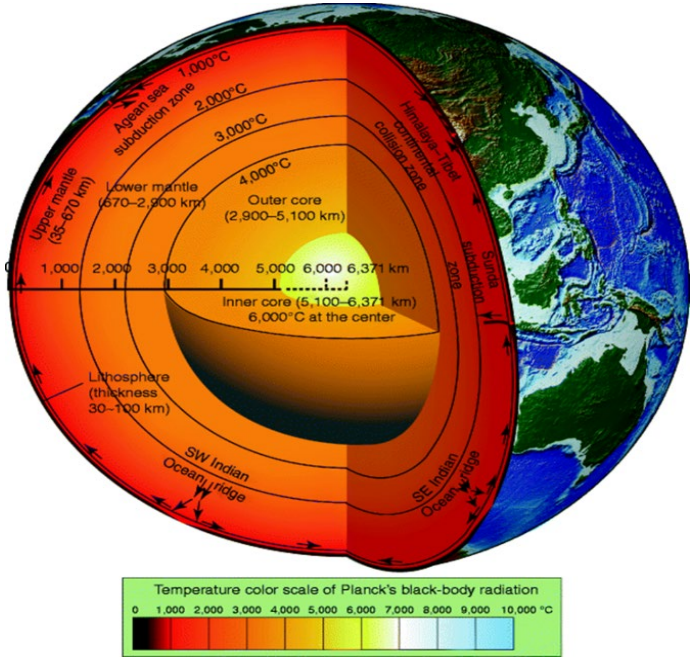
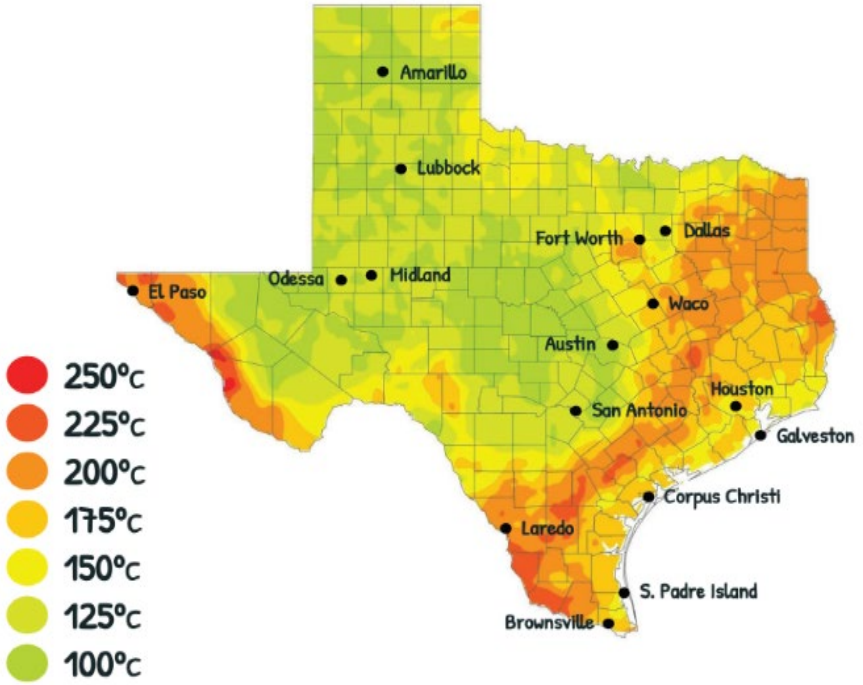
Geothermal Energy Revolution





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American Association of Petroleum Landmen
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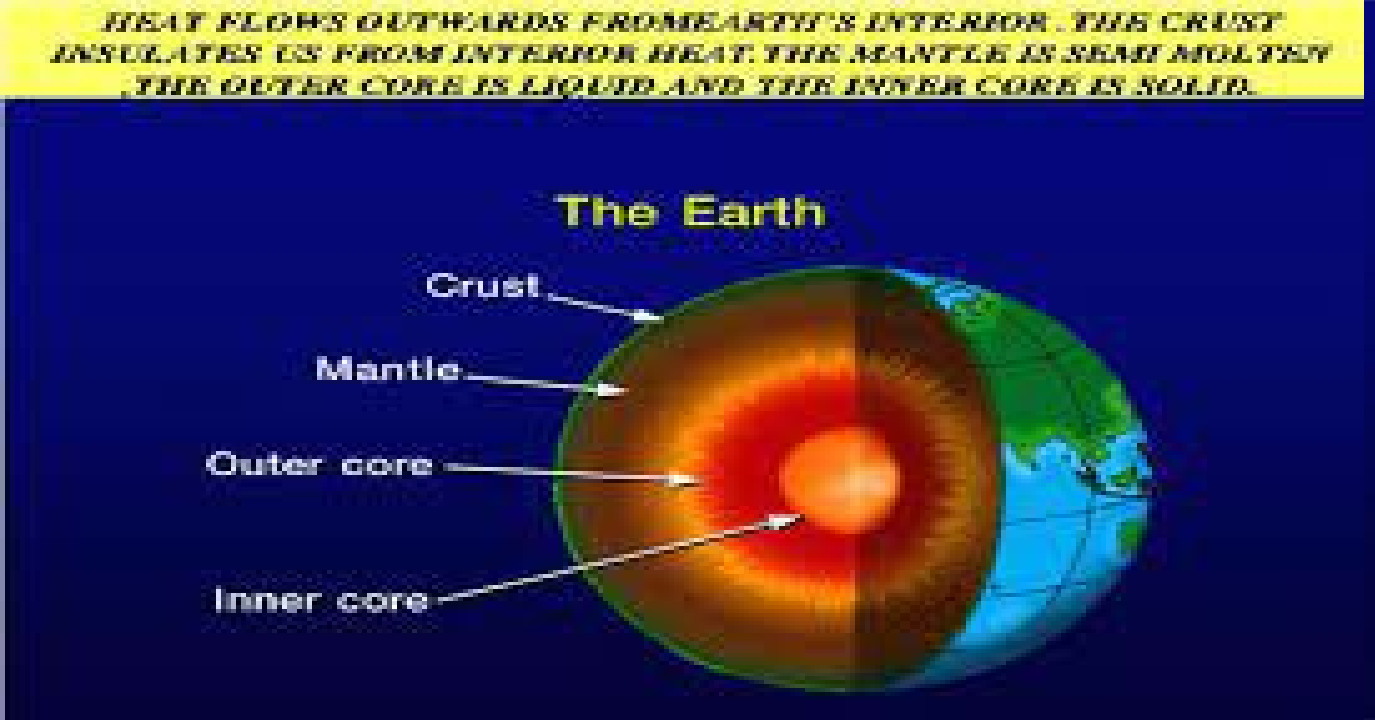
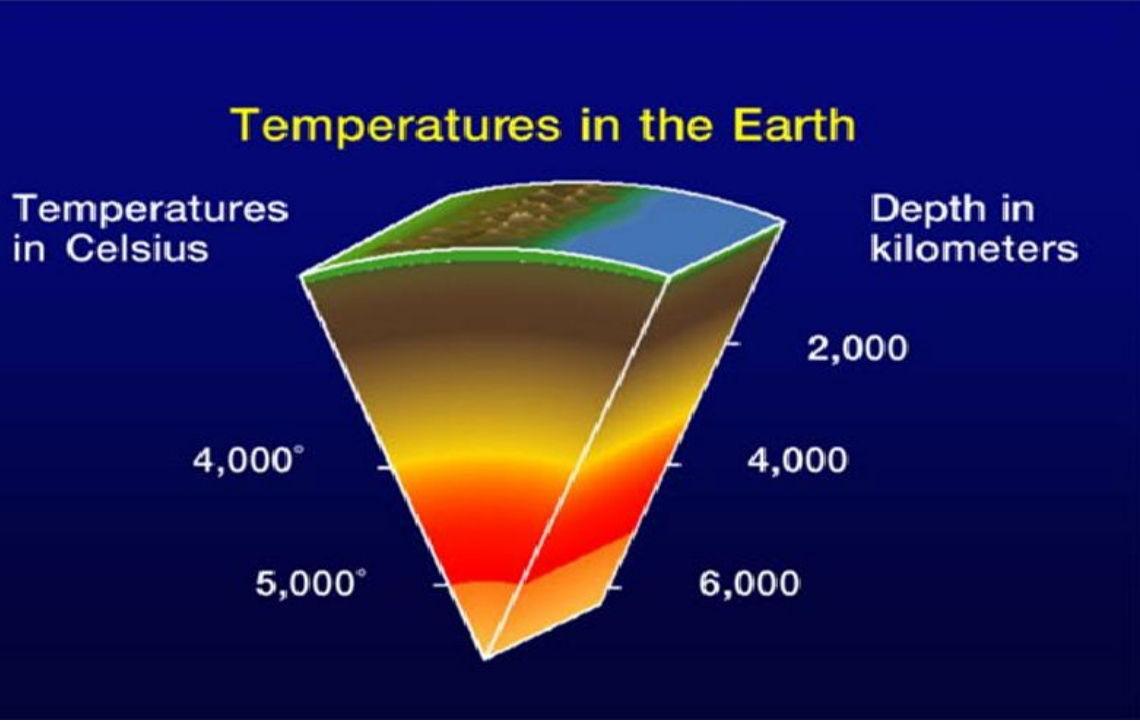
Dallas, Texas

