

Geothermal Power Overview

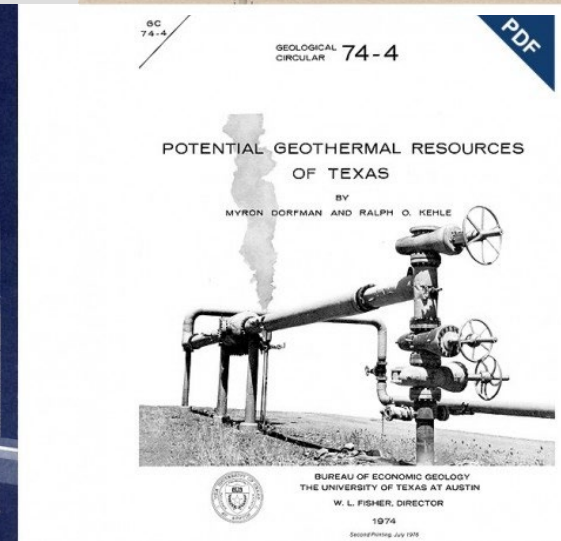
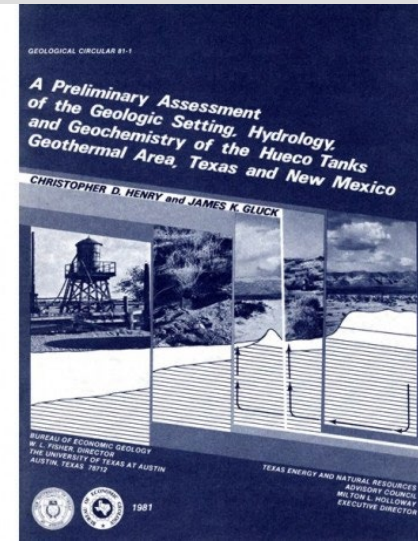
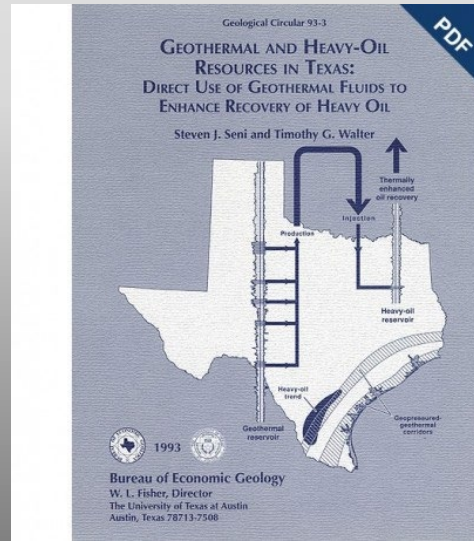
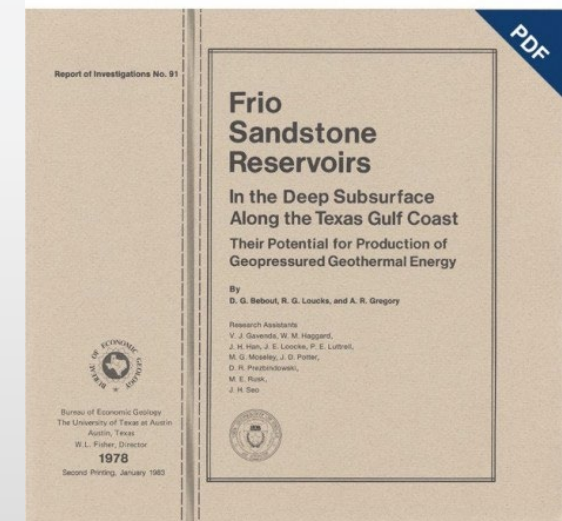
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The University of Texas at Austin
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The Bureau of Economic Geology

- The Bureau of Economic Geology established in 1909, is the oldest research unit at the University of Texas at Austin and is also the State of Texas Geologic Survey. 150+ FTEs
- We focus on:
 - Applied research – solving near-term problems
 - Industry research consortiums, including the newly formed **HotRock** geothermal
 - Government and privately funded research
 - International energy and environmental research projects (we are not just Texas)

The Bureau and Geothermal Energy

- Academic geothermal community is pretty small
- We have been in geothermal since its first boom in the US in the 70's
- Foundational work is still relevant
- We have a strong and growing geothermal team from across UT Austin
- Launching a geothermal industry research consortium; *HotRock*



Ken Wisian, Ph.D., Major General USAF (retired)

Associate Director, Bureau of Economic Geology, The University of Texas at Austin

Education:

Ph.D.	Geophysics	Southern Methodist University
M.S.	Geology	Centenary College of Louisiana
M.S.S.	Strategic Studies	US Army War College
B.A.	Physics	University of Texas at Austin
Graduate		USAF Test Pilot School



Expertise:

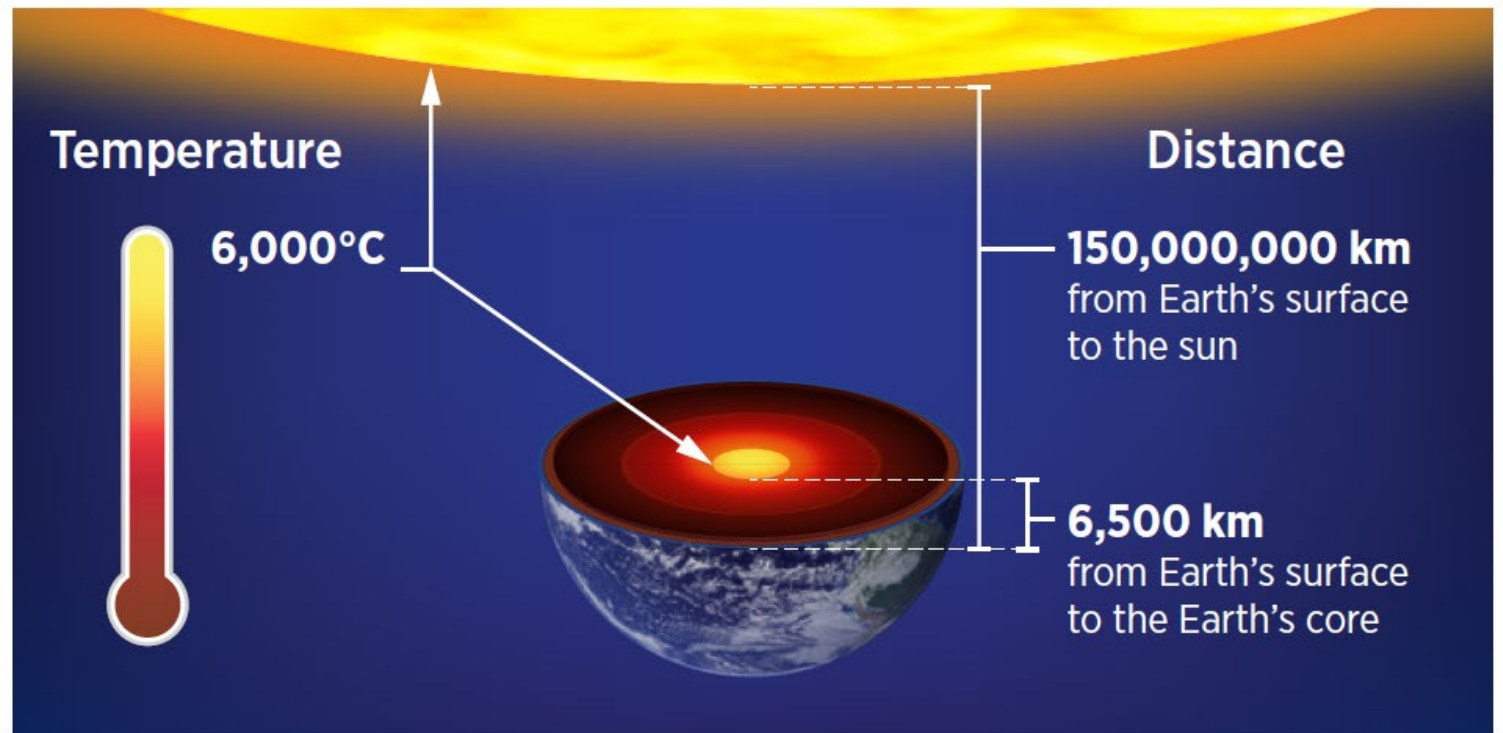
Thermal geophysics, geothermal systems, resource assessment, geothermal exploration, sensors, well logging, fluid & heat flow modeling, planetary geology

