DoD and Geothermal

Clean, base-load energy generation inside the wire

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

Associate Director, Bureau of Economic Geology

The University of Texas at Austin

ken.wisian@beg.utexas.edu

Bureau of Economic Geology

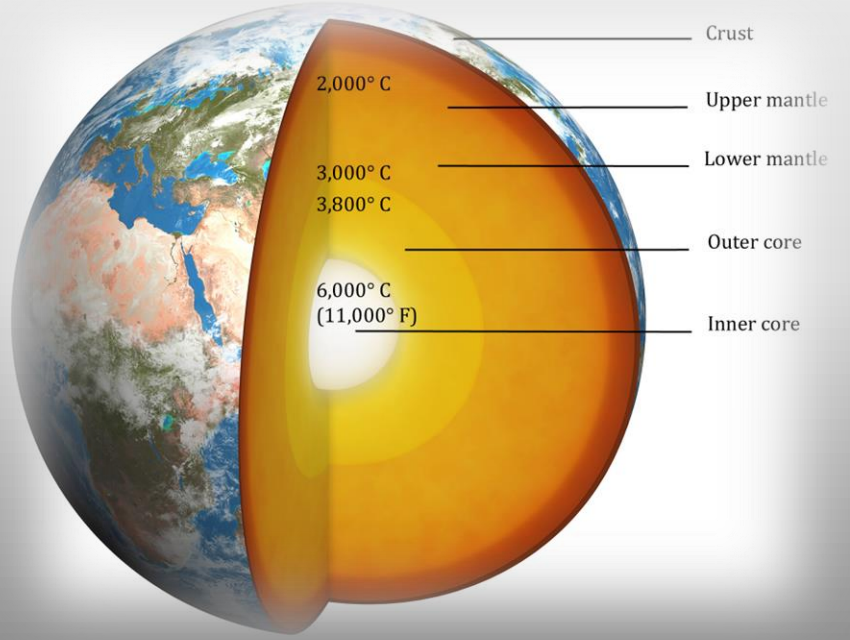
TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences

A solvable critical vulnerability

- Problem: The Department of Defense (DoD) has a *critical need for unbreakable power*, but also a nearly complete dependence on commercial power suppliers. This creates an unacceptable strategic vulnerability
  - A successful attack on the US power grid or a direct hit by a Solar Coronal Mass Ejection, could hobble the DoD

- Background: Geothermal energy; clean, baseload electricity generated off the heat of the Earth, has been a small part of the US and world energy picture for a hundred years – that is *changing now!*

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



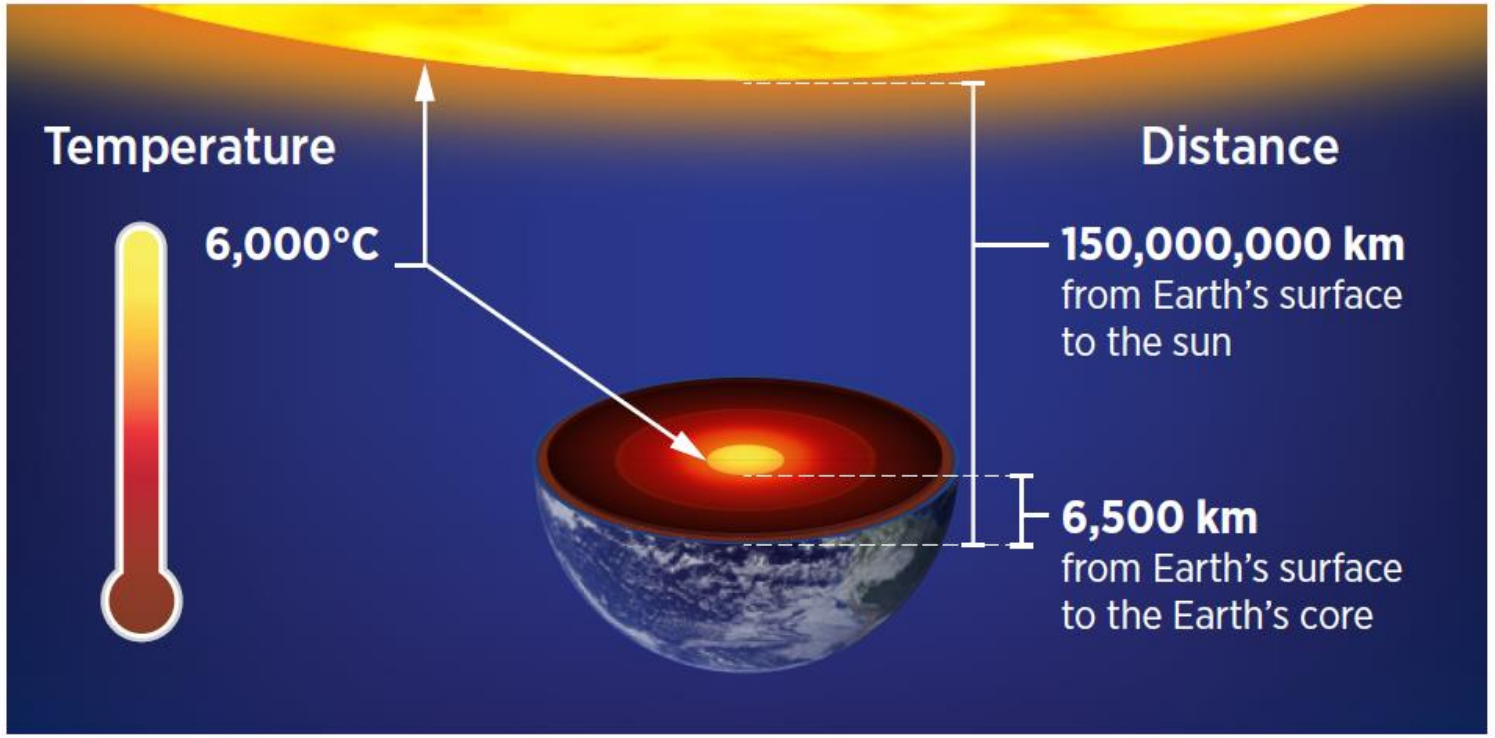
Solution: Construct geothermal power generation plants "inside the wire" at DoD facilities.