HEAT FLOWS OUTWARDS FROMEARTH'S INTERIOR. THE CRUST INSULATES US FROM INTERIOR HEAT. THE MANTLE IS SEMI MOLTEN . THE OUTER CORE IS LIQUID AND THE INNER CORE IS SOLID.

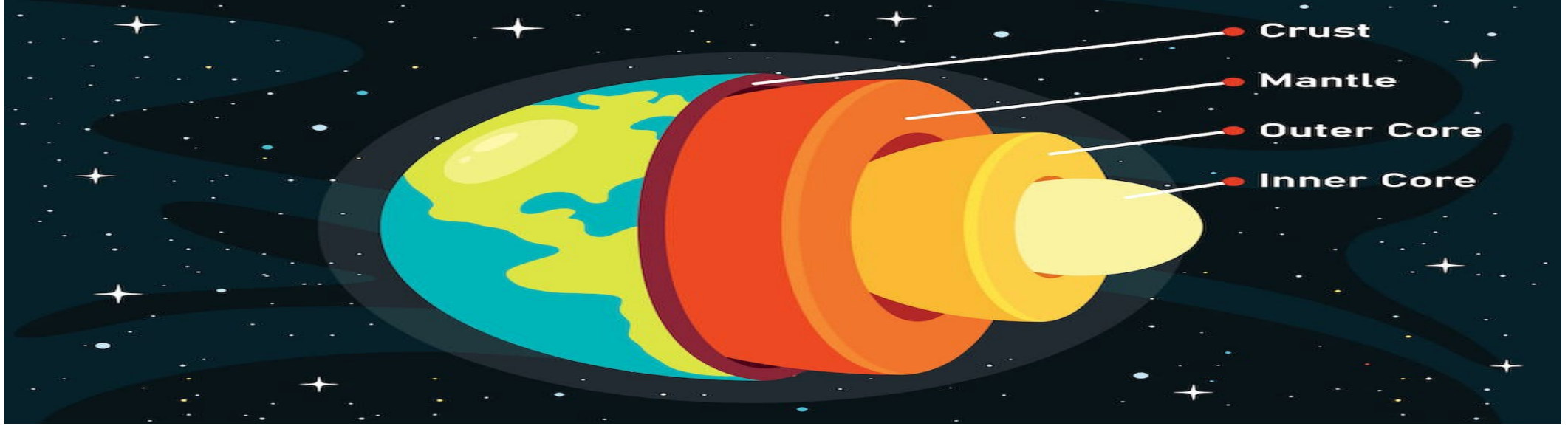




Geothermal energy is the heat energy which emanates perpetually from the earth's core. An unending supply of boundless energy.

The core of the earth is as hot as the sun: over 6,000°C, or 10,832°F.

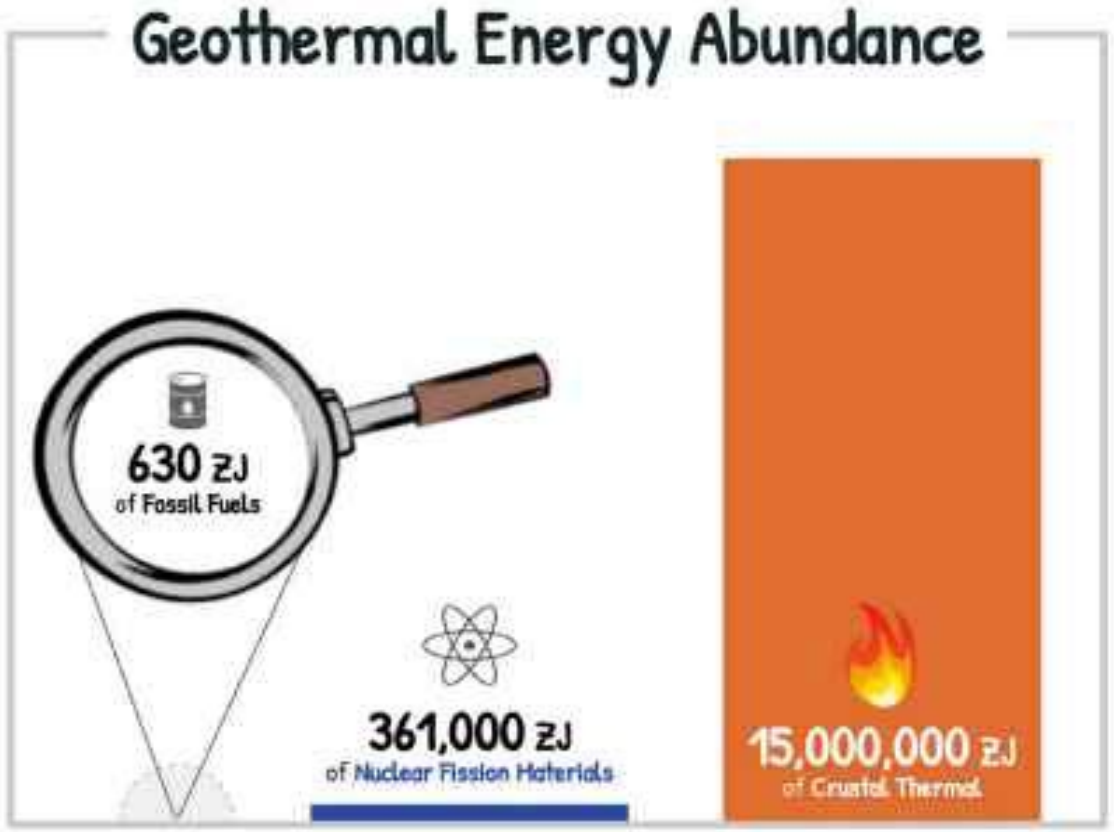
The crust of the earth acts as both a layer of insulation as well as a planet-sized battery which harvests and stores all of that energy - enough to power the planet millions of times over without emissions.



- **The Earth's accessible geothermal energy is more than 50,000 times greater than the global total of oil, gas, and coal combined.**

- **Geothermal energy is essentially inexhaustible because it emanates from the Earth's core and does not deplete even when used for power generation.**

- **Humanity has relied on the much smaller subsurface resource for power through the industrial revolution and modern times, while the much larger resource remains largely untapped.**



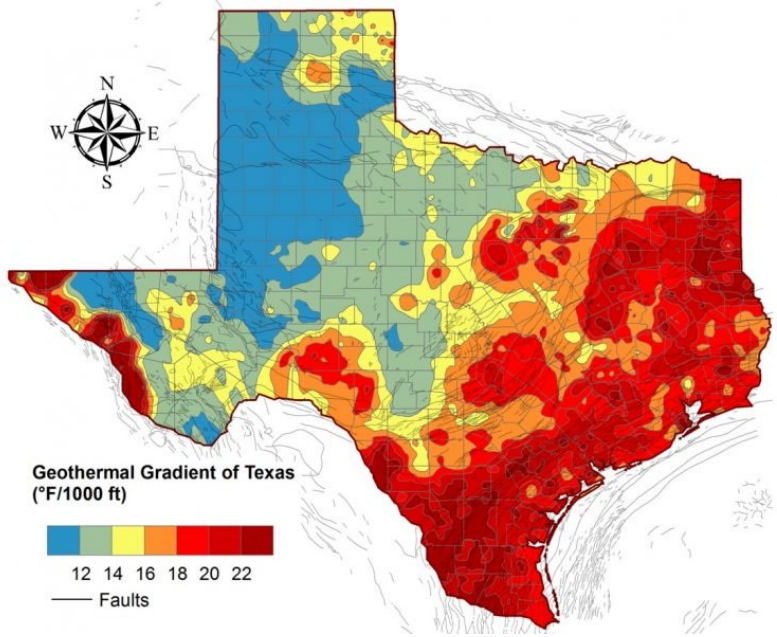
Comparison:

Earth's total fossil fuels & fission fuels versus Earth's total geothermal energy.

