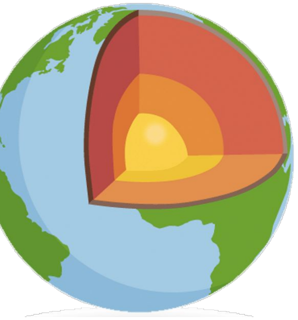
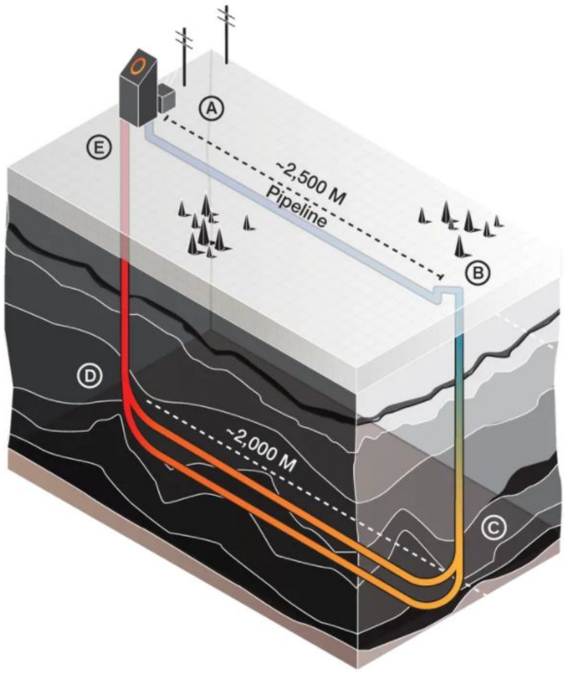


Developing New Mexico's Geothermal Heat and Electricity



Sept 20, 2022

(Senator Gerald Ortiz y Pino)

Dr. Shari Kelley

Tom Solomon

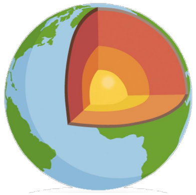
Neil Ethier / Eavor

Rural Economic Opportunities Task Force

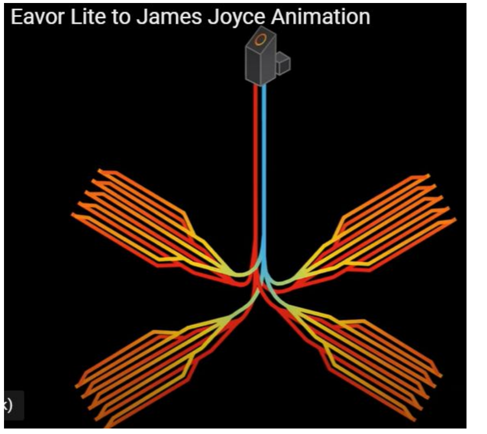
EAVOR 12min geothermal explainer **video**

Agenda: Developing NM Geothermal

- **Geothermal overview & goal**
- **Geothermal development bill - concept**
- **Development opportunities**
- **Questions and answers**



Why Geothermal Heat Energy & Electricity?

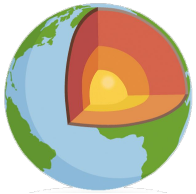


- Clean, zero emissions source of heat & electricity
- A world-class 24x7 power source in New Mexico
- May provide “last 10%” of clean energy transition
- Sustainable economic development for NM
- Re-use skills & drilling rigs from the oil industry.
    - A ‘just transition’ for workers - drill for heat

Geothermal Working Group

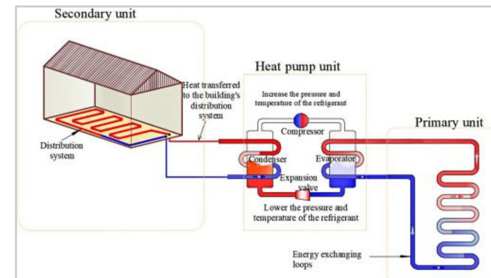
Meeting biweekly since Feb 2022

- Senator Gerald Ortiz y Pino
- Senate Pro Tem Mimi Stewart
- Senator Bill Soules
- Tom Solomon, facilitator
- Sanders Moore
- Abbas Akhil
- Dr. Shari Kelley, NM Tech
- Dr. Olga Lavrova, NMSU
- Dr. Patricia Sullivan, NMSU



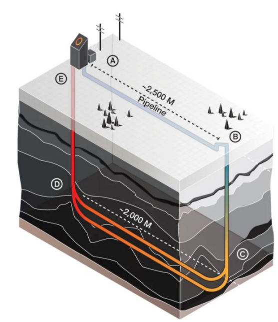
Geothermal Goal

Our goal - Pass a geothermal energy development bill for 2023 to support the two-phase development of geothermal (GT) energy in New Mexico:

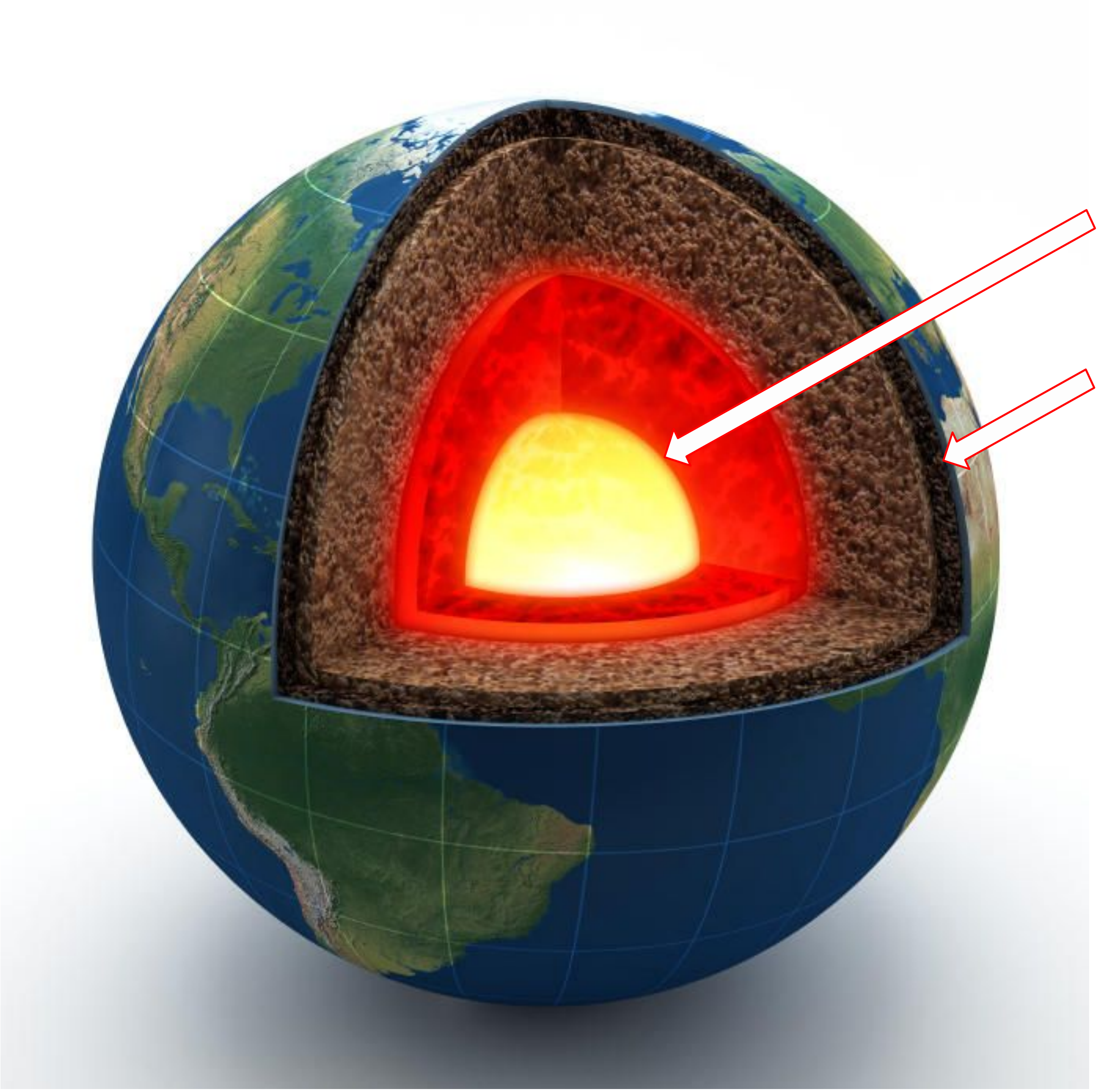


Phase 1) In the **2020**'s expand known existing geothermal resources: heat pumps for buildings, in green houses, hot springs & spas, for clean electricity (Lightning Dock), etc.

