Super Hot Rock ‘SHR’ Geothermal

Benefits, Status, New Developments

Presented at GEMS - SwRI

San Antonio – November 19, 2024

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ACKNOWLEDGEMENTS

I would like to acknowledge the following persons and organizations who graciously gave me permission to use their graphics in this Presentation:

- Clean Air Task Force – ‘CATF’
- Thunder Said Energy
- Mazama Energy (AltaRock Energy & Blade Energy Partners)

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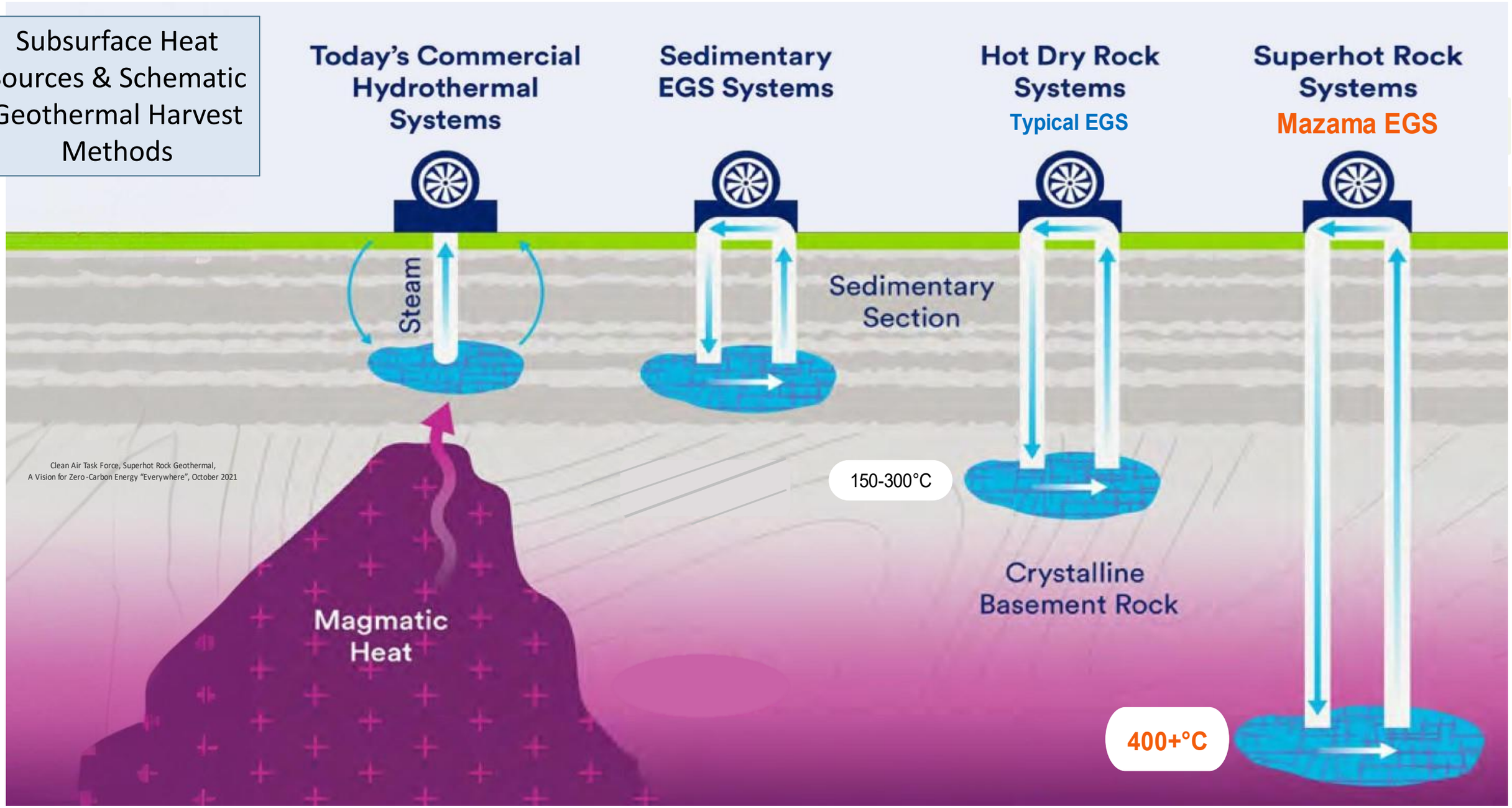
At a depth of 10 kilometers, the earth's crust holds 100x more energy than all known fossil fuel reserves

Yet, only 0.4% of the total U.S. utility-scale electricity is generated from geothermal

Subsurface Heat Sources & Schematic Geothermal Harvest Methods



Clean Air Task Force, Superhot Rock Geothermal,
A Vision for Zero-Carbon Energy "Everywhere", October 2021

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Super Hot Rock ‘SHR’ Geothermal

- What is Super Hot Rock Geothermal?
- Why is SHR Beneficial & Important?
- Where is SHR Found?
- What is the Geothermal Industry Status of SHR?
- What are the SHR Developments Advancing Geothermal Use?

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Super Hot Rock ‘SHR’ Geothermal
What is Super Hot Rock Geothermal?

- SHR Geothermal does not have a precise definition, but it is generally considered as:

  +400 degC = +752 degF

- SHR Geothermal is natural subsurface heat from earth’s core or radio isotope degeneration at any depth wherein the heat fits the above characterization.

