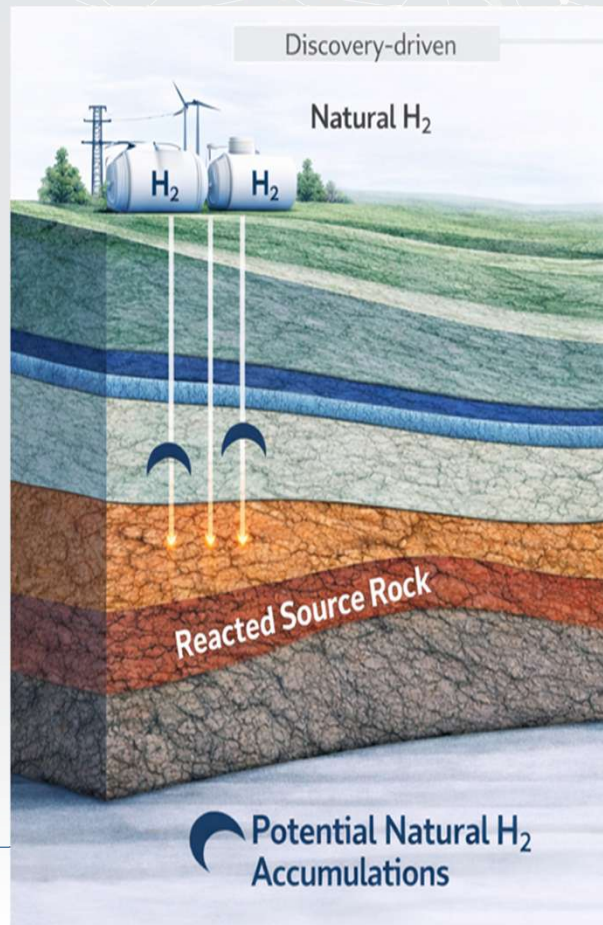
Natural hydrogen accumulations are exceedingly rare:

Only one on Earth **producing** free-gas in Mali at 0.3-3BOE /day

And one deep well in France producing H₂ dissolved in water

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Ferrous iron deposits and mines are present across the world: >15 wt% requires prospecting at target depth

Production scalable 30k-1,000,000 tonnes / year

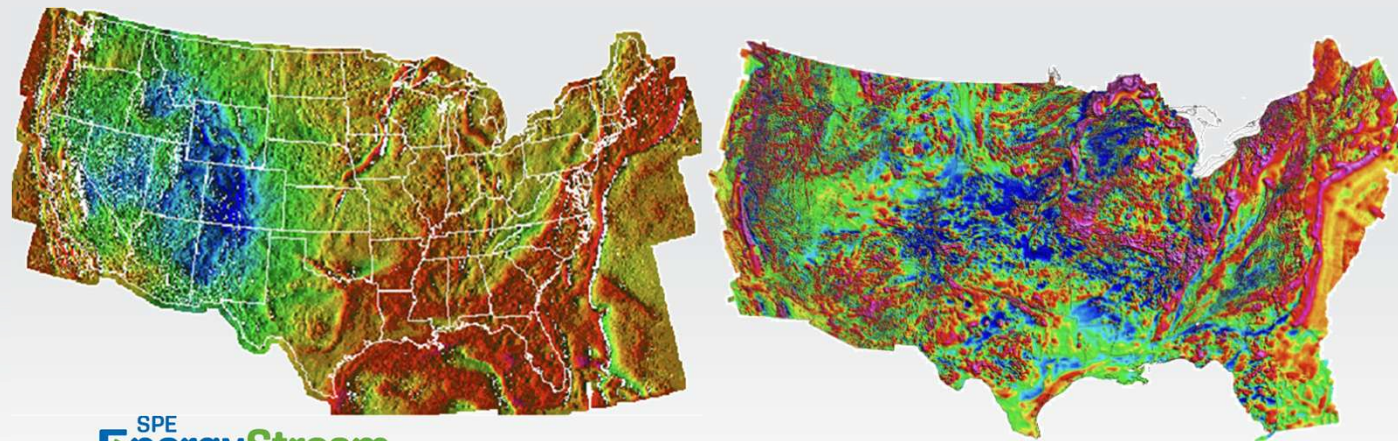
Multiple examples in low H₂-potential organic analogues using the same thermal stimulation method e.g. Experimental Scheme 9874 and oilshale projects in Colorado