Project management (>\$1Billion projects), technology development, systems integration, developmental test and engineering, risk management

Intro – Earth's Heat

- **~47TW** of heat flow 24/7 out of the Earth
- Even better – **thousands of times this amount of energy is extractable heat stored in the upper 10 km of the crust**

GeoVision, DOE



Geothermal Systems

(we are not talking heat pumps for your house)

- **All you need to generate power is a temperature difference** – between the rock at depth and the surface
 - In most power plants the heat is from burning fossil fuel or uranium, for geothermal we get the heat (free) from the Earth
- **Conventional Geothermal**
 - Mines hot water or steam in the ground
- **Geothermal Anywhere**
 - Mines the heat in the rock
 - Enhanced Geothermal Systems (EGS), Advanced Geothermal Systems (AGS), Closed Loop Geothermal Systems (CLGS) ...naming is not settled...
- Unlike wind & solar, **All Geothermal are 24/7 – Baseload!!!**

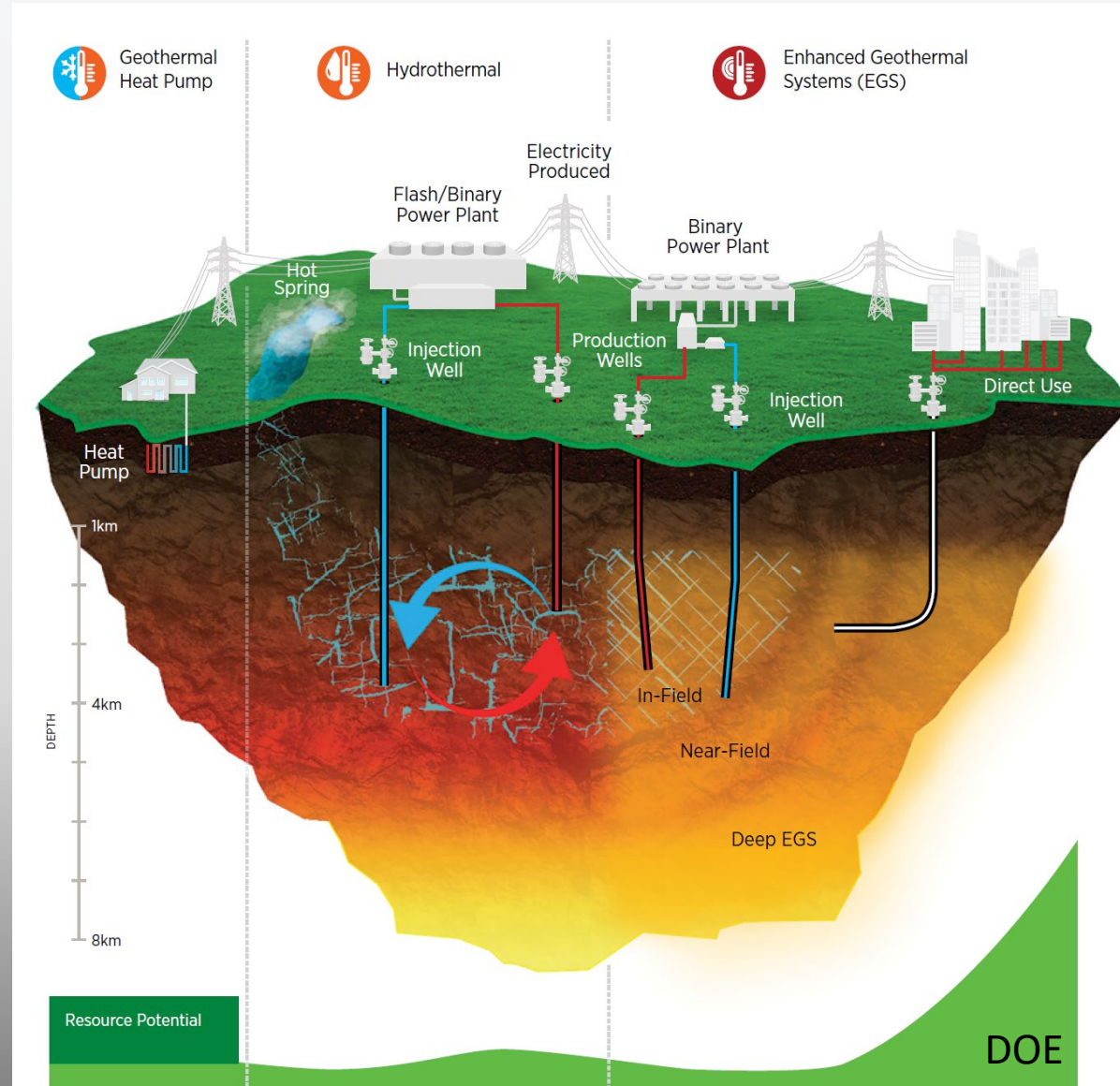
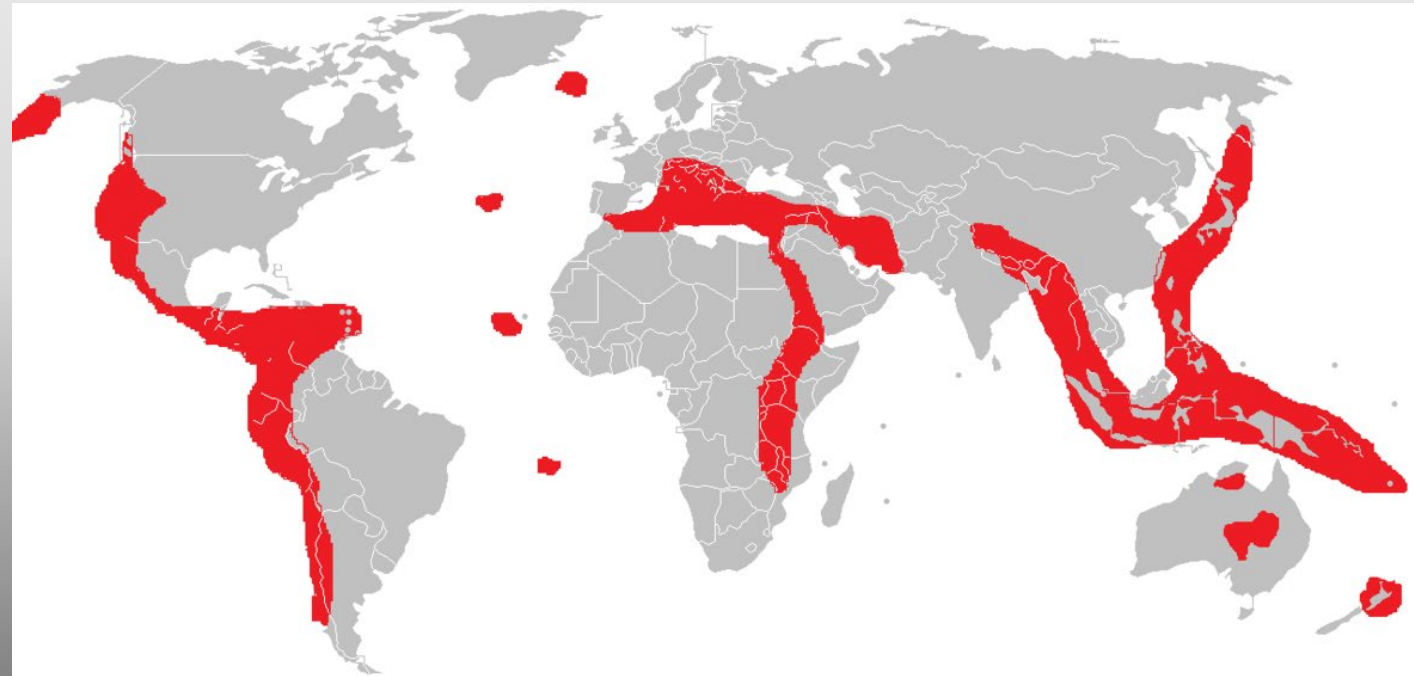