- SHR Geothermal applicability is anywhere this SHR heat can be captured and transferred to surface for direct or converted energy use.

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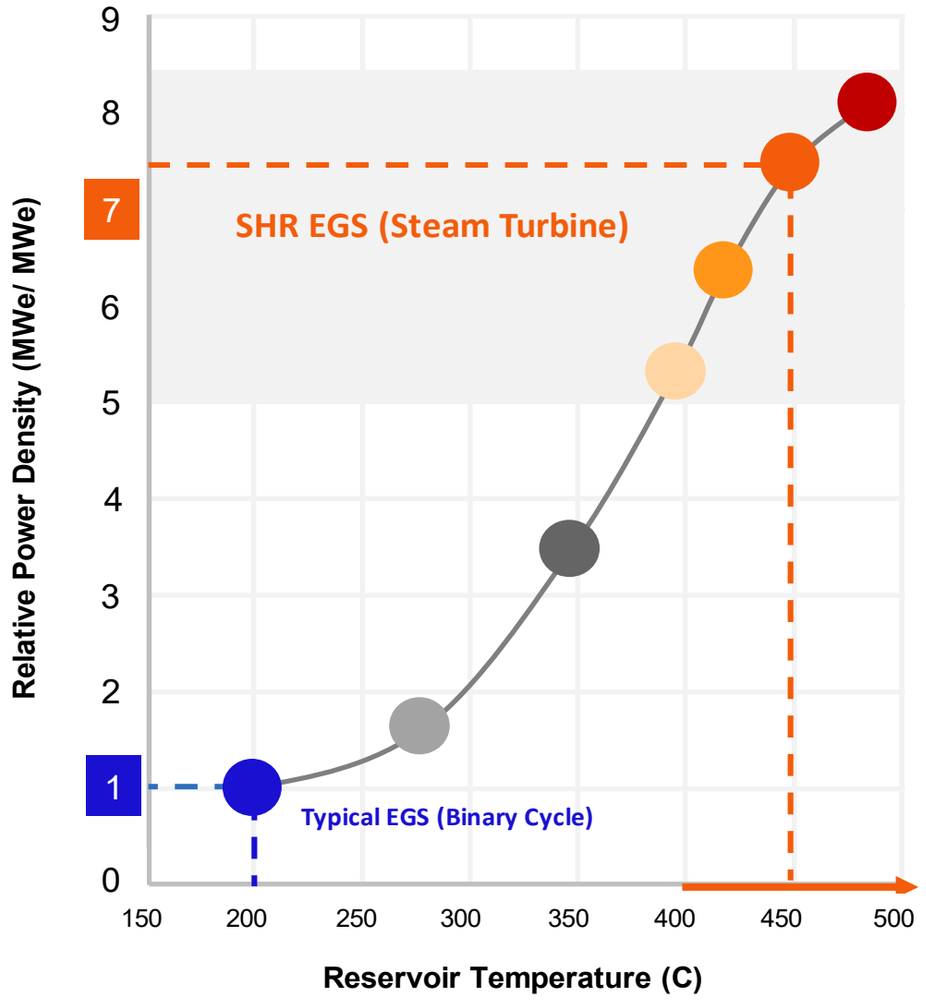
SHR EGS well yields 5-8x more power density than a typical EGS well at 200°C[iii]