Phase 2) promote longer term development of advanced geothermal electricity to provide the final 10% of clean NM grid electricity through the **2030**'s: 1 to 3GW.



Geothermal Energy: Using Earth's Heat



The temperature in the **inner core** is ~5,200°C or **9,392°F**

Five miles underground it can be 204°C or **400°F** *

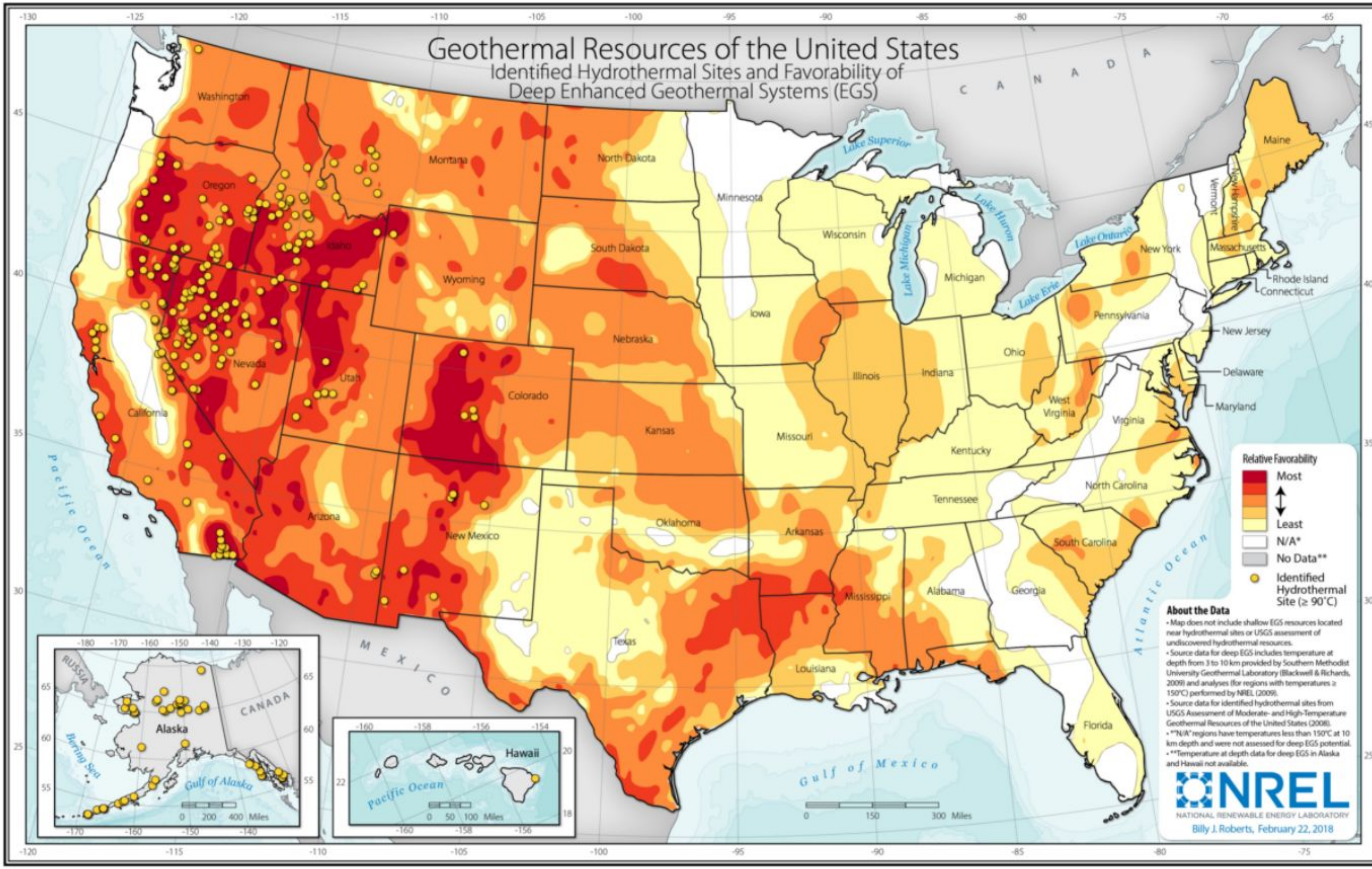
Temps can be higher at shallower depths where the crust is thinner.

* Well above boiling temp of water, ie **212°F** at sea level.

https://earthscience.stackexchange.com/questions/240/is-the-earths-hot-inner-core-necessary-for-life
https://education.nationalgeographic.org/resource/core

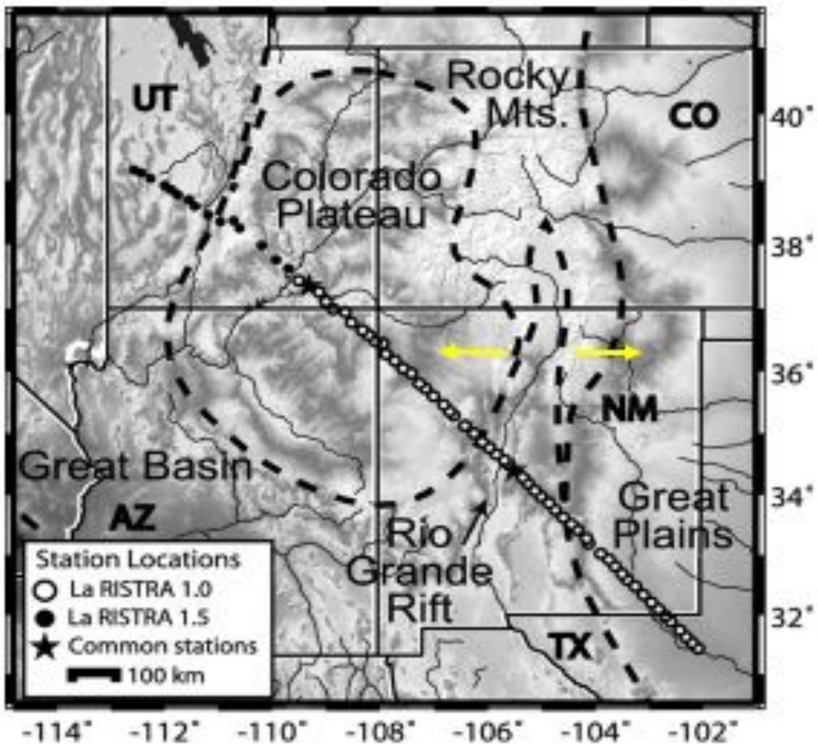
NM Ranks #6 in Geothermal Resources

NREL map at depths of **3km-10km** (~10k to 33k ft)