- These plants possess significant advantages:
  - Physical security: on-base location is secure and includes the ability to ramp-up security as needed
  - Electro-Magnetic Pulse (EMP) resiliency: the short electricity transmission distances largely eliminates EMP issues
  - Baseload energy supply: geothermal power is "always on" and dialable up to maximum capacity
  - Self-contained: no outside resupply (petroleum) needed, indefinite lifetime, minimal maintenance
  - Scalable: Need more power, drill another well (to an extent)
  - Safe: no combustion or radioactivity involved
  - Green: little to no pollution/greenhouse gas emissions

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**

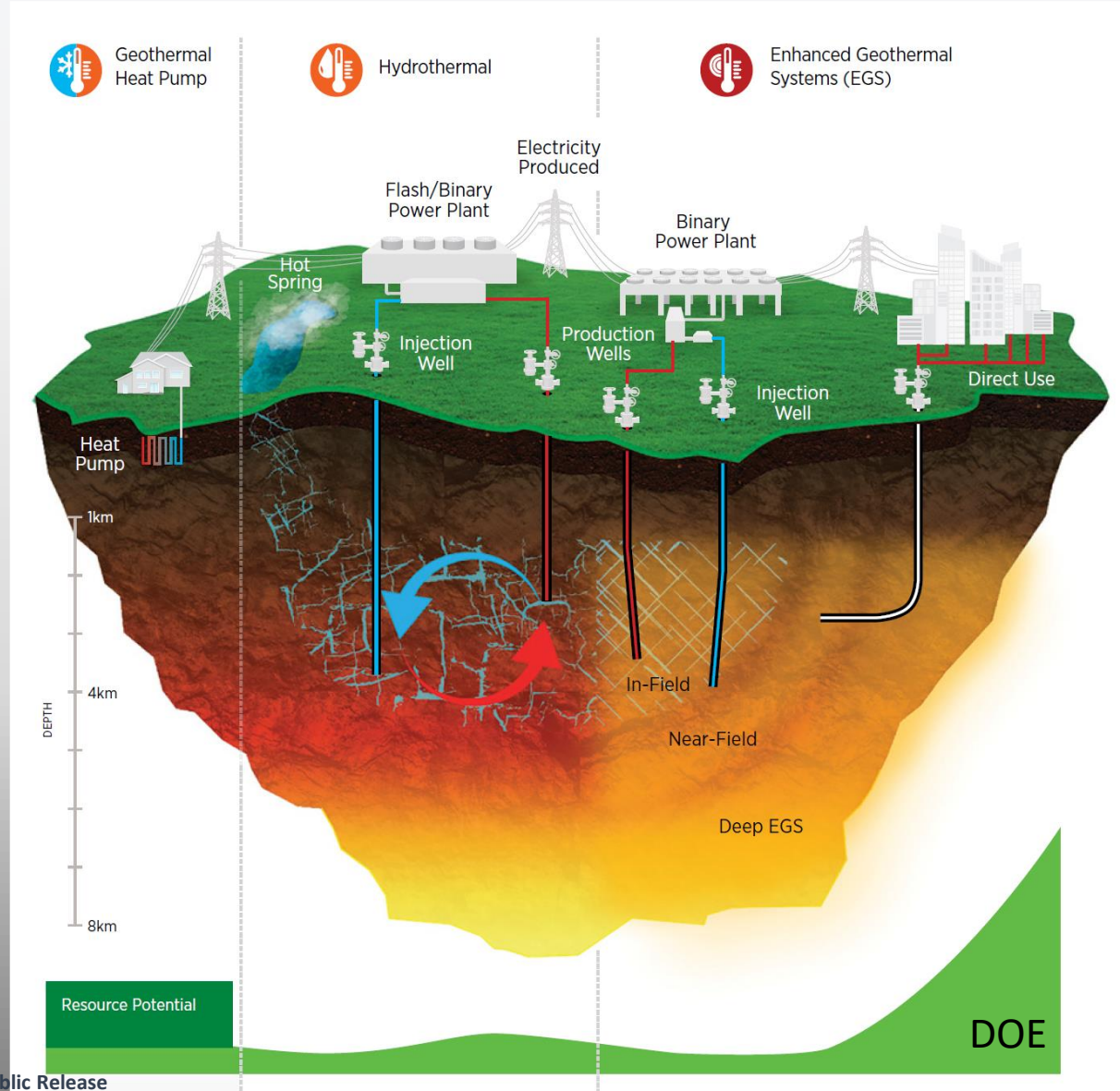
GeoVision, DOE



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!!!**



Intro – Plate Tectonics – *Conventional* Geothermal

- 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 –
- Geographically very restricted
- Mature industry

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

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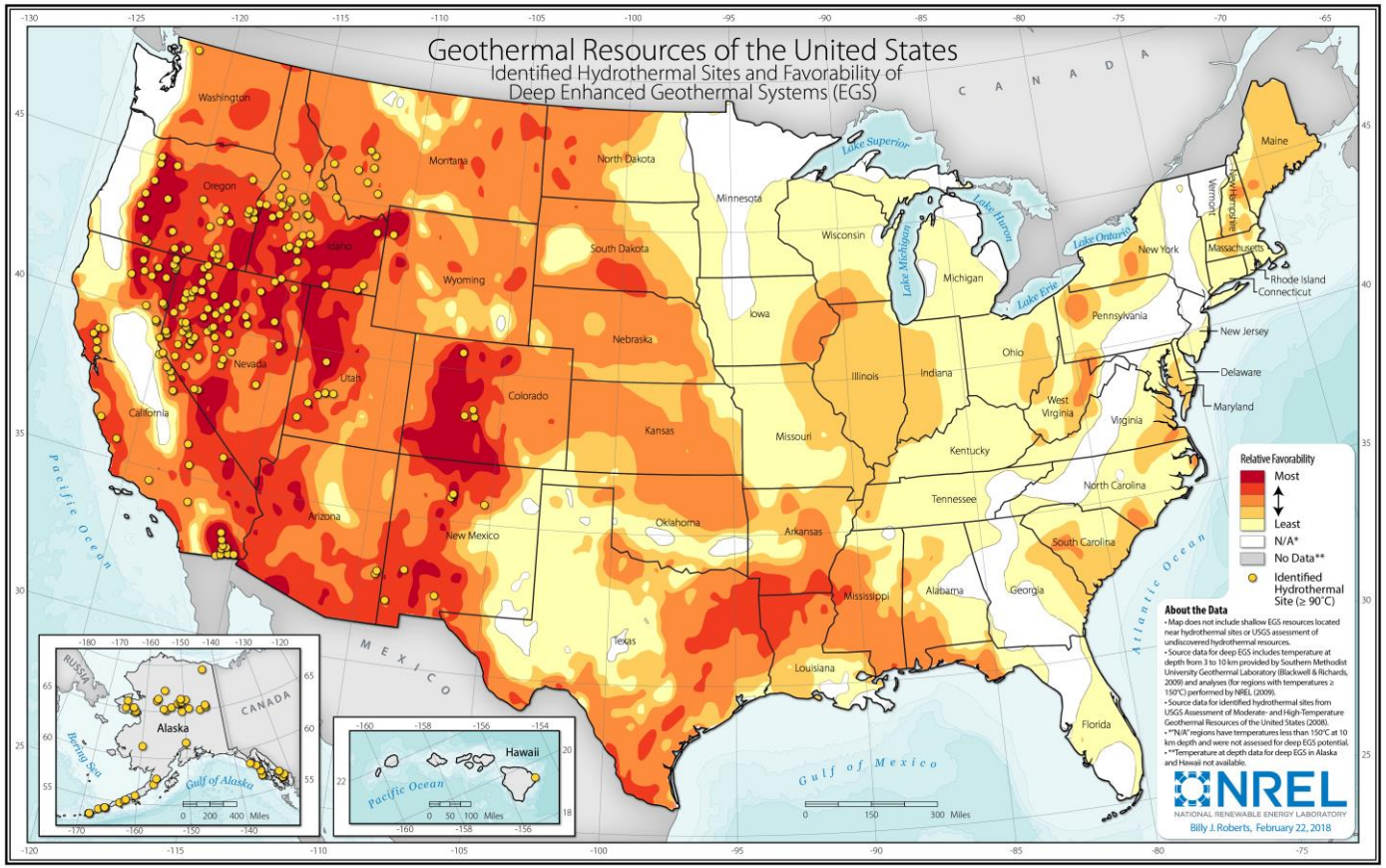
Geothermal Anywhere