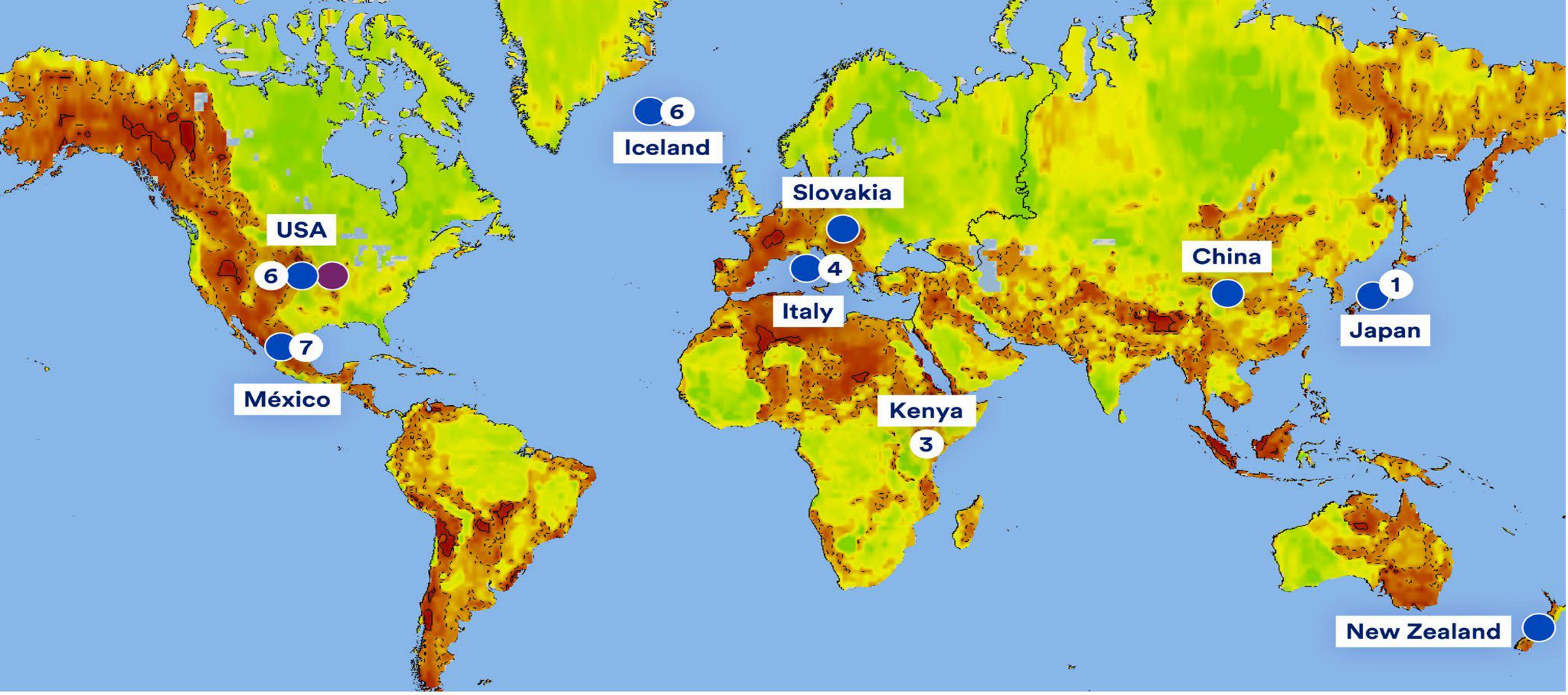


SHR EGS:

- Higher thermal energy density (enthalpy)
- Superior power conversion efficiency

At 450°C:

- **Generate 7x more power per well**
- Require 80% fewer wells
- Use 70% less water



(#) Countries where wells have reached SHR conditions

Countries with SHR R&D projects

Countries with proposed SHR demonstrations

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Super Hot Rock 'SHR' Geothermal

Why is Super Hot Rock Beneficial and Important?

- SHR provides the substantial benefits of Closed-Loop Geothermal systems by –
  - *Providing **Continuous, Clean (Green) Energy***
    - *Producing Heat Energy while Keeping Bad Substances (poisonous & corrosive gases & liquids) in their downhole formations*
  - ***Dispatchable production** with **higher thermal efficiencies***
  - ***Long +25 years productive life** with **Low OPEX***
  - ***Small footprint** – saves precious surface property & reduces NIMBY*

- SHR Geothermal is **natural subsurface heat** from tectonic plate movements allowing exposure of earth's molten rock core or radio isotope decay at any depth wherein the heat fits the above characterization.

- SHR Geothermal production is enhanced by using supercritical carbon dioxide (sCO2) in the drilling cycle + supercritical water (sH20) in the production cycle.

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Geological Estimates of SHR Energy in U.S.

CATF 2024

	7.5km = 24,608ft. depth			10km = 32,810ft. depth		
Country	Area (km2)	Developable Area (km2)	Potential (GWe)	Area (km2)	Developable Area (km2)	Potential (GWe)
United States	**245876.3**	**2458.8**	**379.9**	**573373.0**	**5733.7**	**886.0**

Super Hot Rock 'SHR' Geothermal

What is the Geothermal Industry Status of SHR?

- SHR is globally ubiquitous – yet quite unknown (as is Geothermal generally)
  - *Iceland has been very successful with the only operating Geothermal field in the world – (yet had a recent initial well failure)*
  - *Drilling industry technology gaps known, identified, being worked & filled*
  - *O&G industry developments & know-how compounding applicability*
  - *Newberry, Oregon development just recognized by U.S. DOE GTO with ~$20MM grant to Mazama Energy*
  - *CATF map with 5km & 7.5km SHR depths globally indicates areas of potential practical developments*

- SHR accessibility limited by –
  - *Access & distance to energy use market*
  - *Upstream CAPEX of SHR wells – yet costs quickly dropping*
  - *Speed of investments into new technologies*