Plate Tectonics – *the limiting factor till now*

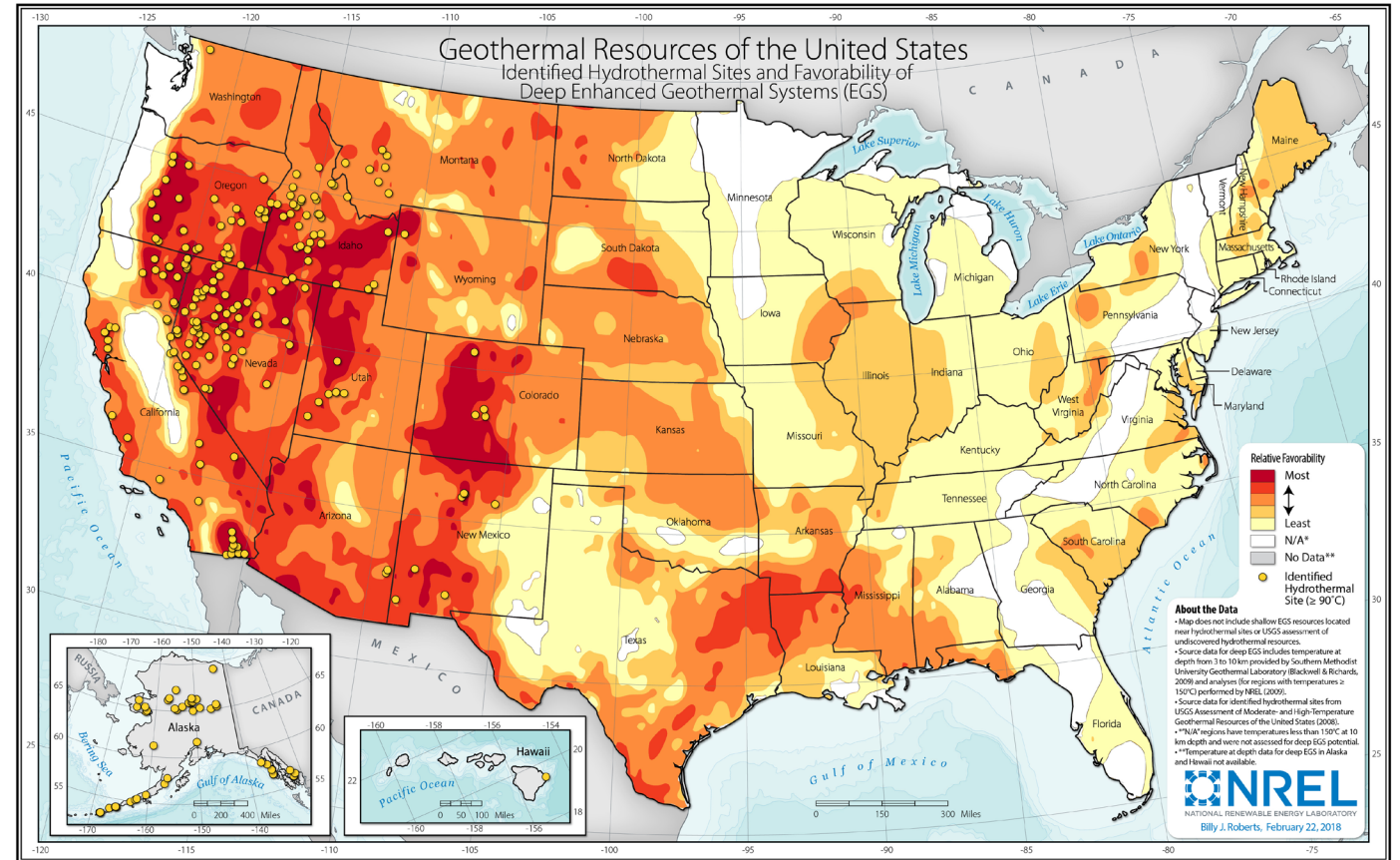
- **Determines the “Conventional” Resource Location**
- US (west of the Rockies) is the world’s largest producer of geothermal energy but it is <0.5% of the US grid –
- **Until now - geographically very restricted**
 - Still has ~3x growth potential



https://energyeducation.ca/encyclopedia/Geothermal_electricity#cite_note-6 Adapted from: R. Wolfson, "Energy from Earth and Moon" in *Energy, Environment, and Climate*, 2nd ed., New York, NY: W.W. Norton & Company, 2012, ch. 8, pp. 204-224

Geothermal Anywhere

- Uses an artificial circulation system to “hoover up” heat, concentrate it and bring to the surface
- Opens up much more of the Earth to viable geothermal production
- Multiple recent geothermal leases issued in Texas

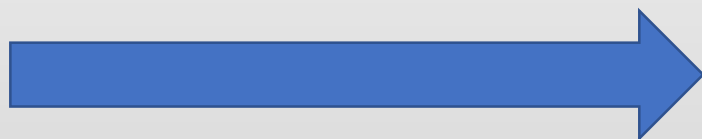


Why the excitement now?

Decarbonization
requirements, ESG,
Stakeholder Pressure

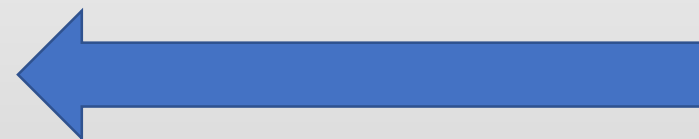


Advances in Oil & Gas
drilling, engineering and
supporting areas



**Geothermal
Anywhere**

Advances in conversion of heat
to electricity

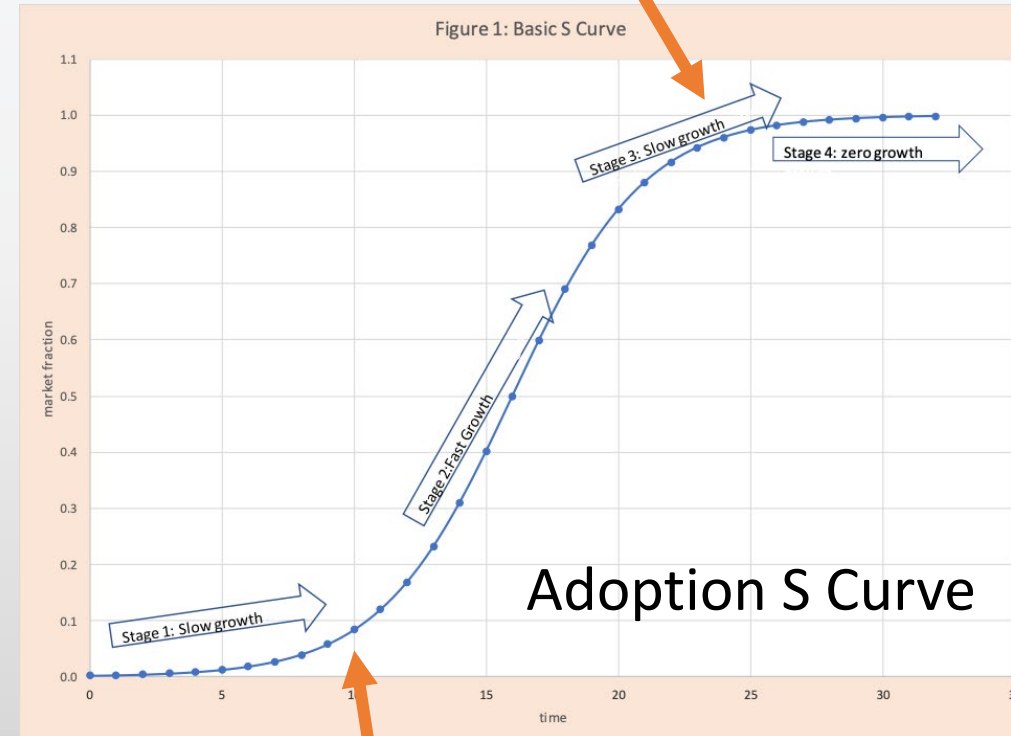


New methods for harvesting heat and
producing energy

The potential

- As happened with O&G multiple times (most recently the shale/frac boom) we are on the edge of a paradigm shift
- Significantly and rapidly diversify our grid (rapid scale-up possible)
 - Currently not in most energy forecasts!
- Perfect pivot for O&G workforce