- Uses an artificial circulation system to “hoover up” heat, concentrate it and bring to the surface
- Renewable to semi-renewable
- **Opens up much more of the Earth to viable geothermal production**

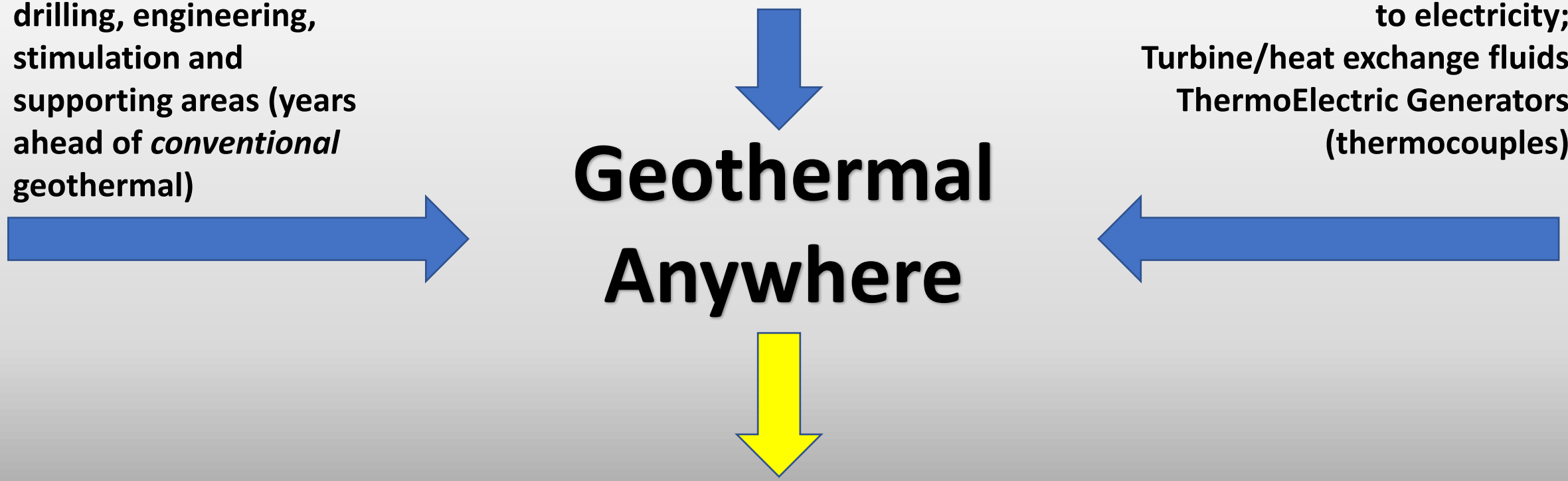


Why the excitement now?

Decarbonization requirements, ESG, Stakeholder Pressure

Advances in Oil & Gas drilling, engineering, stimulation and supporting areas (years ahead of *conventional* geothermal)