Public Data for Prospecting for Hydrogen



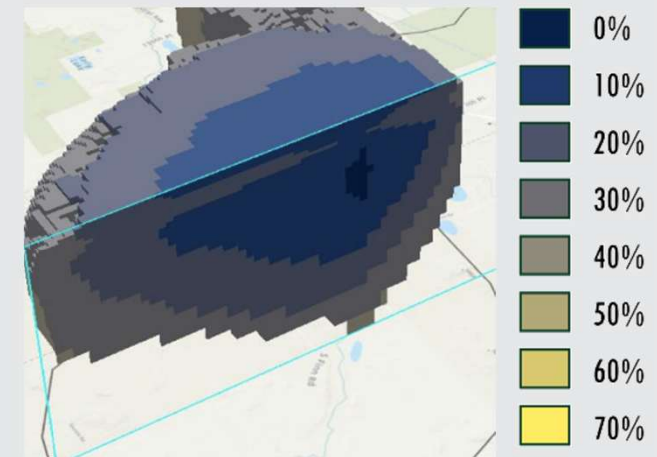
Aerial magnetic and gravimetric surveys can be used to coarsely prospect for source rock

Modelling can indicate the depth, extent, fractional conversion, but the results are non-unique and require verification via Hydrogen production and core analysis



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Depth and percent serpentinization can be inferred from public data

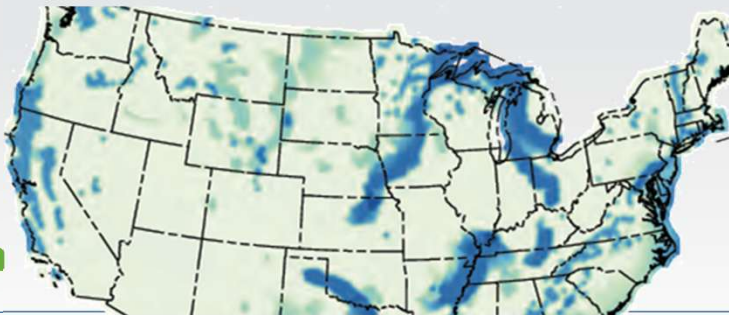
Timeline of Unique Development



- Historically proven heater technology for >80-years (tonnes/day 1940-1960)
- First of its kind application for geology
 - Laboratory data for >60-years
 - Next generation heaters for 5-10-years
- First of its kind surface handling
 - Existing individual components utilized in a novel way
- Early-stage commercial application of surface prospecting

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Subsurface Heating: Built on Decades of Experience

Hydrocarbons

Bitumen Upgrading

Svenska Skifferolie Aktiebolaget and Husky use heaters to upgrade bitumen in Sweden & California

Exxon Oil Shales

Exxon prepares for an oil shales project in Colorado

Shell In-Situ Oil Shale

Royal Dutch Shell pilots in-situ oil-shale and bitumen upgrading in Canada & Colorado