Conventional (hydrothermal) geothermal



Geothermal Anywhere

Geothermal Anywhere Advantages

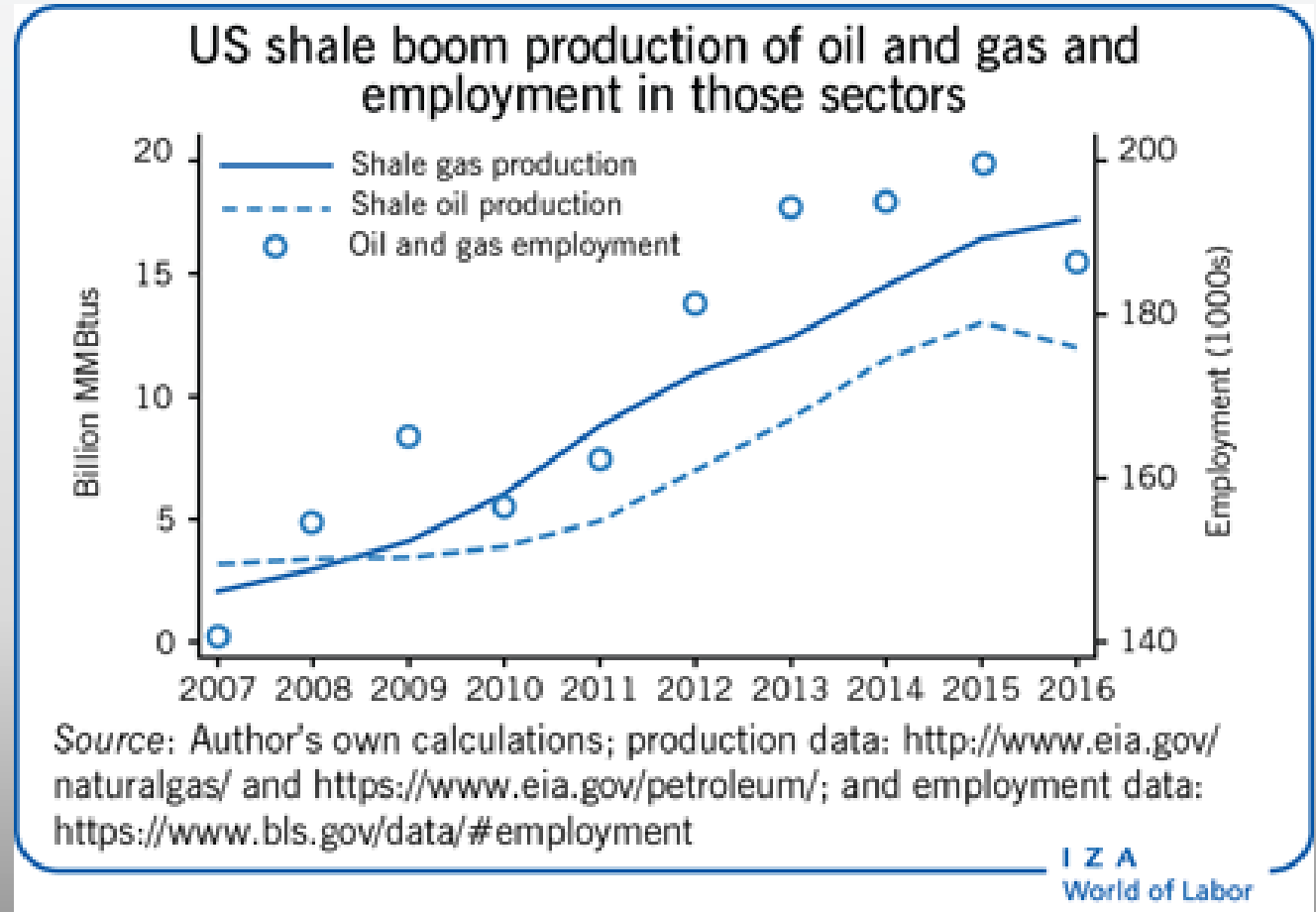
- **Baseload** /Load following
- Extremely resilient
 - No supply logistics
 - EMP resistant (short transmission distances)
 - Weather/disaster resistant
- **Low to zero (to slightly negative) carbon**
- Price-competitive with other electric sources
- Install where power is needed
 - reduced transmission issues
 - **Great for remote/rural/island settings** also
 - Small footprint
- Direct use for heating and cooling where temperatures are low, or by using the “waste” heat from power plant
 - Actually the most energy efficient use of geothermal heat
 - ~80% versus ~15% for electricity generation (at lower temperatures)



WikimediaCommons https://commons.wikimedia.org/wiki/File:NesjavellirPowerPlant_edit2.jpg#/media/File:NesjavellirPowerPlant_edit2.jpg

Jobs from the shale boom 2007-2016

- Geothermal Anywhere has similar potential but with a softer/broader tail
 - It will take many decades to build out the world
- Geothermal Anywhere is at about 2005 on this scale
 - Now is an excellent time to jump in



Who are the players?

- **Startups lead the way**

- With some academic support
 - The academic geothermal community is very small
- Funding rounds appear to be going well
- Also several exotic drilling tech startups

- DOE – traditional funder of geothermal R&D

- DoD is jumping in

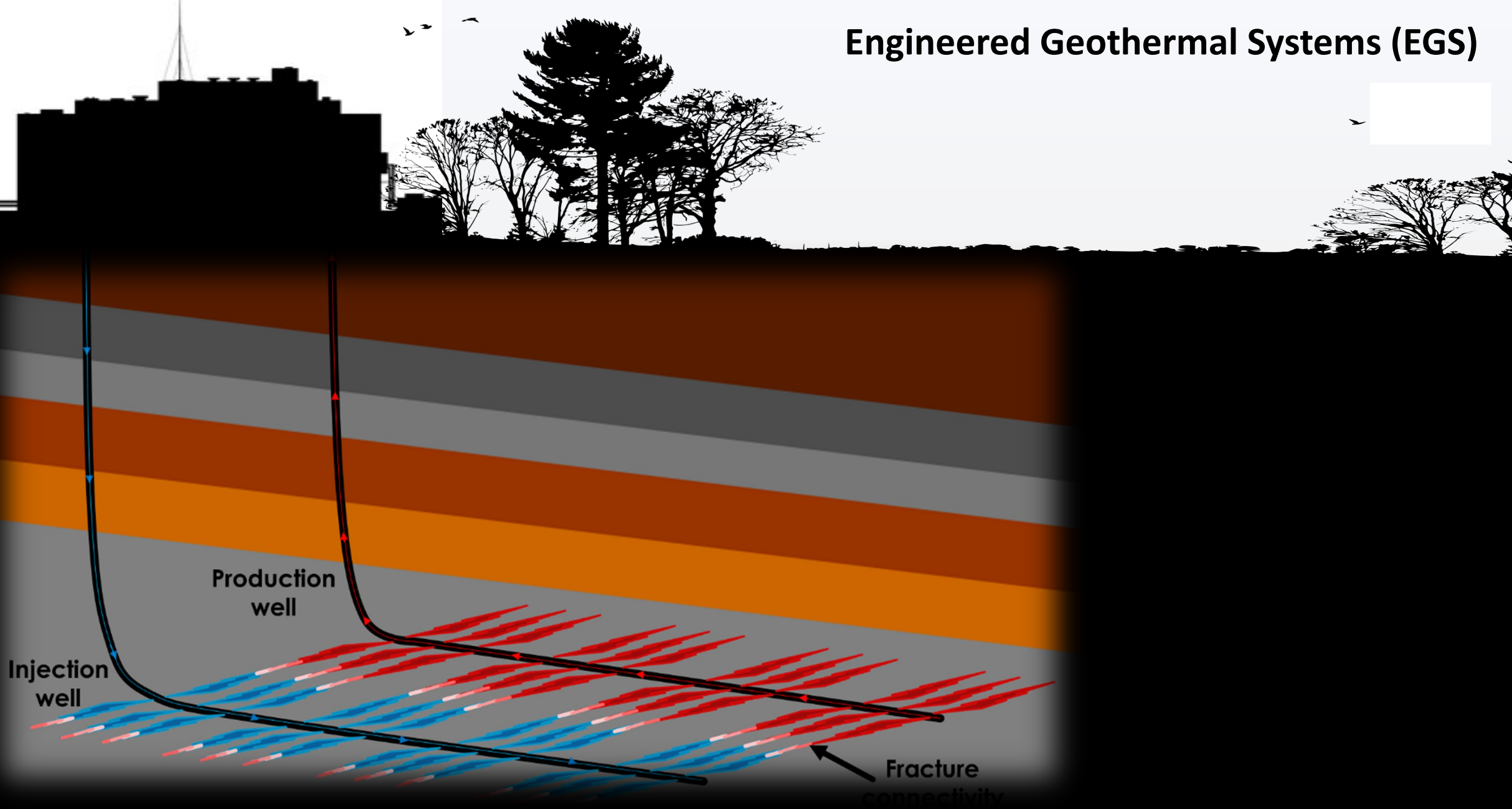
- Geothermal is the USAF #1 new energy priority (above SMRs)
- Perfect early adopter
- Solves a critical vulnerability