Fossil fuels = less than one pixel compared to geothermal energy.

Measurements in zettajoules ("zj"). Source: Adapted from Dourado, 2021.

Remember: geothermal energy does NOT deplete.



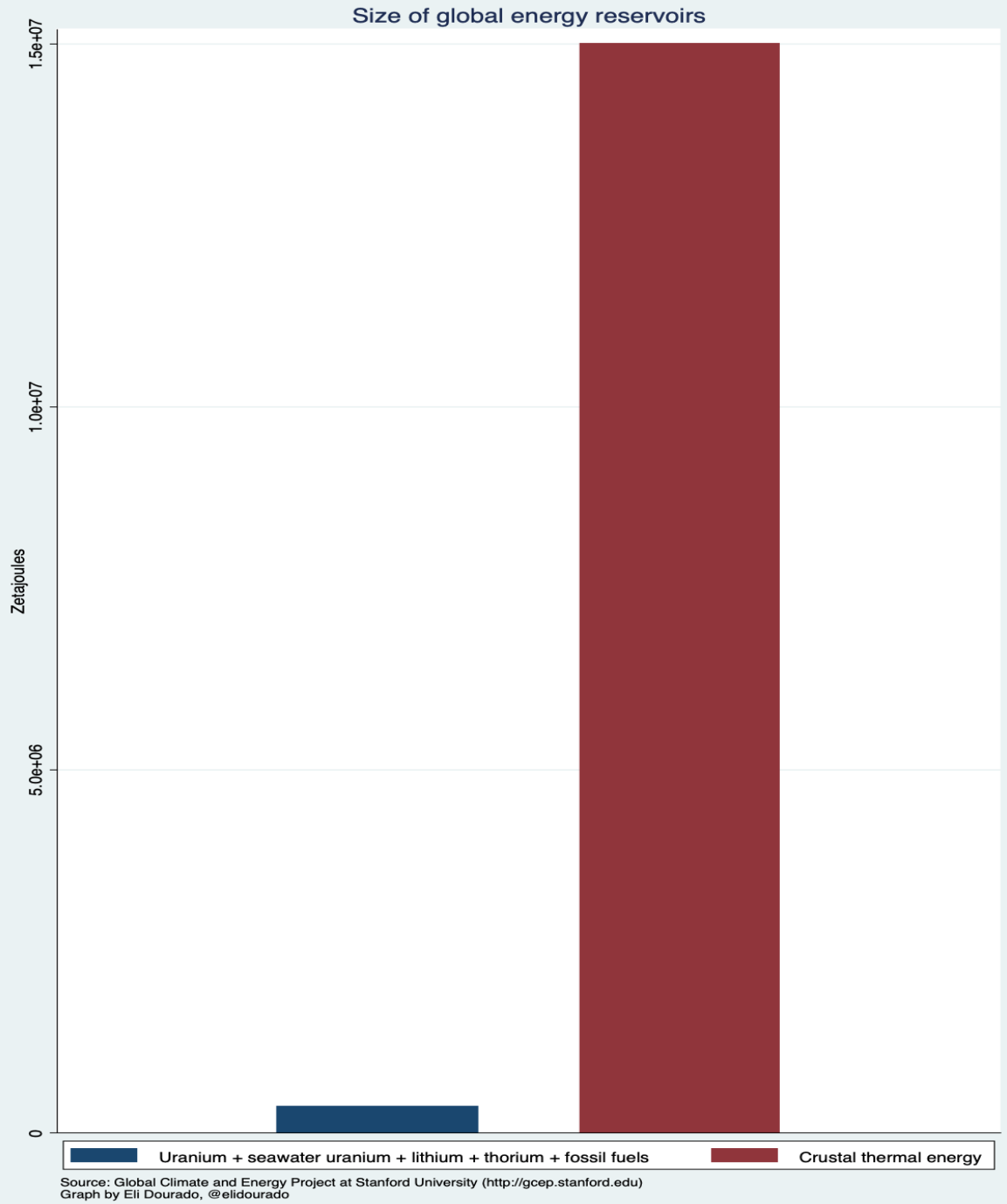
- **The heat energy in the subsurface of Texas surpasses the world's total annual energy consumption**.

- **Texas's available geothermal energy is about 500,000 times** its annual electricity generation (500 million+ MWh) or equivalent to **163 trillion barrels of oil**.

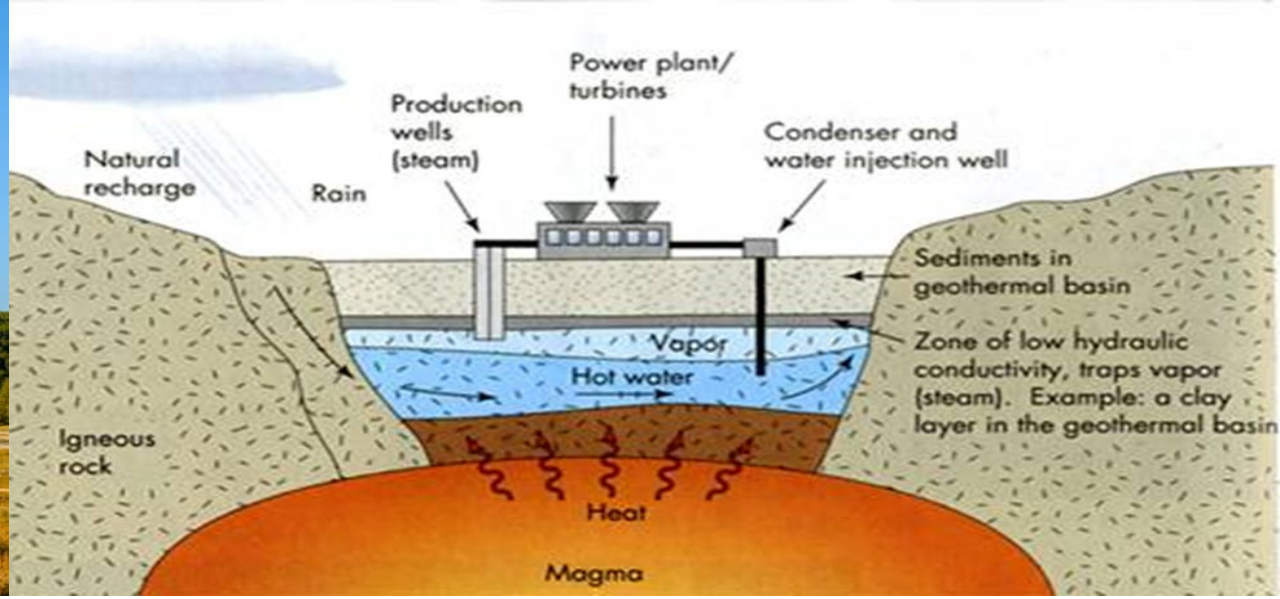
- There is enough geothermal energy to meet electric and thermal demand in Texas for thousands of years (likely all of humanity's future) just a short distance under our feet.

Summary – the amount of heat energy in the subsurface of the earth is enormous, almost incomprehensible, and it is inexhaustible (because it emanates perpetually).
Not to mention carbon-free, baseload, 24/7, AND DISPATCHABLE.