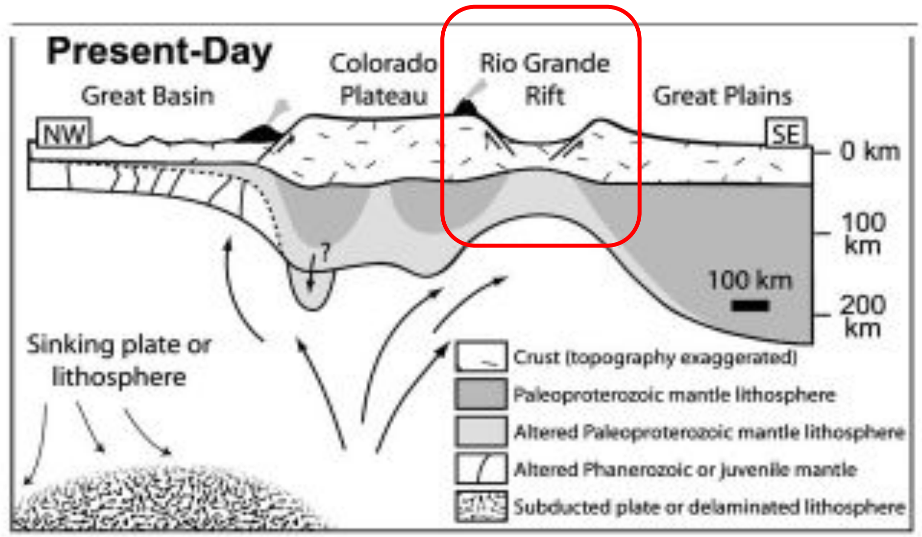


Rio Grande rift heat source

LA RISTRA seismic experiment



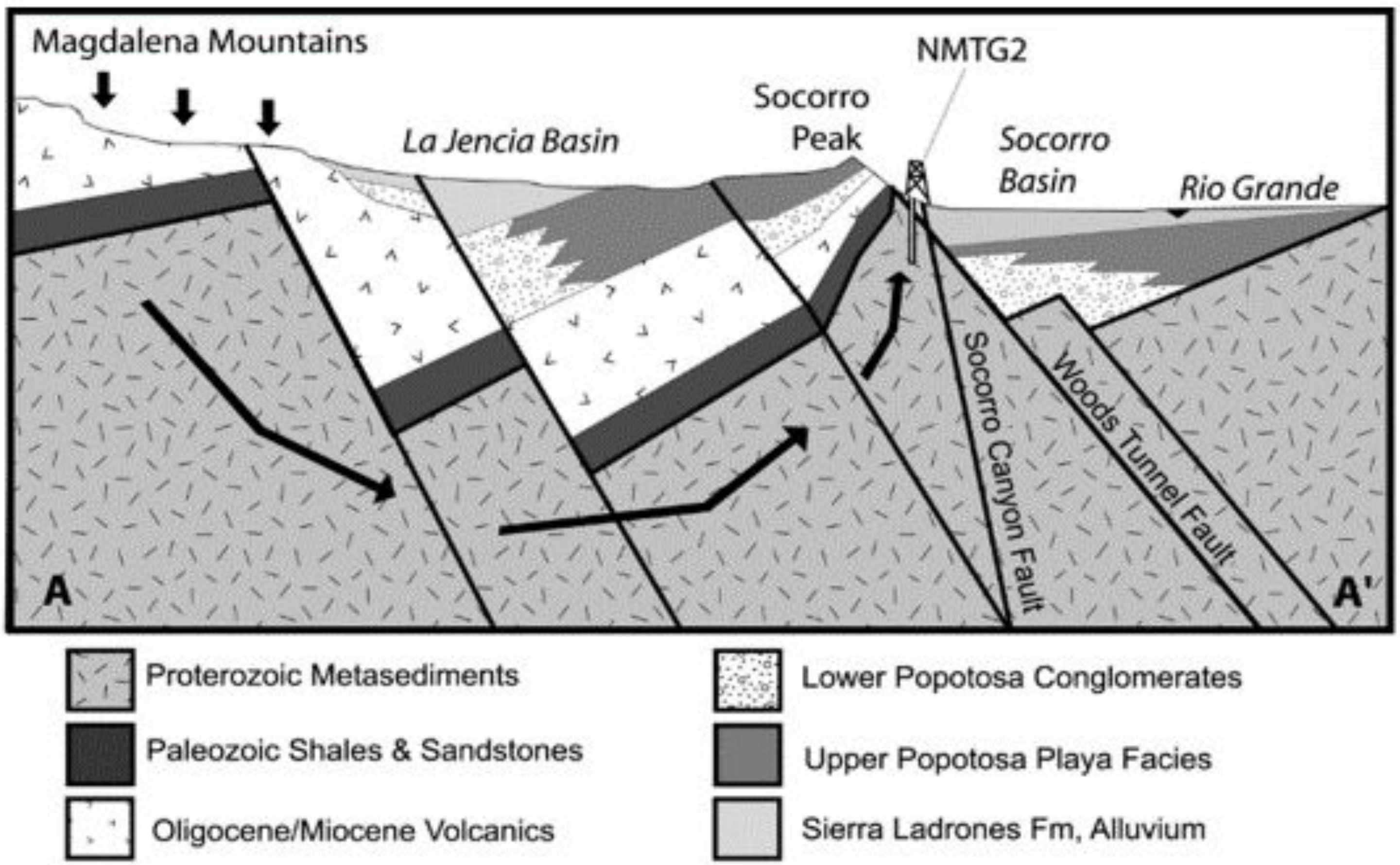
Interpreted cross sectional view



Wilson et al., 2008

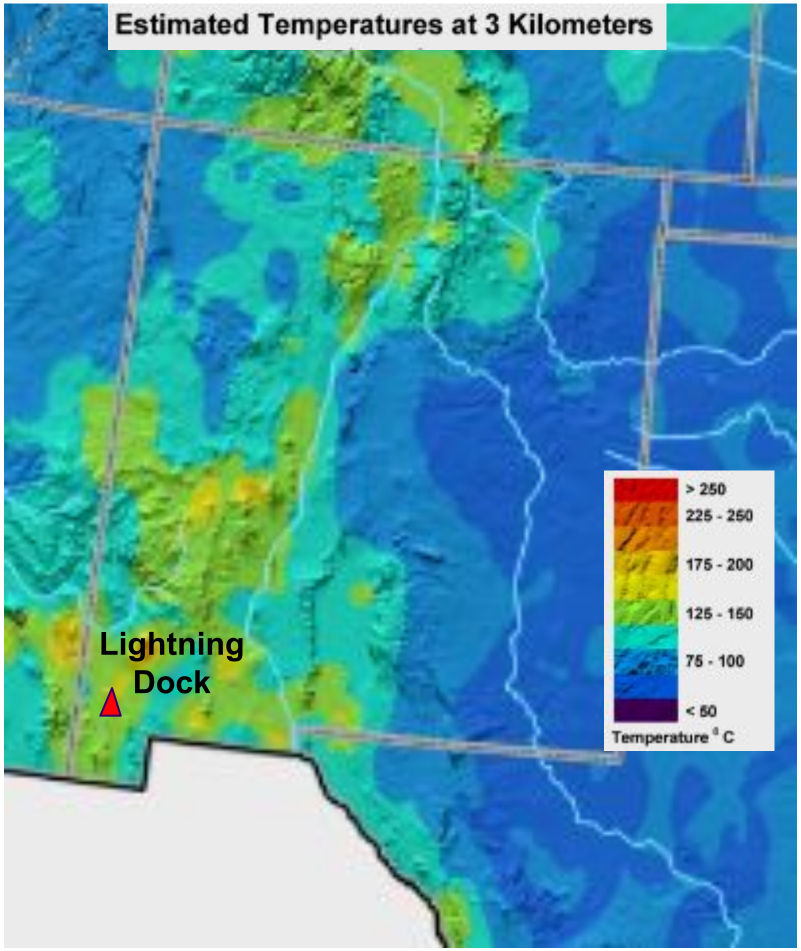
Extension associated with the Rio Grande rift causes thinning of the crust, upwelling of hot mantle, and elevation of subsurface temperatures along the Rio Grande corridor. Thinning also occurs in the Basin and Range of SW NM.