- The major energy, utility and related companies are largely still watching

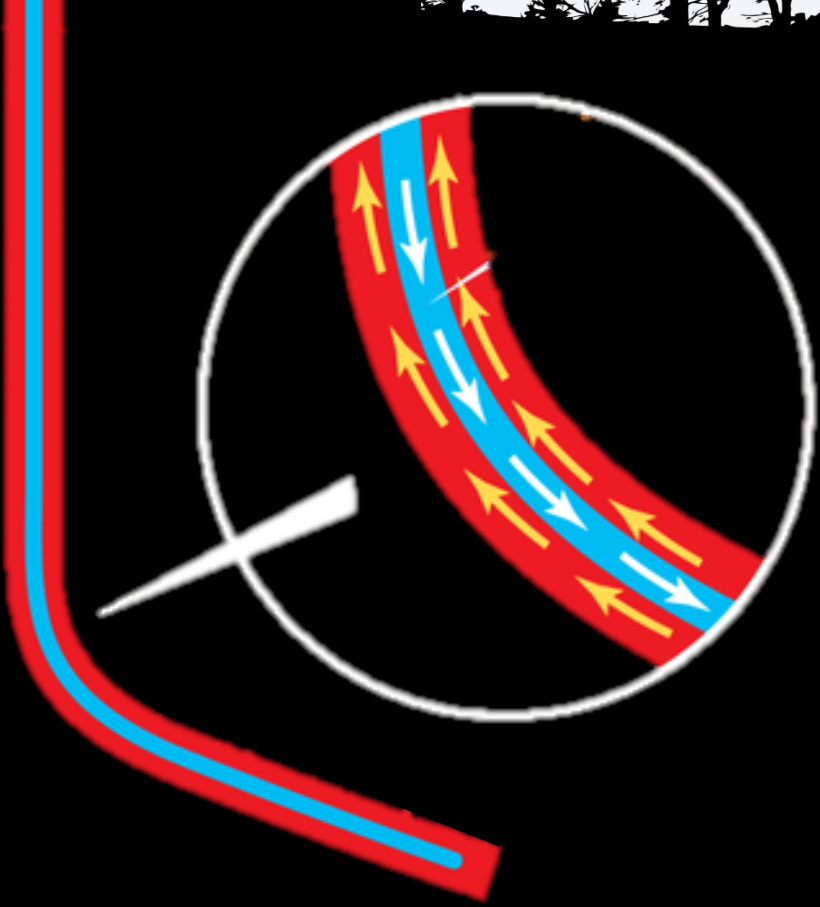
- All show strong interest and most have geothermal teams set up
- A trickle of acquisitions
- Some old learning still persists
- Want to see proven ROI



Engineered Geothermal Systems (EGS)



Closed Loop Systems (CLS/AGS)



Courtesy of Greenfire Energy
Image not to scale

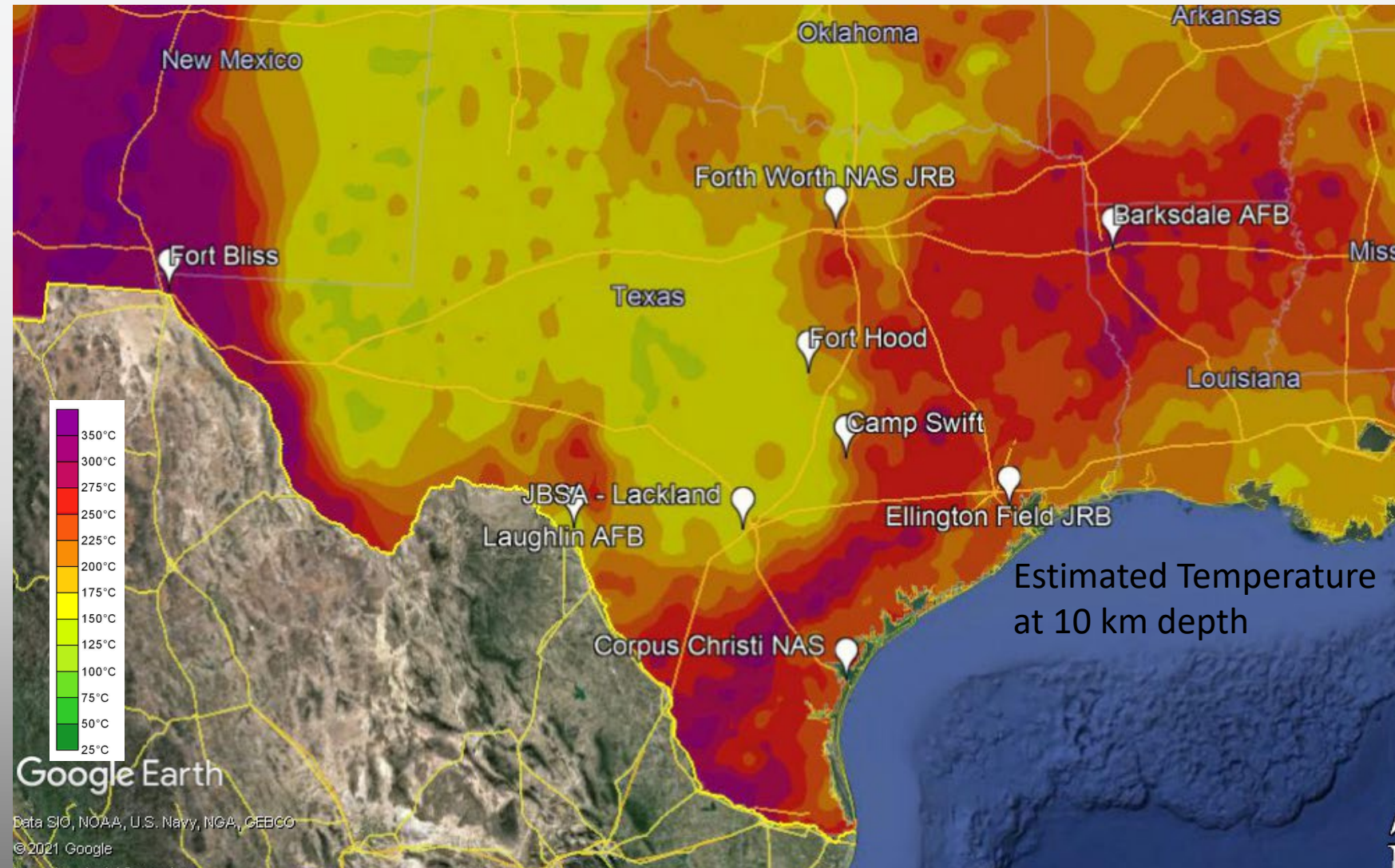
Courtesy of Eavor
Image not to scale

A little bit on risk

- Relative to Oil & Gas
 - ***Conventional Geothermal*** – similar to Oil & Gas
 - Searching for fluid
 - Risk remains high till well test
 - ***Geothermal Anywhere***
 - Searching for heat/temperature
 - Generally lower risk (you will hit your temperature eventually)
 - Fracture-based (very different from oil and gas fracking – fracture development)
 - Risk remains till the stimulation at the end of drilling
 - Non Frac-Based
 - Less risk than above, but more complex drilling likely needed
 - Many km of laterals -> \$\$