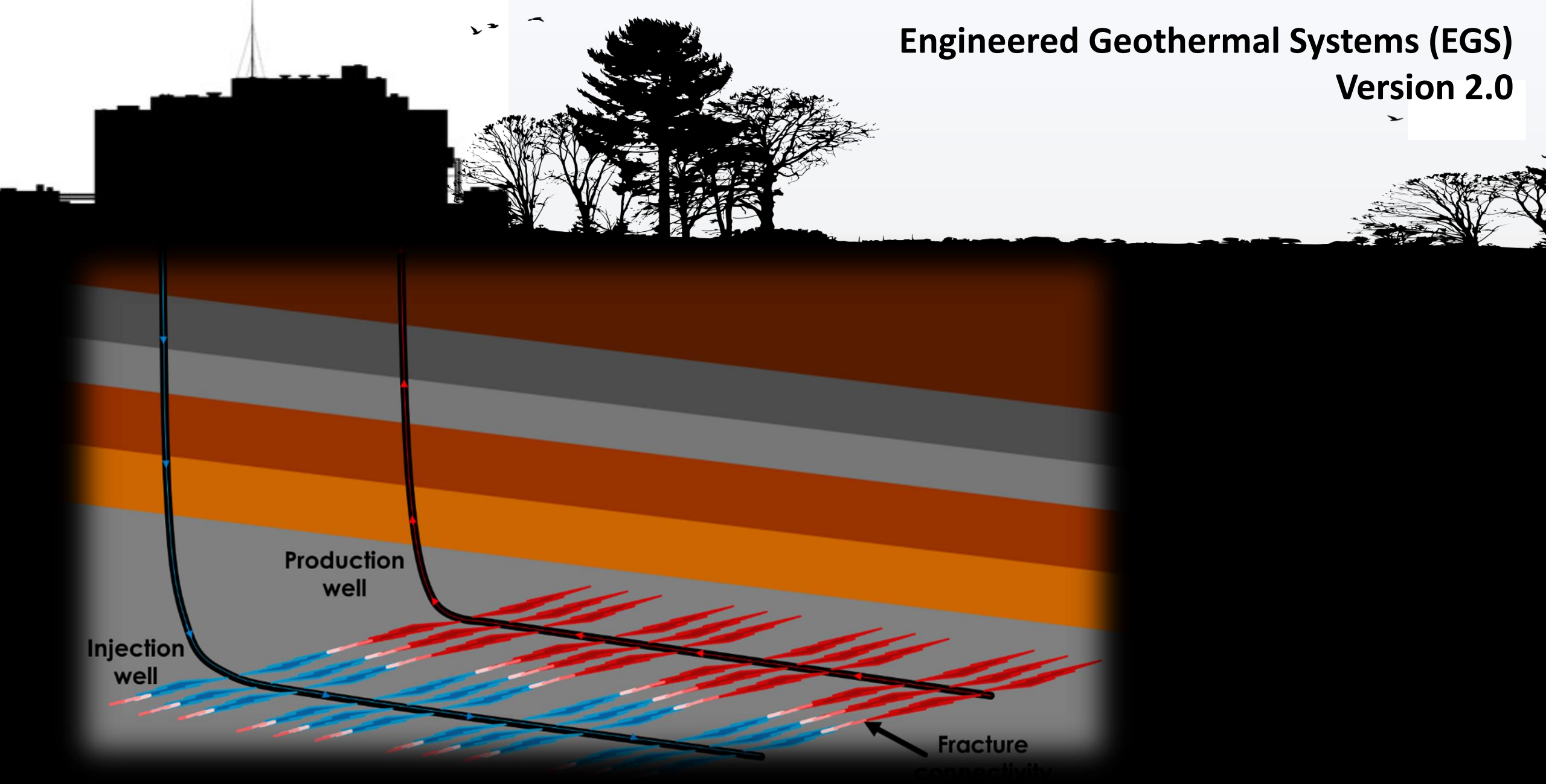
Advances in conversion of heat to electricity; Turbine/heat exchange fluids ThermoElectric Generators (thermocouples)



Geothermal Anywhere

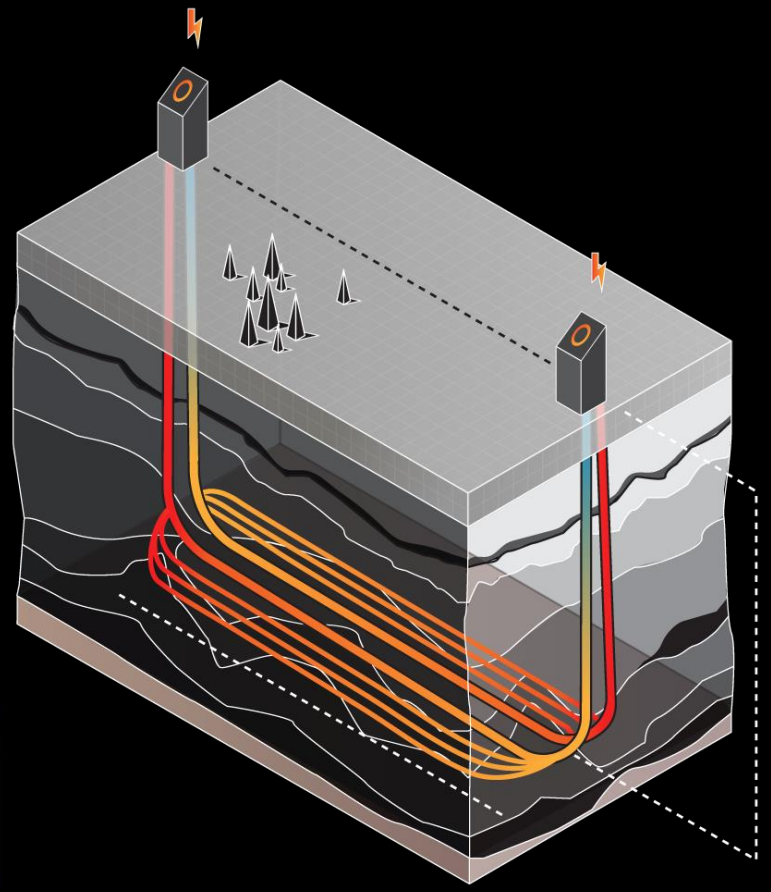
New methods for harvesting heat and producing energy