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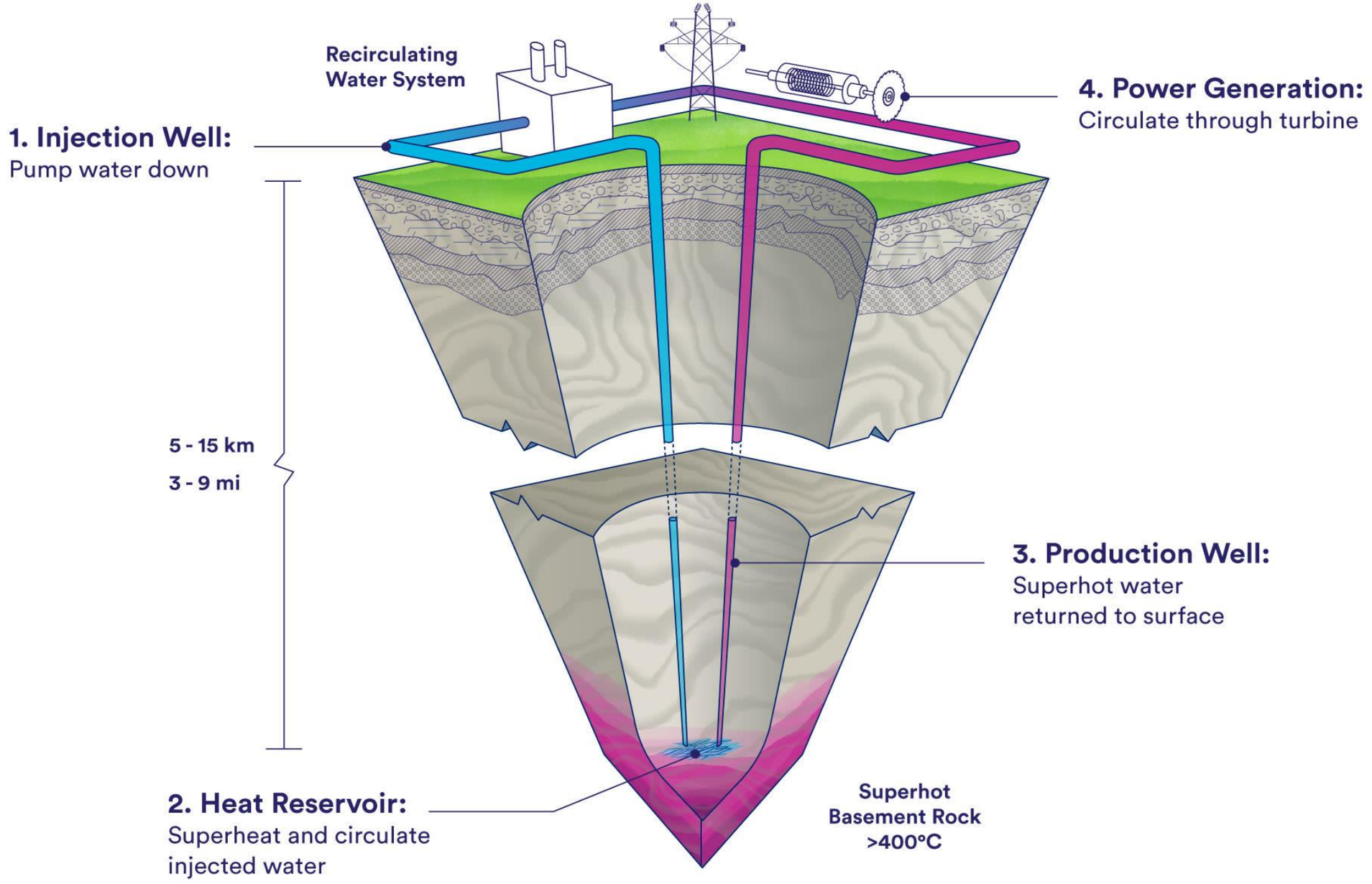
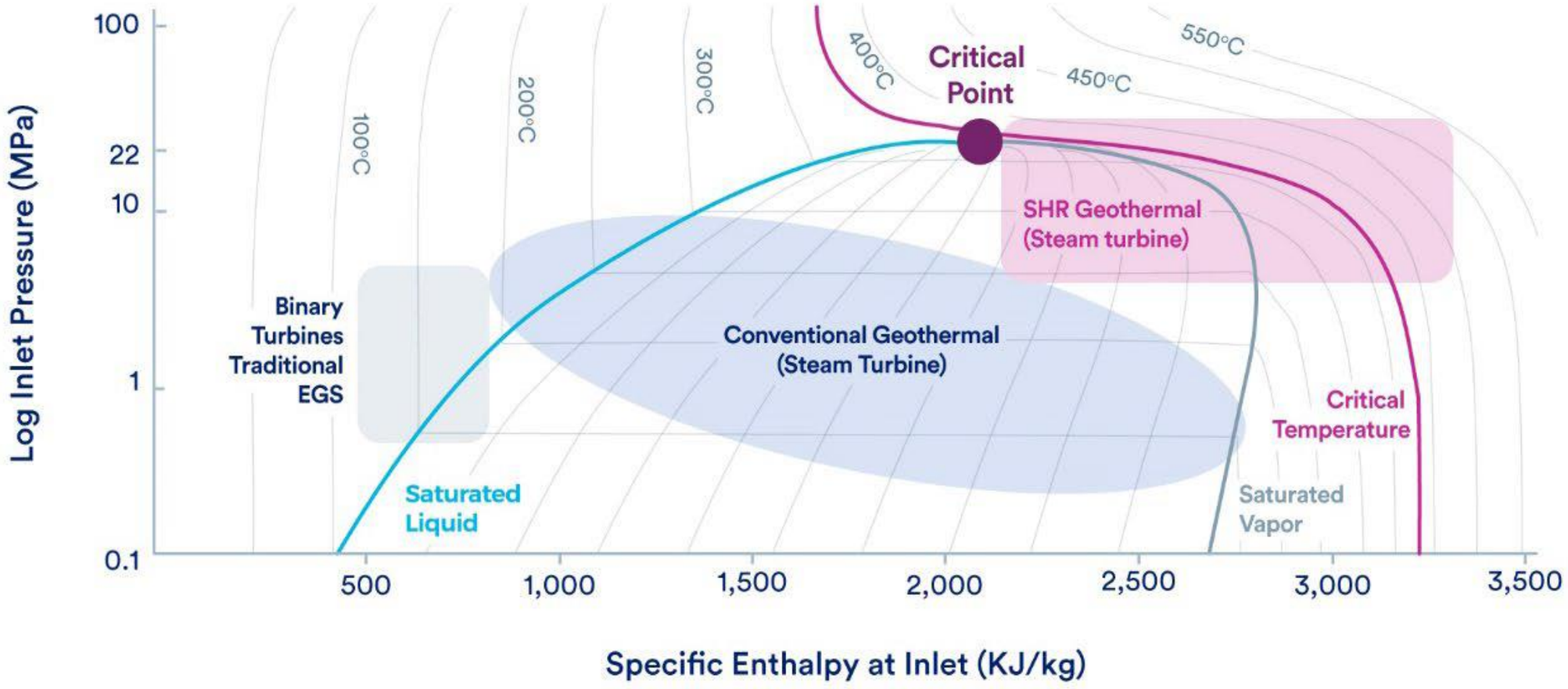