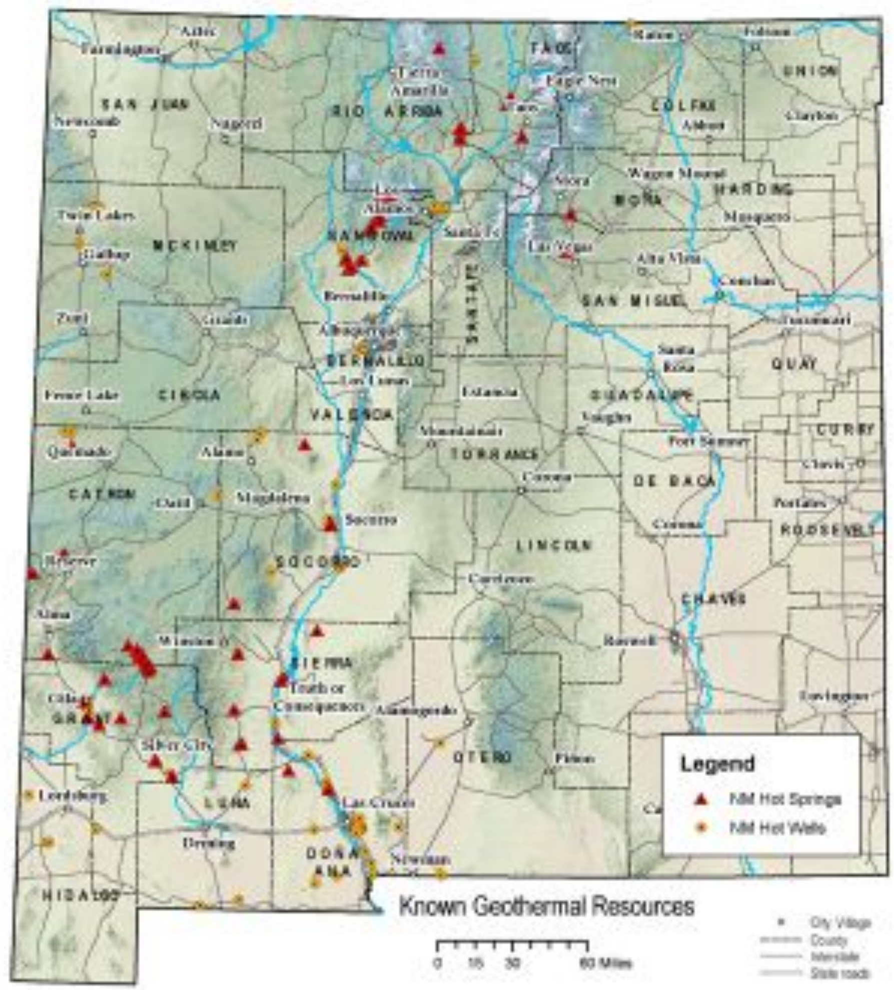
Gravity-driven system, Socorro



Precipitation percolates into the subsurface, where it is heated by elevated temperatures associated with the Rio Grande rift extension. Heated groundwater moves back up to the surface along rift-related faults.

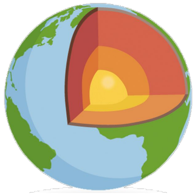
NM Regions of Known or Potential Geothermal Resource (USGS)





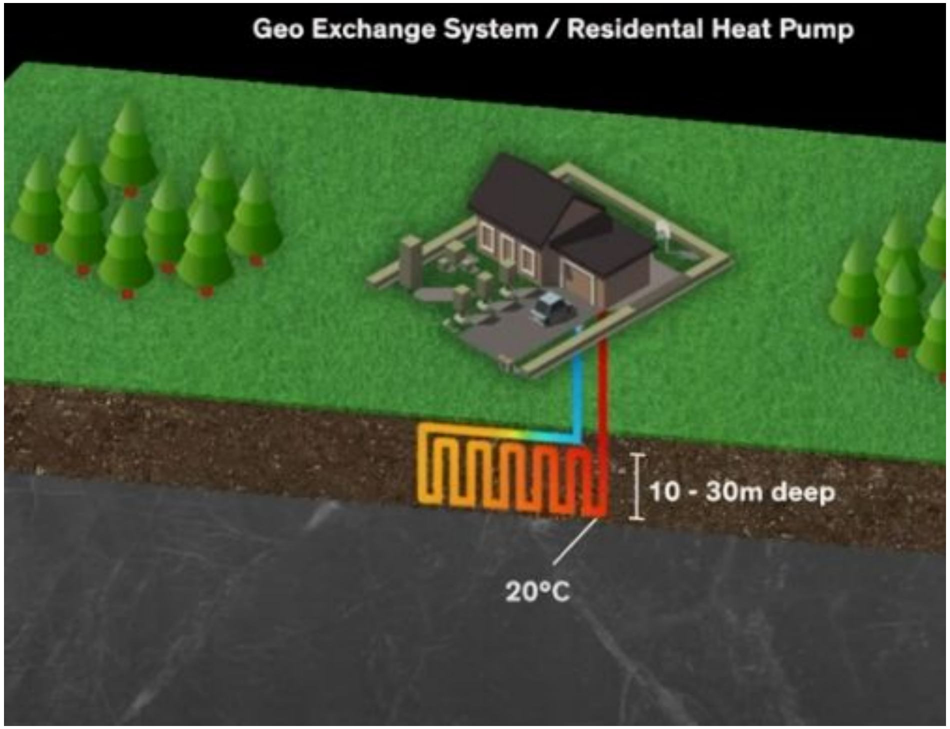
Both the high temperatures (>125°C) estimated at 3 km and the location of known resources are generally associated with extension in the the Rio Grande rift/Basin and Range.

https://my.usgs.gov/eerma/data/index/4f4e483ce4b07f02db4f1bb8
https://my.usgs.gov/eerma/data/index/4f4e4a63e4b07f02db637aab



Types of Geothermal in Phase 1

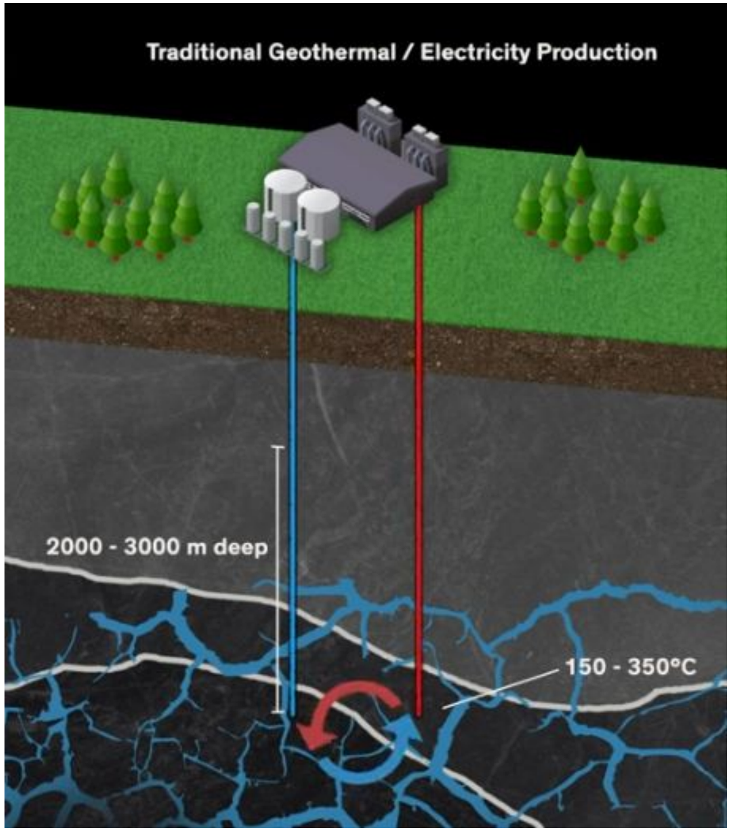
Phase 1: Expand known existing geothermal resources



Ground source heat pumps for buildings

Hot springs & spas, like Jemez Springs

Geothermal Electricity in Phase 1



Geothermal electricity is **cost competitive today with natural gas**.
(Lazard 2021)

Ex:
Lightning Dock

Traditional geothermal electricity generation uses **existing** underground hot water.