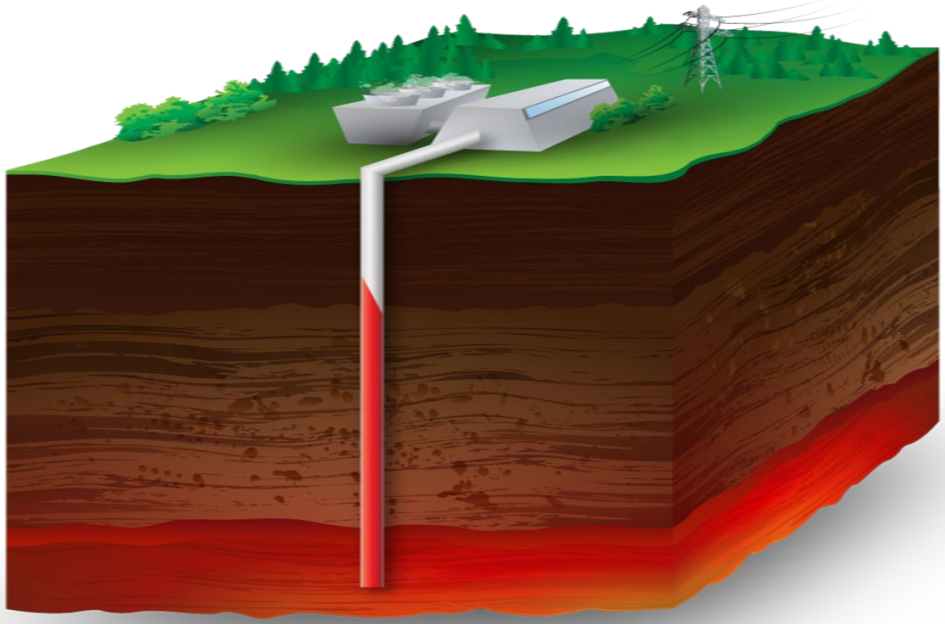
This is the Promise of Geothermal Energy



- If this is true, then why don't we have much more geothermal energy?
- In short – technology and economics.
- Until now.



- Conventional geothermal energy requires two things:
  - Very hot rock and water.
  - Think hot springs. Think Yellowstone, Iceland, The Geysers in California.
  - Places where there is very hot rock near the surface in conjunction with natural water aquifers.
- That is why Iceland runs on geothermal energy.
- Unfortunately, naturally blessed places with these ideal conditions are rare around the world.



Now: Hot Dry Rock (Next-Generation Geothermal)

- Rocks that do not naturally flow steam or water
- Drilling for temperature, not water supply

Now: Next Generation Geothermal.

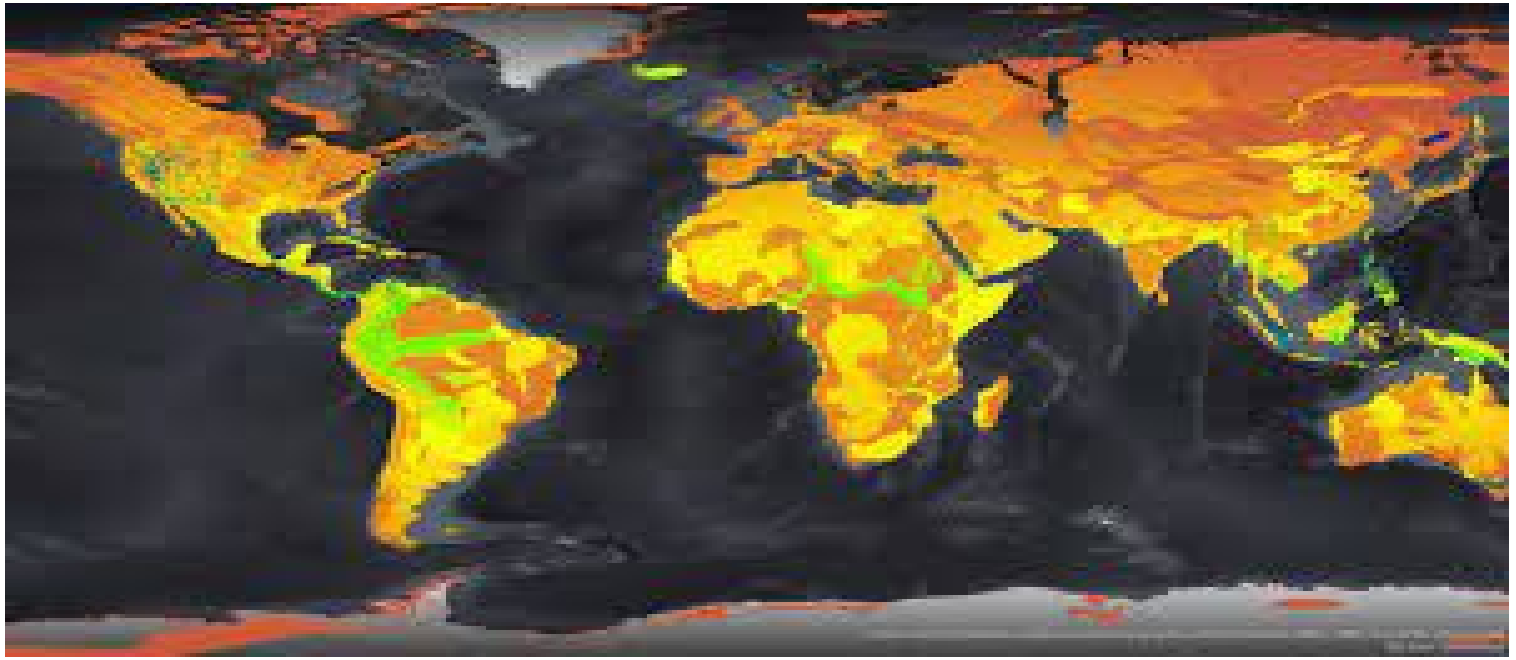
- Hot rock is accessible worldwide, not just in isolated geothermal zones.
- Now, with Next Generation Geothermal, we will bring the water to the rock.
- Even better, advanced fluids—like supercritical CO_2 or other efficient heat carriers—can be used instead of water.

•The **Age of Global Scalable Geothermal Energy** is now upon us.

•**Scalable**: Geothermal Energy Plants can be built almost anywhere worldwide -- and produce power at competitive costs, regardless of rock type, porosity, or water presence.

•**Technology Advancements (Why Now?)**: Next Generation Utilizes advanced oil & gas drilling and fracking techniques, hyper-efficient turbines, and efficient heat transfer technologies.

•**Key Benefits**: Baseload (24/7), dispatchable, renewable, emissions and carbon-free, protected from adverse weather, not dependent on wind or sunshine, and small surface footprint.