Engineered Geothermal Systems (EGS) Version 2.0



Courtesy of Geothermix
Image not to scale

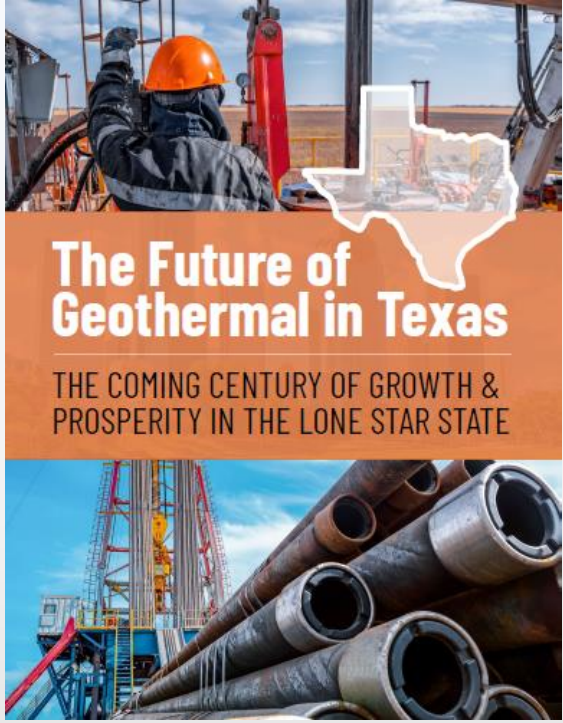
Closed Loop Systems (CLS/AGS)
Fork & Multilateral Doublet

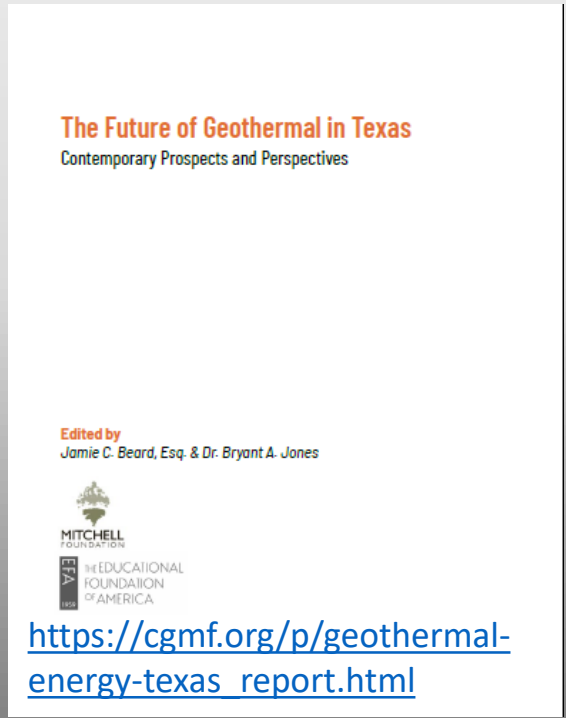


Courtesy of Eavor
Image not to scale

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 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
- Coal Plant Conversion - InnerSpace funding
- Big-data/ML applications
  - Great problem for ML
    - We have huge core and well log library
- Energy storage
  - Looking for project funder
- Direct Use
- System modeling
- Economics, Social/DEI/ESG, Powering CO_2 capture and storage





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

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HotRock Geothermal Research Consortium

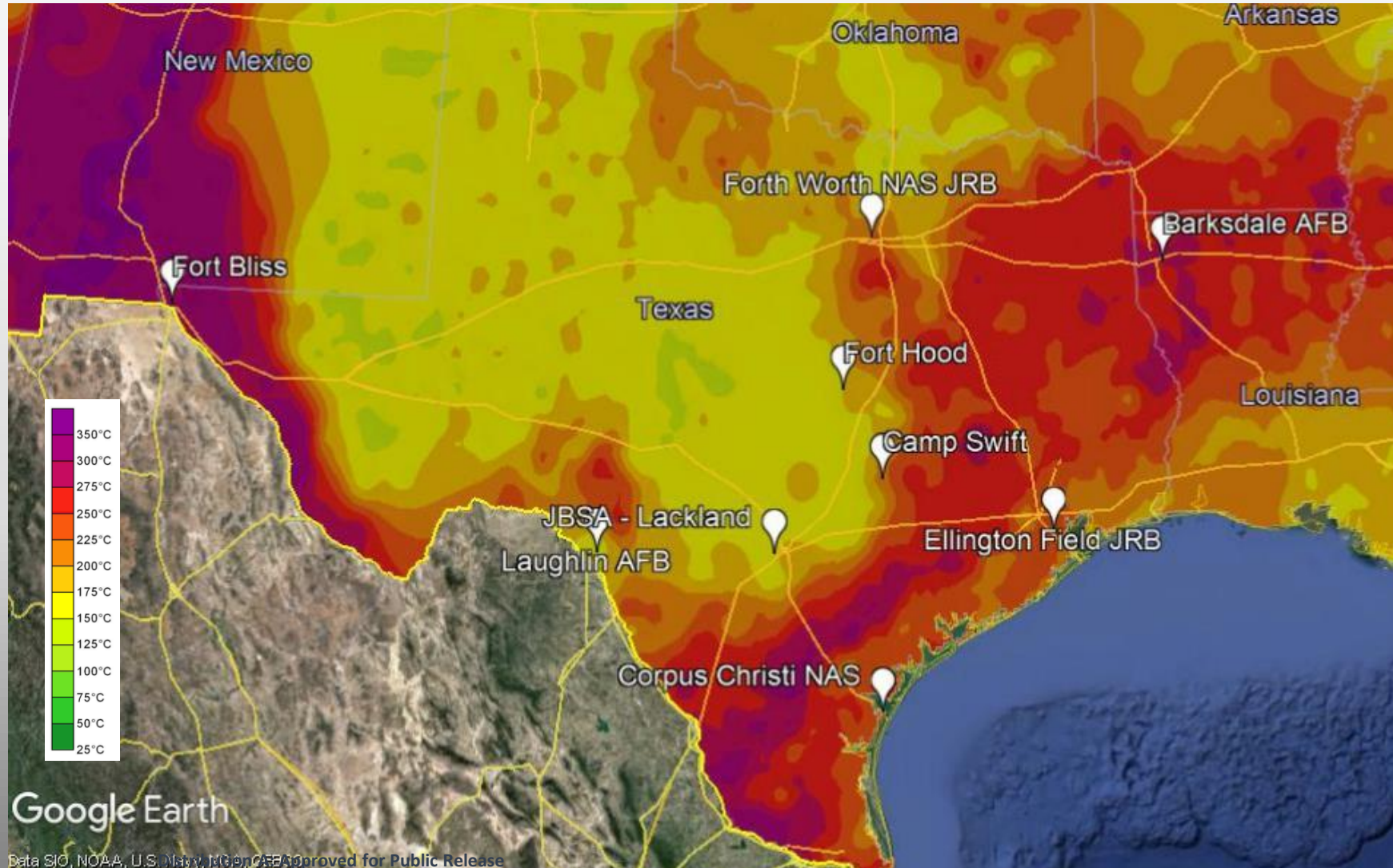
- Vision – an industry-funded research consortium to find and fill the science, technology, economics, policy, and entrepreneurship gaps needed to further develop the geothermal-anywhere ecosystem; led by the Bureau, the organization with the skills and proven track record to lead major enterprises
- 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