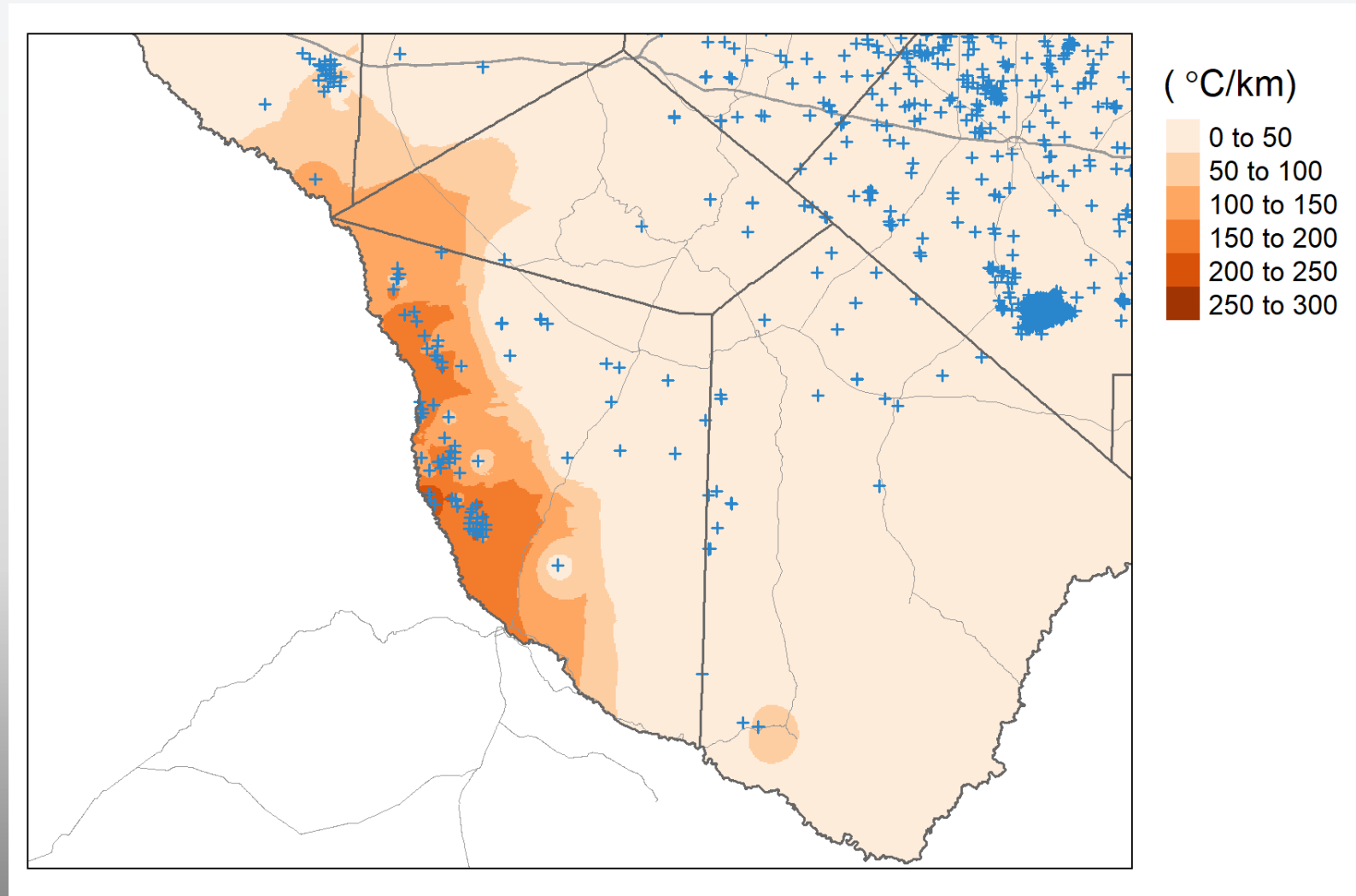
Texas' Geothermal Potential as an example

- Variety of geologic / thermal settings across the state
- Good infrastructure
- Friendly environment
- Outside the “conventional” geothermal zone
- Strong private, utility and energy company interest
- **Multiple recent geothermal leases issued in Texas**



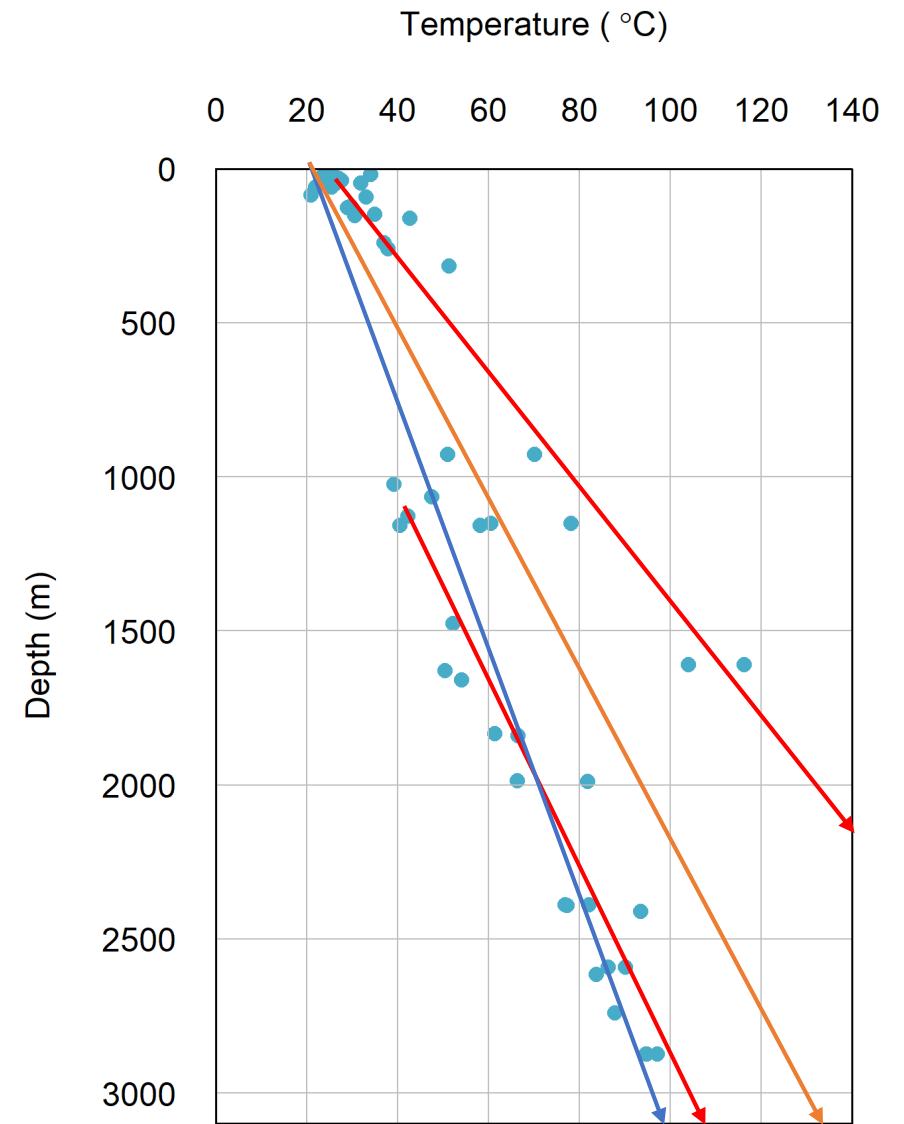
More refined view of Presidio and surrounding Counties – good news / bad news

