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# GEOHERMAL

ABUNDANT SUSTAINABLE ENERGY –  
OVERVIEW & OPPORTUNITIES



*Honua Resources*



Partnership of Honua Resources LLC & SEB Solutions LLC

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New York City | Houston

NOVEMBER 21, 2023





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# AGENDA

- Introduction
  - Geology 101 – Anatomy of the Earth
  - Geothermal Advantages
  - Military (DoD) Advantages
  - Growth in Geothermal
    - Heating & Cooling
      - Geoexchange (Heat Pumps) - GHPs
      - District Heating/Cooling
    - Energy Production
      - Power Plants
      - EGS Geothermal
      - AGS Geothermal
      - Repurposing Infrastructure to EGS Geothermal
      - Ultra Deep
    - Geothermal Related Secondary Products
  - Our Company – De-risk, Optimization and Operations
  - Conclusion
-

# TEAM

\*Over 40 Years of Combined Experience



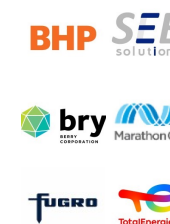
**Eric Peterson, MSc., MBA ('26)**  
Geophysicist



Honua Resources



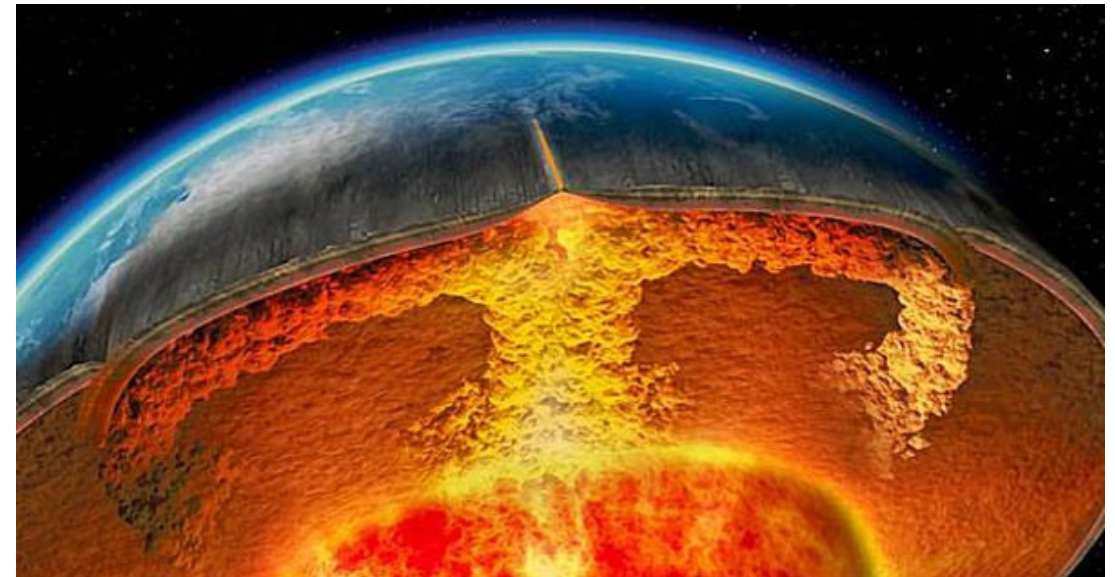
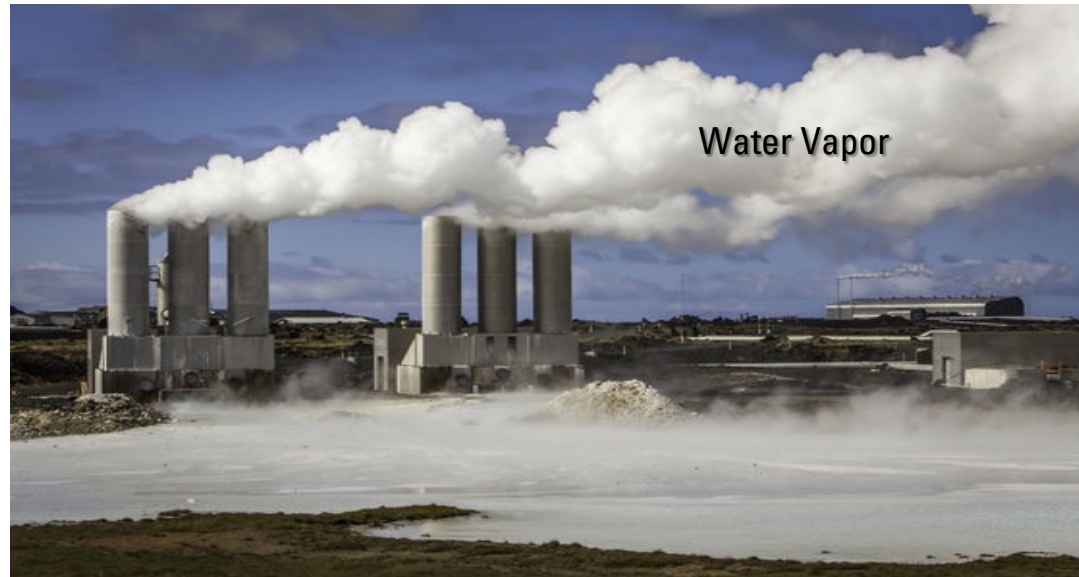
**Sebastian Bayer, MSc.**  
Reservoir Modeler



# INTRODUCTION

Geothermal Energy, a remarkable and sustainable solution harnessing the Earth's natural heat. As the global demand for clean and renewable energy continues to surge, geothermal power emerges as a powerful contender in the race towards a greener future.

In this presentation, we'll delve into the fascinating world of geothermal energy, exploring its principles, benefits, and its crucial role in the transition towards a more sustainable energy landscape. Join us as we embark on a journey through the depths of the Earth, uncovering the boundless potential that lies beneath our feet.

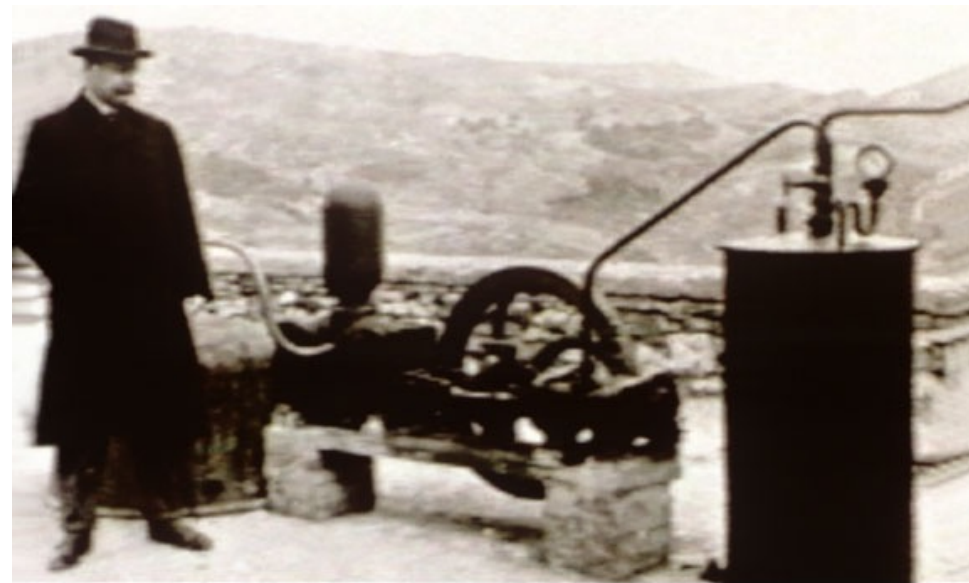


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# HISTORY: FIRST GEOTHERMAL WELL



On 4 July 1904, at Larderello, Piero Ginori Conti powered five light bulbs from a dynamo driven by a reciprocating steam engine using geothermal power. In 1905 he increased power production to 20kW.

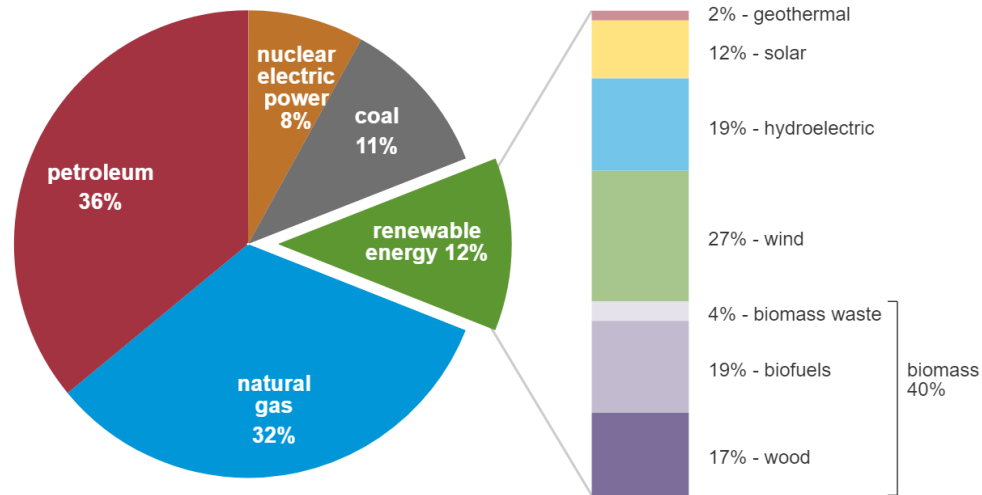


First Geothermal Power Plant, 1904, Larderello, Italy

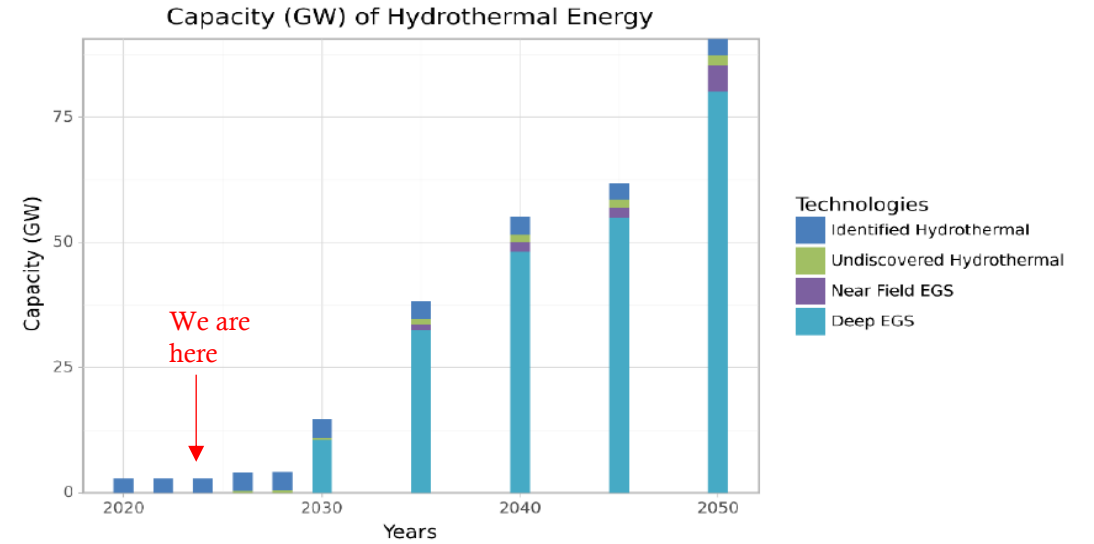
# Geothermal is in its Infancy of an Industry with Billions of Dollars in Revenue Potential

## GEOHERMAL MARKET

British thermal units (Btu)



Source: EIA 2021



>100X Growth Potential

0.7%

3.9 GW

90 GW

The DOE believes only 0.7% of geothermal's potential has been realized in the USA

USA geothermal market size in 2019 (DOE - NREL)

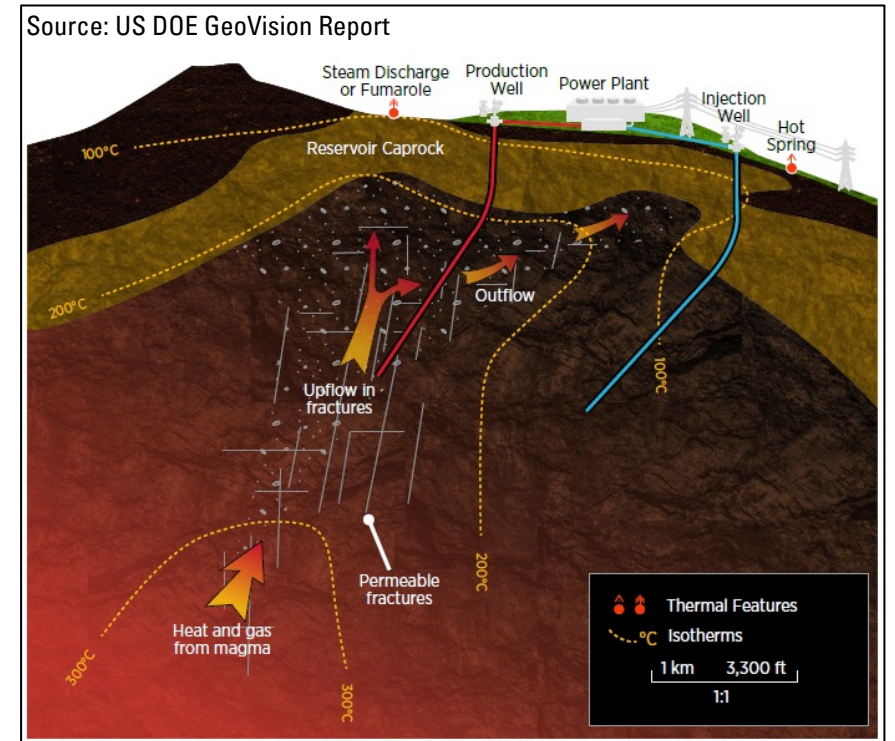
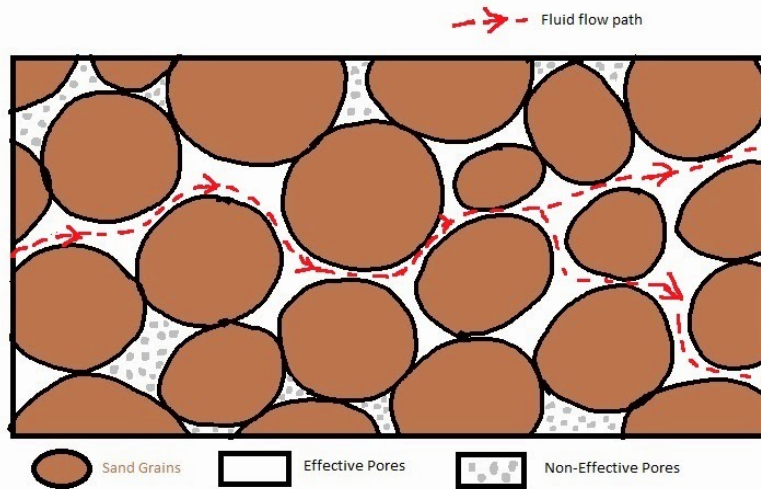
NREL believes improved technology could lead to multiples higher output by 2050 in the USA

Source: NREL 2023 - Enhanced Geothermal Shot Analysis for the Geothermal Technologies Office