Why go after DoD?

- The perfect early adopter
  - Prioritizes Effectiveness over Cost Effectiveness
    - Can pay a premium (but you have to get to the right channel – first-line folks are bound by cost effectiveness)
  - Comfortable with working leading edge technology
- The emerging "Geothermal Anywhere" paradigm, if proven, allows for scaling up geothermal power to an extent that will get DoD's attention
- Secondary
  - regulatory and permitting advantages and disadvantages
  - Relatively easy government $$ looks good to startups and VC
- Major note – Direct use does not get much attention, but is easier, much more efficient and can significantly reduce electricity demand
  - Heat can be used for cooling!

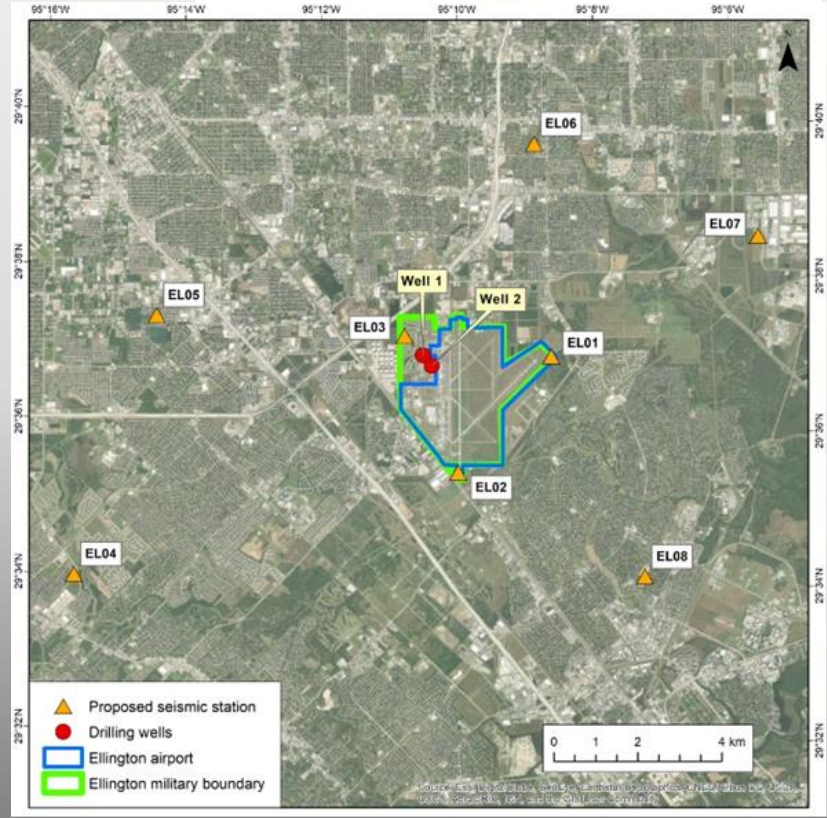
Texas as a (non-limiting) example

- Variety of geologic / thermal settings across the state
- Many military facilities
- Good infrastructure
- Friendly environment
- Outside the “conventional” geothermal zone