*Gas CC $60/MWh, GT $75 https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/
Eavor video https://www.youtube.com/watch?v=PtQmGPmyLA0

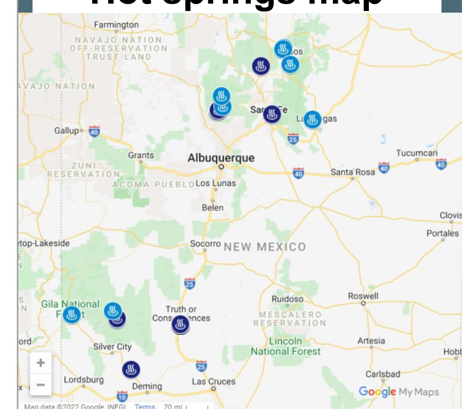
Geothermal in New Mexico Today

- **Masson Farms**: 2nd largest GT greenhouse in US
  - 20 acre GT greenhouse complex in Radium Springs
  - Geothermal saves 93% on heating bill. Employs ~200

- **Lightning Dock** electric plant near Lordsburg
  - 15 MW geothermal electric generation for PNM

- **29 hot springs** in New Mexico
  - Ex: San Antonio Hot Springs, Jemez Springs, Gila Hot Springs, *Black Rock, Faywood,* Ojo Caliente, etc.

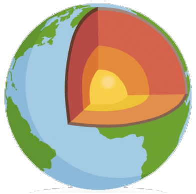
Hot springs map



- **AmeriCulture aquaculture** farm near Lordsburg
  - Tilapia fingerlings aquaculture farm w/ GT heating from a 400 ft well

AMERICULTURE

- **Ground source heat pumps** for buildings
  - Several known school facilities in APS and RRPS & the Abq Simms bldg



A Geothermal Development Bill

Senator Ortiz y Pino, sponsor

Amend New Mexico geothermal energy statutes* to promote developing New Mexico's geothermal resources and further NM geothermal research:

- Create or enhance a **State geothermal central authority** - eg to apply for federal grant $
- Appropriate $ to grow state geothermal **agency capacity** for permitting: ECMD GT office
- Fund a **NM university geothermal center of excellence** for geothermal programs and a geothermal consortium.
- Add incentives for geothermal development such as **production tax credits, energy generation income tax credits, corporate income tax credits and gross receipts tax deductions**
- Provide the ability to use **state economic development incentive programs** for geothermal projects, including LEDA, TiDDs, IRB's etc.
- Create a **geothermal grant fund and program**
- Encourage use of **heat pumps** for new government buildings.
- Draft a separate 2023 version of SB68, tax credits for ground source heat pumps

*NM geothermal statutes include: **71-5-1 to 24, 71-9-1(EMNRD), 19-13-6 & 19-2-7 (SLO)**

Note: ECMD is the Energy Conservation and Management Division within EMNRD

Over $600M in GT Federal Funds

- **$84M** for geothermal energy in the **Infrastructure** Investment and Jobs Act
- **$500M** for "Clean Energy Demonstrations on Current and Former **Mine Land**".
  - Up to five clean energy projects (incl geothermal) in geographically diverse regions
- **$13M** for Community Geothermal district heating
  - The U.S. DOE announced future awards up to $13M for projects that help communities design and deploy **geothermal district heating** and cooling systems.
- **$10M up to $165M** for advanced geothermal solutions via the "GEODE program"
  - "leveraging technologies and workforce from the **oil and gas** industry"

https://static1.squarespace.com/static/5924f2cf6a49635bbfd9b7a1/t/611fb3ebeafded3e4712082d/1629467647015/HR+3684.pdf

Some GT Development Opportunities

For phase 1

- **Zia Pueblo** DOE study 2012-2013
- **Mesa del Sol** integrated cascading community GT development
- Revive 1980's **NMSU geothermal projects**

- **NMTech** campus district heat proposal of 2010
- **Expand Lightning Dock** geothermal electric plant
- **'Well of opportunity' on Navajo land:** a pine seedling greenhouse
- Low grade heat (129°F-180°F) for **drying chile, onions**, etc
- Revisit 1980's **Jemez Springs** attempt to develop hydrothermal

Zia Pueblo 2012-13 Geothermal Study

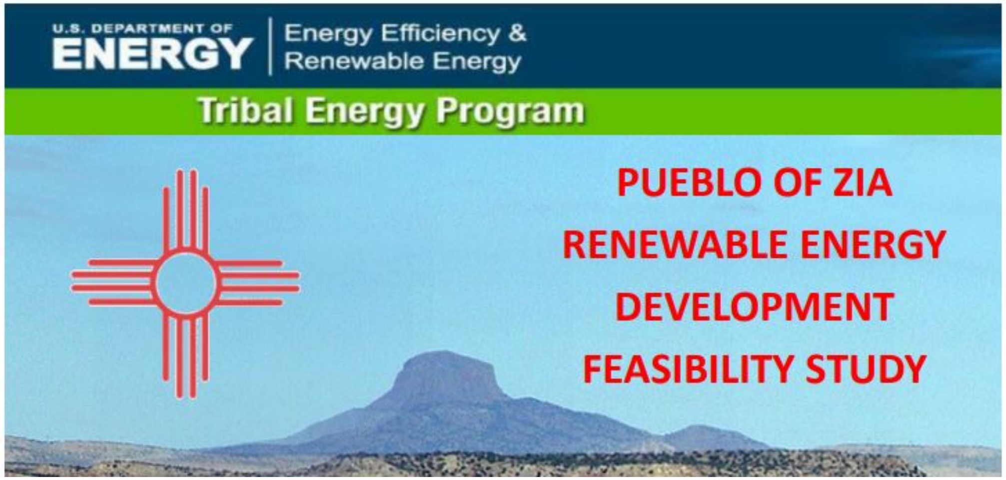
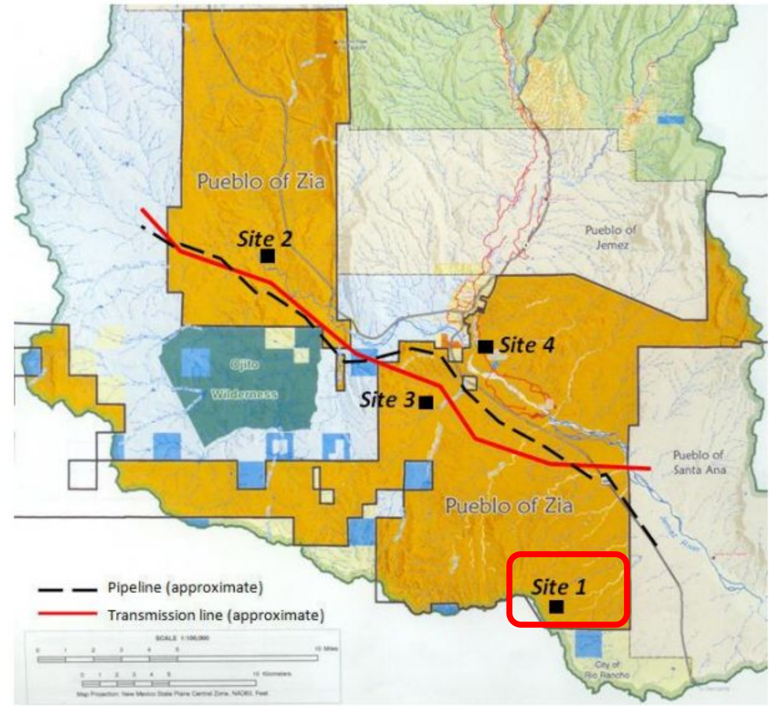


Figure 1.1 Developable Sites at Pueblo of POZ

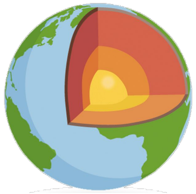


About 20 miles north of Albuquerque

The Pueblo of Zia (also referred to as "Zia Pueblo") conducted a comprehensive feasibility study for best-use application(s) for development of renewable energy resources on its tribally held TRUST lands (i.e., Trust Lands of Zia Indian Reservation). The feasibility study is essential for determining the technical and economic viability of a future renewable project(s) on Zia tribal lands, including the potential economic and environmental benefits for the Tribe.