# WHAT IS GEOTHERMAL

1. Heat
2. Flow (Permeability & Porosity) of Water/Gas

“relating to or produced by the internal heat of the earth.” – Oxford Dictionary



**Heat**

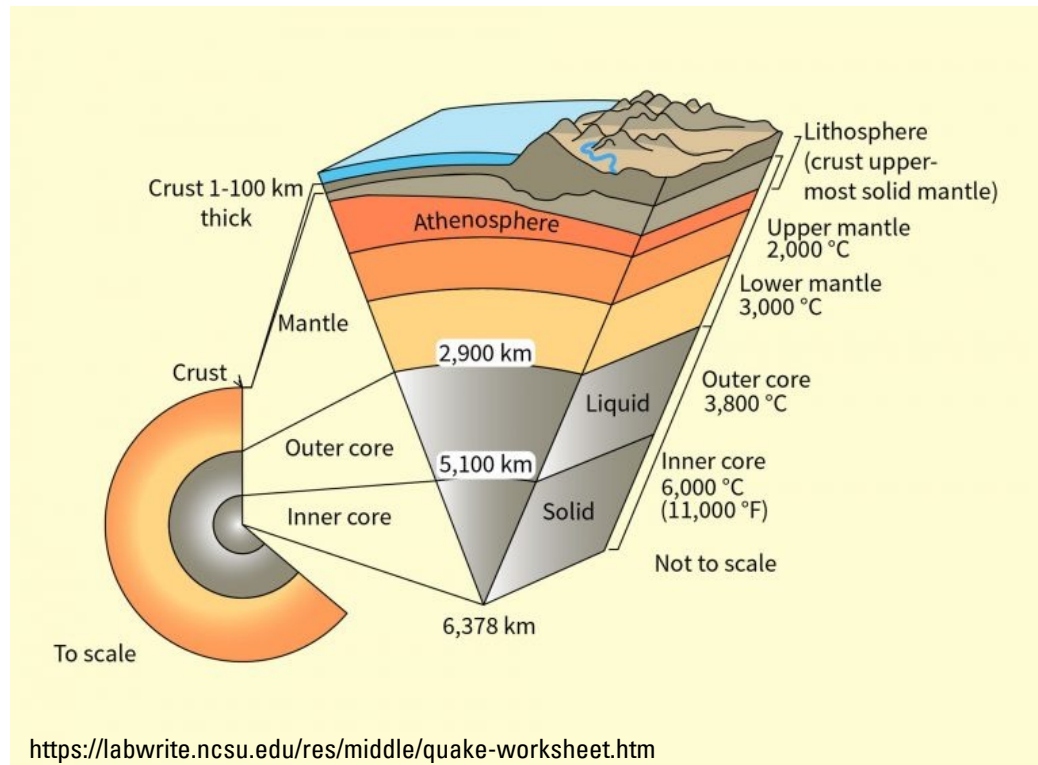


**Flow**

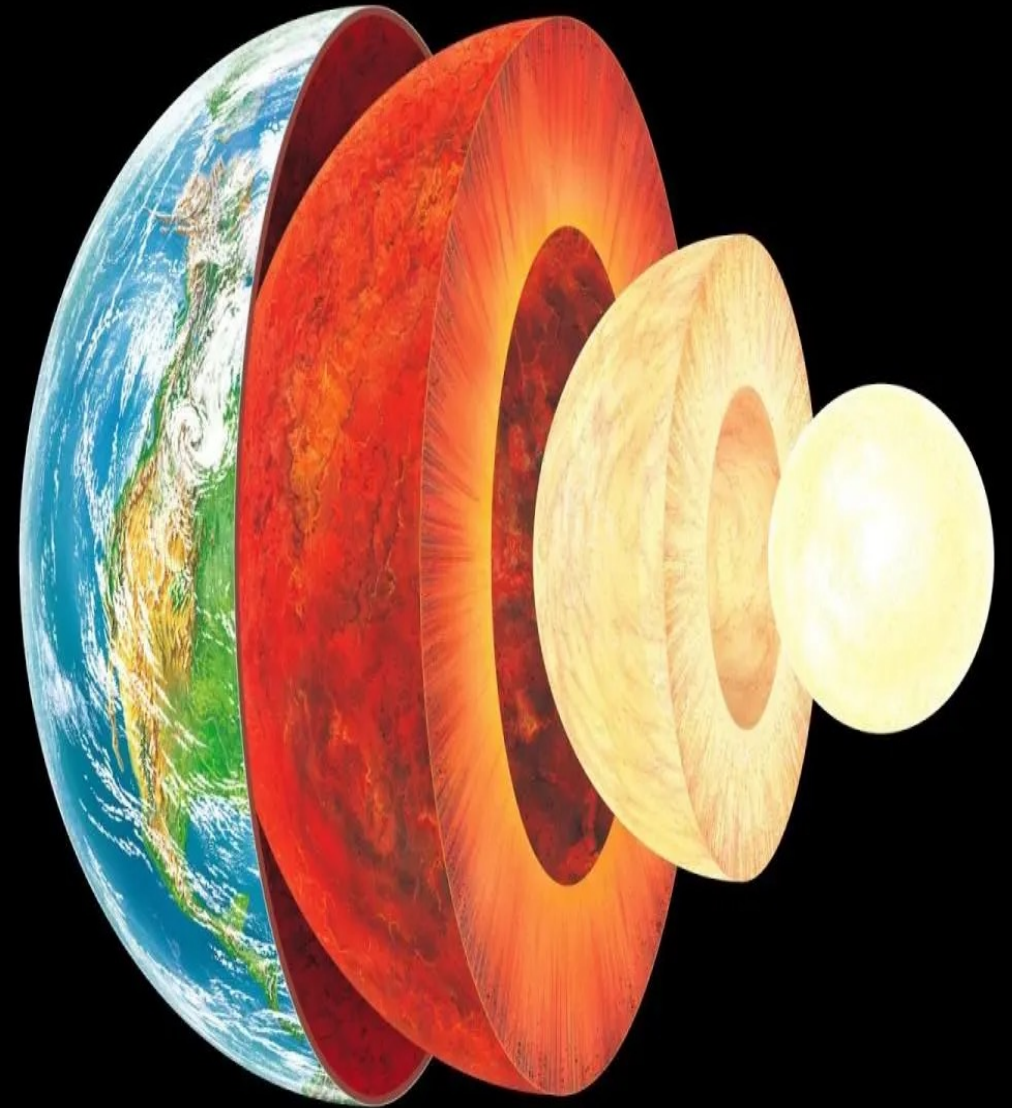


**Geothermal**

# TOPIC ONE



## Geology 101 – Anatomy of the Earth





# RADIOACTIVE DECAY OF ISOTOPES DRIVES GEOTHERMAL

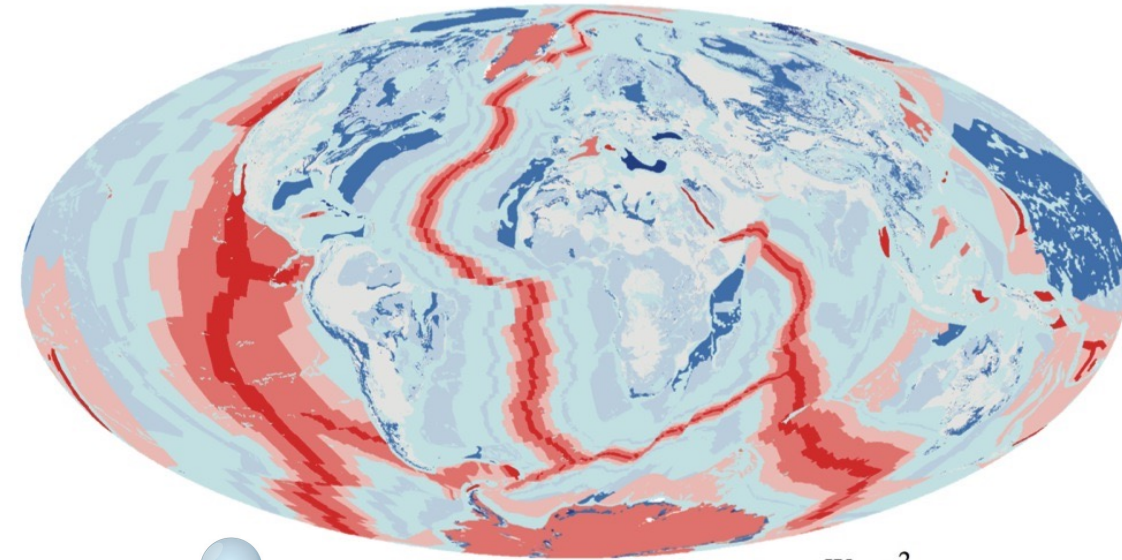
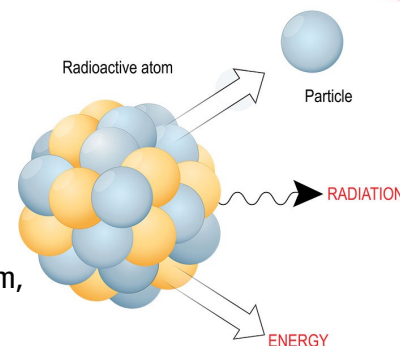
Earth's internal heat budget is fundamental to the thermal history of the Earth. The flow of heat from Earth's interior to the surface is estimated at  $47 \pm 2$  terawatts (TW) and comes from two main sources in roughly equal amounts: the radiogenic heat produced by the radioactive decay of isotopes in the mantle and crust, and the primordial heat left over from the formation of Earth.

Earth's internal heat travels along geothermal gradients and powers most geological processes. It drives mantle convection, plate tectonics, mountain building, rock metamorphism, and volcanism. Convective heat transfer within the planet's high-temperature metallic core is also theorized to sustain a geodynamo which generates Earth's magnetic field.

## GEOTHERMAL

Abundant sustainable energy – Overview & Opportunities

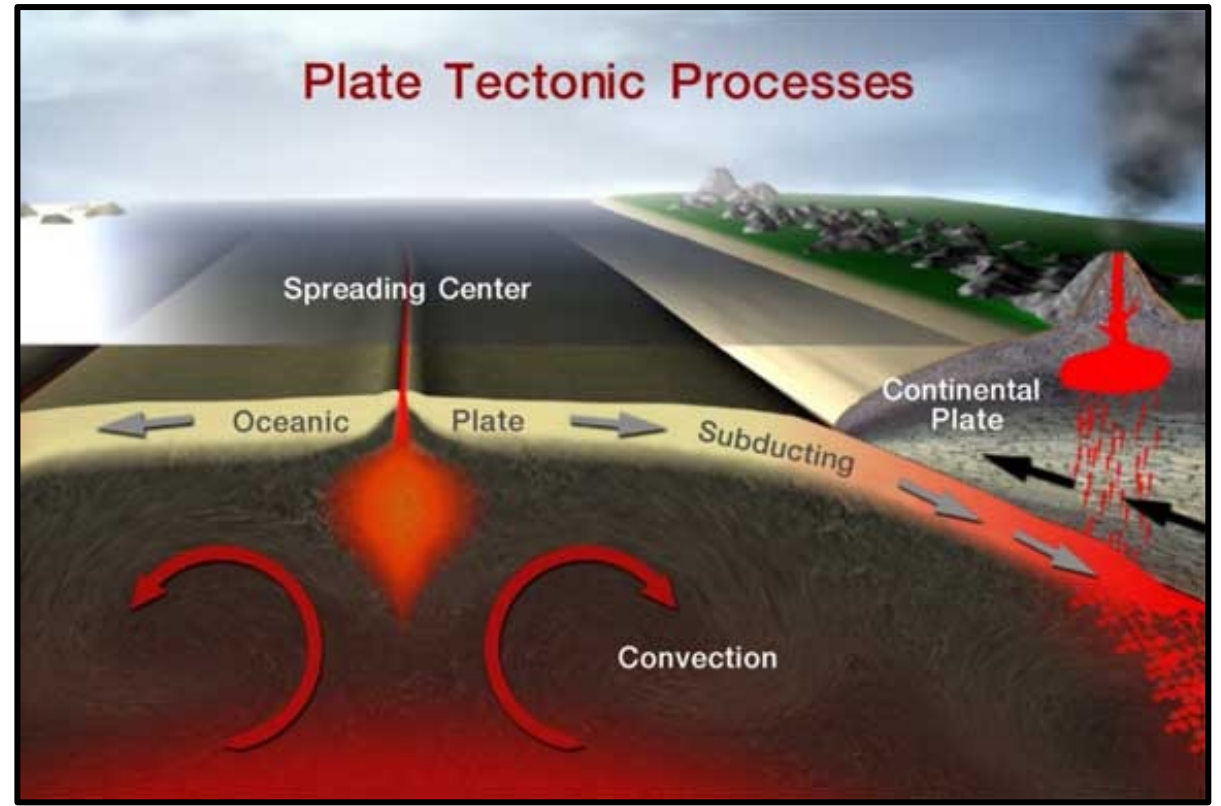
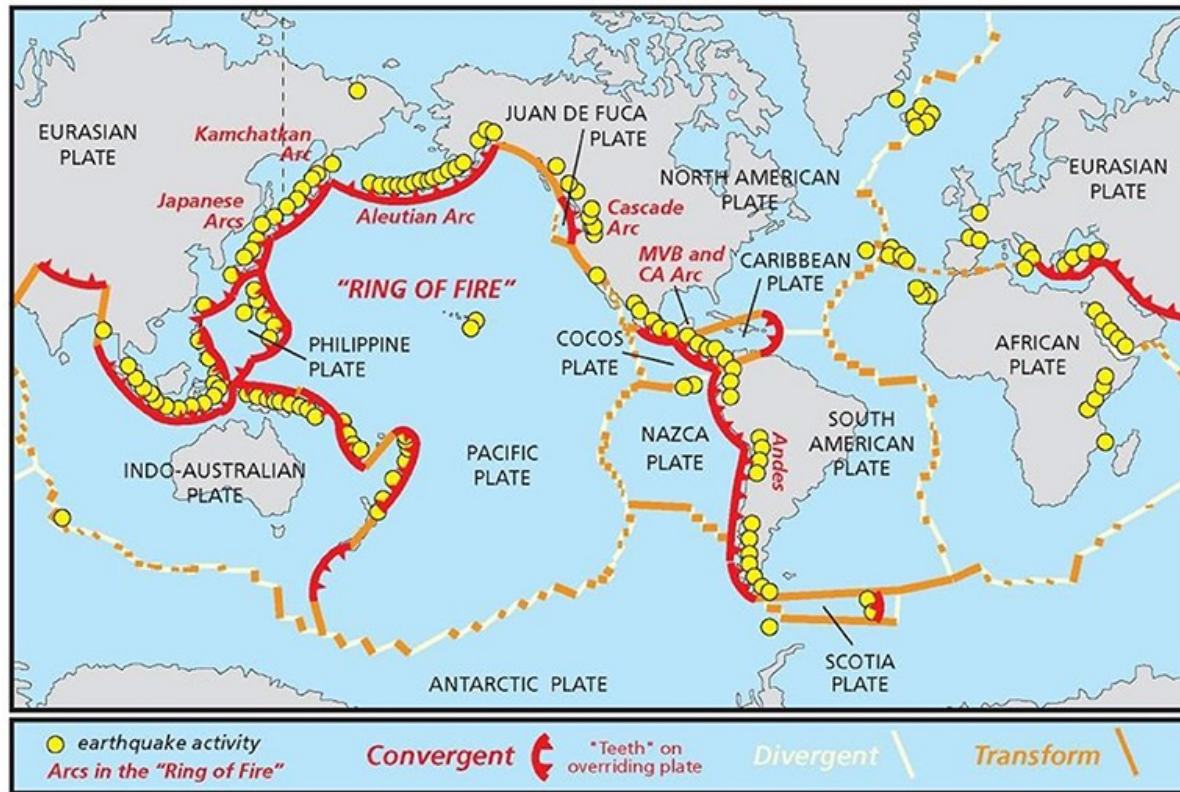
Radioactive potassium, uranium and thorium



$\text{mW m}^{-2}$



# GEOLOGY 101 – ANATOMY OF THE EARTH



## GEOHERMAL

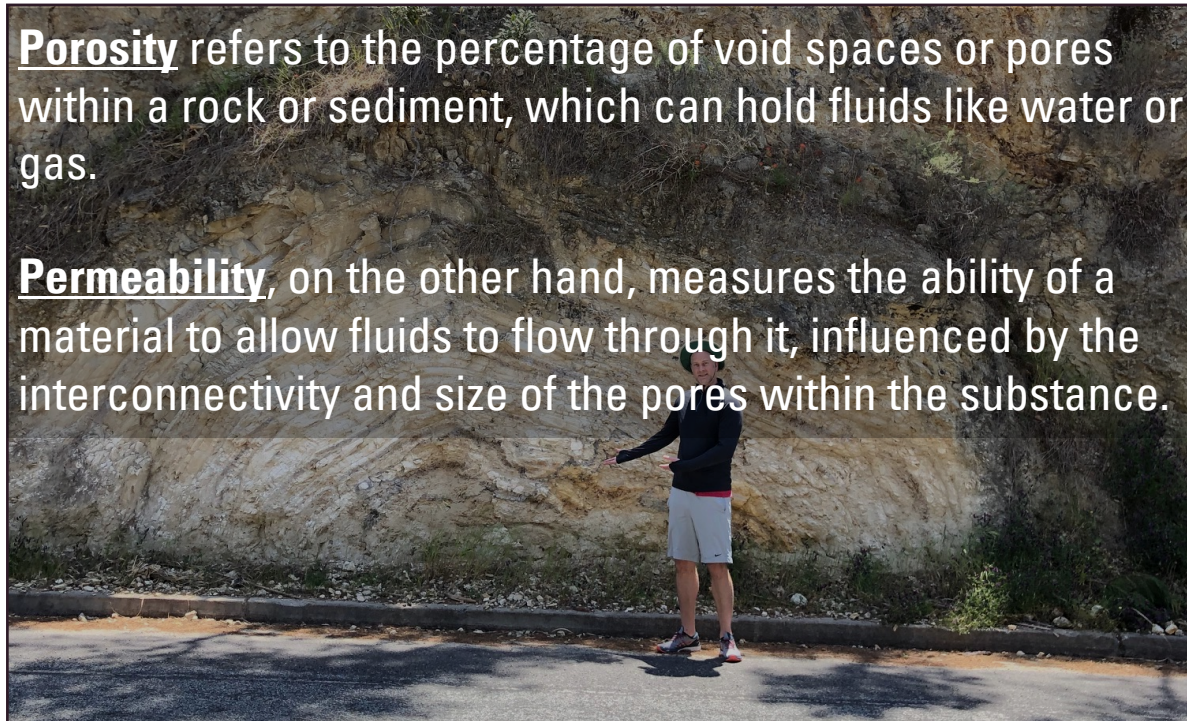
Abundant sustainable energy – Overview & Opportunities

# GEOLOGY 101 – ANATOMY OF THE EARTH

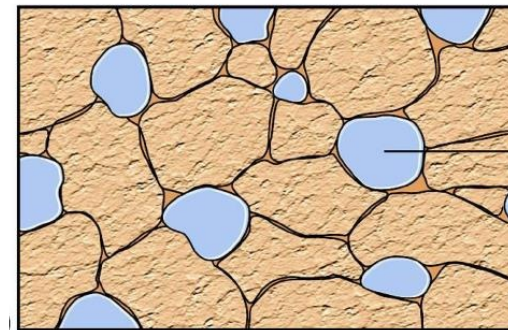
Flow = Porosity + Permeability

**Porosity** refers to the percentage of void spaces or pores within a rock or sediment, which can hold fluids like water or gas.

**Permeability**, on the other hand, measures the ability of a material to allow fluids to flow through it, influenced by the interconnectivity and size of the pores within the substance.