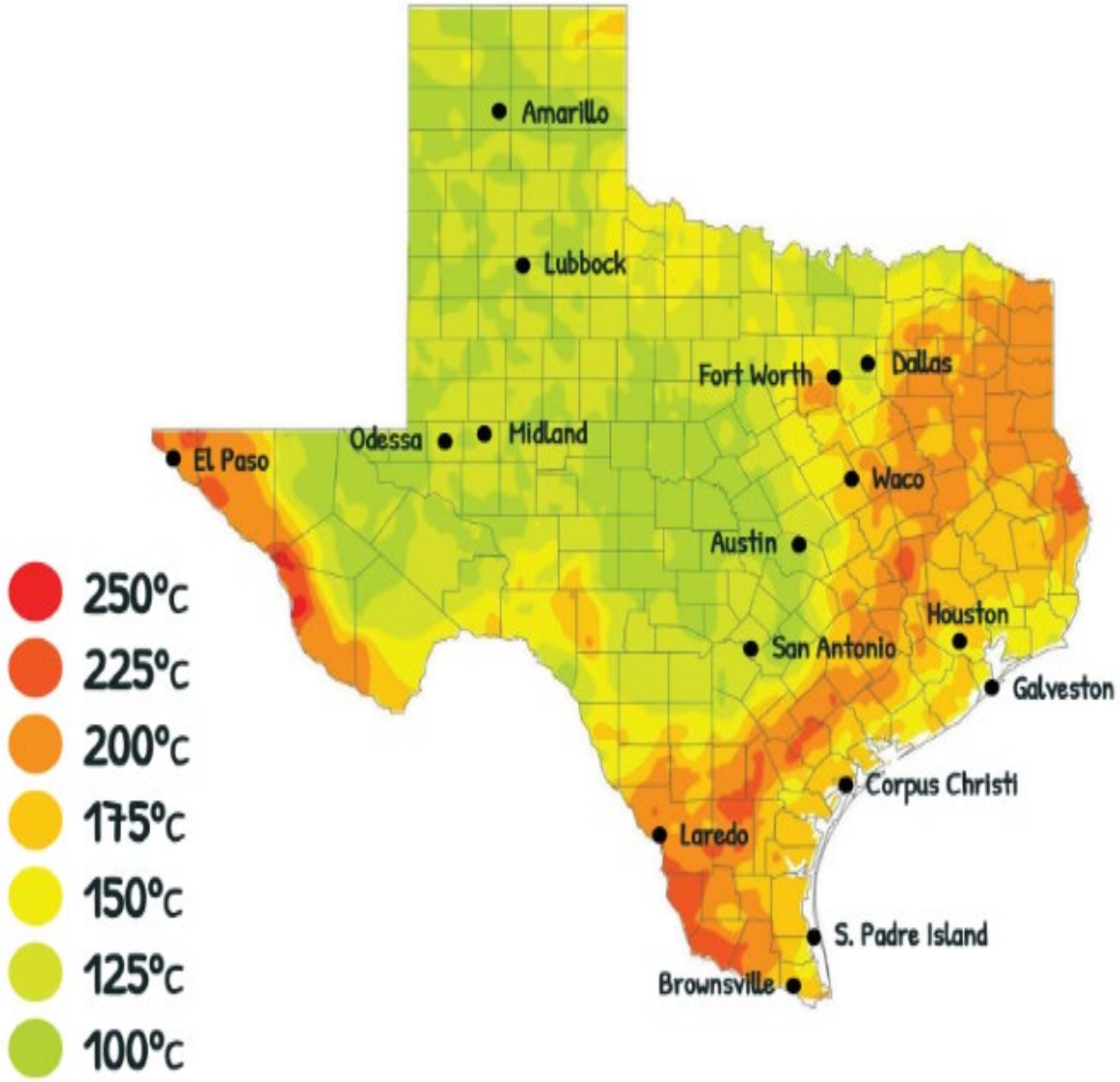


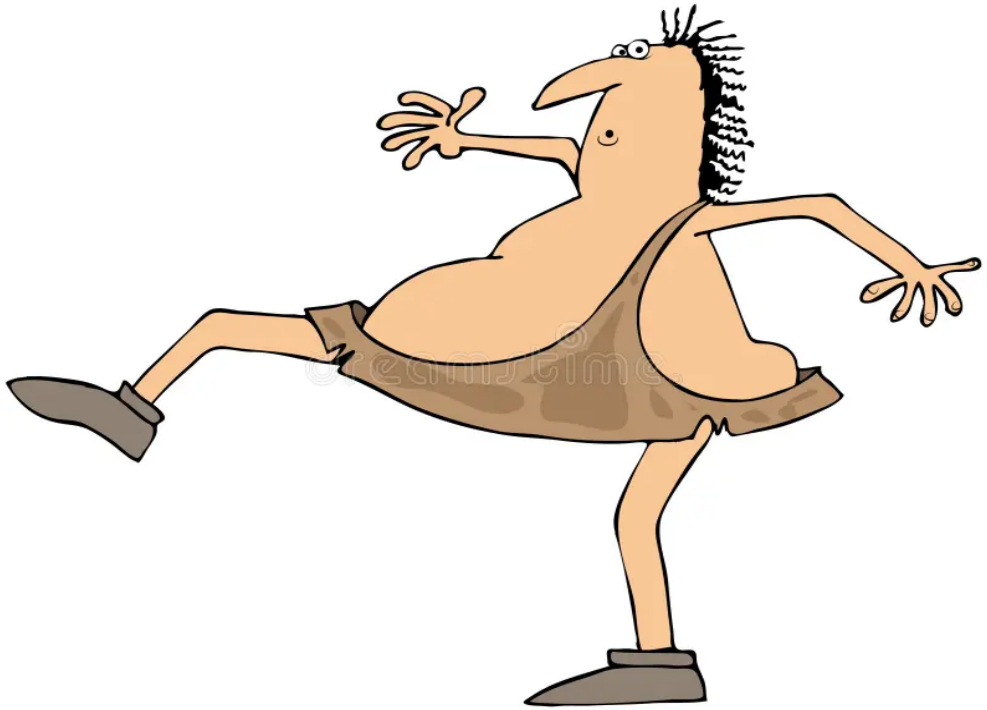
- **Hot dry rock**: Found beneath Texas, the U.S., and globally.
- **Global potential**: Sufficient heat exists for power generation almost everywhere across the planet.
- **Texas potential**: Heat resources suitable for electricity production are abundant across much of Texas.
- **Texas advantage**: Excellent geology, world-wide expertise in oil and gas, and favorable permitting offer strong potential for geothermal development.

- **Prime hot rock**: Located near Texas's major population centers, ~6.5 km (4 miles) deep.

- **Grid access**: Ideal for connection to the Texas electricity grid.

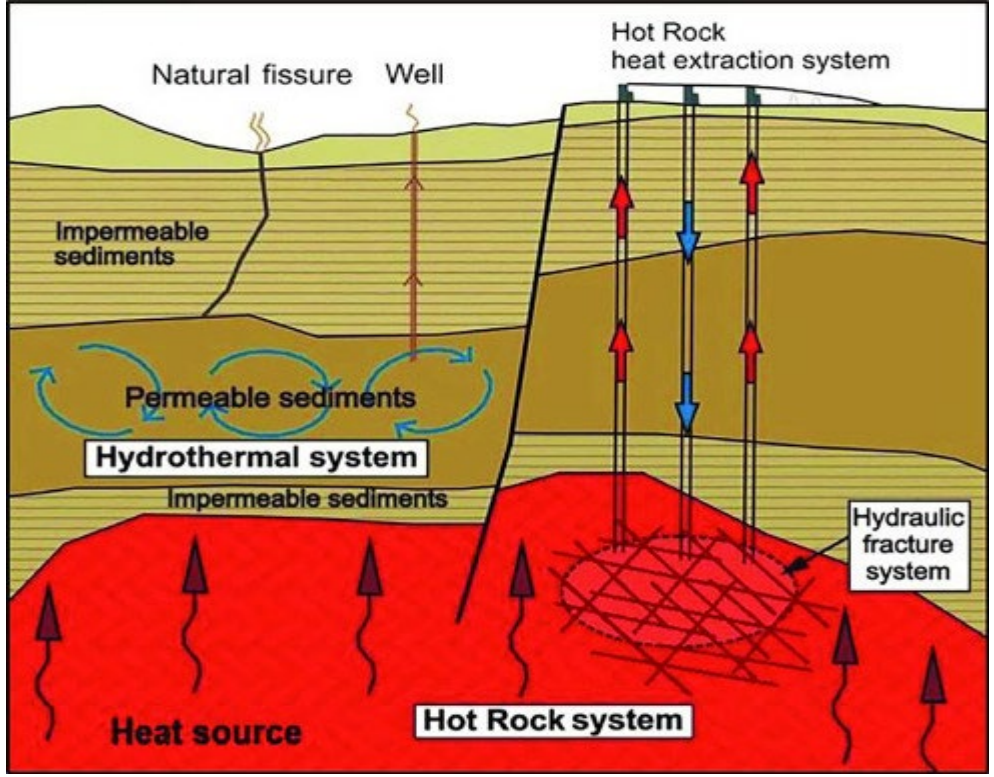
- **Location**: Follows Eagle Ford Shale, then from Houston to Dallas, East Texas to Louisiana. Also, from Big Bend to El Paso in West Texas.