Note: Not to scale. Underground flow conduits for water may either involve below-ground piping or fracture networks (pictured).

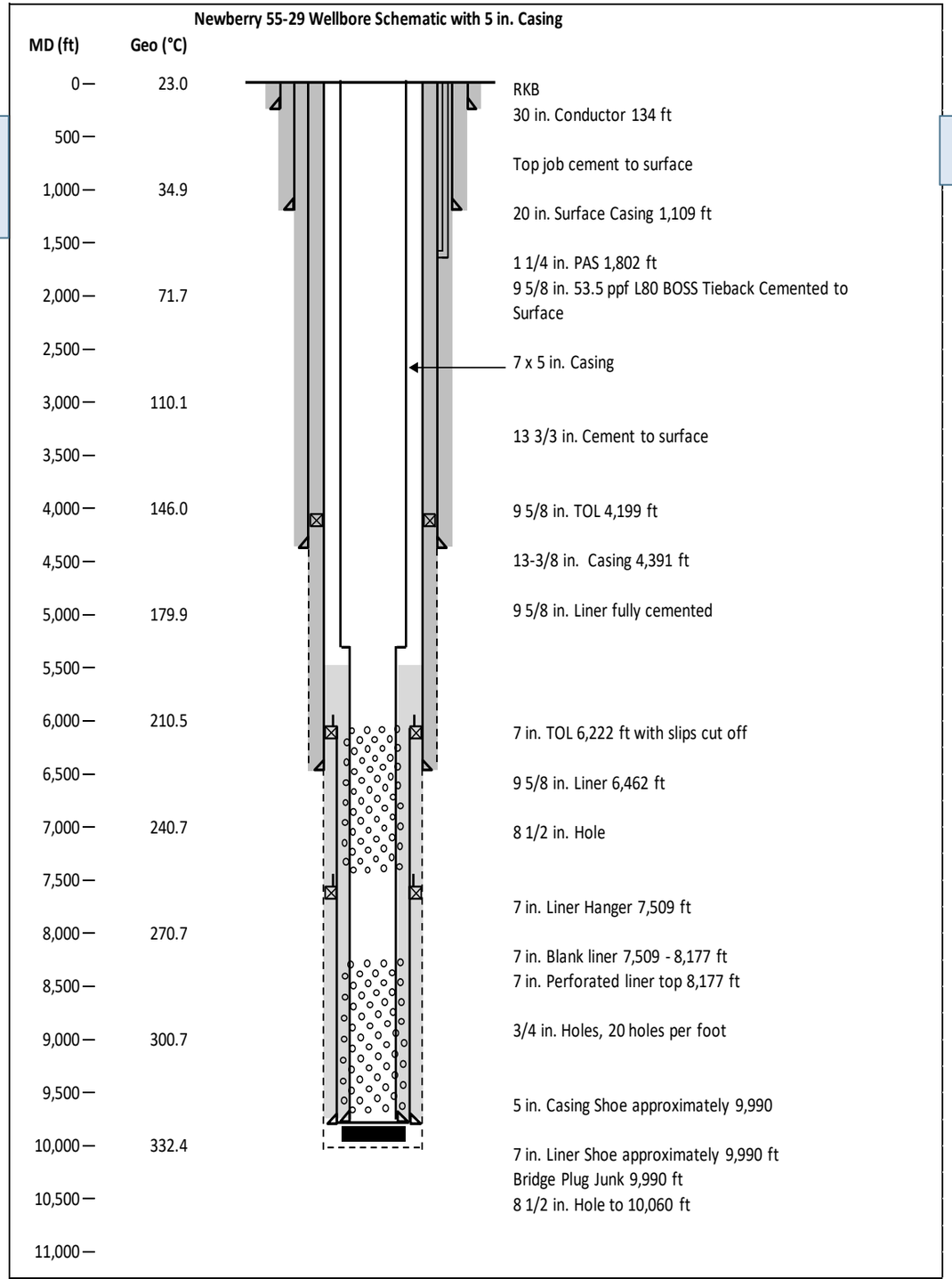
Super Hot Rock ‘SHR’ Geothermal

Turbine Inlet Enthalpy - SHR vs. Conventional Geothermal



Cladouhos & Callahan - 2023

SHR Well Completion Design



Actual, yet shown as example only.