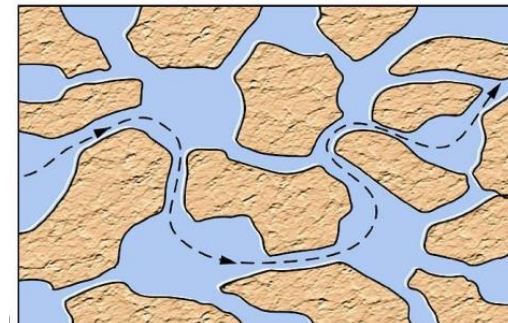


Poor Flow











Good Flow

1 mm



Water

## TYPICAL PERMEABILITY OF AQUIFERS

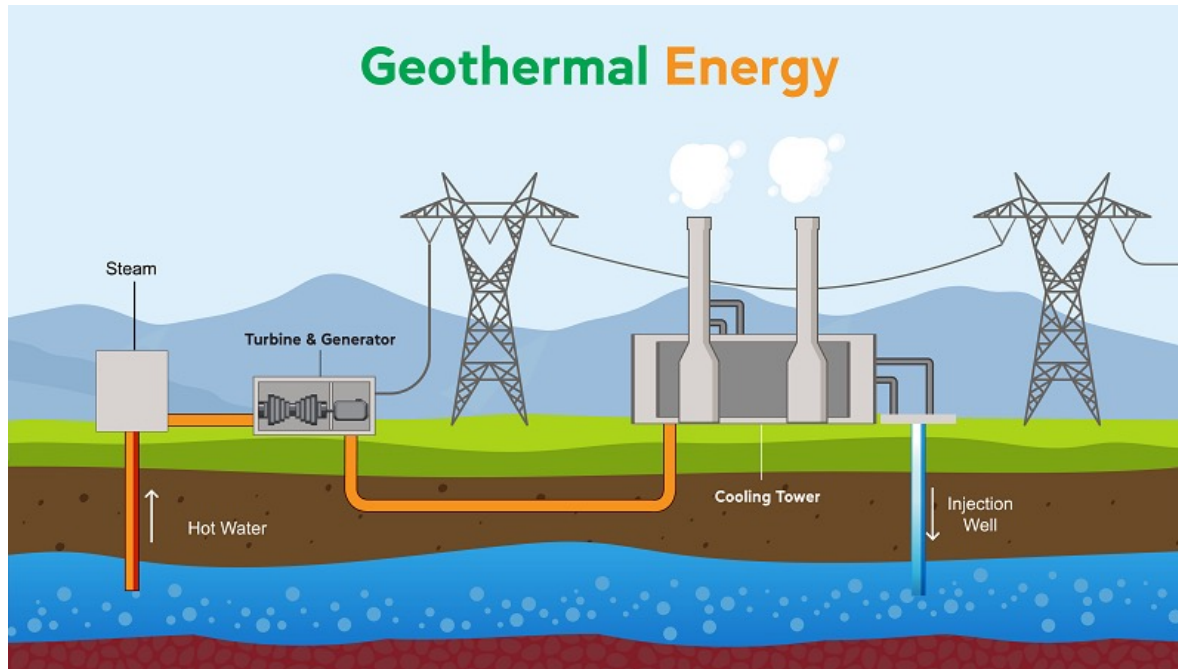
	<b>GRAVEL</b> Highly Permeable - water flows rapidly 300 feet/day to 3000 feet/day		<b>LIMESTONE</b> Permeable - water flows through fractures and solution cavities 0.1 feet/year to 3 feet/day
	<b>SAND</b> Permeable - water flow is moderate to rapid 0.03 feet/day to 3000 feet/day		<b>SANDSTONE</b> Impermeable to Permeable - water flows through fractures and areas where cementing material dissolves 1 foot/100 years to 3 feet/day
	<b>SILT</b> Slowly Permeable - water flows slowly 0.1 feet/year to 1000 feet/year		<b>SHALE</b> Impermeable - water rarely flows through shale unless shale is fractured 1 foot/100,000 years to 0.1 feet/year
	<b>CLAY</b> Relatively Permeable - water barely moves 1 foot/10,000 years to 0.1 feet/year		<b>ROCK</b> Extremely Impermeable to Highly Permeable - rock rendered porous by fracturing, water flows through fractures 1 foot/100,000 years to 300 feet/day

©VMI

**THE GEYSERS**  
~725MW  
Northern California



# CONVENTIONAL GEOHERMAL (HYDROTHERMAL)

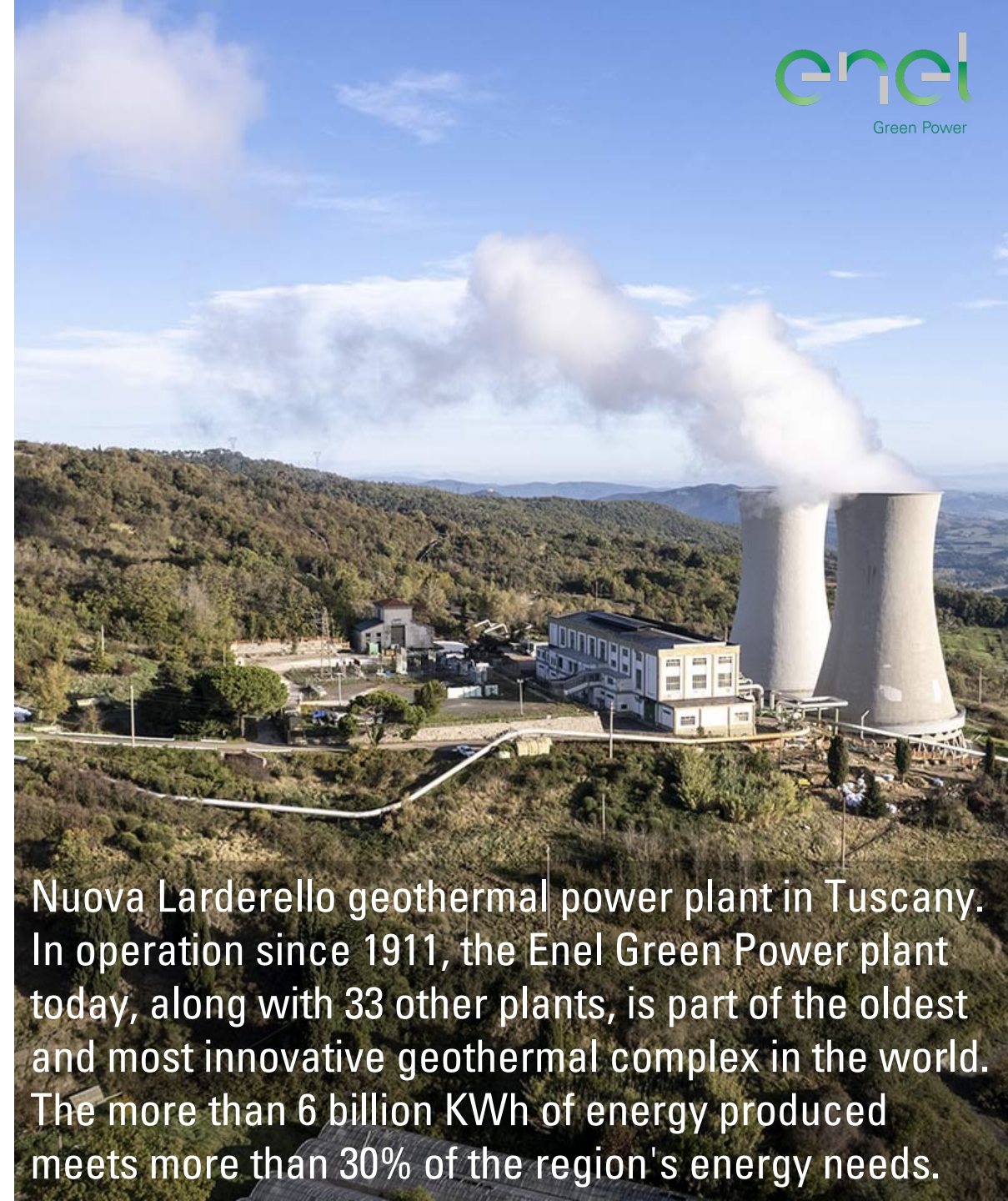


<https://www.greenesa.com/news/geothermal-energy-types-uses-advantages>



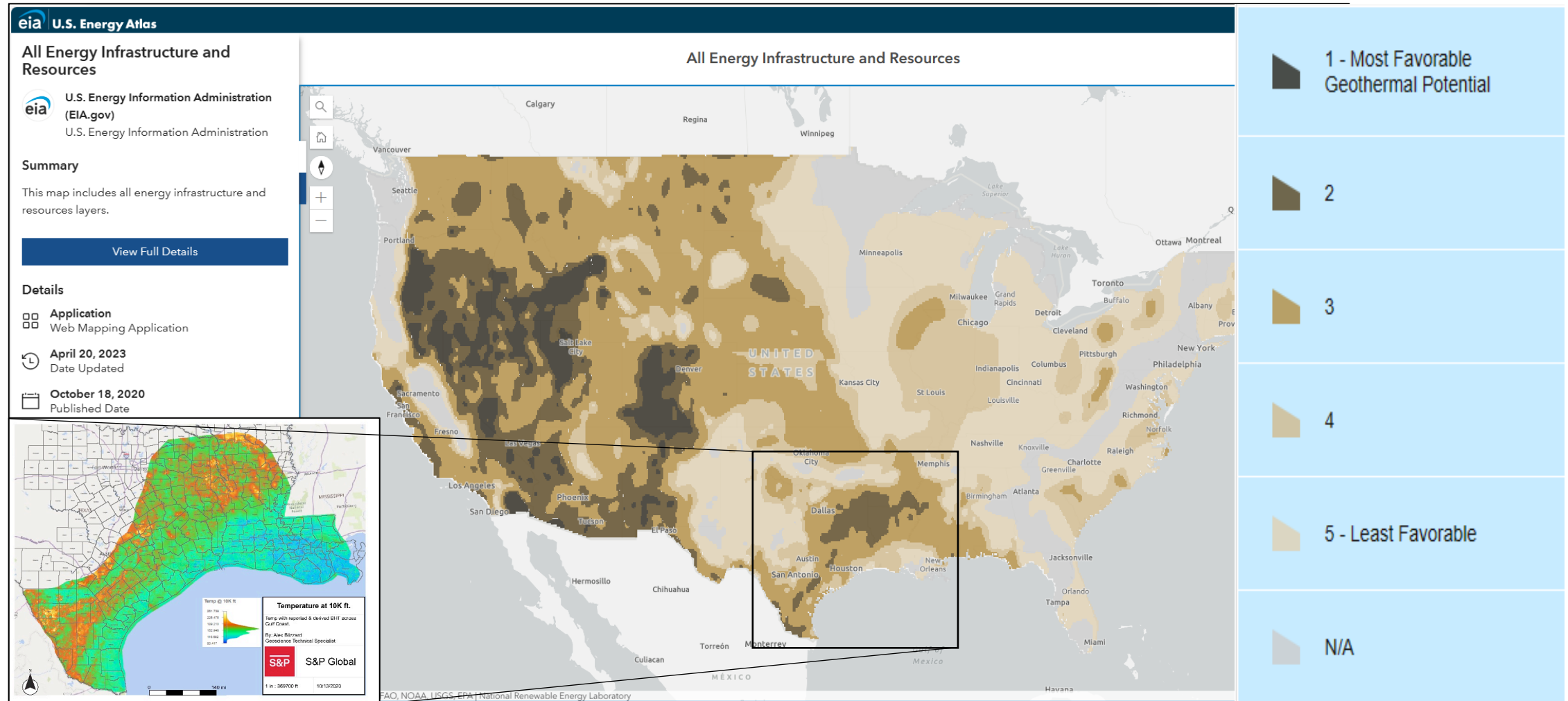
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# GLOBAL CONVENTIONAL GEOTHERMAL (HYDROTHERMAL)



Nuova Larderello geothermal power plant in Tuscany. In operation since 1911, the Enel Green Power plant today, along with 33 other plants, is part of the oldest and most innovative geothermal complex in the world. The more than 6 billion KWh of energy produced meets more than 30% of the region's energy needs.

# GEOHERMAL POTENTIAL MAP (LOWER 48)

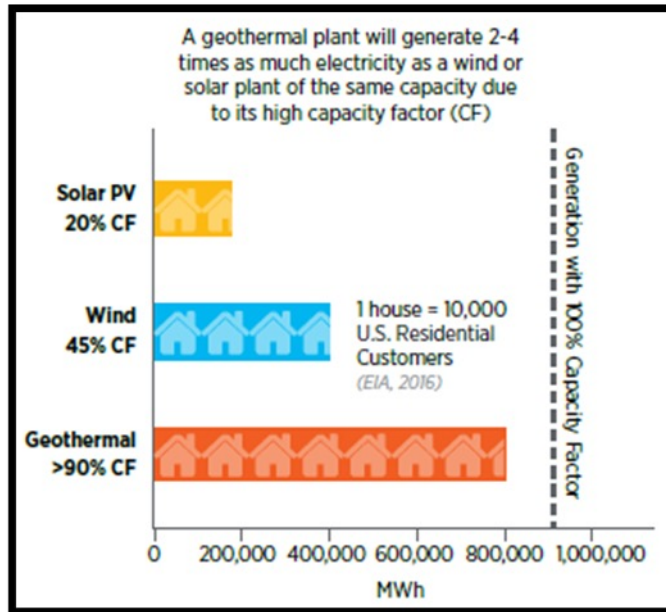


**GEOHERMAL**  
Abundant sustainable energy – Overview & Opportunities

Source: S&P Global – Temperature map at 10k feet depth  
<https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore>

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# TOPIC TWO



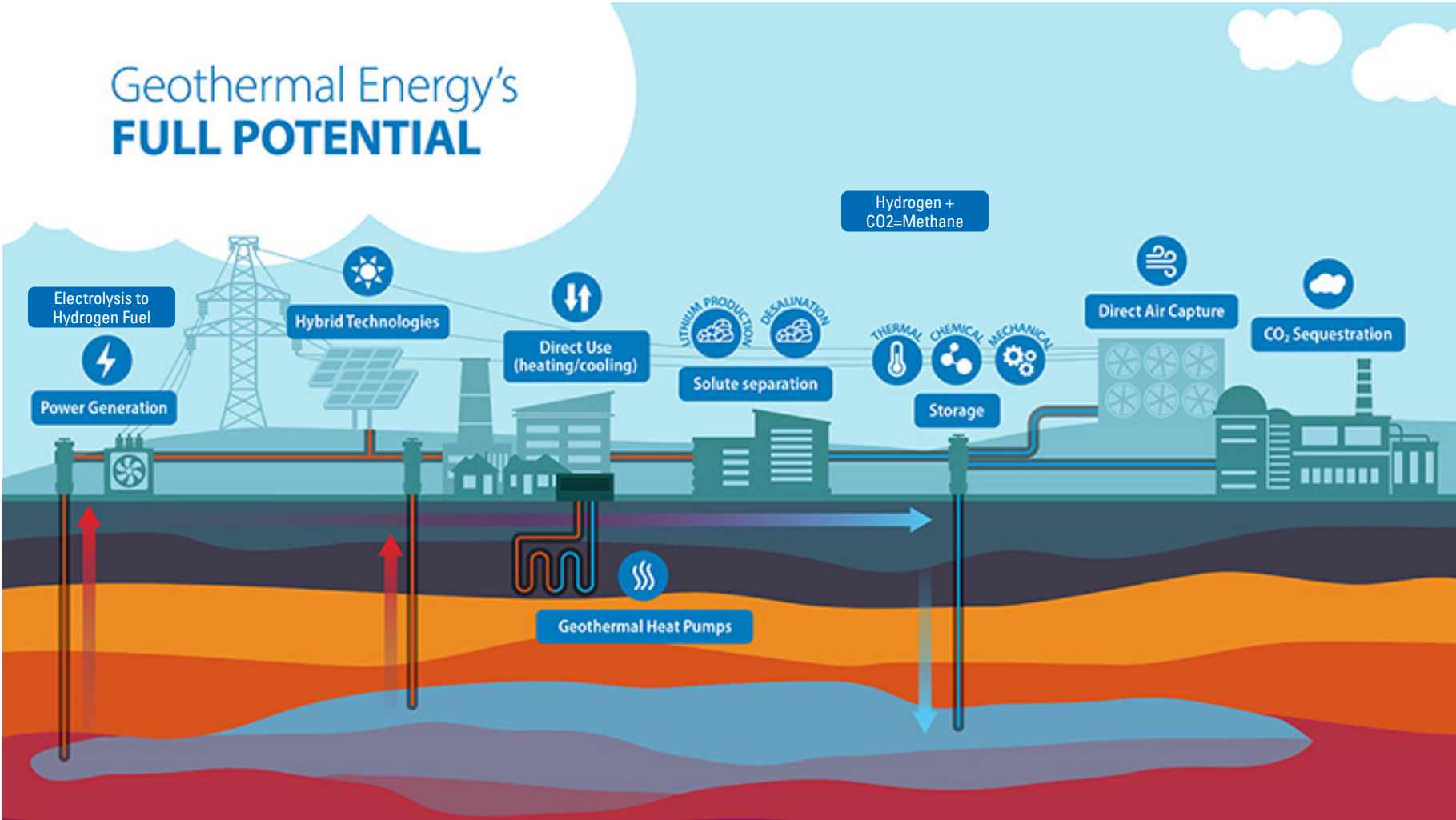
Source: US DOE GeoVision Report

## Geothermal Advantages

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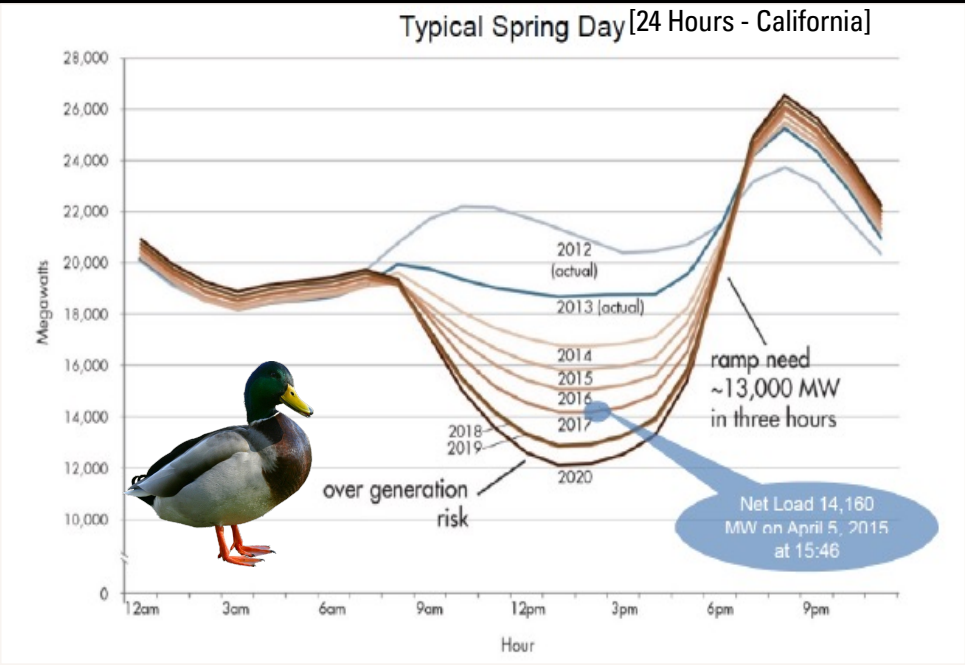