Geothermal Energy Potential: **Site 1 presents the best potential geothermal site** from a strictly geologic point of analysis. This site will require the highest up front drilling cost, and delivers the best economics at a levelized cost of $79.90/MWH. Site 3 is the second best site with a levelized cost of $106.20/MWH.

https://www.energy.gov/indianenergy/pueblo-zia-2012-project



Mesa del Sol Geothermal - Jim Witcher

Concept ***demonstrating <u>four cascading benefits</u> of geothermal development.***

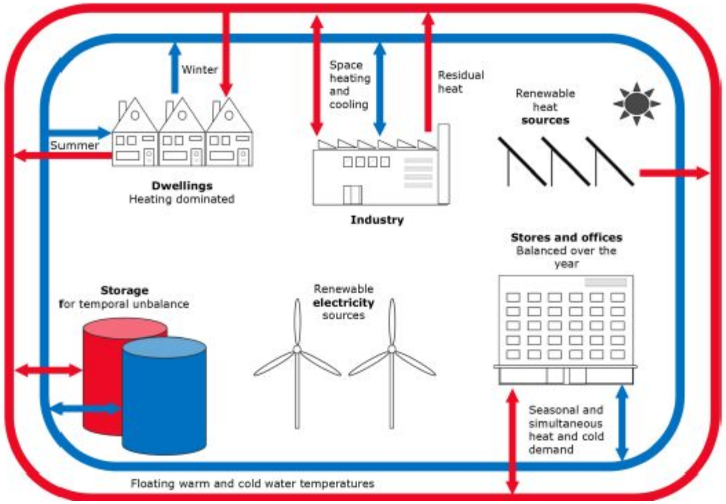
Mesa del Sol is a development south of the Albuquerque Airport

- **Clean Electricity Generation** (rough estimates)
  - 4-5MW clean electricity generation from a **13k ft well** w/300F GT water from the "Santa Rosa sandstone" formation. Need ~1000 gal/min at **300F** for a 5MW plant. Drilling costs $6-8M per well from site prep to completion over 1-2 months with a very large drilling rig. Need two wells, one for production, one for re-injection, costing $12-16M.
  - Add $3M per MW, ie $15M to build a 5MW plant. Say $30M total up front investment.
  - Might site 2-3 of these plants depending on available geothermal water flow, tbd.

- **Geothermal district heat for Mesa del Sol** like Reykjavik
  - Use outflow water from the heat exchanger before re-injection, to heat homes and businesses (eg Netflix).

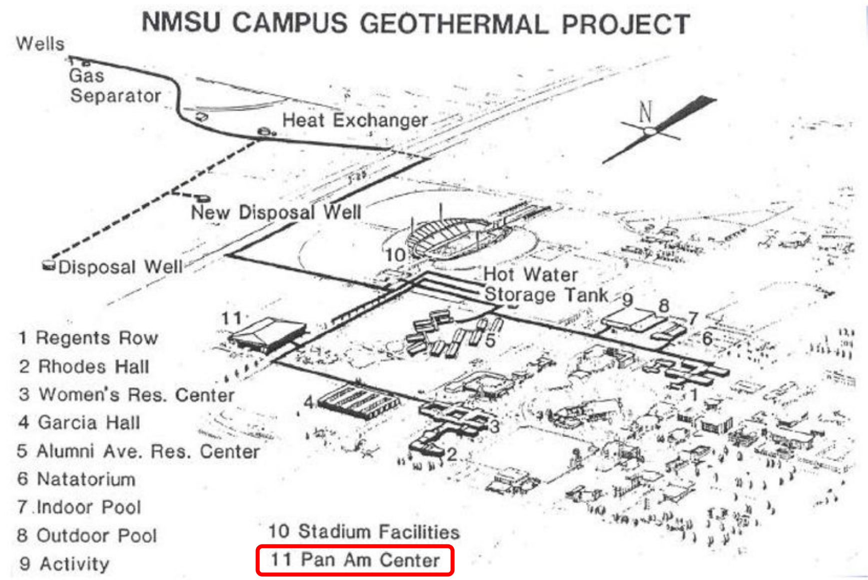
- **Industrial processes using low grade heat**
  - For greenhouses
  - Ideas include drying chilis, onions. pistachios, adobe making, Ag products need 54C-82C (129F to 180F).

- **Hot Springs/Spa tourism using outflow water**



NMSU Geothermal Project

(1979 to 2015)



- Between 1973 and 1979, NMSU experienced a >400% increase in the cost of natural gas. (somewhat similar to recent raising costs for energy worldwide).
- **An appropriation from the New Mexico Legislature provided funds for the design and construction of the NMSU Campus Geothermal Project** [1]
- NMSU Geothermal Projects provided domestic **hot water** and **space heat to dorms, athletic facilities and academic buildings.**
- In 1994, the Geothermal **Aquaculture** Facility (GAF) was built.
- **By 2015 all wells were decommissioned.**

Well	Depth ft	BHT °F	Year Completed	Casing in.	Depths ft	Diameter in.	Depths ft	Remarks
PG-1	860	145	1979	10 ID 10 ID screen	0-750	17	0-860	Produces 142°F T = 6,500 gpd/ft
PG-2	507	122	1979	6	507	9 7/8	507	Produces 18 gpm at 118°F from 451 to 171 ft depth; well currently not in use.
PG-3	870	150.4	1980	18 ID 10 ID 10 ID screen	0-60 0-750 750-860	26 18 18	0-60 26-750 750-860	Produces 146°F T = 40,000 gpd/ft Well currently not in use.
PG-4	1,015	-150	1986	14 8 5/8 8 5/8 screen 5 9/16	0-684 658-744 744-971 972-1,015	17 ½ 12 1/4 12 1/4 7 7/8	0-684 684-733 733-960 982-1,015	Produces 146°F Specific capacity 100 gpm/ft
GD-2	464	-110	1980	8 5/8 cement 8 5/8 Cement plug	0-348 348-464 464-486	14 3/4 14 3/4 14 3/4	0-348 348-464 464-486	Injection well on NMSU Golf Course Slotted screen at 370-380 ft; 390-464 ft T = 9,000 gpd/ft