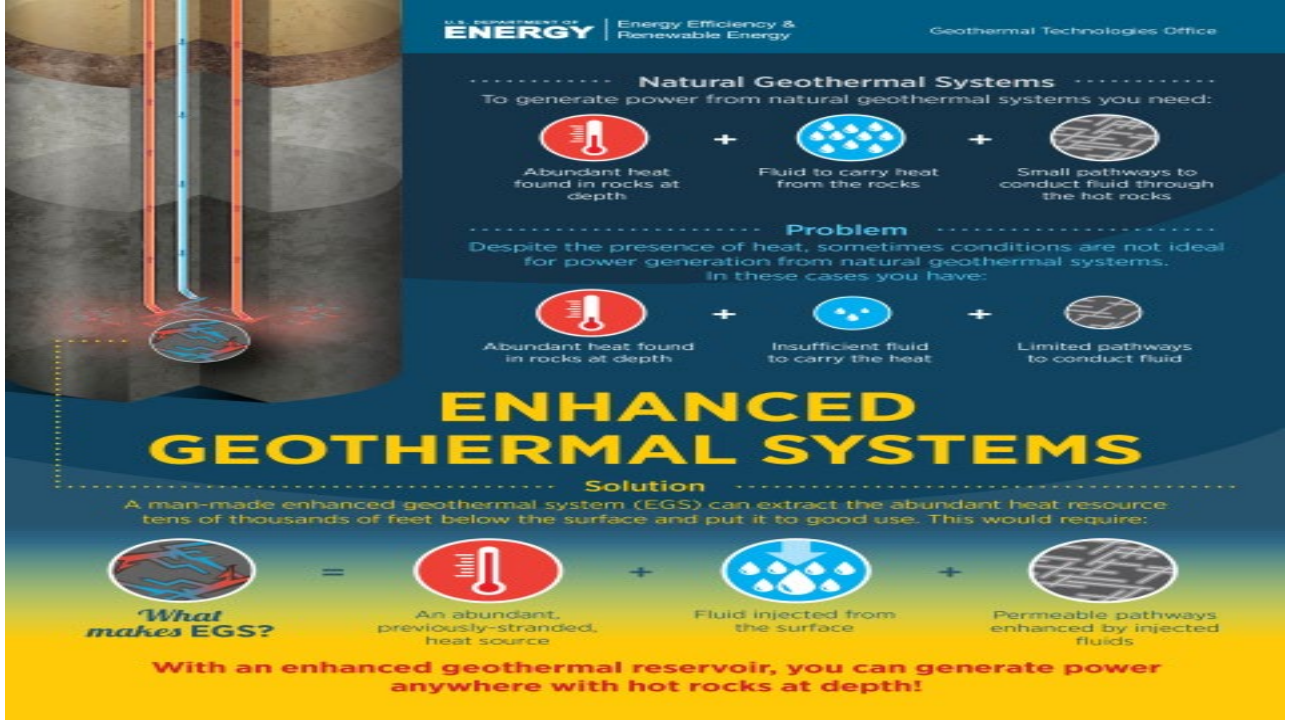


- **Geothermal Energy Anywhere**.
- This is the next giant step in humanity's energy evolution.
- Prometheus gave us fire. Fire advanced humanity out of the stone age and through the metal ages.
- Fire and steam drove the industrial revolution.
- Our most recent big step was the shale revolution.

- Texas and the world is beginning a geothermal energy revolution similar to or greater than the shale revolution.
- Geologists have always known that there are tremendous amounts of oil and gas trapped in shale rock. The problem was how to produce the oil and gas economically.
- Geologists have always known there are enormous amounts of geothermal heat.
- Similarly, the problem has been how to economically convert this enormous amount of heat into affordable and usable energy or electricity.



Currently, there are several major areas of technology development in scalable geothermal concepts, many of which are being led by companies here in Texas.

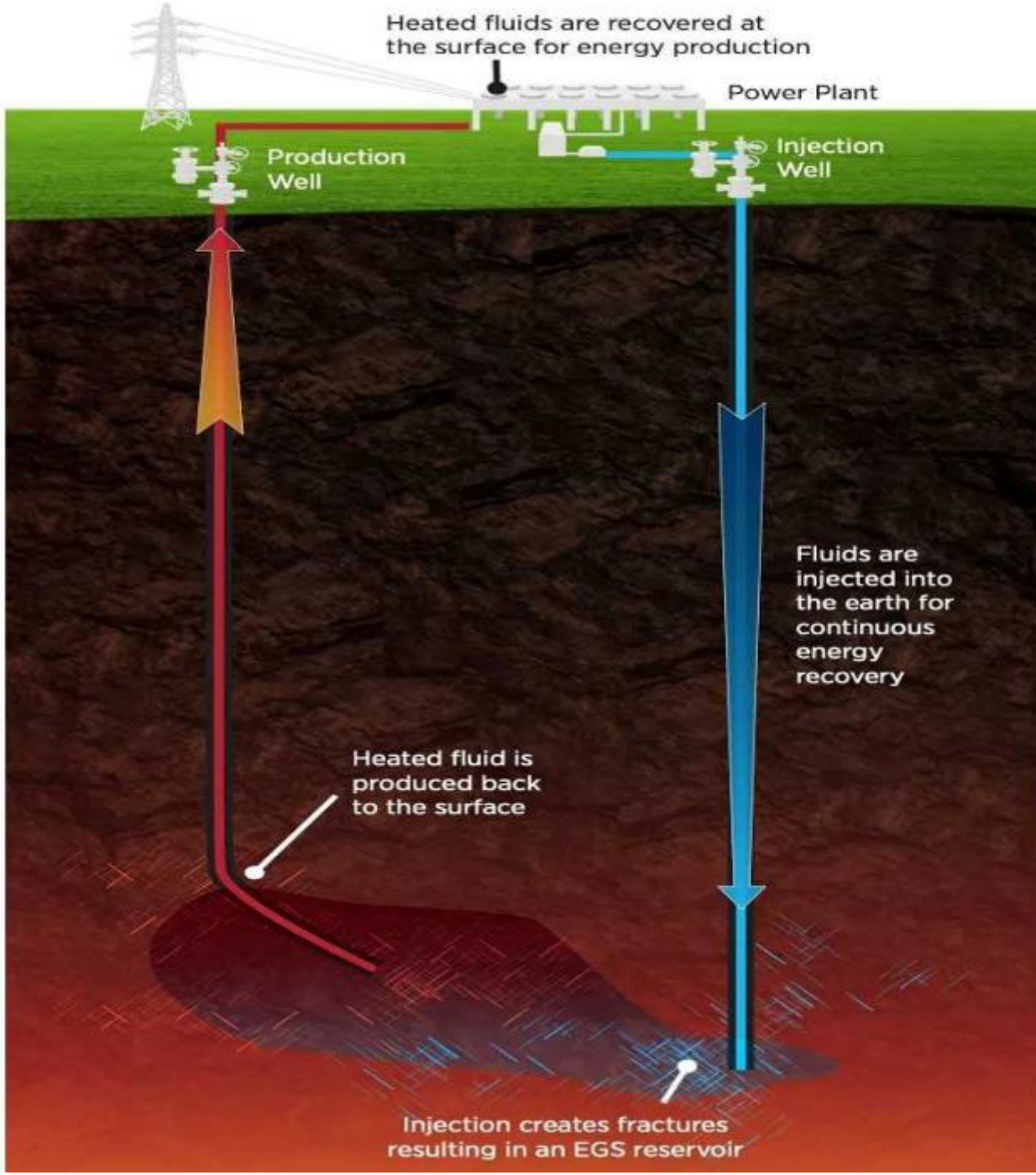


Next Generation Geothermal Energy Technologies in Summary:

1. Enhanced Geothermal Systems
2. Closed-loop Geothermal Systems
3. Heat Roots, Multi-System Hybrids, and Pressure Geothermal
4. Geothermal Energy Conservation Wells
5. Super-Hot Rock