# GEO THERMAL HAS MANY USES

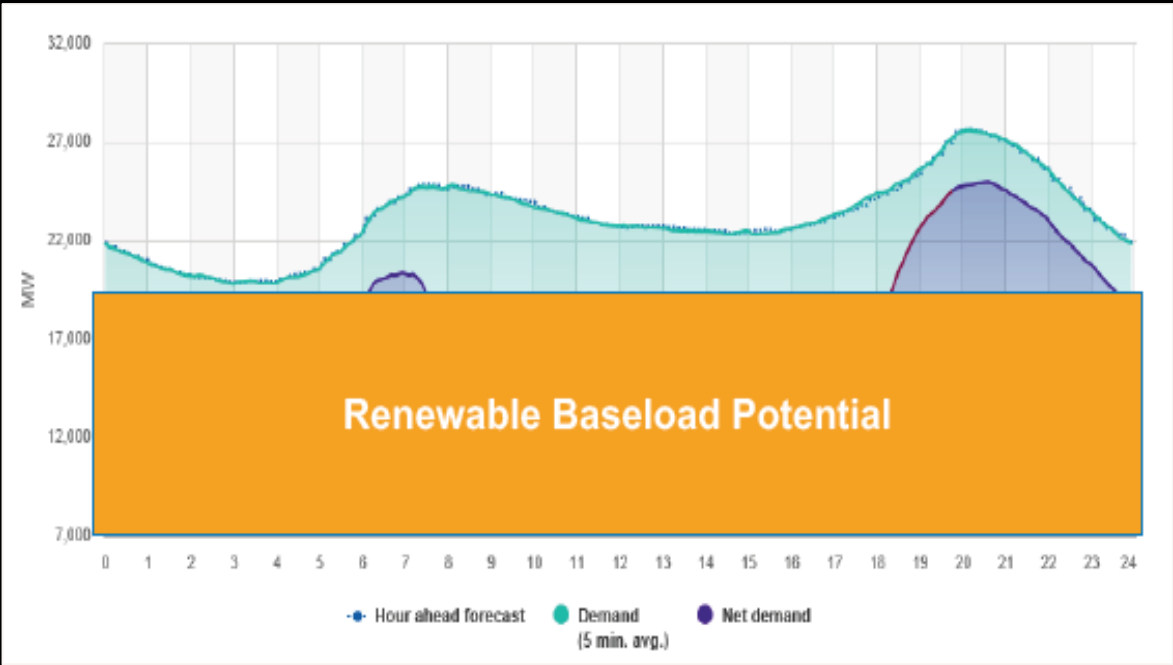




# GEOHERMAL FLATTENS THE DEMAND CURVE!



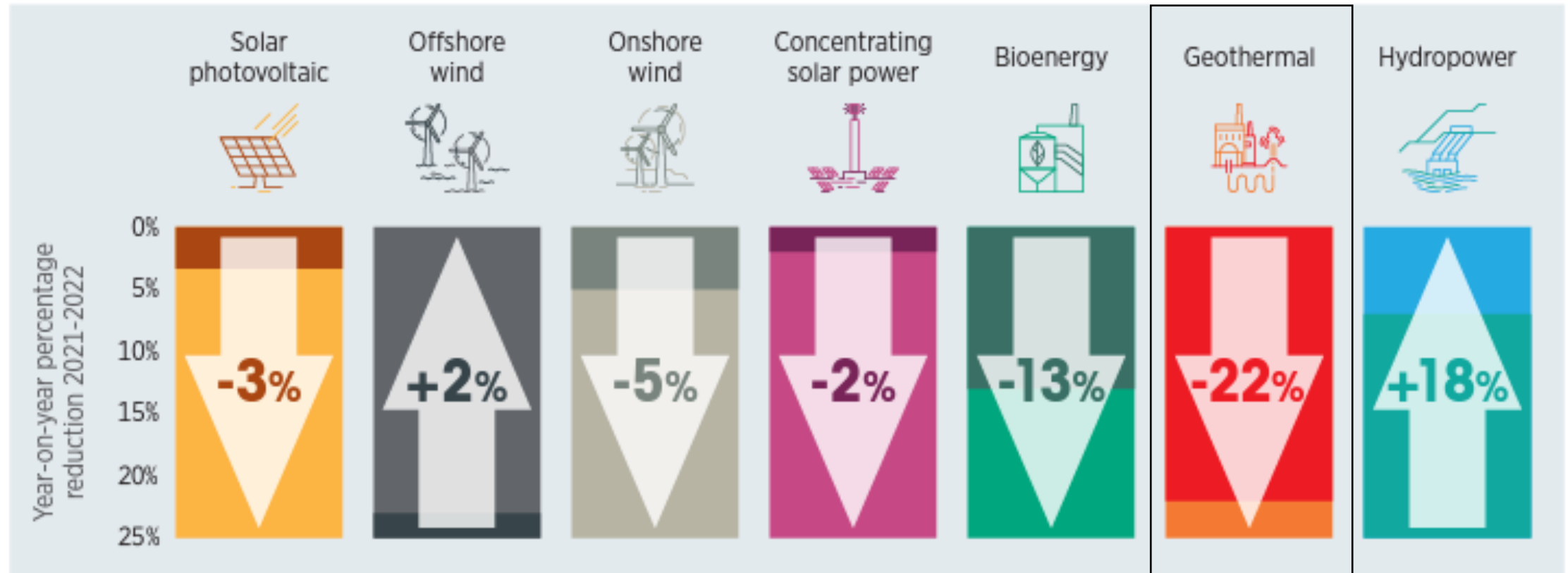
The Duck Curve



Baseload Geothermal helps with high demand fluctuations

- Variable Renewable Energy (VRE) i.e. Solar or Wind only produce energy when the conditions are right thus creating the Duck Curve. High ramp up in demand in early evening hours. Geothermal helps with fluctuations and is consistent 24/7 Baseload Clean Energy!
- Future Solar installations may not be economic!

# LEVELIZED COST OF ELECTRICITY (LCOE)



Between 2021 and 2022, the global weighted average levelized cost of electricity (LCOE) of ten newly commissioned geothermal projects fell by 22% to USD 0.056 kWh. This statistic was reported by the International Renewable Energy Agency (IRENA) - Drilling of production and injection wells is a main cost driver for geothermal projects.

In the case of geothermal, decreased installed costs and the constantly high capacity factor were the driving factors for a more competitive LCOE in 2022.

## GEOHERMAL

Abundant sustainable energy – Overview & Opportunities

<https://www.thinkgeoenergy.com/irena-reports-22-lower-lcoe-of-geothermal-projects-in-2022/#:~:text=IRENA%20reports%20a%20general%20increase,22%25%20to%20USD%200.056%20kWh.>

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# TOPIC THREE

Military (DoD) Advantages

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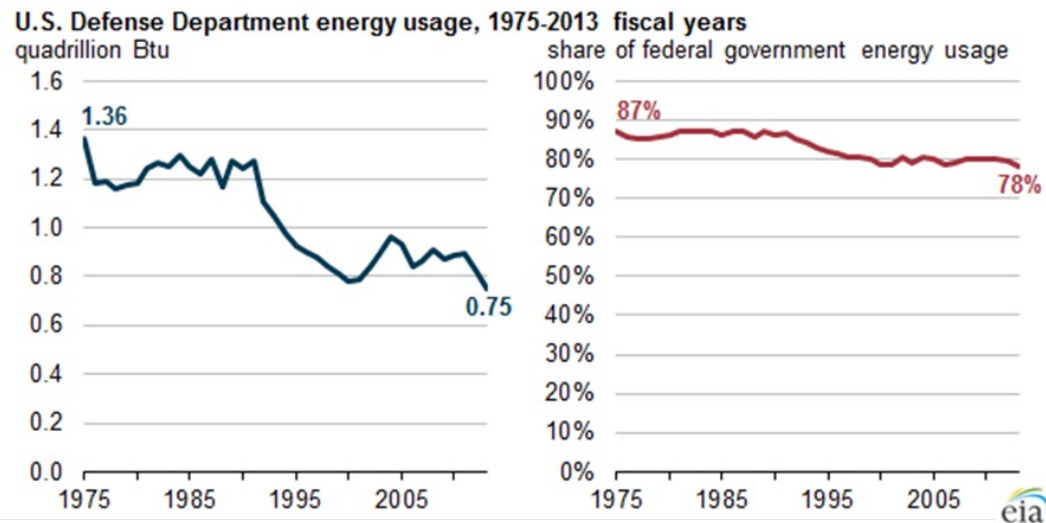


The DoD is the largest single consumer of energy in the USA

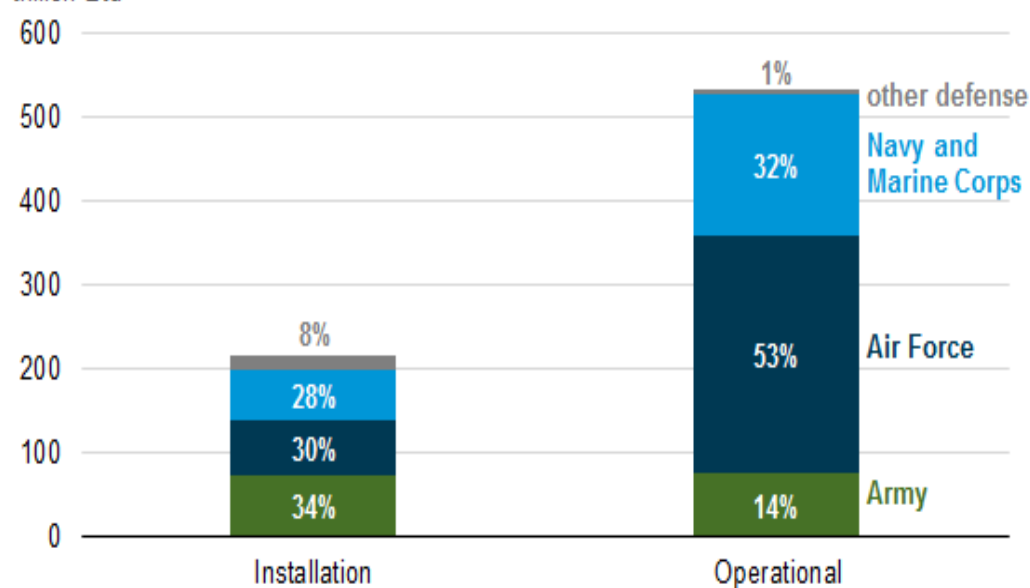
# DEPARTMENT OF DEFENSE – ENERGY DEMAND

DoD energy consumption across almost 300,000 buildings worldwide from more than 500 installations. The U.S. Air Force uses the largest portion of operational energy (53%), consisting mostly of jet fuel

## US DoD ~78% of Government Energy Usage



U.S. Defense Department energy consumption, 2013 fiscal year



<https://www.eia.gov/todayinenergy/detail.php?id=19871>

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# DEPARTMENT OF DEFENSE - SUSTAINABILITY

## Support of U.S. climate change initiatives



## Protect the DoD from energy price fluctuations



When managed appropriately – an inexhaustible fuel supply

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GEOHERMAL

Abundant sustainable energy – Overview & Opportunities

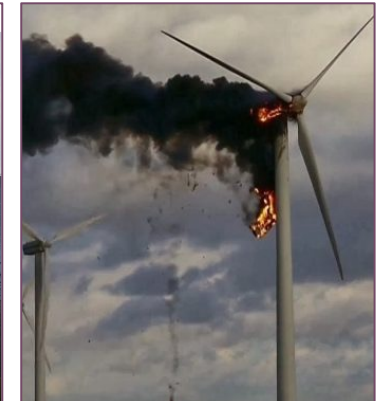
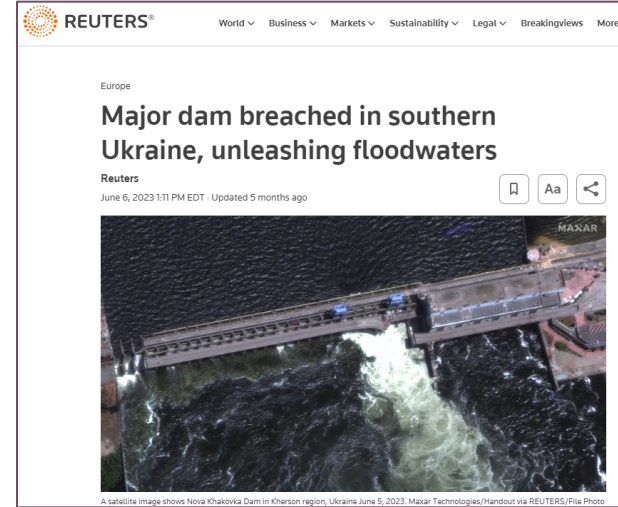
# ENERGY ABOVE GROUND - HIGH RISK TARGET

## Ukrainian solar plant partly resumes operations after bombing

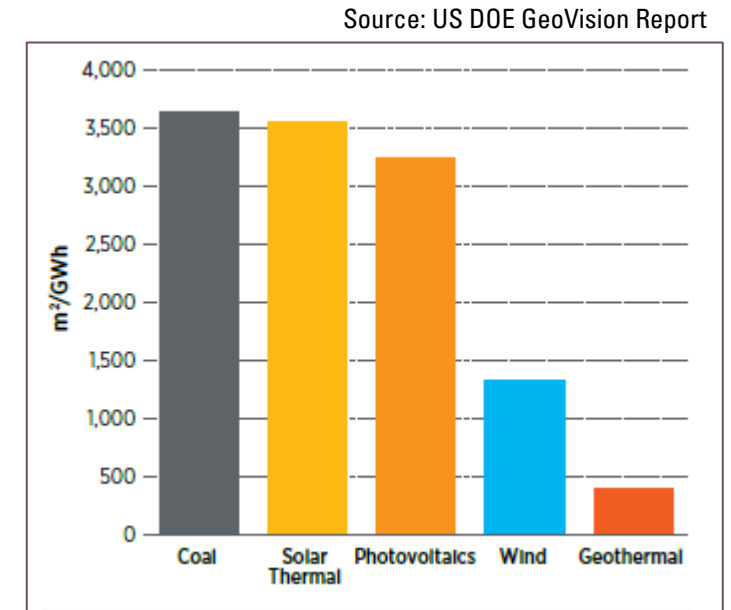
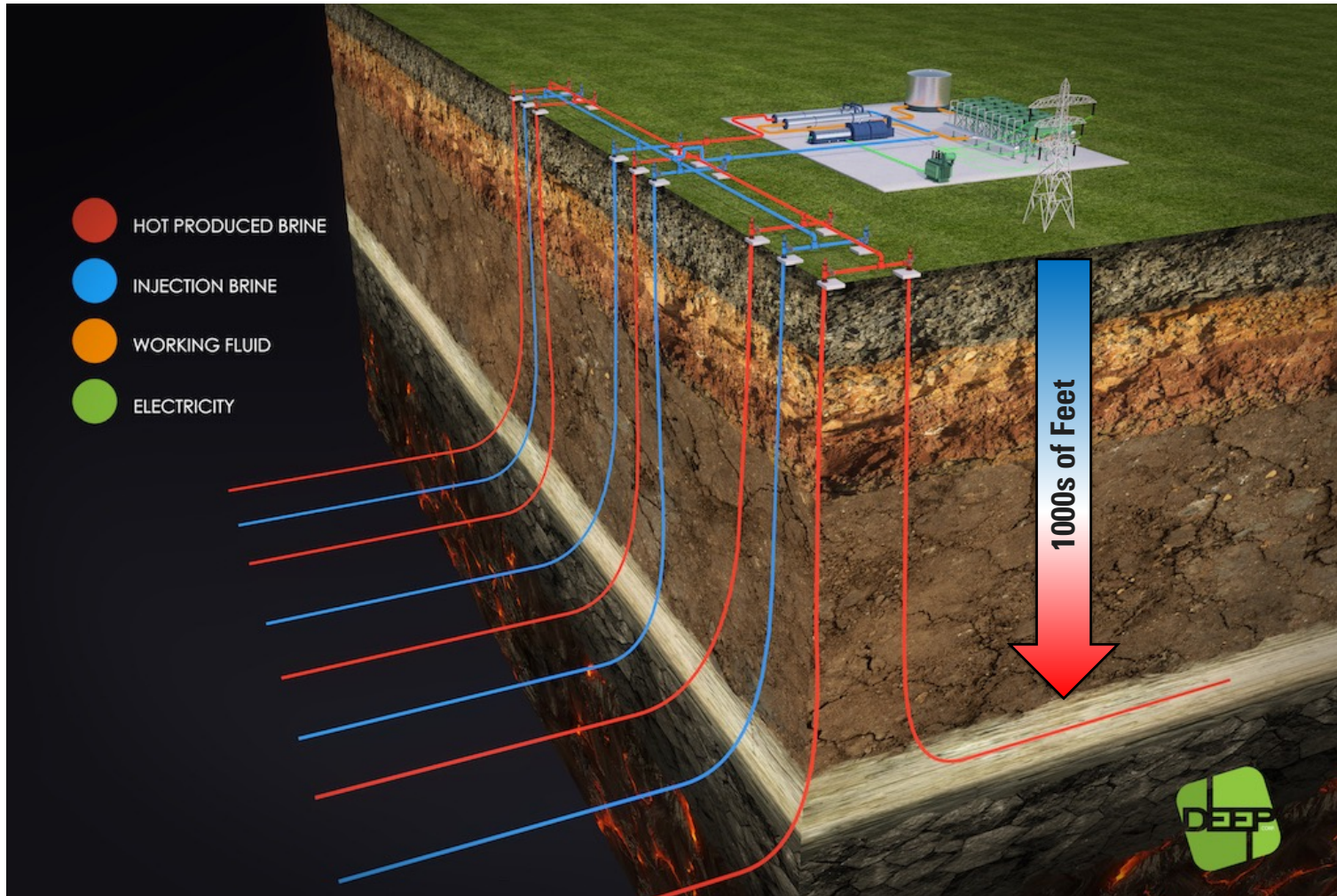
A Russian missile attack hit a 3.9 MW solar plant last week, damaging 416 solar panels and four string inverters.

JUNE 2, 2022 PV MAGAZINE

UTILITY SCALE PV EASTERN EUROPE UKRAINE



# ENERGY BELOW GROUND - LOWER RISK TARGET



Small land footprint compared to other energy generation technologies

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# TOPIC FOUR

Growth in Geothermal

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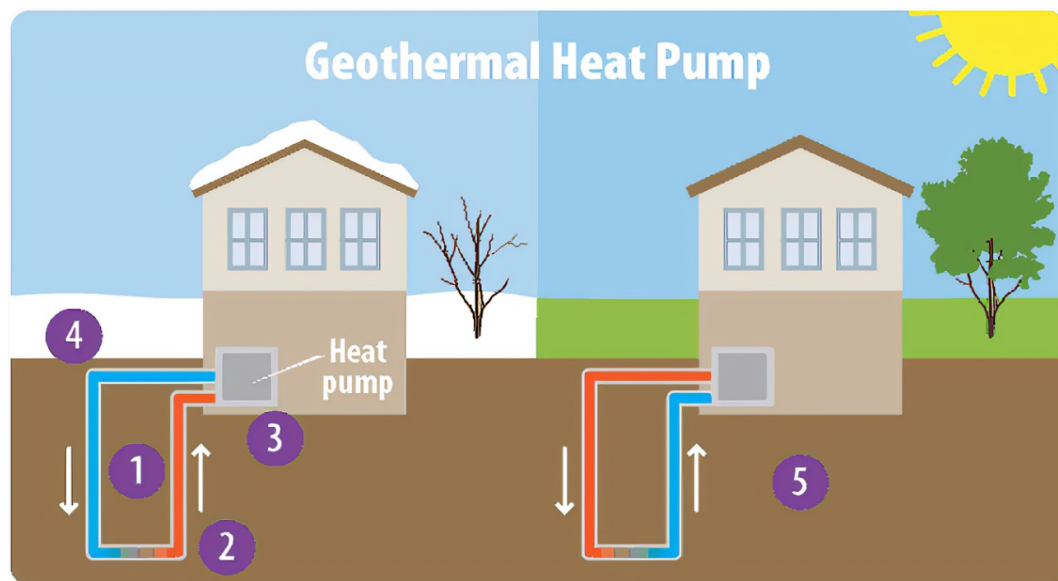
\*GHPs can be installed anywhere where the surface can be accessed below where seasonal temperatures penetrate

10 Feet to 100+ Feet Depth



# GEOEXCHANGE (HEAT PUMPS) OR GHP

Take constant 55 degree Fahrenheit temps useful for heating and cooling homes



It is expensive upfront but over 5-10 years it pays itself off and then lasts decades. About 2 million of these heat pumps in the USA right now. Some places requiring new builds to have the heat pump. They still require some electricity to run the compressor but it operates at 25% of level of contemporary HVAC system.