US Air Force, AFWERX STTR Phase 2 (complete)

- Development 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



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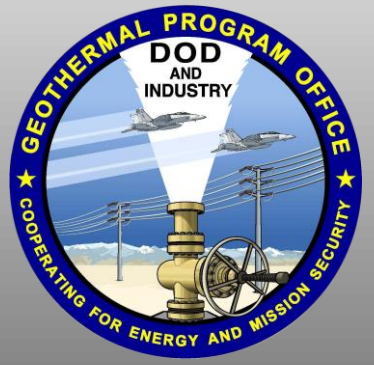
More on DoD activity

- **DoD** (DIU) has issued a call for prototype plants at ~~four~~ 6 bases
  - Not putting up much money, but promising a non-compete PPA upon successful demonstration
  - JBSA (San Antonio)
  - Mountain Home, ID
  - Fort Irwin, CA
  - Fort Wainwright, AK
  - Two Navy Bases
- USAF SAF/OEA rates geothermal as the **#1 new energy prospect above** Small Modular Reactors (SMR)
- Note: there is a Navy Geothermal Program Office that has run a field in California for decades – they need more resourcing



Innovation Principles & Projects

INNOVATION: PRINCIPLES

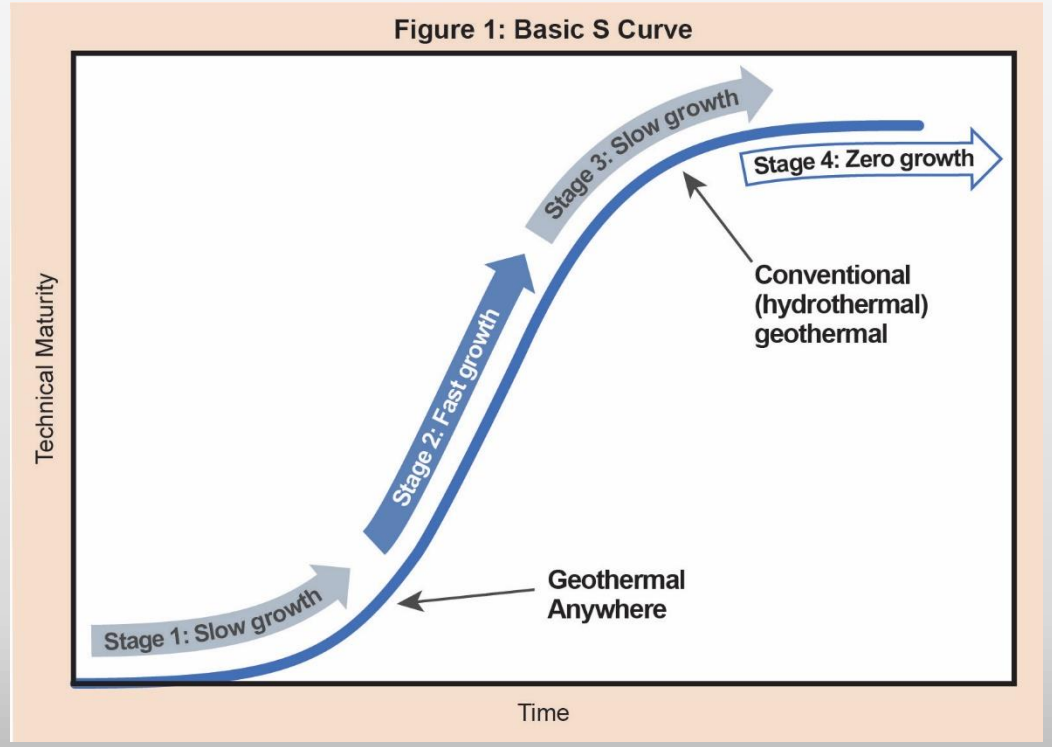
- Resilience and Mission Focused
- Creatively Leverage All Acquisition Tools (e.g., Other Transaction Authorities)
- Leverage and Combine All Appropriate Funding for Comprehensive Solutions (DAF, Vendor, Federal agencies, State, Financiers)
- Move at Commercial Speed
- Long-Term Planning Horizons with Concrete Near- and Medium-Term Milestones (e.g., geothermal pilots)
- Teaming for Success - Air Force, DoD, Federal Gov't, States, Utilities, Vendors

INNOVATION: PRIORITY PROJECTS

- Closed-Loop Geo (prototypes)
- Small Modular Reactors
- Long-Duration Energy Storage
- Green Hydrogen
- Electric Vehicle Support Equipment (EVSE)

The potential

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



Bottom Line

- **Geothermal Power can solve a major strategic and systemic vulnerability**
- DoD has realized this and is starting to act
- Potentially huge civil benefit to DoD as the early adopter
  - Think about technology that the military and NASA have led the way on

https://goenergylink.com/blog/what-is-geothermal-energy-storage/

By the way – there is geothermal in space

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