- Much hotter nearer the border
- The hot zone has mostly shallow wells
 - Less reliable
 - May be due to water movement
 - Needs a deep well to test (\$\$)



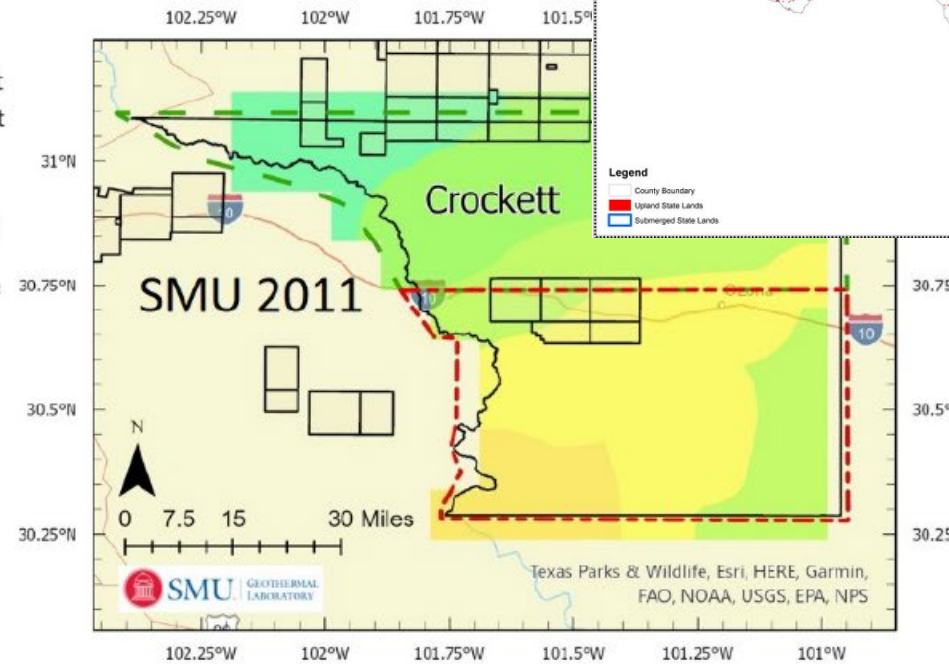
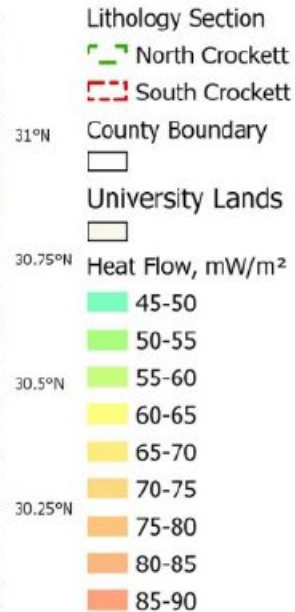
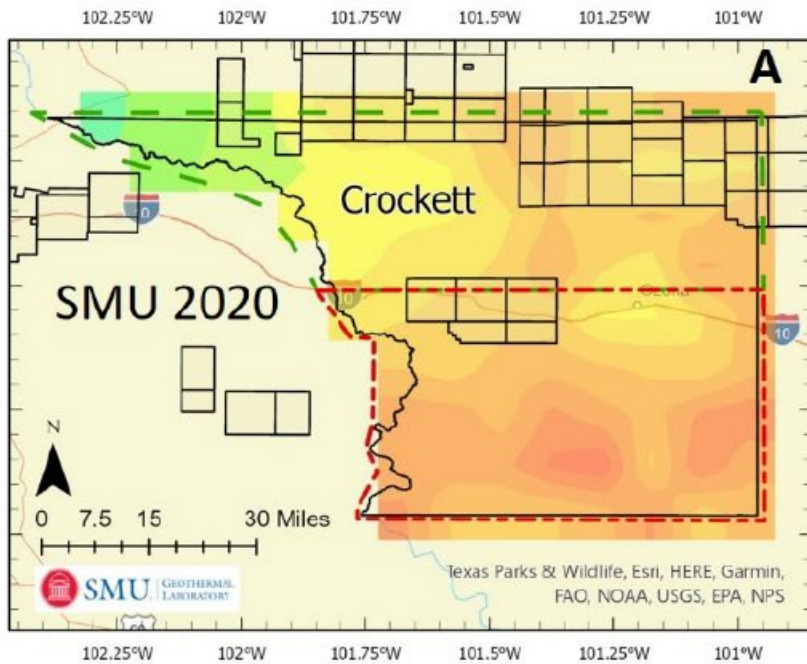
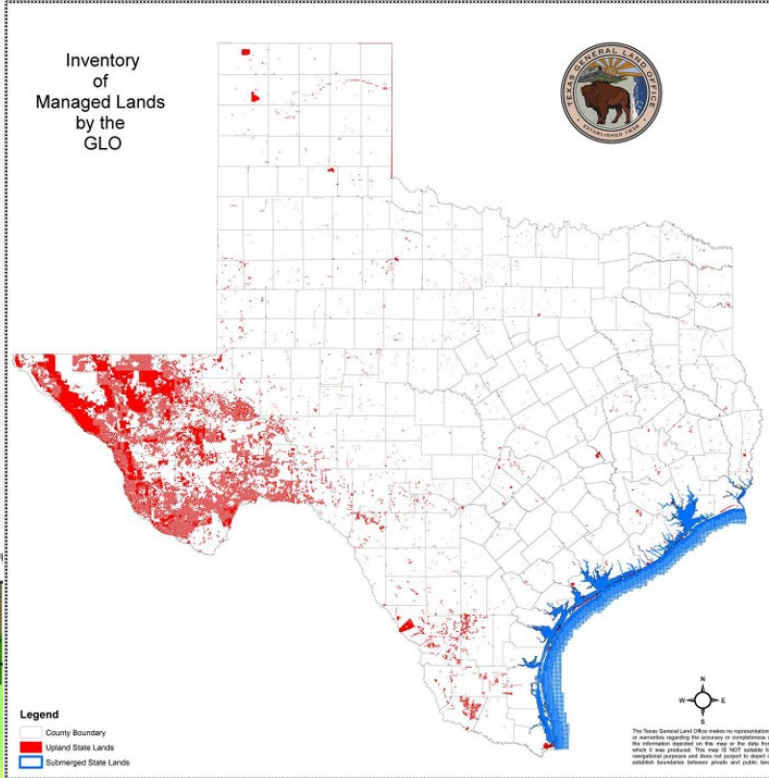
Presidio County Temperatures

- Two distinct trends
 - Hotter one has few deep data points – needs further investigation
 - Reaches 150°C (300°F) by about 2.5 km (8,200 ft)
 - Cooler one probably not viable at this time
- Geographic/Geologic correlation
 - Two distinct regimes with a large transition zone
 - Data fits →
 - Map-based estimations → →
- Bottom line: economics might be much better than previously realized



Presidio County

Crockett County Example

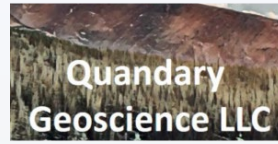


- Shows similar increase in resource

Legal Issue – Who Owns the Heat?