Dandelion Geothermal Geothermal heating, cooling, and domestic warm water system	VS	Fuel Oil Fuel oil furnace, central air conditioning system, and domestic water heater
\$1,532 - Heating \$295 - Cooling <b>\$1,827 Total Costs</b>	Yearly Operating Cost	\$2,896 - Heating \$512 - Cooling <b>\$3,408 Total Costs</b>
\$36,540	20 Year Operating Cost	\$68,160
\$54,540 - \$61,540	Total 20 Year Price	\$83,600
<b>\$22,060 - \$29,120</b>	<b>Savings Over 20 Years</b>	\$0
\$0 down financing available	Financing	Financing not always available via contractor

\*GHPs can be installed anywhere where the surface can be accessed below where seasonal temperatures penetrate

10 Feet to 100+ Feet Depth



# DISTRICT HEATING & COOLING

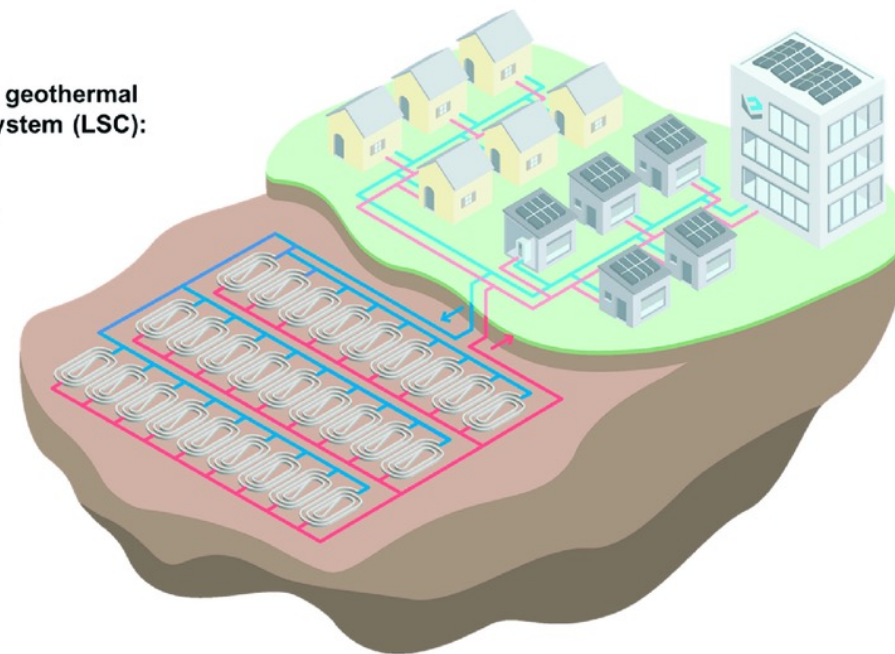
## THERMAL ENERGY NETWORKS

**Larger scale in surface area and/or depth than residential for heating and cooling communities**



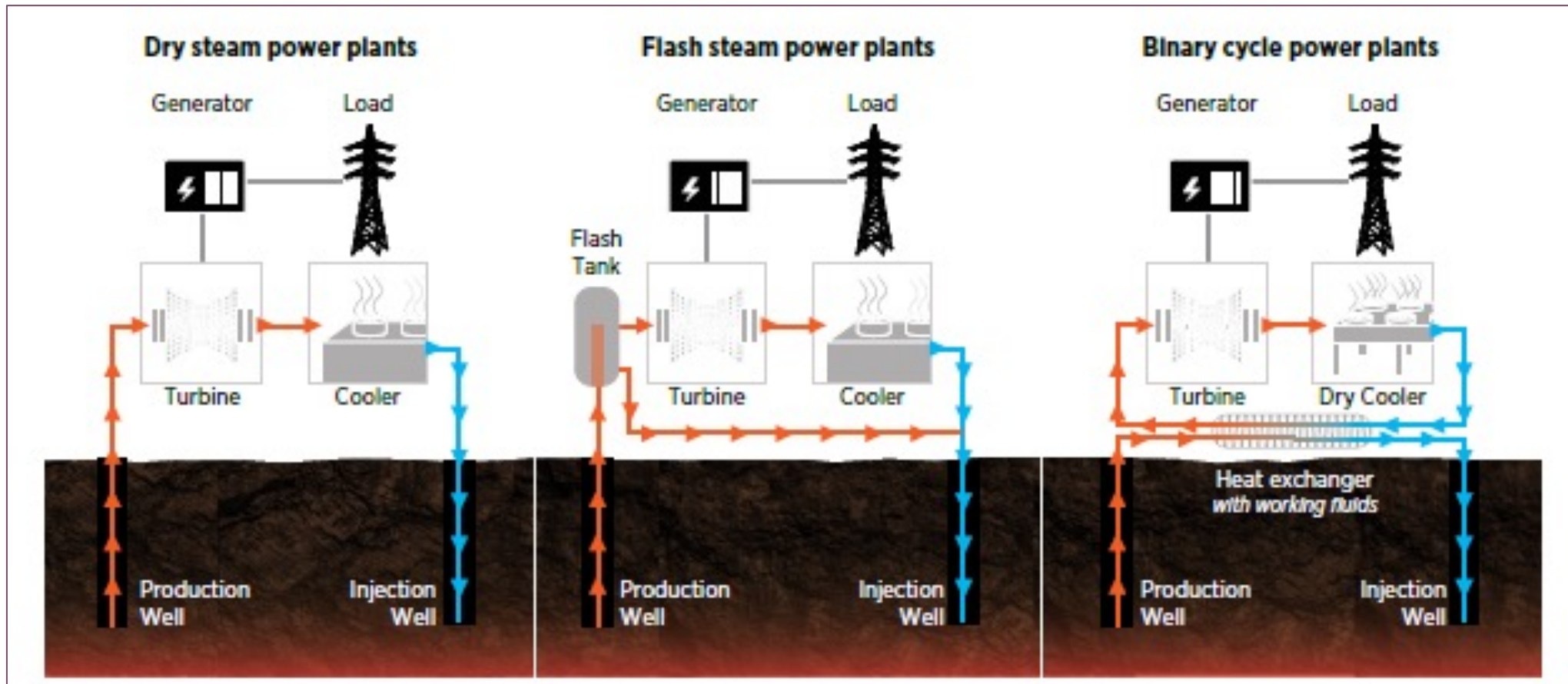
**A University Campus, City Block, Hotel, Office Building, Stadium and Airport**

**large-scale geothermal collector system (LSC):**  
≥ 1,000 m<sup>2</sup>  
≥ 25 kW  
≥ 50 kWh/y



# GEOHERMAL POWER PLANTS

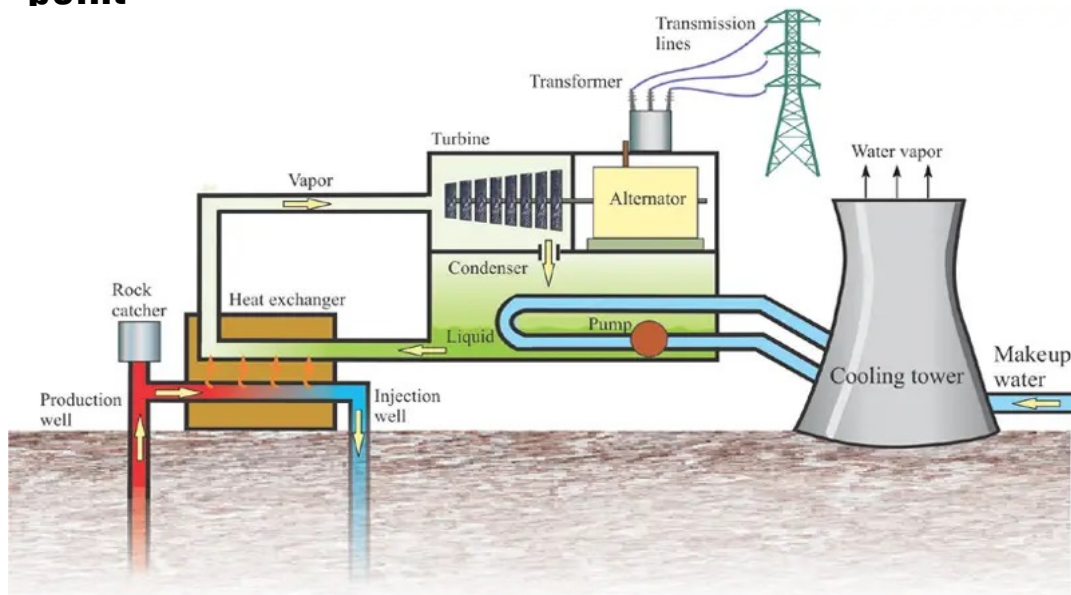
1000 Feet to 20000+ Feet Depth



Source: US DOE GeoVision Report

# BINARY GEOTHERMAL

Hot fluids cycle through a Heat Exchanger containing a gas that evaporates at a lower boiling point



1000 Feet to 20000+ Feet Depth



In the 1950s and 1960s binary powerplants came about. It is the concept of taking heat that is very hot but not hot enough to be in a gas state (below boiling point 212 degrees F) and transfer it to another fluid that evaporates at a lower temperature like an alcohol and make steam out of that secondary fluid and that fluid turns a turbine to make electricity.

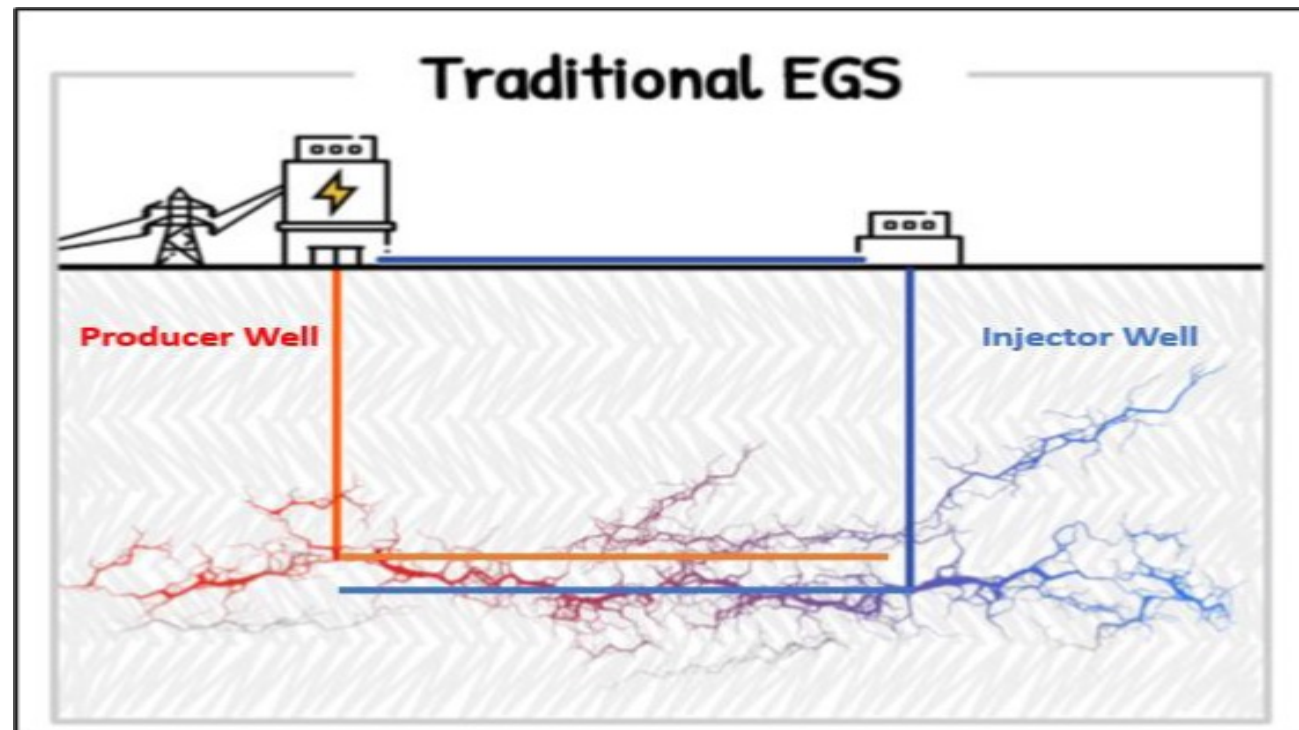


~36MW Binary-Cycle Geothermal Electrical Generating Plant in Raft River, Idaho

# ENHANCED GEOTHERMAL SYSTEMS (EGS) 1000 Feet to 20000+ Feet Depth



Using engineering and creating Flow through use of hydraulic fracking and/or introducing a liquid or gas to the hot dry reservoir rock system

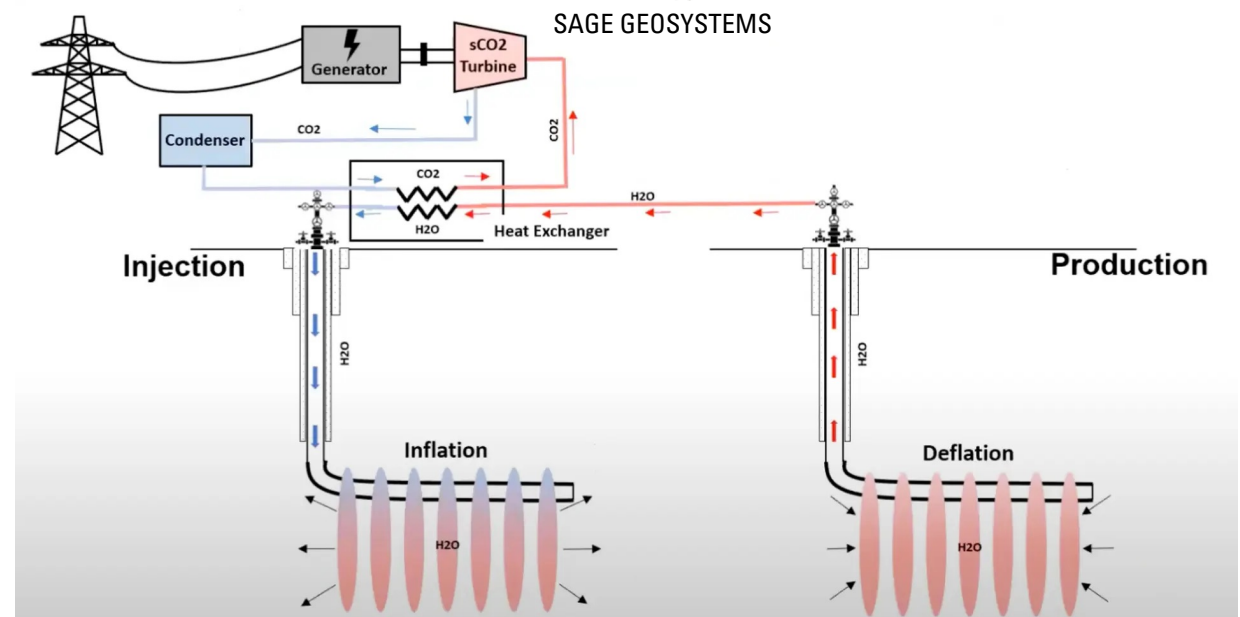


[https://www.txgea.org/wp-content/uploads/2023/01/The\\_Future\\_of\\_Geothermal\\_in\\_Texas\\_Executive\\_Summary.pdf](https://www.txgea.org/wp-content/uploads/2023/01/The_Future_of_Geothermal_in_Texas_Executive_Summary.pdf)

# ENHANCED GEOTHERMAL SYSTEMS (EGS) 1000 Feet to 20000+ Feet Depth



**Fervo** is based in Houston, TX and their Nevada test well in 2023 successfully drilled 2 binary wells that produced over 3.5MW of electricity in their initial field trial.



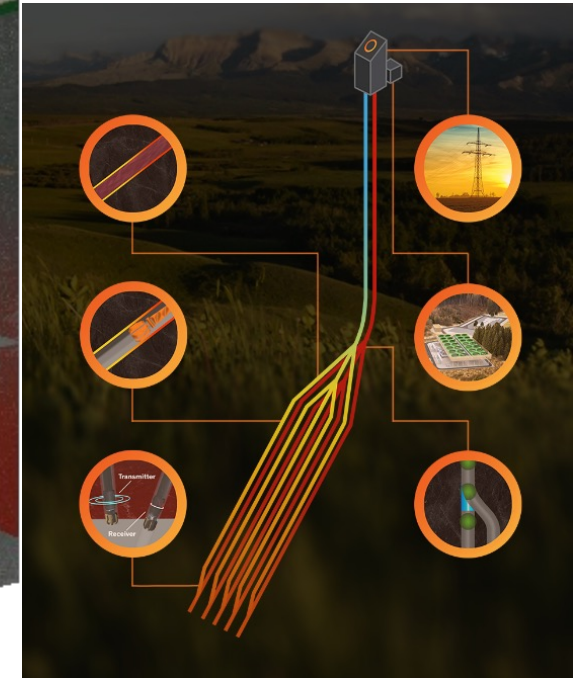
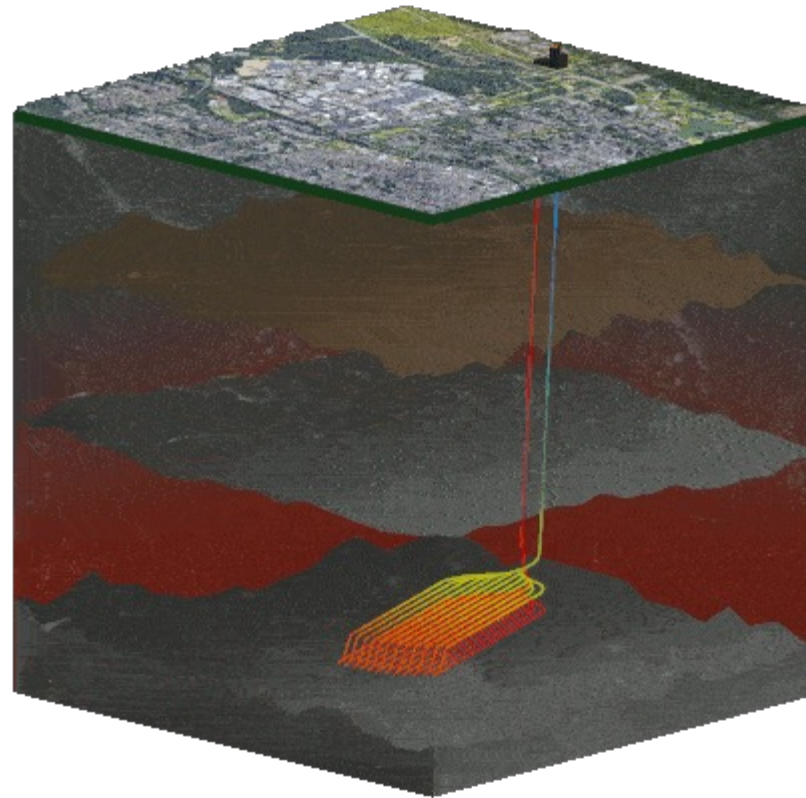
**Sage Geosystems** is based in Houston, TX and working on a test in various basins including the Permian and Ellington Field in Texas. They are developing a 'Huff and Puff' system that they believe 20 wells can create 50MW of electricity

# ADVANCED GEOTHERMAL SYSTEMS (AGS) 1000 Feet to 20000+ Feet Depth



**Eavor** is based in Canada and they drill a closed loop system as well as circulate a proprietary “radiator fluid” that removes heat just like radiator fluid removes heat from a car engine. Eavor-Loop generates industrial-scale electricity or produces enough heat for the equivalent of 16,000 homes with a single installation.