Super Hot Rock ‘SHR’ Geothermal

What are the SHR Developments Advancing Geothermal Use? (1 of 4)

- **Drilling & Completions** -
  - *SHR PDC drill bits now available*
  - *SHR drilling fluids developing, incl. sCO2 in target zone – cuttings transport modeling now*
  - *MPD-UBD techniques work – RCD sealing elastomers developing*
  - *Well designs already established*
  - *Casing & Tubing tubulars identified – connections need qualification*
  - *Cements & Grouts developed & testing – incl. high thermal transfer grout*
  - *Electronics advancing past 350degC, yet very expensive – need higher temp. ratings*
  - *Misc. equipment & services already available*
  - *SHR stimulation (beyond EGS “Thermal Lattice”) testing underway*
  - SHR Geothermal enhanced by supercritical carbon dioxide (sCO2) in the drilling cycle

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Super Hot Rock 'SHR' Geothermal

Critical Considerations for SHR Wells

General Well Design Considerations & Est. Effects for SHR Wells - Well Completion - SHR Formation (Partial List 1 of 2)				
Well Life Stage	**Drilling**	**Installation**	**Injection**	**Production**
Well Status	Mud Circulated Cooling	GT Static - Circ. Cooling	Calculated Cooled	Calculated Heated
Duration	8-12 Months	8-10 Weeks	10-20 Years	10-20 Years
Well Completion				
Affected Components	Installed Casing & Cement	Installed & New Csg. & Cmt.	All Csg., Tubing & Cmt.	All Csg., Tubing & Cmt.
SHR Formation				
GT Grad. Variance - Top/Bottom degC	100 / 100	20 / 300	100 / 100	300 / 0

General Well Design Considerations & Est. Effects for SHR Wells - *Well Completion - SHR Formation* (Partial List 2 of 2)				
Well Life Stage	**Stimulation**	**Workover**	**Thermal Cycling**	**Plug & Abandonment**
Well Status	Calculated Cooled	Variable - Cooled - GT Static	ble - GT Static - Circ. C	Circ. Cooled - GT Static
Duration	2-6 Weeks	1-2 Months	riable - Plan & Unplanr	4-6 Weeks
Affected Components	Unisolated Csg. & Cmt.	Tubing, Unisolated Csg. & Cmt	All Well Components	Unisolated Csg. & Cmt.
SHR Formation				
GT Grad. Variance - Top/Bottom degC	100 / 100	100 / 100	/ariable - 0-300 / 100-0	100 / 100-0

Super Hot Rock ‘SHR’ Geothermal

What are the SHR Developments Advancing Geothermal Use? (2 of 4)

- **Production –**
  - *Closed-Loop system in hot dry rock – no makeup water withdrawal or need*
  - *Supercritical water (sH20) in the production cycle*
  - *Thermosiphon effect increases circulation efficiency*
  - *Site surface facilities, turbine & power plant close to well pad*

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SHR Technology Gaps & Bridging the Gap

Table 3 - SHR Well Construction Technology Gaps - General, Non-Proprietary		
System Component	Technology Gap	Bridging the Gap*
Tubular Thermal Stresses		
Tubular Pipe Body	WSD or LCF Design	Tubular Loc. & Life Exp. Calc. - Design & Test
Pipe Connections	WSD or LCF Design	Tubular Loc. & Life Exp. Calc. - FEA & Test
Cement Thermal Stresses		
Non-SHR Temp. Exposure	High Temp. Tranients	Cement Loc. & Life Exp. Calc. - Design & Test
SHR - well fluids isolated	X-HT Grout	Cement Loc. & Life Exp. Formulate - Test
SHR - well fluids exposure	X-HT Grout inhibited	Cement Loc. & Life Exp. Formulate - Test
Sealing against SHR	SHR & Fluid Samples	Life Exp. Cycling - Bonding Test
Sealing against Tubulars	Metallurgy Samples	Life Exp. Cycling - Bonding Test
Tubulars Corrosion		
Formation & Circ. Fluids	Fluids Exposure ID	ID Fluids Early - Formulate Inhibitor - Test
Cement Contamination		
Formation & Circ. Fluids	Fluids Exposure ID	ID Fluids Early - Calc. Degrade Effect - Test
Non-Metallic Seals		
Non-SHR Temp. Exposure	High Temp. Tranients	Seal Loc. & Life Exp. Calc. - FEA & Test
SHR - well fluids isolated	High Temp. Tranients	Seal Loc. & Life Exp. Calc. - FEA & Test
SHR - well fluids exposure	SHR & Fluid Samples	Seal Loc. & Life Exp. Calc. - FEA & Test
Formation & Circ. Fluids	SHR & Fluid Samples	Seal Loc. & Life Exp. Calc. - FEA & Test

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Super Hot Rock 'SHR' Geothermal

What are the SHR Developments Advancing Geothermal Use? (3 of 4)

- Site, Permitting, Operating License, Supplies & Support -
  - *Geothermal OPEX low overall – simple wells, correct metallurgy needed downhole & surface, corrosion & scaling & fouling early mitigation*
  - *Low-no emissions – No methane, CO2, gases, oil, produced water or minerals disposal*
  - *Sound & visually inobtrusive-benign – no human or wildlife interference*
  - *Surface disturbance limited to field access & pad roads, well & process pads - rights-of-way are needed for power lines to grid/market*
  - *Compatible with other uses above, at ground level, above – i.e. o&g fields, mining, industrial facilities, wind & solar, recreation (forest, mountains, plains) & commercial*
  - *Permits for other uses may cover Geothermal & SHR use*

- Community Effects –
  - Skilled employment during construction & operations
  - Economic uplift from supporting local development
  - Local power availability, royalties, use & transit fees