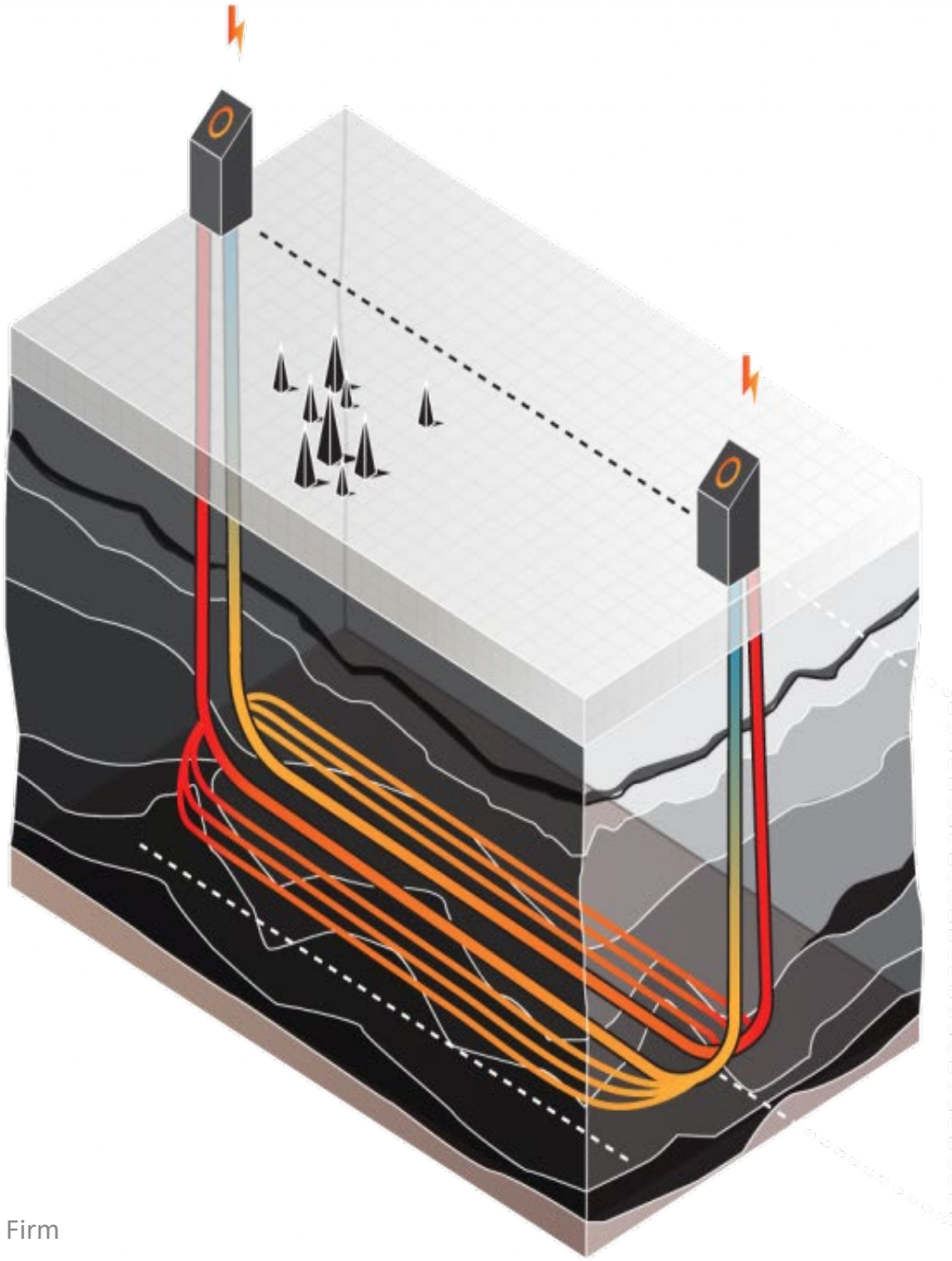
#1: Enhanced Geothermal Systems

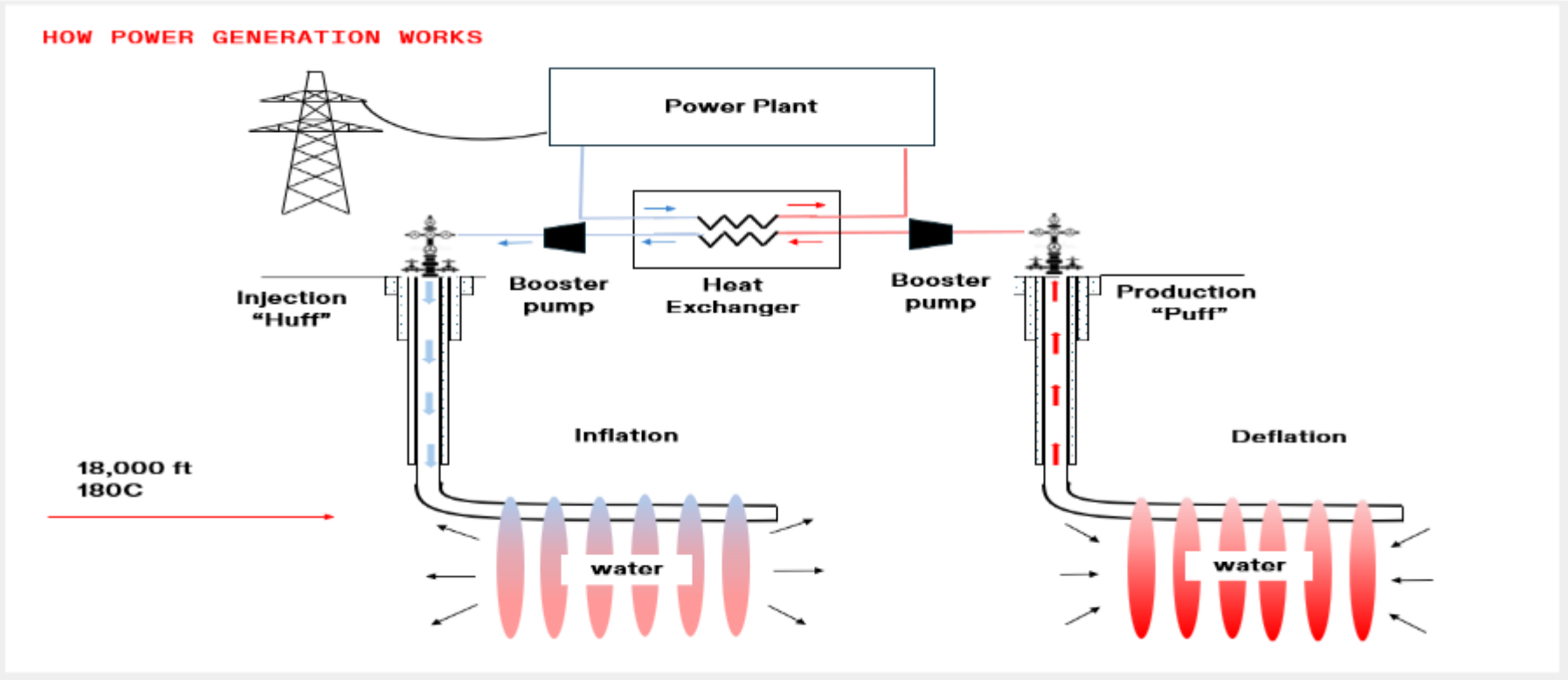
These systems feature one or more injection wells where water goes into the ground and one or more production wells where steam comes out of the ground to drive electric turbines on the surface.



#2: Closed-loop Geothermal Systems

These feature a closed network of pipe drilled and placed into the ground into which working fluid is injected, becomes geo-heated, and then returns through the production well of the system and used to generate electricity.





#3: Heat Roots, Multi-System Hybrids, and Pressure Geothermal

- **Concept**: Combines closed-loop systems with larger heat capture.
- **Fracture Pattern**: Uses advanced hydro-fracturing to create a downward tree root-like design of fracs.
- **Heat Transfer**: Captures more subsurface heat and channels it up the well bore.
- **Efficiency**: Injects working fluid to power hyper-efficient turbines.

#4: Geothermal Energy Conservation Wells.

- **Concept**: Abandoned oil and gas wells or newly drilled wells are used as efficient energy storage wells.
- **Solves the problem of intermittency and curtailment** when paired with wind and solar.
- **Process**: Fluid is injected during low demand. It becomes geopressured and potentially geo-heated. When released, the geopressured water runs Pelton or impulse turbines to produce electricity.
- **Dispatchable**: Multiple well and fracture designs allow for 24/7 cycling turning wind and solar into reliable dispatchable energy.

- Today's drilling technologies are limited by the temperature and pressure at which the drill bits begin to fail. Roughly 350+°C.

- However, Super-Hot Rock exists at **≥ 374 °C (705 °F)** and **≥ 22.1 MPa (≈ 3,200 psi)** pressure.

- Above this point, water becomes **supercritical**—neither liquid nor vapor but a dense, highly energetic fluid that can carry heat up to **ten times** more efficiently than steam.

6. Super-Hot Rock.

- Leading Examples:

* **Sage Geosystems** – Drill to depth limit then frac to super-hot.
* **Quaise Energy** – Gyrotron Powered Millimeter wave drilling vaporizes boreholes.

- If successful, not only will geothermal energy capacity increase by up to a factor of ten but cost of geothermal energy should decrease by a similar amount.

Federal Support and Policy:

- **The U.S. Department of Energy** (DOE) - significant investments in geothermal research and demonstration projects.
- **DOE Geothermal Technologies Office** - funds innovations in subsurface science, drilling efficiency, and reservoir management.
- **DOE FORGE** (Frontier Observatory for Research in Geothermal Energy) initiative - serves as a field laboratory to advance Enhanced Geothermal Systems research.