[1] Cunniff, et al., 1983

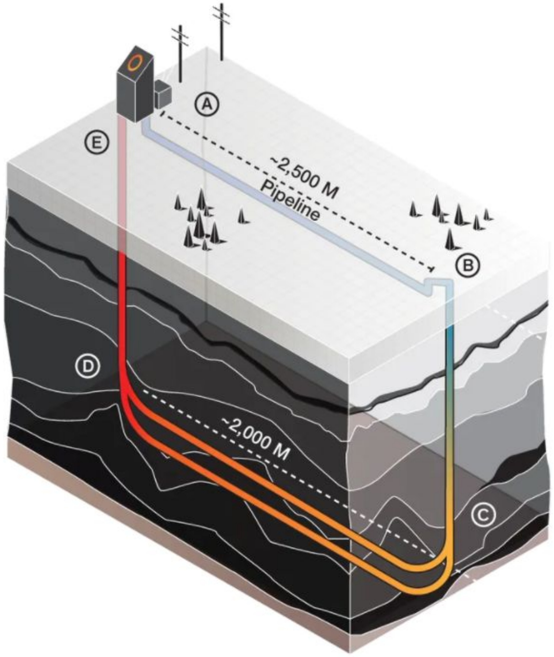
Phase 2: Adv. Geothermal Electricity

- Advanced geothermal (AGT) electric generation

- Last 10% of clean energy transition

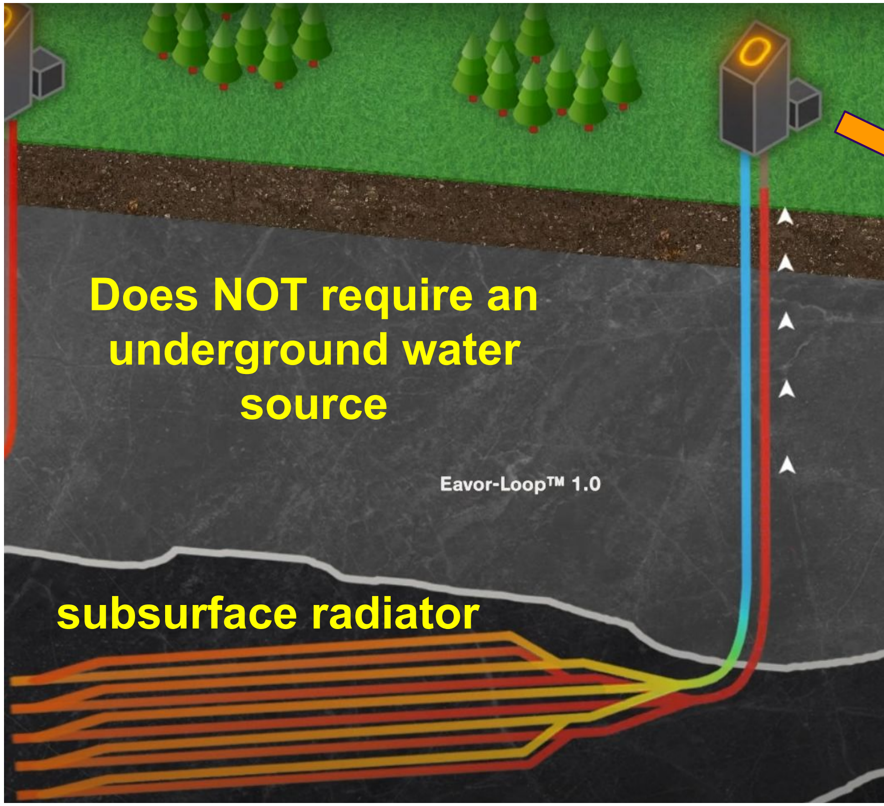
- Build **1-3 GW** of advanced geothermal electricity into 2030's

➡ **Need to solve two drilling tech problems**: drill bits to survive higher temps & drill through harder rocks.

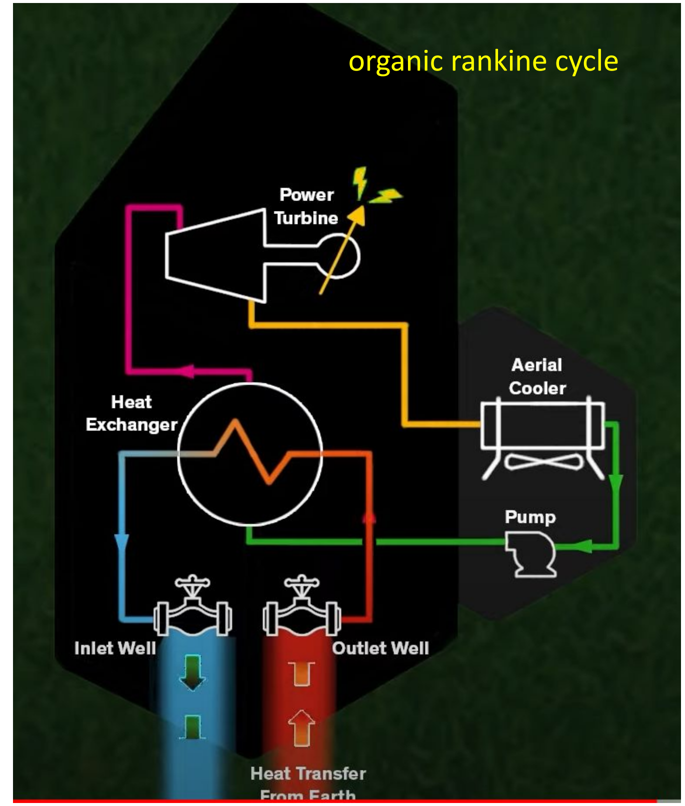


Geothermal Phase 1 & 2 - AGT

Phase 1&2: Advanced Geothermal



Power plant at the surface



Advanced Geothermal electricity generation.

Drill closed loops in underground hot rock. Inject a surface fluid to extract heat from a subsurface radiator. Transfer that heat at the surface through a heat exchanger to a working fluid in a separate loop to drive an electric turbine.

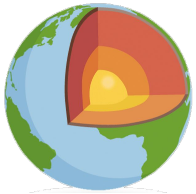
Eavor video https://www.youtube.com/watch?v=PtQmGPmyLA0

Sandia Labs Geothermal Research

Sandia's work in subsurface access, monitoring, and modification of the subsurface is aimed at the development of enabling technologies and reducing the cost and risk associated with drilling in harsh, subterranean environments.
A large portion of the cost and risk of generating electricity from geothermal sources is associated with drilling and completion of wells. Because of this, Sandia has primarily focused on developing improved drilling and completion technologies such as diagnostics while drilling, high-temperature electronics, advanced drill bit technologies, and wellbore integrity technologies to reduce and mitigate problems associated with loss of circulation.

- Computational modeling
- Enhanced Geothermal (EGS) collaboration
- Energetic simulation - drilling test rig
- Geothermal Energy and Drilling Technology
  - Hard rock drilling facility
  - High temperature electronics facility
  - HOT High Operating Temperature facility

https://energy.sandia.gov/programs/renewable-energy/geothermal-research/



Top Geothermal Energy Startups

We've spoken to Fervo and Eavor

Fervo Energy - **USA** | Funding: **$166M**

Fervo Energy commercializes proprietary technology to own, develop, and operate geothermal assets as the dispatchable foundation to a 100% clean energy future.

Quaise - **USA** | Funding: **$58M**

Quaise is an energy company pioneering millimeter wave drilling technology to access deep geothermal energy.

AltaRock Energy - **USA**|Funding: **$36.5M**

ARPA-e project AltaRock Energy focuses on the development of geothermal energy resources and Enhanced Geothermal Systems (EGS).

Tetra Corp **USA** drilling w/ pulsed power

Eavor Country: **Canada** | Funding: **CA$85M**

Eavor's solution, Eavor-Loop, takes a traditional niche energy source (geothermal) and makes it scalable by removing the need for either volcanic-type temperature or permeable aquifers.

GreenFire Energy - **USA** | Funding: **$2.6M**

GreenFire Energy develops and deploys innovative technology to unlock the world's largest source of continuous renewable energy.