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Super Hot Rock ‘SHR’ Geothermal

What are the SHR Developments Advancing Geothermal Use? (4 of 4)

- **Investment -**
  - *Upstream CAPEX of SHR wells – costs quickly dropping*
  - *Speed of investments into new technologies*
  - *Project funders need confidence & certainty of resource ownership, technological & operations application & market user contracts*

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Super Hot Rock 'SHR' Geothermal

MAZAMA delivers best-in-class <$40/MWh cost for a 20-year, 100 MW project

Typical 200°C EGS:

60 total wells

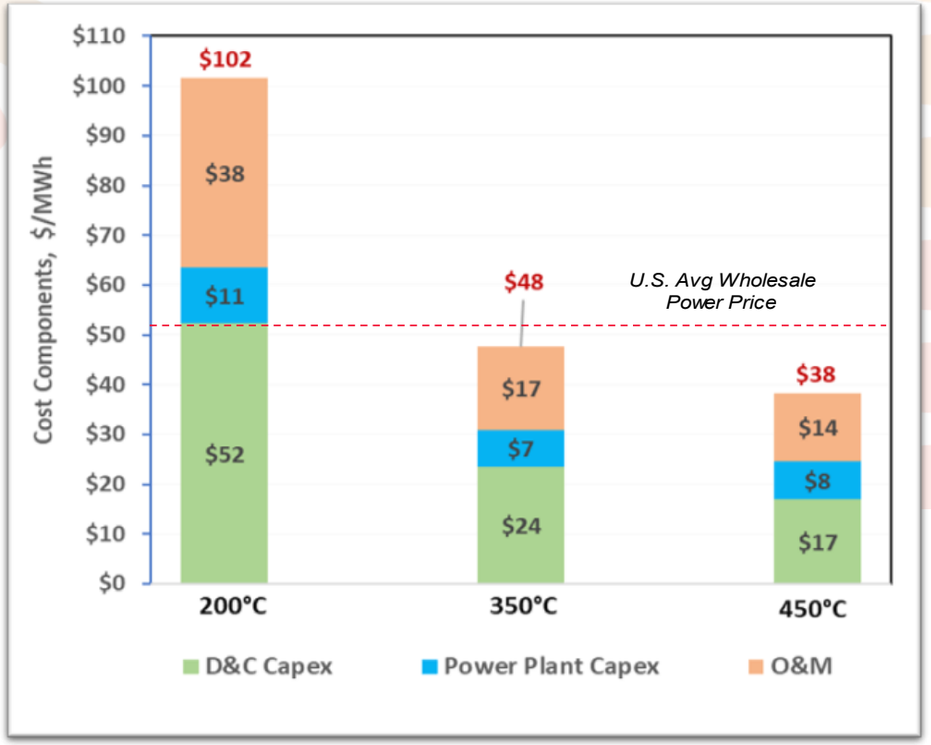
Cost: >**$100/MWh**[ii]

MUSE™ **at 450°C:**

10 total wells

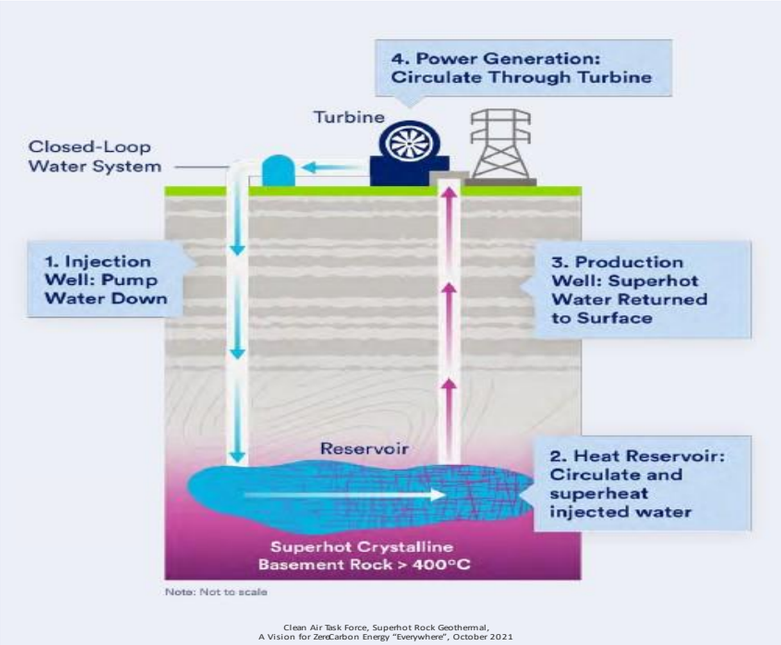
Cost: **<$40/MWh**[ii]

Before Production Tax Credits



Mazama
MUSE™ - Modular Unconventional Superhot Energy

Mazama's *MUSE*™ is the synthesis of our advancements to drive down cost of EGS



Clean Air Task Force, Superhot Rock Geothermal, A Vision for ZeroCarbon Energy "Everywhere", October 2021

Horizontal wells: Maximum rock contact

Thermal Lattice: High-rate, fracture flow network

Superhot water: Large, efficient power plants

High well capacity: Reduced wells, CapEx

Modular: Integrated, standardized design

MUSE™ - Modular Unconventional Superhot Energy

Newberry:

Least cost path/risk path to demonstrating SHR geothermal power plant

Infrastructure, permits, access, social acceptance

- ARE controls leases and wells, good roads, graded pads ready for construction. Major north south transmission line a short distance away
- Strong support from State of Oregon and Local Community to develop Newberry Resource to Meet State Renewable Requirements
- World-class S&T consortium in-place ready to execute strategy and develop SC resource.