One Big Beautiful Bill

- **Extended clean energy tax credits for geothermal**: Investment Tax Credit and Production Tax Credit extended at full 100% through 2033; with a gradual phaseout by 2036.
- **Transferable tax credits**: Can be transferred in partnerships *or* sold for cash on the open market.
- **Unlocks financing**: Improves geothermal project bankability with predictable returns and tradable incentives.
- **Geothermal Power Accelerator** – DOE led collaboration with 13 states to accelerate geothermal power development.

The United States Department of Defense recently announced their goals to (1) **reduce the cost of enhanced geothermal system electricity by >90%,** (2) **deploy 40 gigawatts of geothermal electricity production by 2035, and** (3) **establish a microgrid on *every* Army base by 2035.**

(Office of Energy Efficiency & Renewable Energy. "Introduction to the Enhanced Geothermal Shot Technology Pathways." U.S. Army Climate Strategy.)

Note: 1-GW can power 800,000 to 1-million average U.S. homes

Texas Support and Policy

- **Who Owns the Heat? Surface or Mineral Estate? SB 785: Establishes that geothermal energy is owned by the surface estate.**
- **Problem (pre-2023): Ownership Unclear**
- No Texas court decision or statute, at the time, squarely determined whether geothermal resources belong to the surface estate or the mineral estate.
- **Confusion** - A 1976 statute said geothermal resources "shall be treated and produced as mineral resources."
- **Key clarification: Regulation ≠ Ownership**
- The 1976 statute directs the Railroad Commission to regulate geothermal **like** oil and gas.
- It does **not** state that geothermal resources **are** minerals, and it does **not** resolve ownership.

- **Legal Conclusions from Texas Law:**
  - A **Mineral** is a tangible substance.
  - **Heat** and **energy** not substances. They are intangible qualities of the earth itself which belong to the **surface estate**.
  - **Steam, hot water, hot brines, and geopressured water** are forms of groundwater which belong to the **surface estate** under Texas law.

- **Legislative Solution:**
  - **SB 785** declares that geothermal energy resources belong to the **surface estate**, unless a recorded instrument provides otherwise.

Texas Support and Policy

- **One Stop Agency Permit Shopping. SB 786** – Consolidates jurisdiction over geothermal energy exploration and development in the Railroad Commission of Texas.

- **Adoption of Orphaned Oil & Gas Wells. SB 1210** – Allows abandoned oil and gas wells to be adopted by geothermal operators.

- **Low Interest Loans and Completion Bonuses for Geothermal Energy. SB 2627 – Creates the Texas Energy Fund**. Creates a state program to provide low interest loans and completion bonus grants for new sources of "dispatchable" electricity generation.

- **Geothermal Energy Storage Is Not a Battery Resource. SB 1762** – provides that a geothermal energy conservation well is not a battery energy storage resource.

Novel Question:

- SB 785 presents a fascinating legal question of first impression:

- May a resource owned by the surface estate have equal rights with the mineral estate?

- As far as this author is aware, no other natural resource has ever been mandated to "be treated and produced as mineral resources" Tex. Nat. Res. Code § 141.002(4) but also declared to be owned by the surface estate. Tex. S.B. 785, 88th Leg., R.S. (2023) (enacted); codified at Tex. Nat. Res. Code § 141.004

Opinion - Because:

• The Geothermal Resources Act of 1975 requires geothermal resources to "be treated and produced as mineral resources" and

• SB 785 states that it "does not change existing law regarding the rights of the dominant and servient estates," then it follows:

Resulting Interpretation:

• Geothermal energy resources are owned by the **surface estate** (absent a controlling recorded instrument)

• But they must be **treated like minerals** — afforded **dominant-estate–type operational rights *EQUAL*** to other mineral resources.

- **Potential Impact**: Electricity from geothermal could equal the amount of all fossil fuel-based electricity production in Texas in as little as 4-years.

- **Requirements**: Transition in technology and investment comparable to the U.S. shift from conventional hydrocarbon reservoirs to unconventional shale development.

- **Geopolitical Impact**: The Texas oil and gas industry transformed geopolitics, turning the U.S. into the No. 1 producing country of both oil and natural gas in the world.
- **Geothermal Potential**: With sufficient capital, the Texas geothermal energy industry can lead the development of geothermal energy at a global scale.
- Texas is positioned to disrupt narratives about the future energy mix.

Using Conservative Assumptions regarding potential energy production, if Texas drilled 15,000 geothermal energy wells per year, in 4 years it would provide enough energy to equal ALL natural gas and oil used for electricity and heat production in Texas.

Before the Shale Revolution:

1999 – Texas drilled 5,615 oil and gas wells.

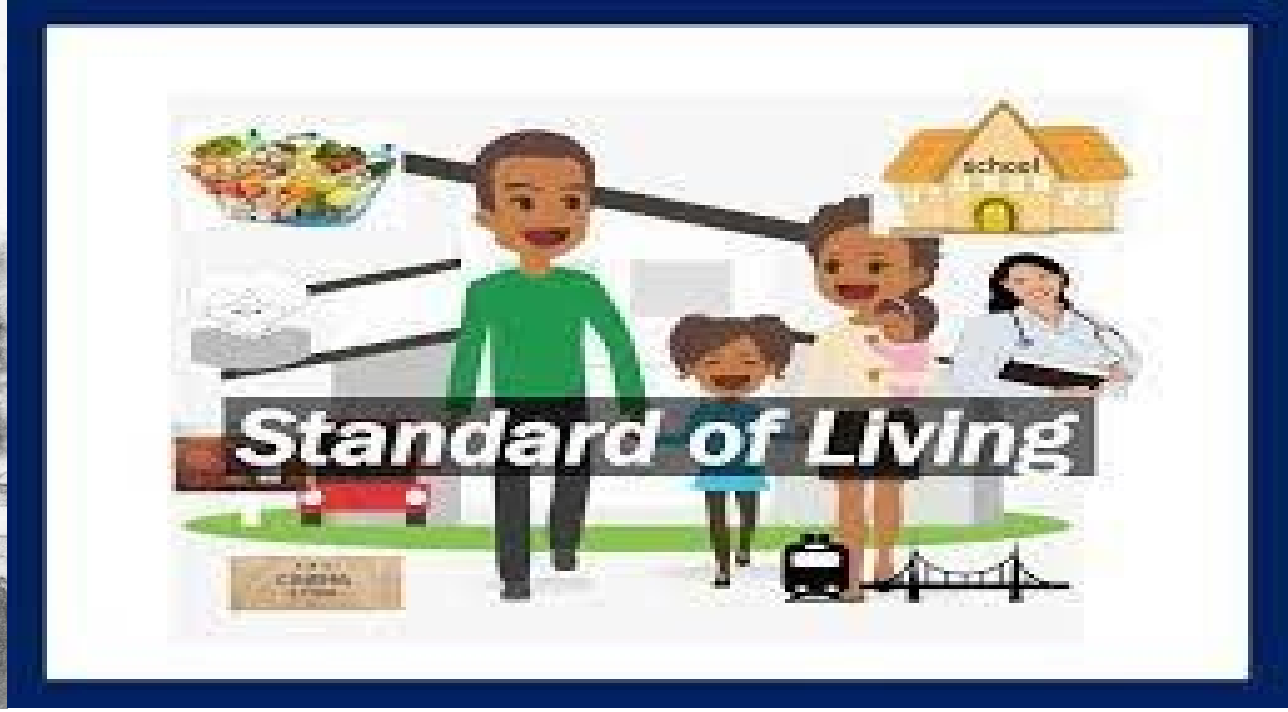
After the Shale Revolution:

Texas drills 15,000 to 20,000 wells each year.

2014 – Peak of 28,584 wells were drilled in Texas.



- In 2023, global investment in geothermal technology was roughly $2-billion.
- Wind power was $200-billion.
- With that amount of funding, we could have 400 full-scale geothermal energy production projects.



- 1859: Edwin Drake drilled the first oil well in Titusville, Pennsylvania -- start of the Petroleum Era.
- Early drilling and extraction methods were laborious, costly, and challenging.
- Petroleum Era led to enormous leaps in human innovation and living standards that were unimaginable at the time.

- Human creativity and brilliance has no limit.
- We can dig holes.
- We can access underground heat.
- We can transfer oil and gas know-how to geothermal energy and unleash the earth's internal perpetual power.