1940-50's

1960-2020's

1970-80's

2010-2025

1990-2010's

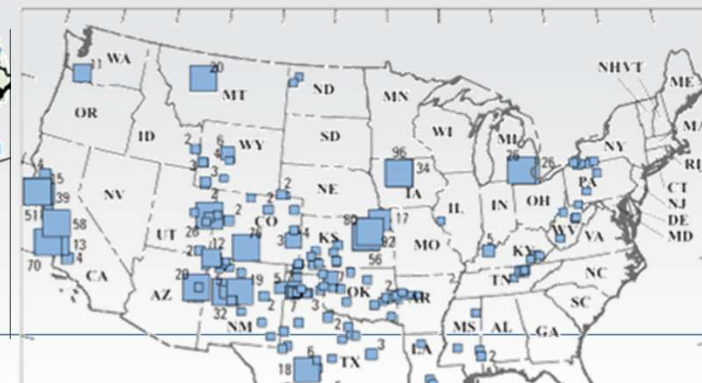
Hydrogen

Serpentinization Lab Experiments

Seeking origins of primordial life

Natural & Stimulated Geologic Hydrogen

2020s - Natural H₂ search
2024 - GeoKiln Thermal H₂ Concept



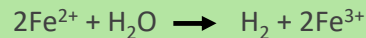
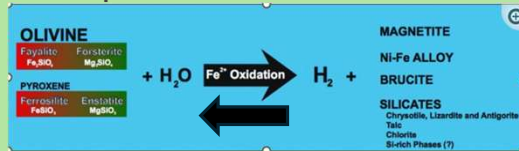
EXPLANATION
Geologic hydrogen concentration, in mole percent—Size correlates with concentration

- 0.5 to 7
- 7.01 to 13.5
- 13.51 to 20
- Greater than 20

Accelerating Natural Hydrogen to Commercial Rates



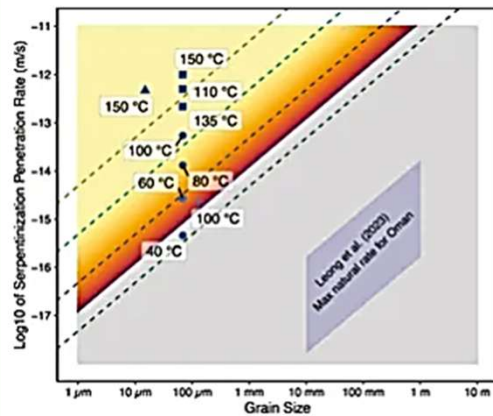
Serpentinization Reaction:



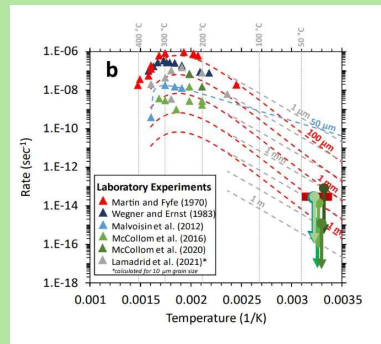
Serpentinization reaction naturally occurs in Earth crust

- Responsible for 100mln+ tons of H_2 diffused within Earth crust
- Slow reaction rate in known iron rich deposits

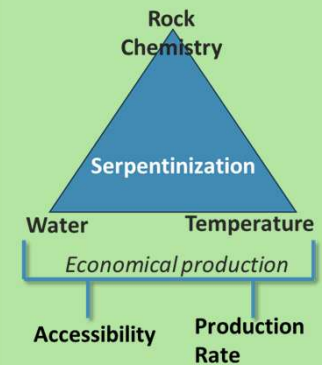
Figure 6



Serpentinization has been shown to rise orders of magnitude from 40°C to 300°C



Conditions for profitable development of H_2 from subsurface



- Right chemistry and water are common
- Controlling temperature via supplying heat expands target areas