Environmental impact, seismic hazard

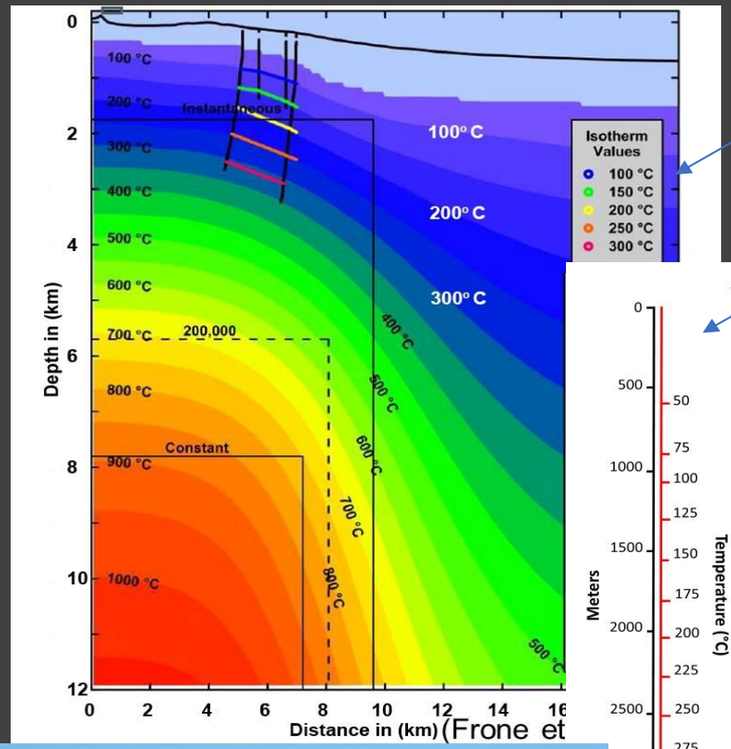
- EIS completed, all permits in place or can be renewed
- Seismic hazard assessment completed with monitoring in place. Low risk for induced seismicity
- Two previous stimulations carried out with no felt seismicity
- All seismic hazard mitigation protocols in place

Temperature at depth, geology, tectonic stress

- Well 46-16 drilled in 2008 to 3.5km is ideal for deepening to BHT of 450C @ 5km (shallowest well option)ARE has deep technical and operating history at Newberry
- Geology well established with very low drilling risk
- Significant seismic data
- 10-yrs of site management and operation experience

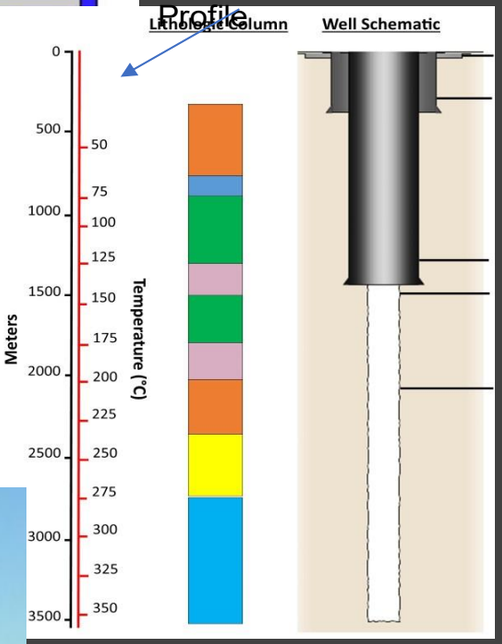
Resource, markets, cost

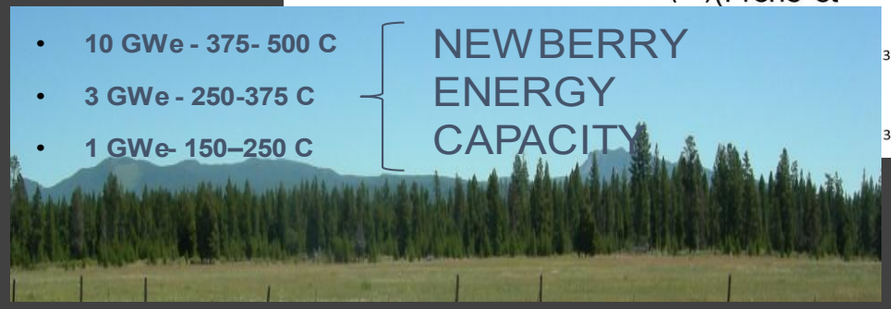
- SC Geothermal Resource ~10GWe could displace Oregon's entire current electric capacity
- Leveraging investment of $55M ($10M ARE, $10M DOE, $35M Davenport)
- $75M required to fund development of SC Well as 5-year program including HT/HP Lab, science and operations
- Fast growing market in Oregon with transmission to California
- LCOE best available tech $50/MWh. Improved tech <$35/MWh



Newberry Temperature Gradients

Well 46-16 Geologic Profile





THANK YOU!

Questions?

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