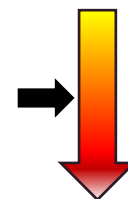
In Alberta, Canada Eavor-Lite™ consists of two vertical wells, joined by two multilateral legs at 2.4km depth, connected by a pipeline at surface.



<https://www.eavor.com/technology/>

# REPURPOSING OIL/GAS TO EGS

1000 Feet to 20000+ Feet Depth



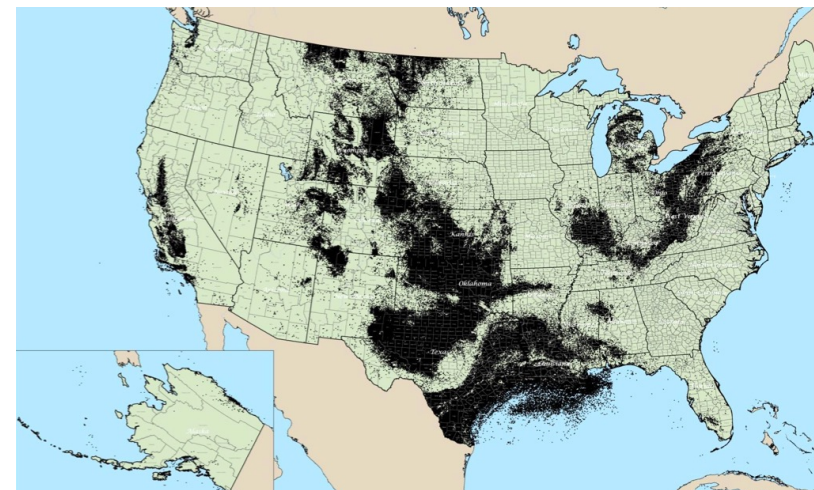
Several Million Wells: Oil/Gas Wells Across The USA



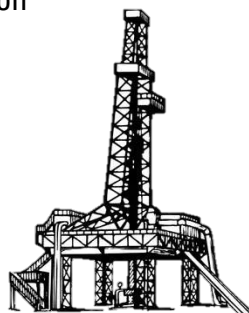
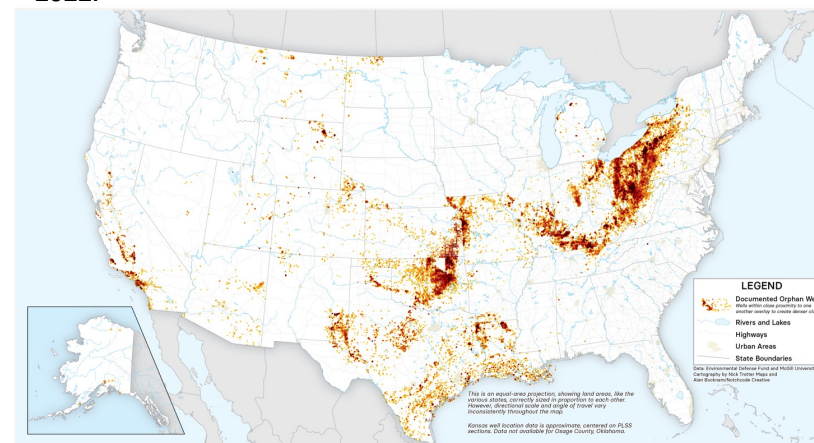
**Depleted:** After several years a well loses production



**Abandoned:** Operator goes bankrupt not sealed properly often leak methane 34x worse than CO2



**Methane Leaks:** The Environmental Defense Fund Map shows the concentration of abandoned wells in the US as of 2022.



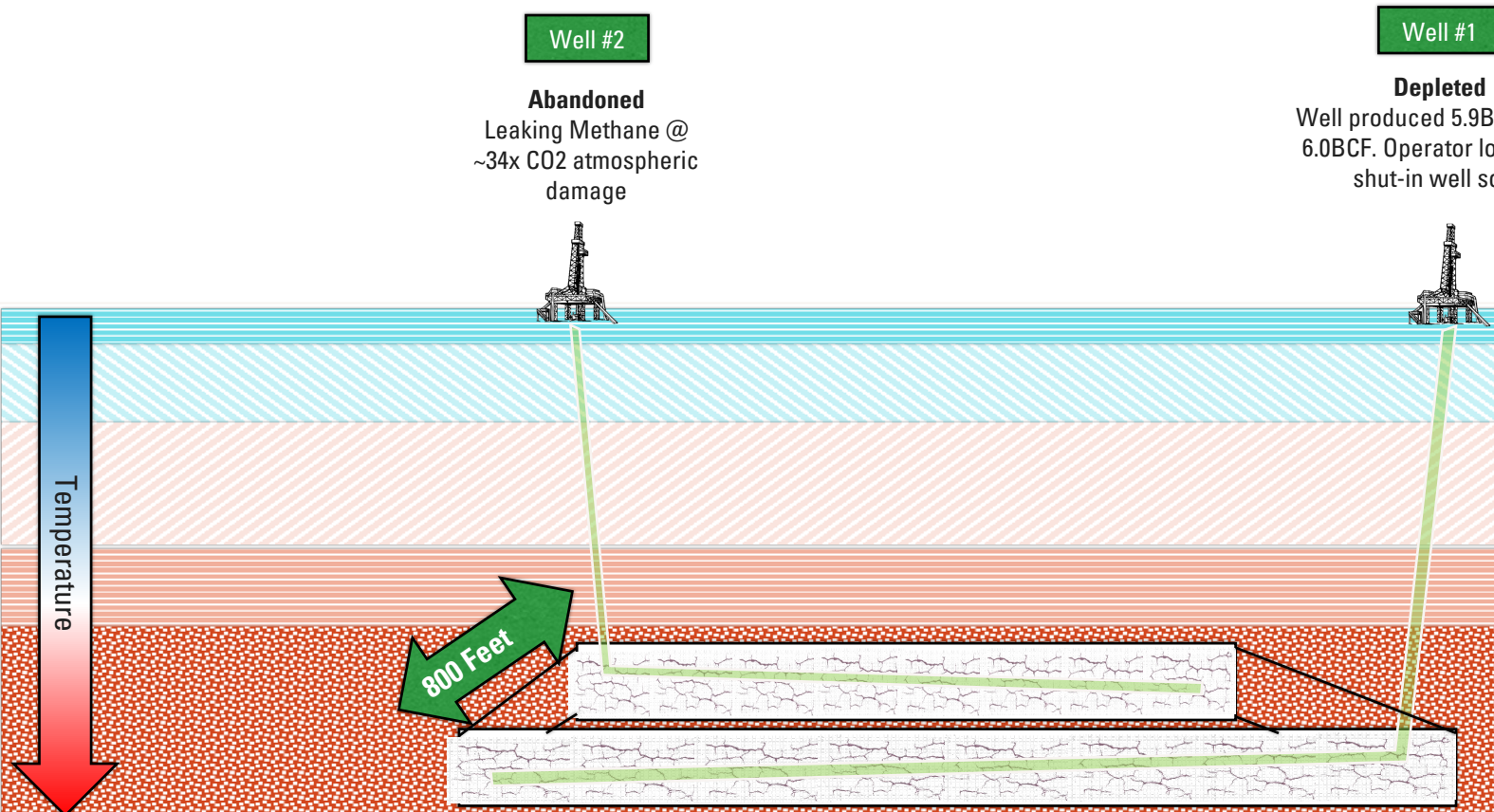
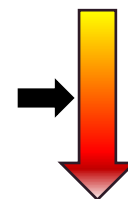
**Expensive Infrastructure:** The Petroleum Industry drills Oil/Gas unconventional wells then mechanically fractures the formation for **\$5MM-\$10MM/well or more!**

**GEOHERMAL**  
Abundant sustainable energy – Overview & Opportunities



# REPURPOSING OIL/GAS TO EGS

1000 Feet to 20000+ Feet Depth



- No need to drill and cut CAPEX by 30-50%

Generation of Variable Volume Based on Visage Simulation

Cross section

Small Volume Case

Well #2

Well #1

Natural Gas Reservoir

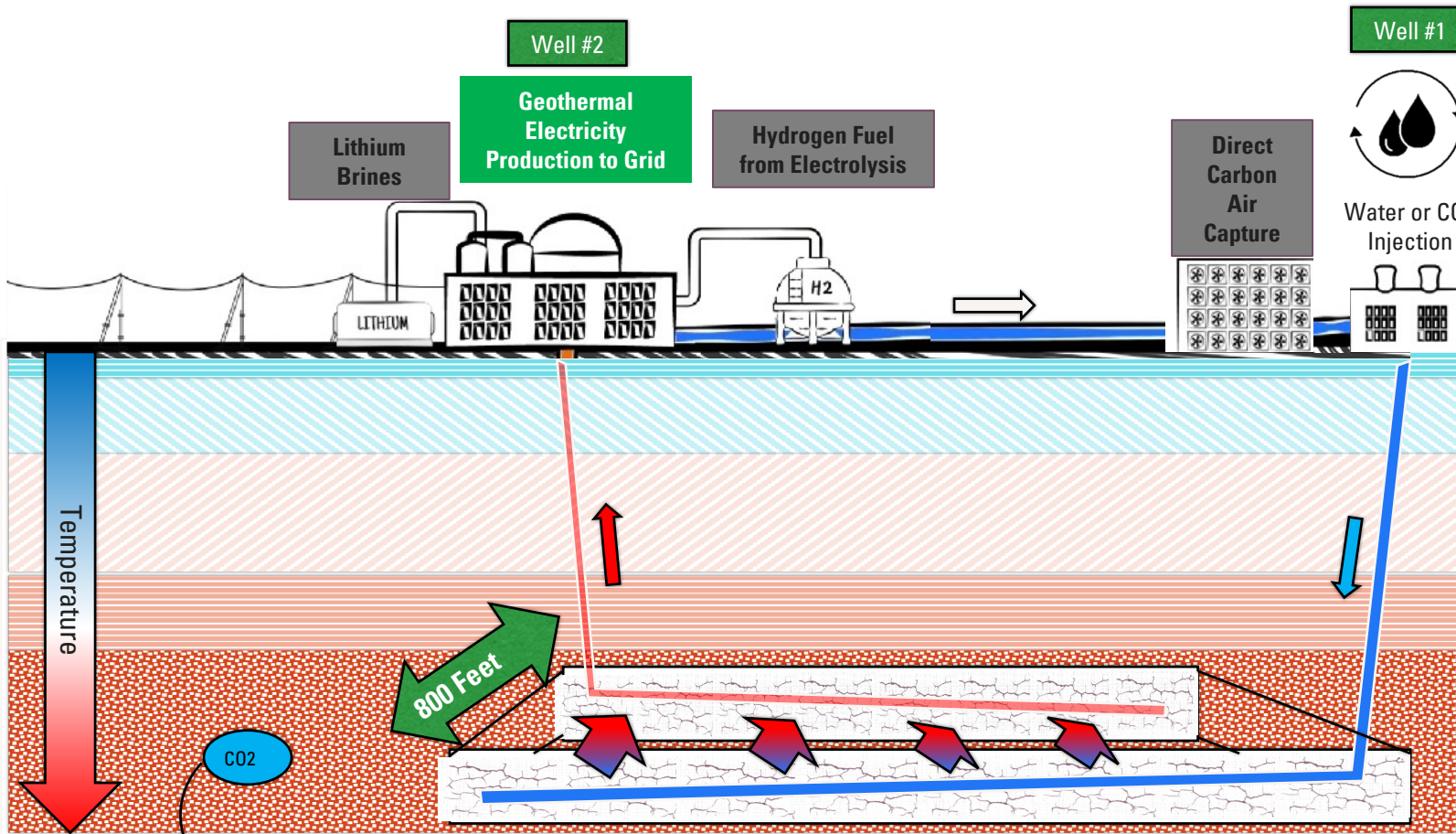
**First Iteration Run**

- Most flow expected
- Some flow expected
- Least flow expected

# Co-Production in Sedimentary Basins

# REPURPOSING OIL/GAS TO EGS

1000 Feet to 20000+ Feet Depth

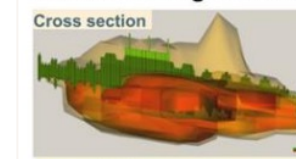


Any CO2 injected and not recovered for energy can be deemed sequestered for carbon tax credit

- Primary Business Sales Model
- Secondary Business Sales Model

Reuse Industrial Waste Water

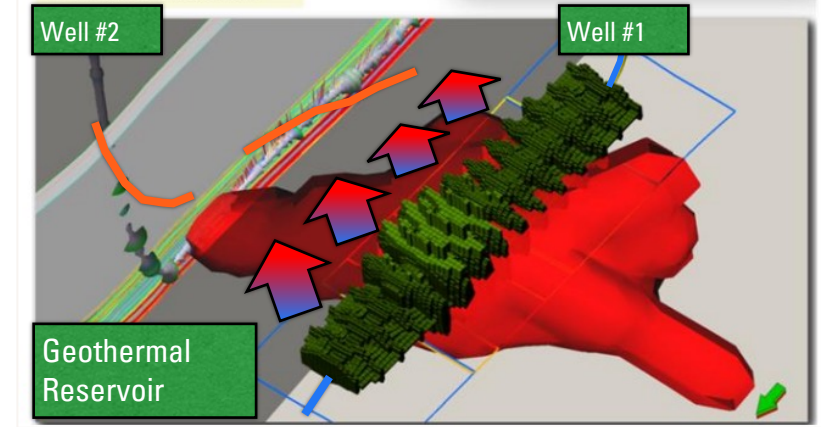
Generation of Variable Volume Based on Visage Simulation



Small Volume Case

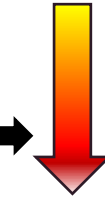
First Iteration Run

- Most flow expected
- Some flow expected
- Least flow expected



# SUPERHOT (ULTRA-DEEP) GEOTHERMAL

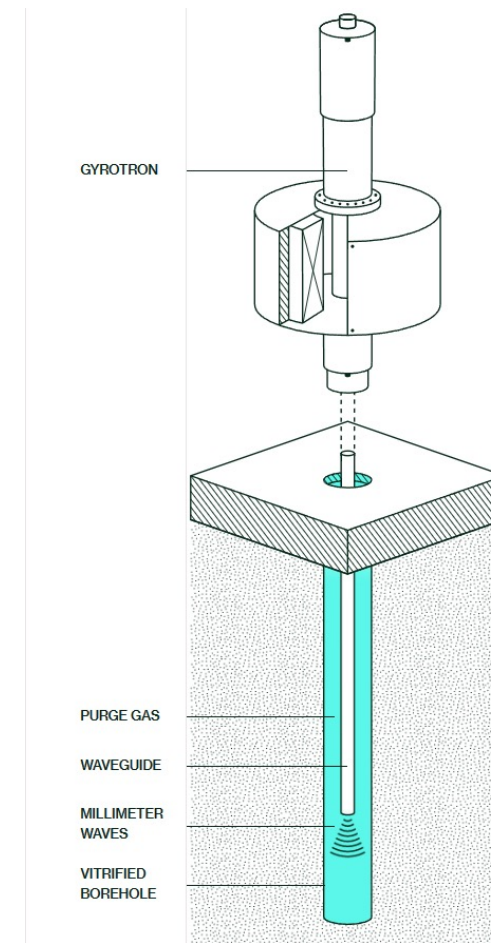
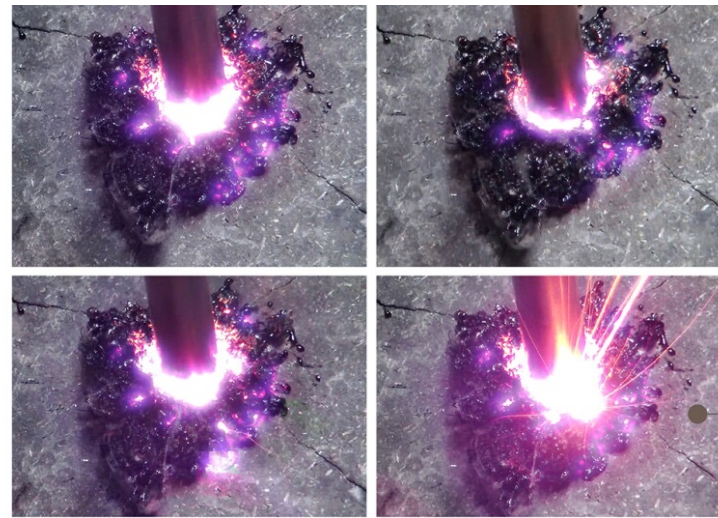
10-20km Depth



## QUAISE

**Quaise** is a startup from MIT using Millimeter wave drilling to unlock the most abundant and powerful clean energy source on Earth by allowing us to drill down to 20 km and 500° C.

Drill conventionally until hit hard rock that would normally destroy drill bits and keep drilling deeper using microwave technology



GEOTHERMAL

Abundant sustainable energy – Overview & Opportunities

<https://jpt.spe.org/microwave-drilling-sounds-like-science-fiction-but-so-does-drilling-down-to-the-hottest-rock>

<https://www.quaise.energy/>

# GEOHERMAL RELATED SECONDARY PRODUCTS

## Hybrid



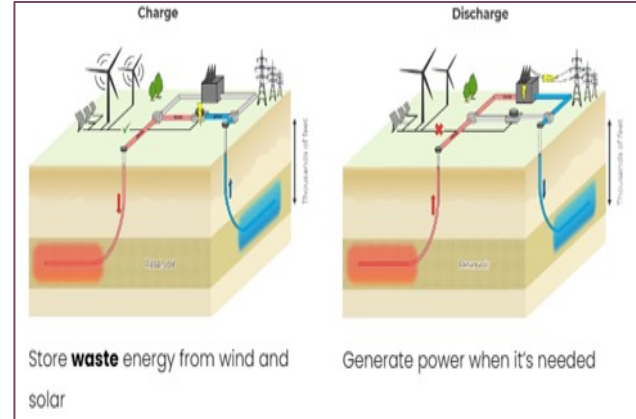
The Stillwater geothermal plant is the first **hybrid** solar geo facility in the nation. In 2014 Enel Green Power added 2 MW of concentrating solar power to the existing geothermal plant and solar photovoltaic field, for a total installed capacity of ~60 MW.