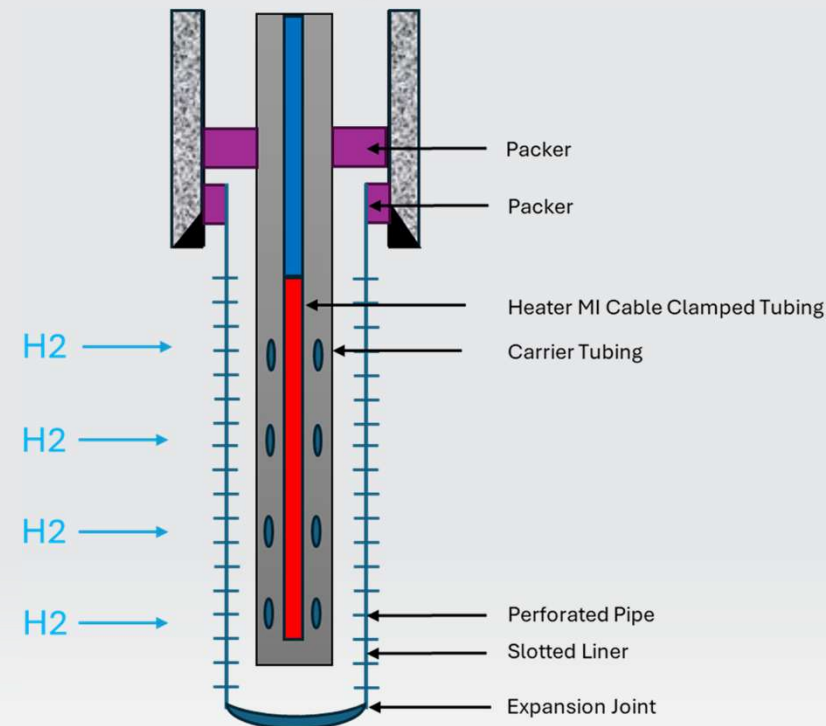
Serpentinization sources in the US



Source: USGS Hydrogen Prospectivity Map

Wells

- Well orientation (horizontal or vertical) follow the geology targeting rich layers or intervals
- Casing and cement isolate the overburden
- Dedicated heater and producer wells or heater producer/wells
- Injectors needed for produced water
- Place pumps outside of heated zone





Surface/Subsurface

A small surface footprint is required

A small surface footprint is required to stimulate a large subsurface volume

Produce, purify and ship to end-user

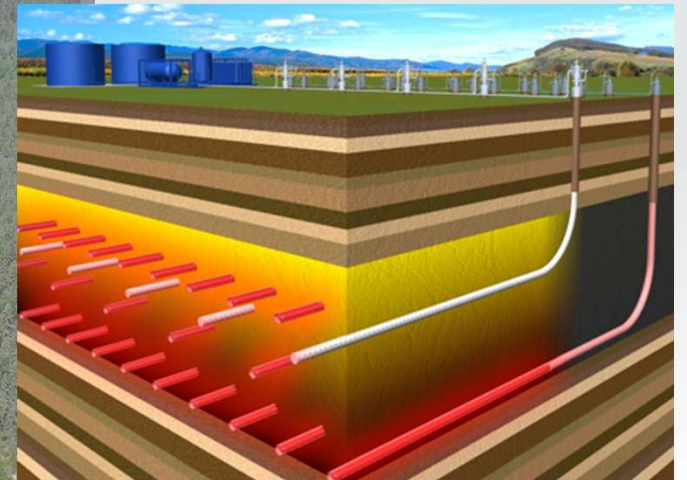
Reservoir is the storage system



Experimental Scheme 9874



Observer Pad

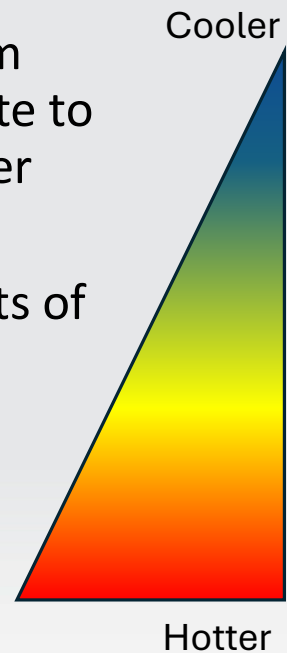


Production Expectations



The produced gases and fluids depend on the local geology, temperature, pressure, and the history

- The initial production tends to be the in-situ water and gases outgassed from the produced water and any residual trapped gases ($S_{gi} > 0$) and tends to relate to the content of the atmosphere at the time of deposition or generated deeper (N_2 , CO_2 , Ar, He)
- Tuff and clay dewatering and decomposition evolve water and small amounts of CO_2
- CO_2 if carbonates are present to thermally decompose and evolve CO_2
- Steam, Hydrogen, (& Hydrogen sulfide if sulfur is present)



Summary



The technology and hardware exists; we need to apply it to the right geology

- Geologic and stimulated geologic hydrogen PRODUCE energy
- Conditions to make stimulated hydrogen are more common than finding an accumulation
- There is a long history of technology development
- Stimulated hydrogen production in multiple analogues have out-produced currently known natural hydrogen accumulations
- Analogues are indicative of production expectations and well response



Questions?

THANK YOU

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