Sage Geosystems - **USA**

Sage combines innovative approaches to heat harvesting with modern oilfield expertise and methodologies to enable geothermal energy anywhere in the world

https://www.energystartups.org/top/geothermal/

Eavor

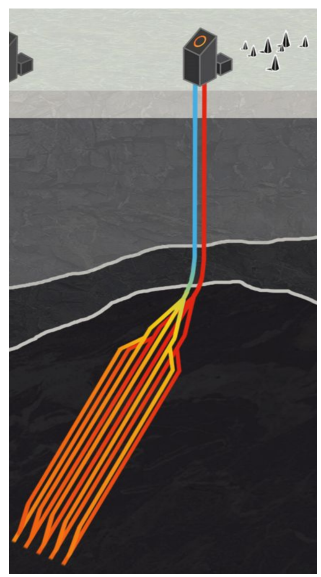
Eavor is currently drilling the deepest and hottest directional geothermal well in history: Eavor-Deep™ at Lightning Dock, NM

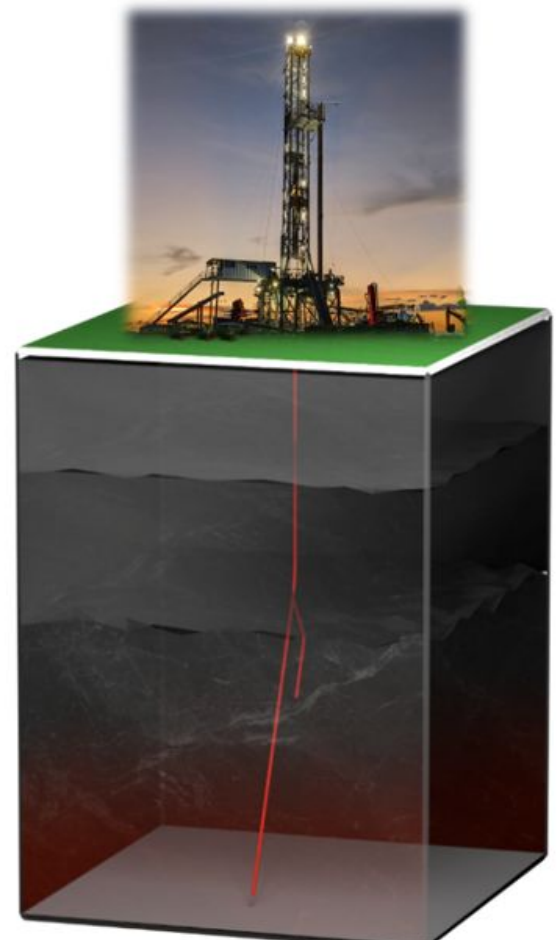
Demonstration well to advance technology to enable economic drilling in deeper and higher temperature rock.

This well will showcase Eavor's proprietary drilling technology and will demonstrate all the components required to construct commercial Eavor-Loops in deep, hot rock.

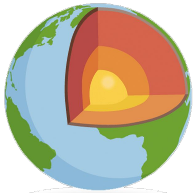
This is a key milestone that unlocks projects at locations in the US, Europe, and internationally.

- Local energy resilience
- Local energy security
- Local energy autonomy
- Scalable
- Firm

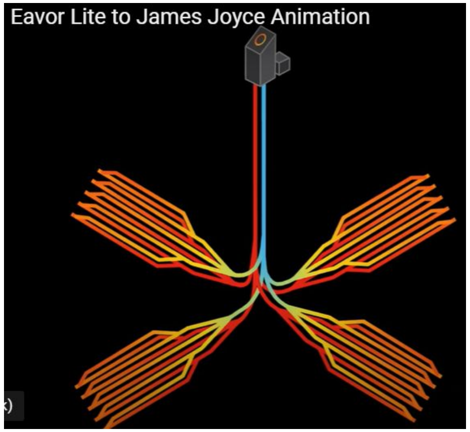




https://www.eavor.com/press-releases/eavor-to-drill-the-deepest-and-hottest-directional-geothermal-well-in-history-eavor-deep/



Summary



- New Mexico is #6 in geothermal resource potential
- It's clean energy for heat & electricity and a worthy investment for sustainable economic development
- Leverages skills & rigs from the oil industry
- Over $600M in federal funding to apply for
- **We request your support** for a 2023 geothermal development bill to better develop this NM resource.

Backup

Geothermal energy use at NMSU (1979-2015)

•**District heating**: heating of a total of 30 building and facilities that include dorms and athletic facilities. Supply temp. is 141 to 148F at 250 gpm. **Campus geothermal system has an annual energy savings compared to natural gas up to several hundred thousand dollars** annually depending upon annual climate, the cost of fossil fuel and maintenance costs for the geothermal system.

•**Geothermal Greenhouse Facility(GGF):** Two 6,000-ft2 greenhouses and a 2,400-ft2 metal storage space, office and workshop comprise the GGF. Water is supplied at 148 F between 25 and 60 gpm

•**Geothermal Aquaculture Facility (GAF):** Two large 6,000-gallon capacity intensive culture systems simulate commercial level production. Geothermal heating is done by cascading a maximum 25 gpm of geothermal water from the GGF bench top heating system to the aquaculture facility. Cascaded hot water arrives at the heat exchanger at 90 to 135F for heating culture water in a closed loop fashion.

Geothermal Greenhouse synergy

- **A development proposal:** Build a greenhouse to grow pine seedlings. Heat with geothermal hot water. May desalinate water for irrigation.
- A 'wells of opportunity' USDA application by Dr. Shari Kelley. Re-use an old oil well in San Juan Basin, 5k-6k ft deep, with 70°C (160°F) water, very high volumes.
- Possible desalination tech to **clean up produced water** for irrigation. Could add solar to offset electricity costs, with bigger pumps. The location is 1.5 mi from the Ojo Encino Navajo chapter house.
- Would **use GT to both heat the greenhouse and also to purify water for irrigation**. The thermal membrane tech is still at lab scale.
- Contact **Laila Sturgis at Navajo Tech, Crownpoint**.

2010 NM Tech Geothermal Proposal

Heating New Mexico Tech's Campus with Geothermal Energy

Mark Person

Schematic diagram showing geothermal district heating system proposed on New Mexico Tech campus.

Continental rift zones like the Rio Grande valley are areas where Earth's crust is being pulled apart and hot mantle rocks are drawn up toward the surface resulting in elevated

2009 to February 2010. This "slim hole" (a well bore with a diameter of less than 7 inches) was drilled to a depth of 1,102 feet at the Woods Tunnel drill site. Temperatures were nearly constant 105.80°F (41°C) between a depth of 400 and 1,102 feet. Hot water flow rates measured during drilling were consistently around 1,000 gallons per minute.

A district heating system for the campus requires temperatures of 149.00°F (65°C), but the produced fluids from the geothermal well are only 105.80° F (41°C). Nevertheless, these fluid temperatures are high enough that this resource can still be used to heat the campus if heat pumps are added to the system. Using our geothermal resources would involve installing a pipeline two miles long from Woods Tunnel to New Mexico Tech and installing a series of heat pumps and heat exchangers to remove the heat from the geothermal fluids. The entire project cost is estimated to be about $3 million. Whereas the up-front construction costs are relatively high, the payback period would still be less than six years. In addition, New Mexico Tech could offset as much as about 6,000 metric tons of CO_2 production per year by switching the heating system to geothermal energy, saving the state about $510,000 per year

Cost of Geothermal Electricity is Competitive with Gas

Today's geothermal electricity competes on cost with natural gas.

- The "all-in" or lifetime levelized costs of energy (LCOE) including construction, fuel, labor, maintenance, etc, show today's **geothermal electricity is cheaper than coal or nuclear,** but costs more than solar or wind. (**per** Lazard 2021)
- GT energy is more or less competitive with natural gas, depending on gas pricing.

Average cost per MegaWatt hour (LCOE per Lazard 2021)

- *Solar PV= $36*
- *Wind = $38*
- Gas combined cycle = $60 (when natural gas was $3.45/MMbtu. Gas on 16-Sep was $8.00)
- **Geothermal = $75**
- Coal = $109
- Nuclear = $168

https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/