## Brine Elements - Lithium



**Geothermal brines** can yield lithium (used in batteries), brought up in the brine solution from thousands of feet underground.

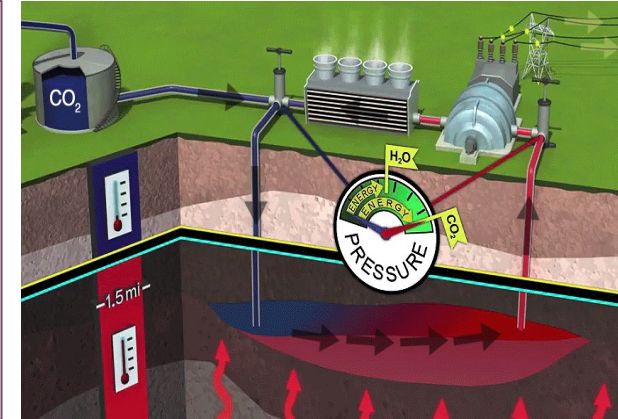
## Geothermal Battery



A **geothermal battery** works by injecting heated water (solar/wind) into non-potable, underground aquifers to store heat for later recovery.

Source: EarthBridge Energy - GeoBattery

## CO2 Storage & Sequestration



**CO2 Storage & Sequestration:** CO2 is easier to pump than water and uses less energy. CO2 that is not recovered from formation can be sequestered. The extracted 'hot' CO2 sets a turbine in motion to produce electricity.

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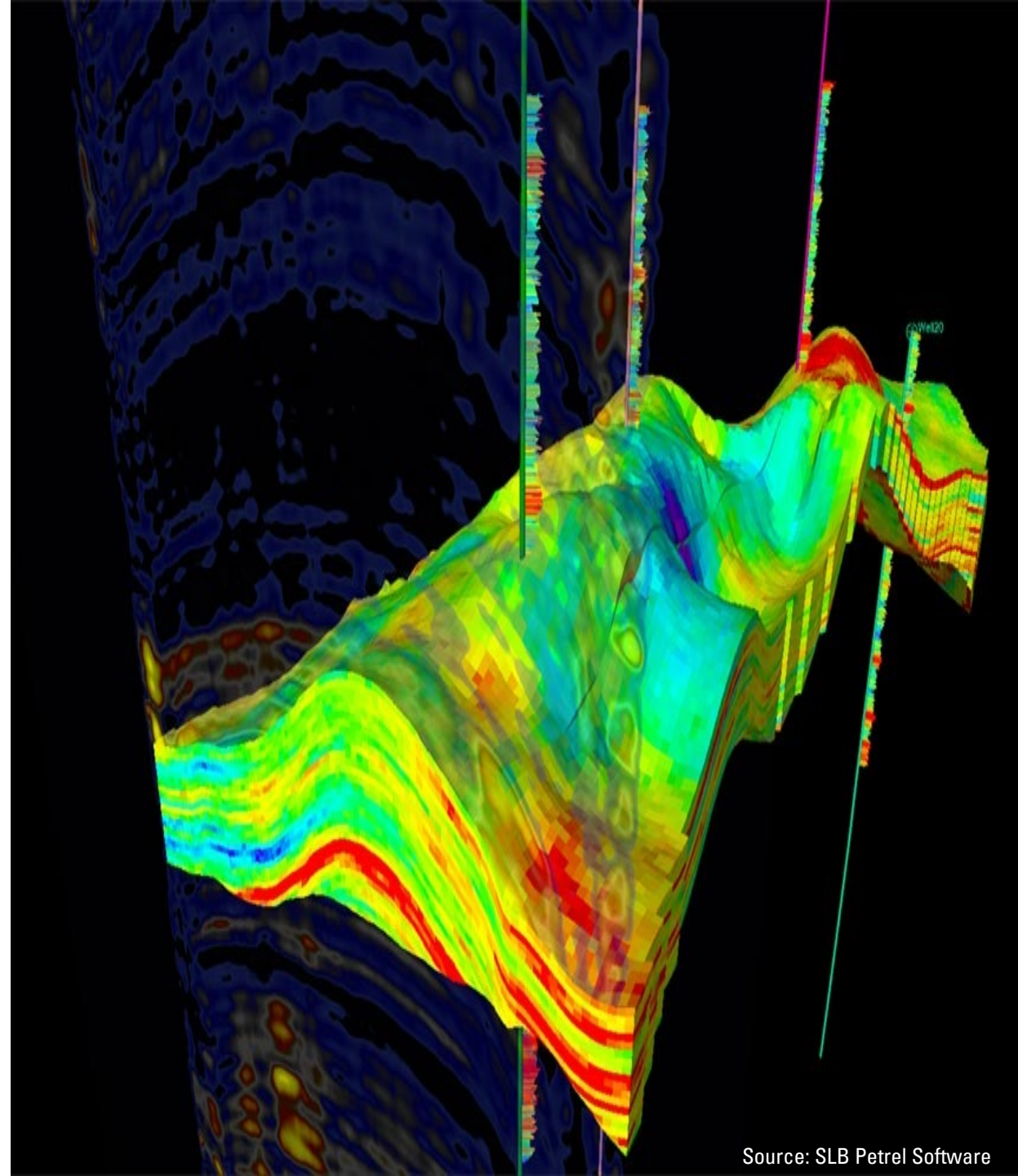
# TOPIC FIVE



## Consulting and Future Operator

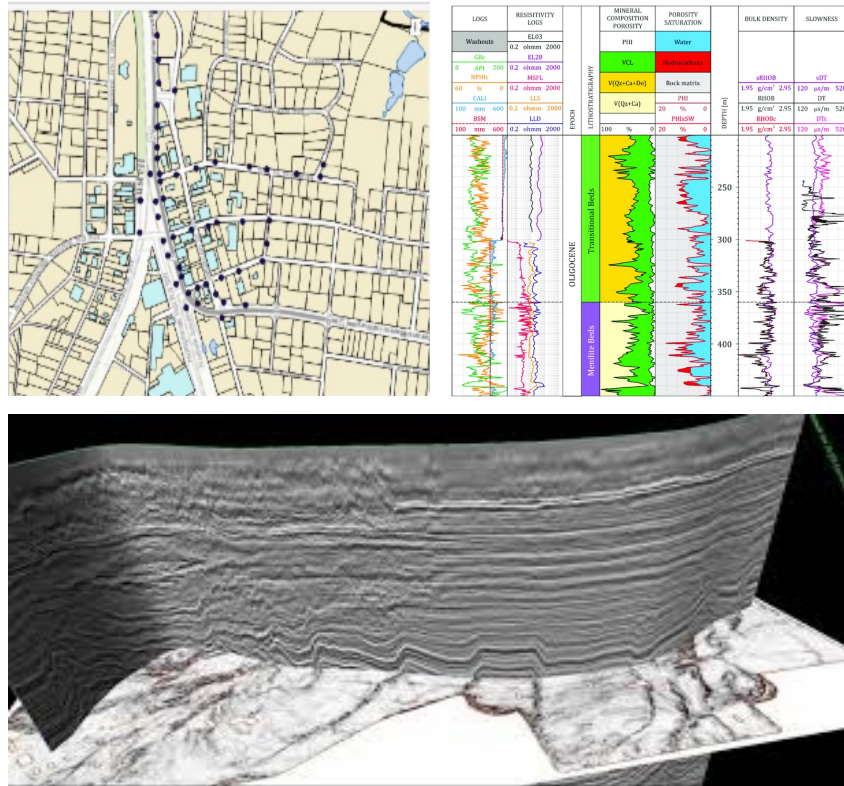
Leveraging Data Analysis for Optimal Geothermal Solutions, with a Focus on De-risking, Optimization, and Operational Excellence in Geothermal Development Projects.

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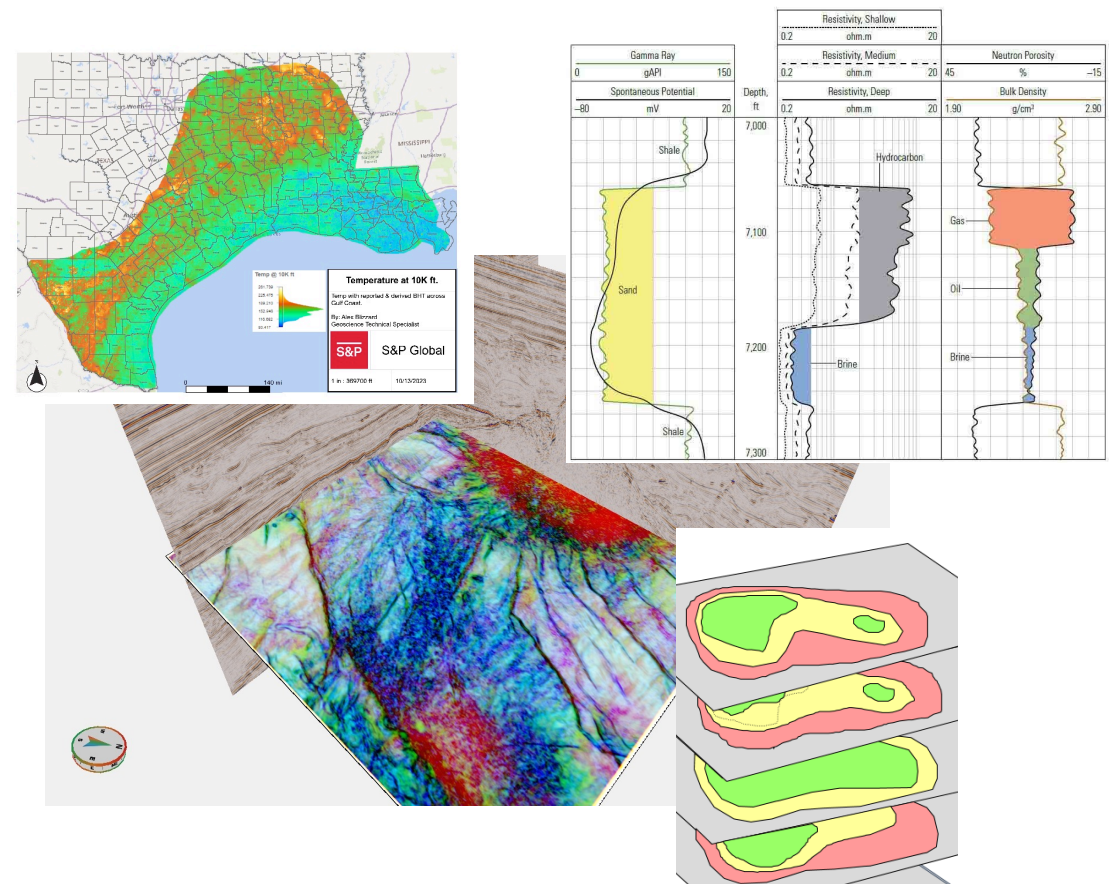
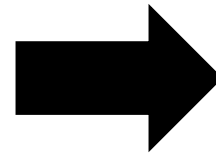


# DE-RISK & OPTIMIZATION

## GIS, Geologic & Engineering Data

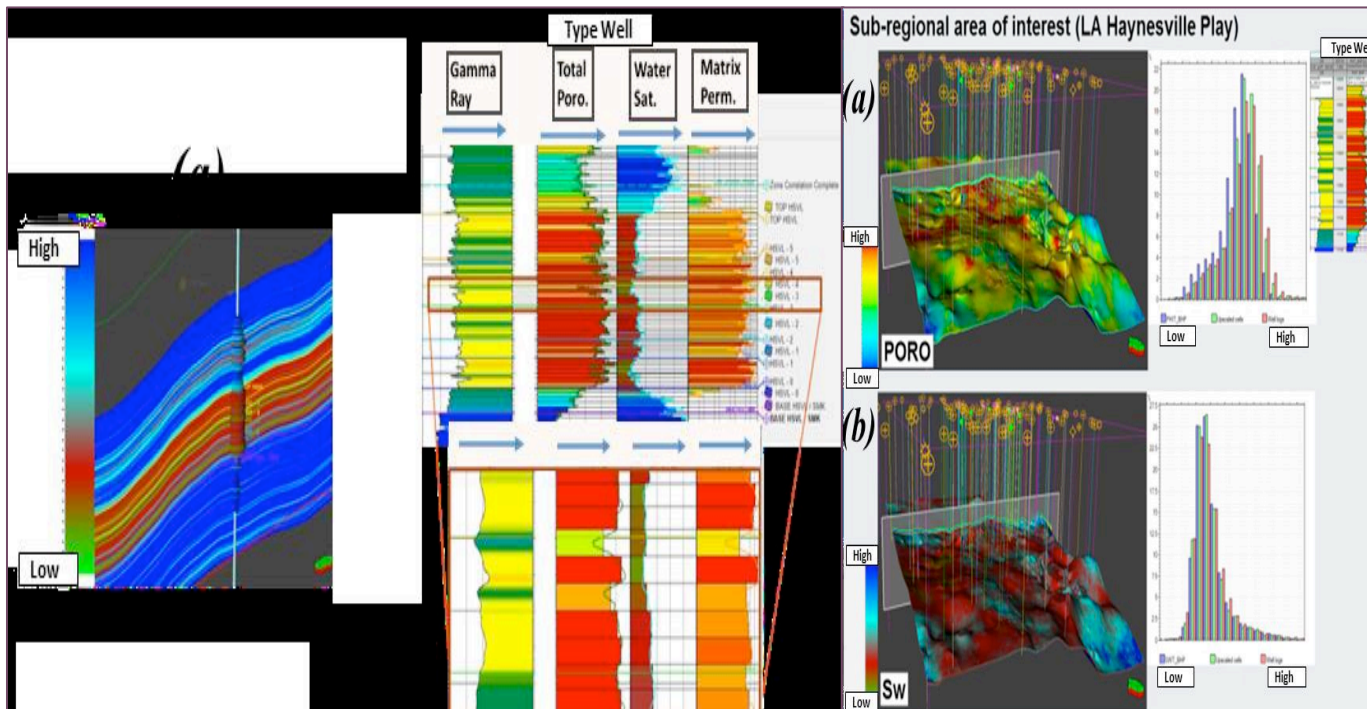


## Maps (Surfaces) and Interpretations

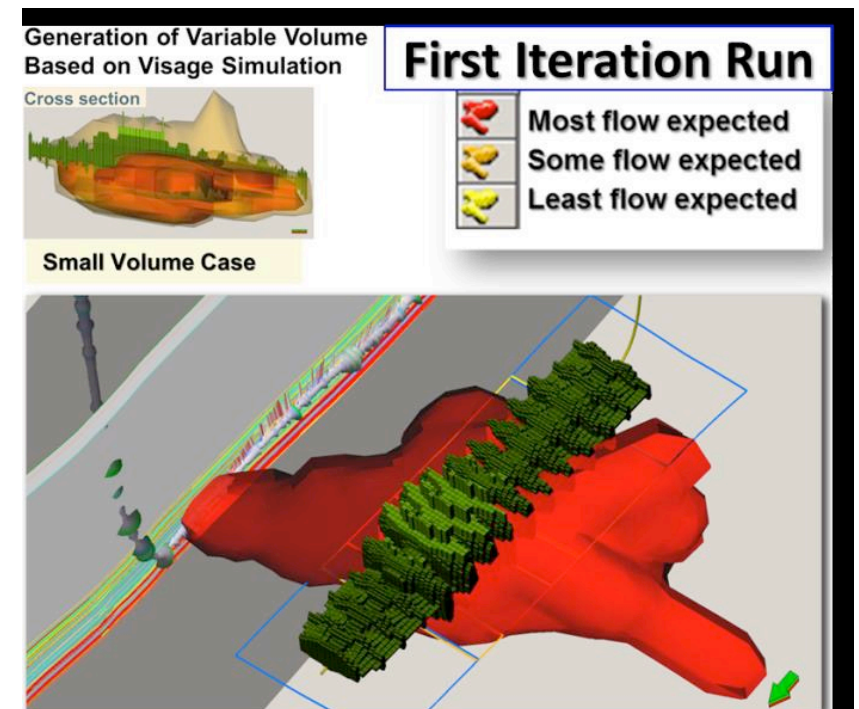


# DE-RISK & OPTIMIZATION

## 3D Rock Property Models



## Reservoir Characterization via Simulations

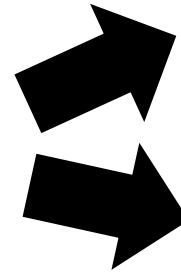
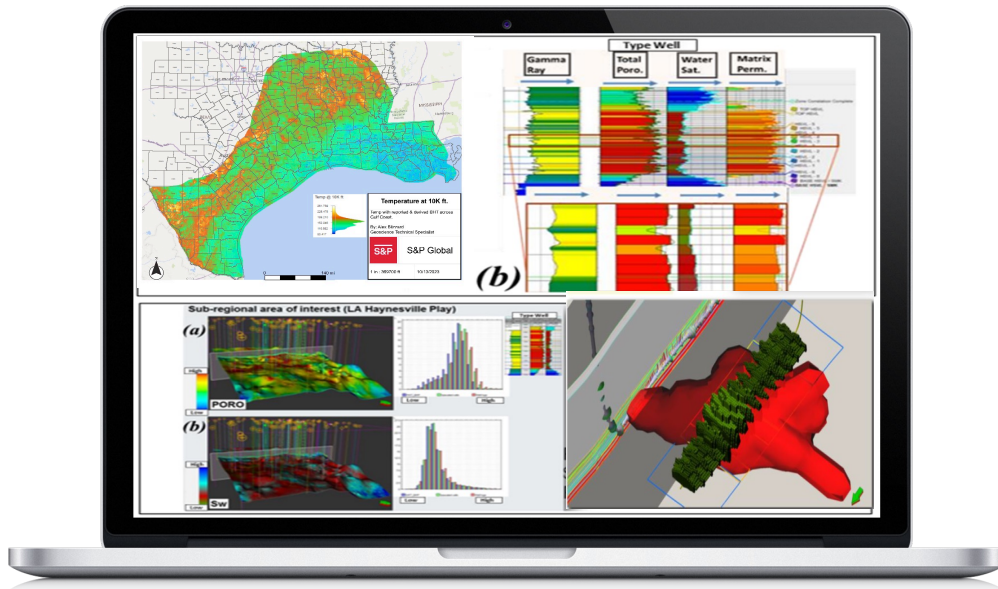


Credit: Geological and Geomechanical Modeling of the Haynesville Shale: A Full Loop for Unconventional Fractured Reservoirs; Bayer & Peterson et al. 2016

# MAKE BUSINESS DECISIONS WITH DATA

Our data products enable us to explore, develop, produce, and optimize the most promising geothermal candidates.