- Varies state by state
 - Are you mining formation fluids or the heat in the rock?
- Largely unresolved east of the Rockies(?)
- Texas – recent legislative session clarified points of law
 - TXGEA – Texas Geothermal Energy Alliance
- Liability issues
 - Induced seismicity – low risk
 - Aquifers/water draw – negligible risk for closed systems





ORMAT

HALLIBURTON

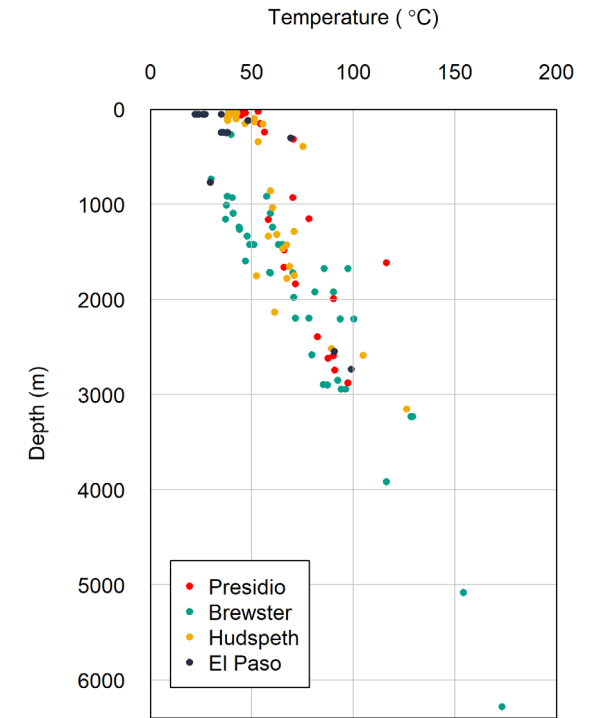


Inflation Reduction Act impact

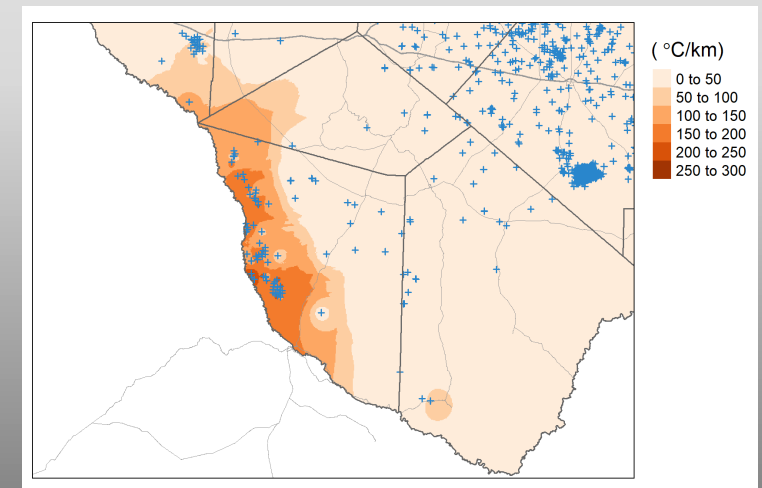
- Geothermal qualifies for Investment Tax Credit or Production Tax Credit at full value (can elect either)
 - Full value: 30% ITC or ~\$26.25 /MWh PTC for first 10 years of production in 2022
 - Full value requires meeting prevailing wage and apprenticeship requirements for project construction. Failure to meet these requirements results in 20 % of the full value
- Bonuses: 10% increase in PTC value (e.g. \$2.6/MWh) or 10 percentage point increase in value of ITC for either of the following
 - Domestic content
 - Energy communities: projects in any of following locations: brownfield site, high unemployment, closed coal mine or power plant nearby
- Transferability and Direct Pay for PTC/ITC
 - Direct pay for non-profit and government-owned utilities (full refundability) - a game changer for public utilities
- DOE Loan Programs Office
 - 1703 Program for "Projects That Employ Innovative Technologies" ~\$45B
 - New 1706 Program, Energy Community Reinvestment Financing
 - \$5 billion appropriated for FY2022 available through FY2026 for which may provide commitments of up to \$250 billion in loans and guarantees

Recent Bureau work in Geothermal

- DoD / USAF / AFWERX / DIU
 - First new geothermal power plant design in decades
 - USAF now rates geothermal as the #1 new energy focus (above SMRs)
- Resource assessments – USGS, local and Private Funding
 - Lots of BHT w/ its inherent problems
 - Working through Texas county by county to build thermal picture
 - Incorporating burial history, radiogenic production & lithology
- Induced seismicity monitoring – DoD and State funding
 - Ongoing work in South Texas and Houston
- Big-data/ML applications
- Direct Use
- System modeling
- Part of two teams with \$150M research proposals under consideration – DOE GEODE and NSF Innovation Engine
- Economics, Social/DEI/ESG, Powering CO2 capture and storage, lithium extraction, Desal

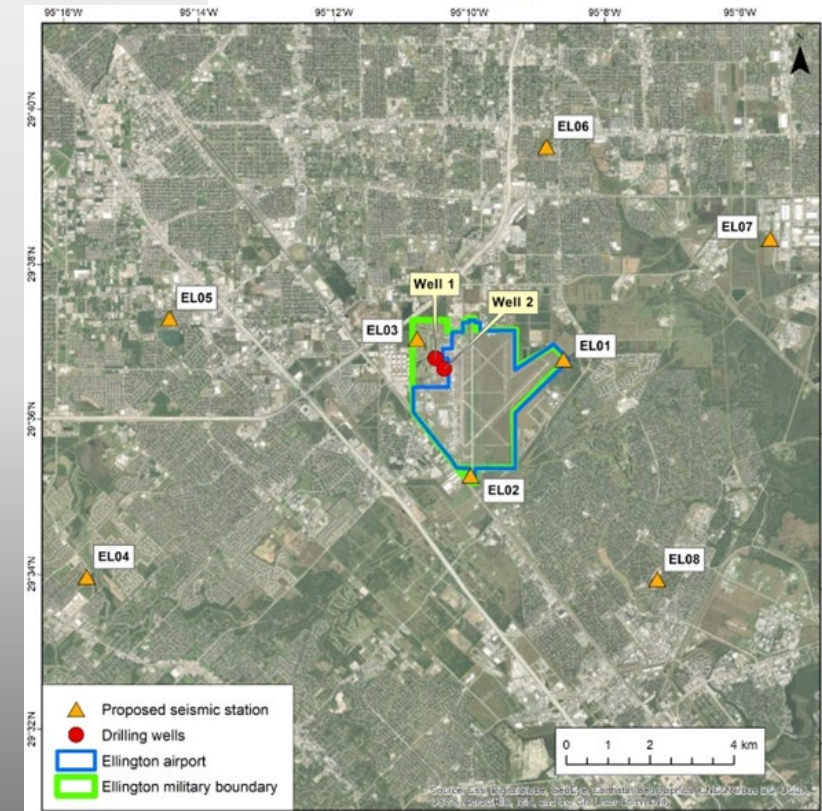


Presidio and surrounding counties raw temperatures and geothermal gradient



US Air Force, AFWERX STTR Phase 2 (complete)

- R&D of a 3MW Geothermal Power Plant at Ellington Field (south side of Houston)
 - Led by Sage Geosystems (start-up)
 - Proof of concept for several component technologies
- In the Gulf Geopressure Zone
 - Other commercial projects brewing along this play?
- A successful project in Houston, “Oil City”, will get attention that a similar project further west would not





THE UNIVERSITY OF TEXAS AT AUSTIN

HotRock Geothermal Research Consortium

- Vision – an industry-funded research consortium to find and fill the science, technology, economics, policy, and entrepreneurship gaps needed to further develop the geothermal-anywhere ecosystem; led by the Bureau, the organization with the skills and proven track record to lead major enterprises
- Scope – subsurface geology and engineering; surface power generation, grids, economics, and policy; direct heat applications for heating and cooling, agriculture, etc.; subsurface thermal storage; hybrid systems; etc.
- Principal investigators – Ken Wisian, BEG; Shuvajit Bhattacharya, BEG; Silviu Livescu, Petroleum and Geosystems Engineering; Nicola Tisato, Geological Sciences



The Future of Geothermal in Texas

THE COMING CENTURY OF GROWTH & PROSPERITY IN THE LONE STAR STATE



The Future of Geothermal in Texas

Contemporary Prospects and Perspectives

Edited by

Jamie C. Beard, Esq. & Dr. Bryant A. Jones



https://cgmf.org/p/geothermal-energy-texas_report.html

The Future of Geothermal in Texas

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If you want to stay informed...

- Think GeoEnergy <https://www.thinkgeoenergy.com/>
- DOE GTO <https://www.energy.gov/eere/geothermal/geothermal-technologies-office>
- Geothermal Rising <https://www.geothermal.org/>
- InnerSpace and PIVOT conference <https://www.projectinnerspace.org/>
- International Geothermal Association <https://www.lovegeothermal.org/>
- Stanford Geothermal Workshop
<https://geothermal.stanford.edu/events/workshop>

Questions?

By the way... there is geothermal in sp

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BUREAU OF
ECONOMIC
GEOLOGY

Back-up slides