## Data Analysis Products



## Best Acreage & Infrastructure



## Optimize Production



Credit: Geological and Geomechanical Modeling of the Haynesville Shale: A Full Loop for Unconventional Fractured Reservoirs; Bayer & Peterson et al. 2016

Source: S&P Global – Temperature map at 10k feet depth

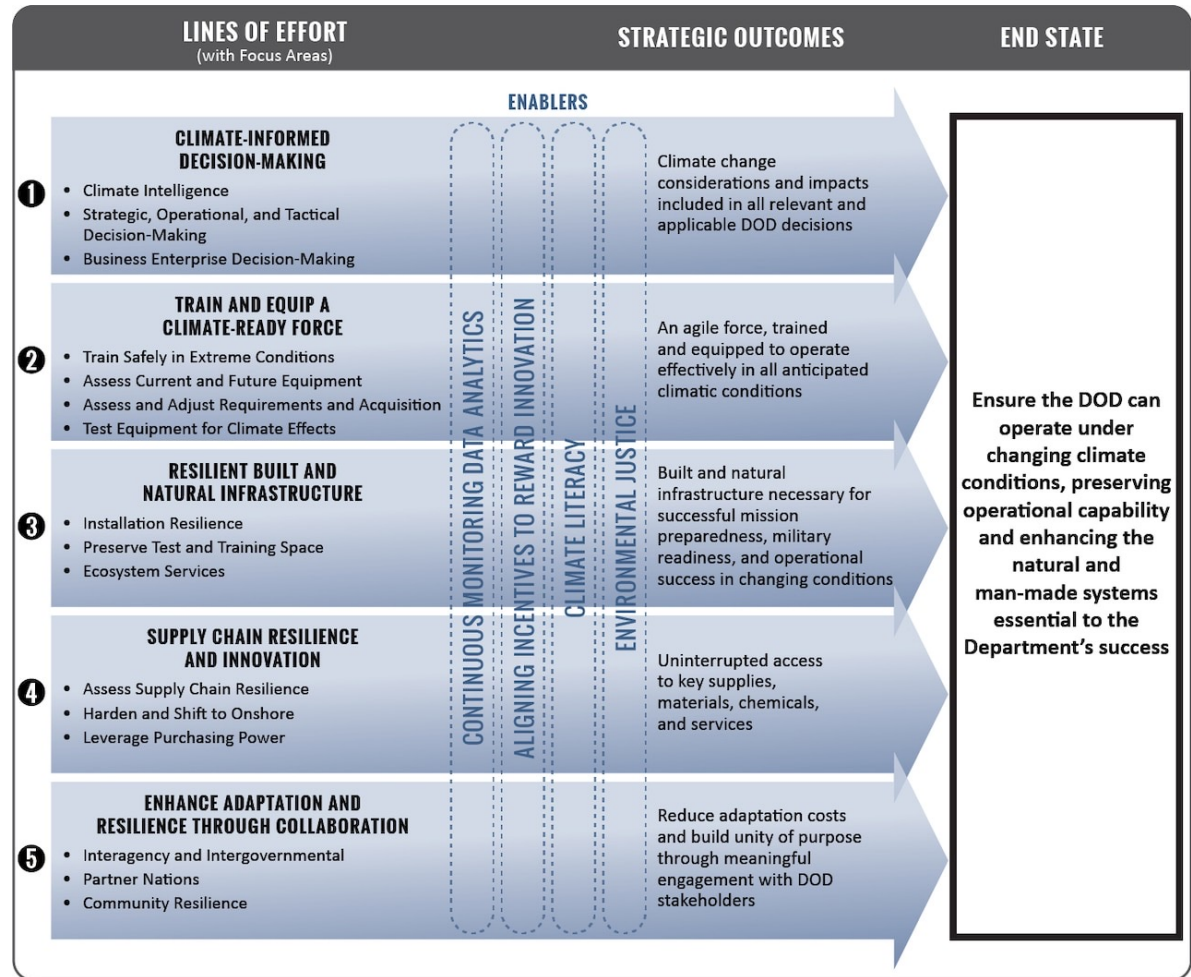
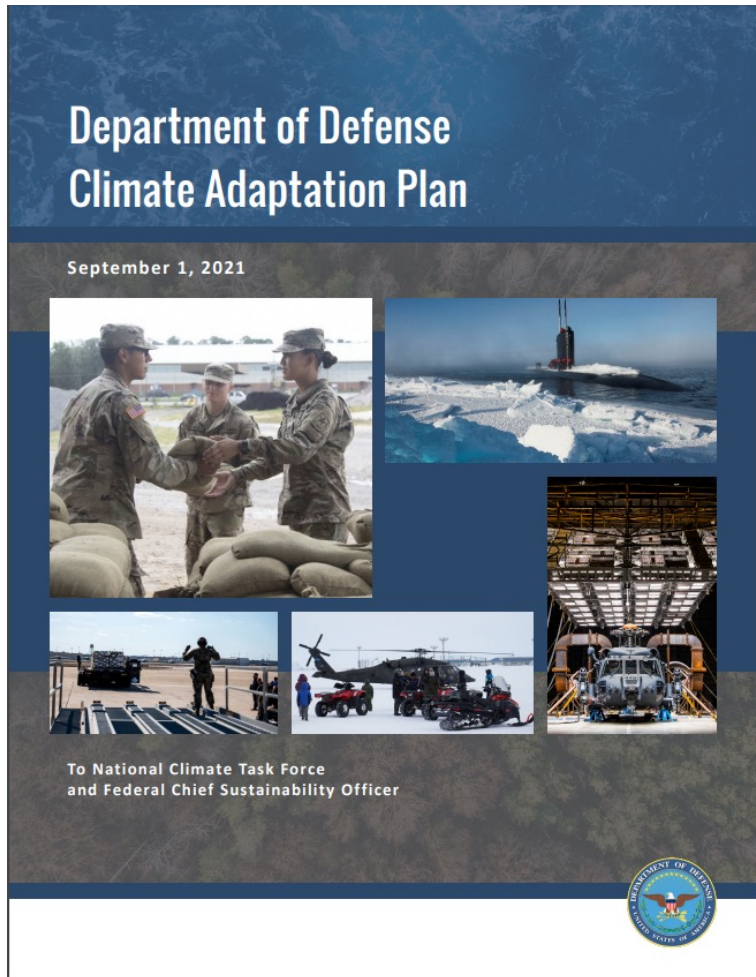
**GEOHERMAL**

Abundant sustainable energy – Overview & Opportunities










Geothermal energy supports DoD sustainability goals

# DOD CLIMATE ADAPTATION PLAN



# GEOHERMAL AND DOD CLIMATE GOALS

DoD Sustainability Goals	How Geothermal Helps
 Improve energy security	Provides reliable baseload power not dependent on weather or fuel supply
 Reduce energy costs	Cost-competitive and stable electricity prices compared to conventional fuels
 Cut carbon emissions	Clean renewable resource reduces carbon footprint
 Increase energy independence	On-site geothermal boosts self-sufficiency and reduces reliance on grid
 Drive new technologies	Investment in R&D of new geothermal systems and technologies
 Integrate renewables	Baseload capacity helps stabilize grids with high penetration of variable renewables
 Expand training opportunities	Hands-on engineering and technical training in growing energy sector

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# DOD GEOTHERMAL ACTIVE PROJECTS



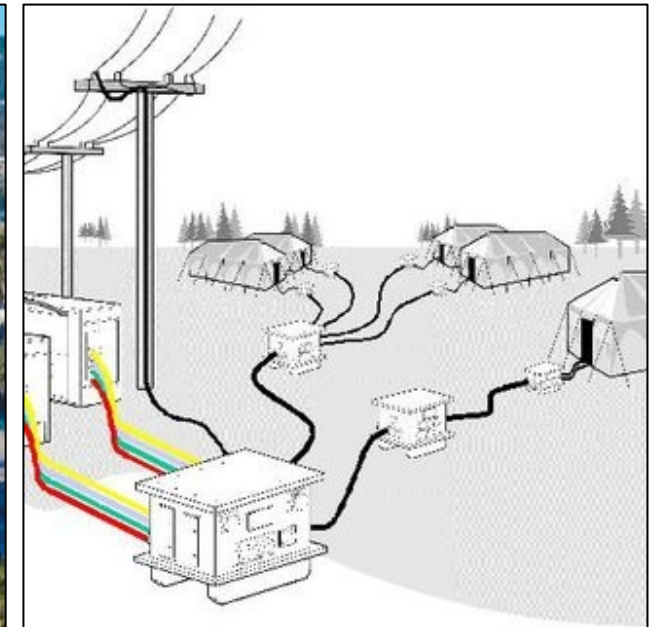
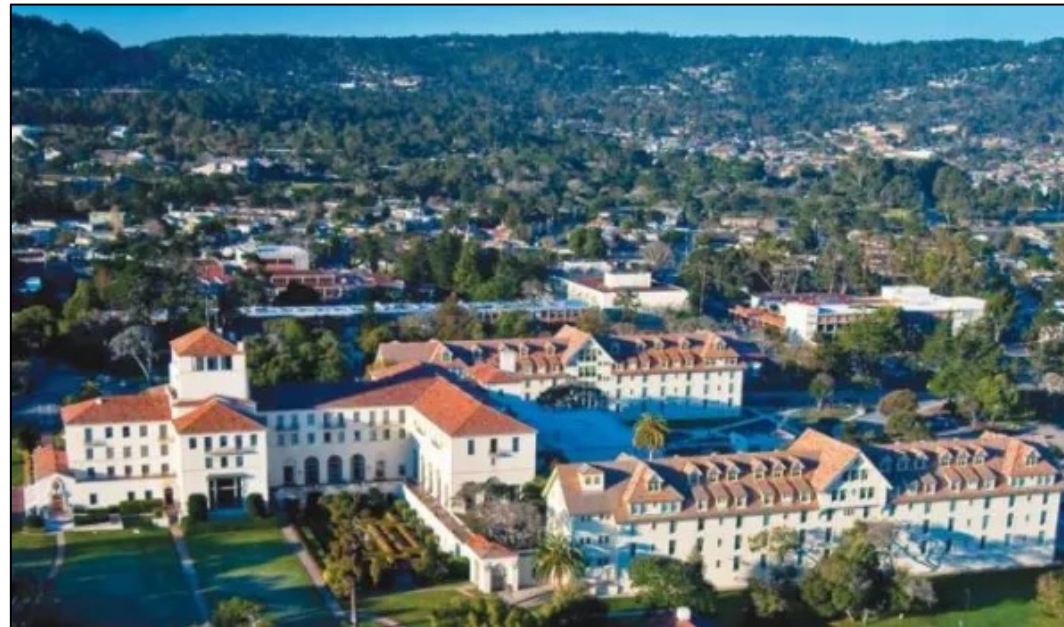
[ABOUT](#) [OUR TEAM](#) [WORK WITH US](#) [SOLUTIONS](#) [LATEST](#) [CONTACT](#)

The U.S. Air Force, The U.S. Army, and The Defense Innovation Unit (DIU) have initiated exploratory geothermal projects at four installations in the United States, completing agreements with three companies: Eavor Inc., Teverra, and Zanskar Geothermal and Minerals, Inc.

- Eavor Inc.'s technology employs a deep closed-loop geothermal solution that involves a subsurface heat exchanger relying on conductive heat transfer rather than convection or reservoir fluid flow. The design requires no stimulation and has minimal water use. Air Force's Joint Base San Antonio in Texas, will explore the potential of this technology.
- Teverra, LLC, is a subsurface technology company providing an integrated project development system that amplifies energy exploration, resource delineation, and production optimization through use of their cutting edge technology suite. Teverra will be conducting activities at Army's Fort Wainwright in Alaska.
- Zanskar Geothermal & Minerals, Inc. is a geothermal exploration and development technology company that has created an AI-enabled discovery platform to more quickly and accurately identify and de-risk geothermal resources. Zanskar will deploy their technology at two installations: Mountain Home Air Force Base in Idaho, and at the Army's Fort Irwin in California.



# WHAT WE CAN DO FOR YOU



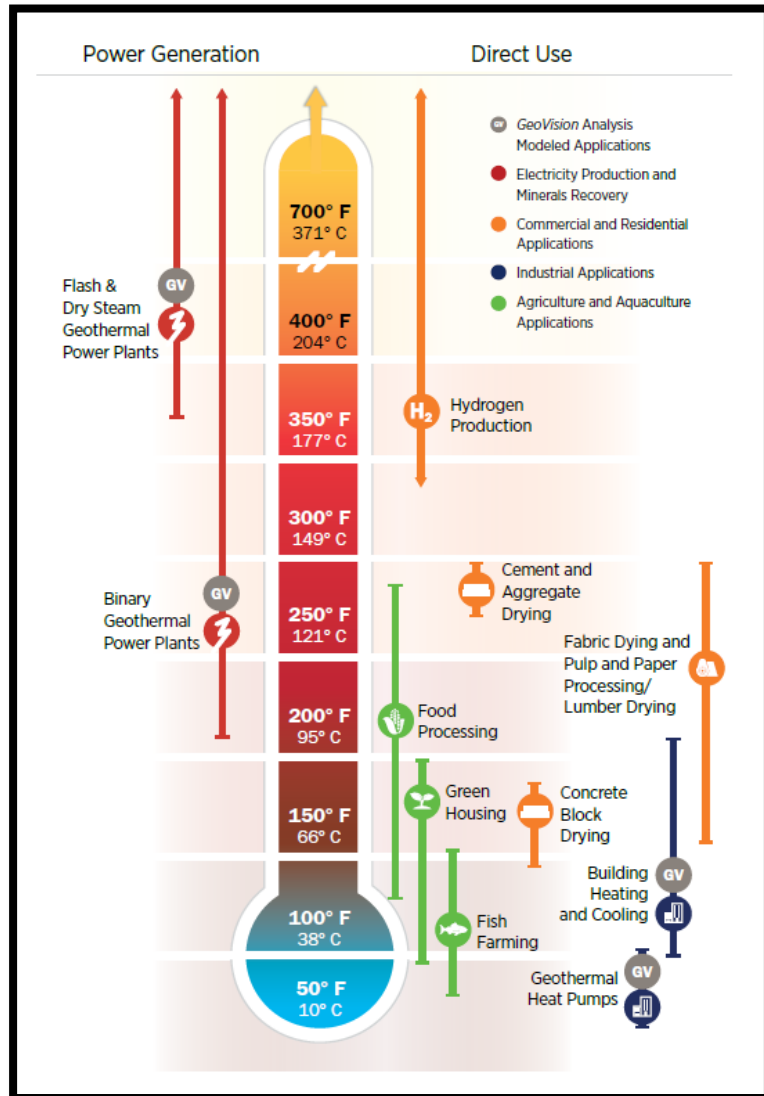
- Provide clean 24/7 Geothermal energy to the DoD & Allies
- Advise using our data analysis techniques on best geothermal options
- Explore, Develop, Operate, Produce, Optimize Geothermal Resources

GEOHERMAL

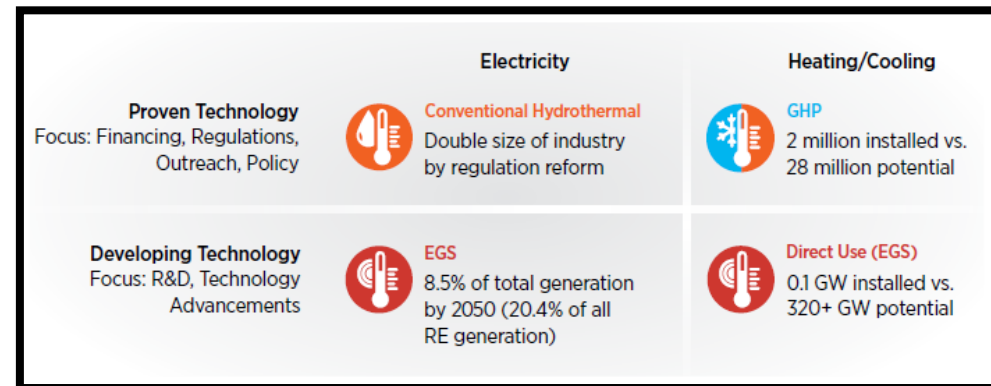
Abundant sustainable energy – Overview & Opportunities

# Off The Grid Power – Energy Independence!!!

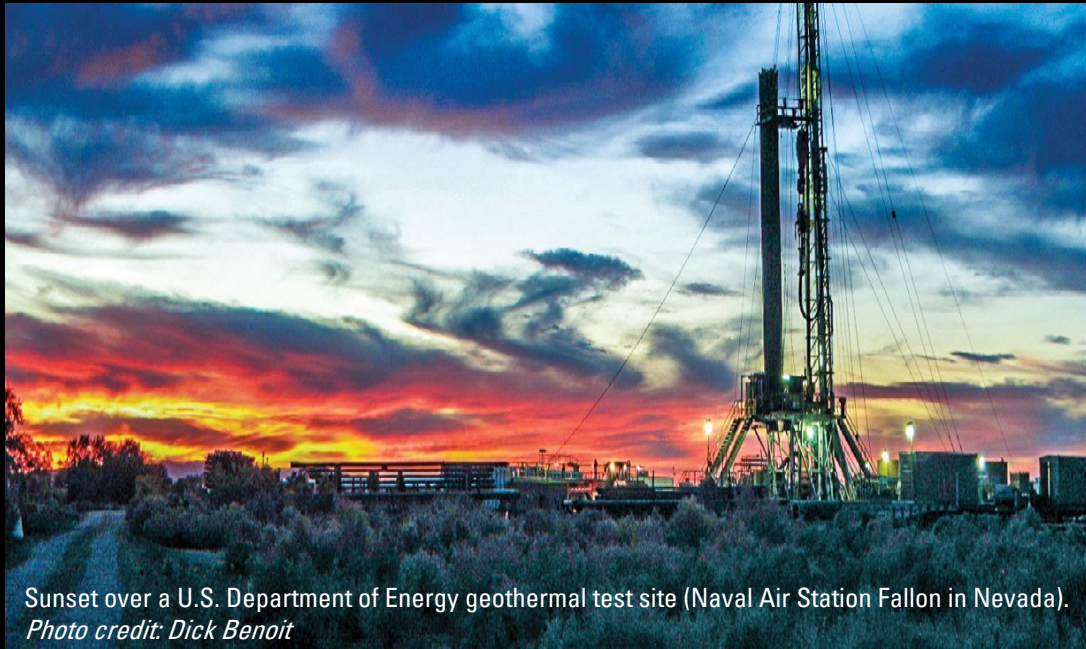
## SUMMARY



- Geothermal is a vast, untapped energy resource with huge potential for growth
- It provides constant, clean baseload power to complement renewables
- Key benefits: sustainable, renewable, reduces emissions, energy security
- With technology improvements and policy support, geothermal can play a major role in the global clean energy transition
- The future is bright for geothermal energy to deliver abundant sustainable power
- We bring geothermal solutions using data analysis to improve costs and performance



Source: US DOE GeoVision Report



Sunset over a U.S. Department of Energy geothermal test site (Naval Air Station Fallon in Nevada).  
*Photo credit: Dick Benoit*



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# THANK YOU

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