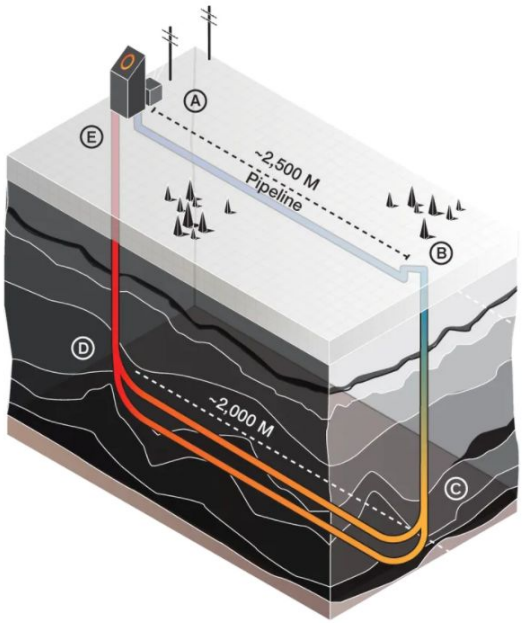
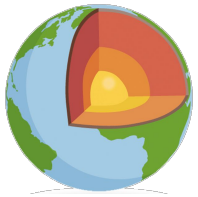
Developing New Mexico's Geothermal Heat and Electricity



LFC
July 19, 2023

Shari Kelley, PhD
Tom Solomon



Agenda: Developing NM Geothermal

- **Geothermal overview, goals & benefits to NM**
- **Geothermal Research & Development status and plans**
- **Q & A**

Geothermal Working Group since Feb 2022:

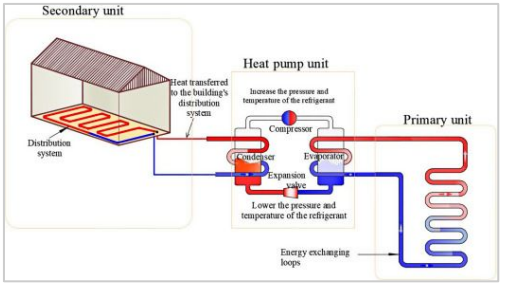
- Senator Gerald Ortiz y Pino
- Senate Pro Tem Mimi Stewart
- Tom Solomon, facilitator
- Dr. Shari Kelley, NM Tech
- Dr. Olga Lavrova, NMSU
- Dr. Patricia Sullivan, NMSU

Geothermal Development: Benefits to New Mexico

- 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 from low temperature resources and ground source heat pumps
- Use skills & drilling rigs from the oil industry.
  - A ‘just transition’ for workers - drill for heat

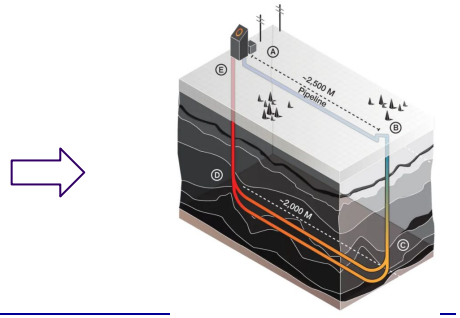
Geothermal Working Group Goals

Our goal - Advance the two-phase development of geothermal (GT) energy in New Mexico.
Pass a 2024 geothermal energy development bill.



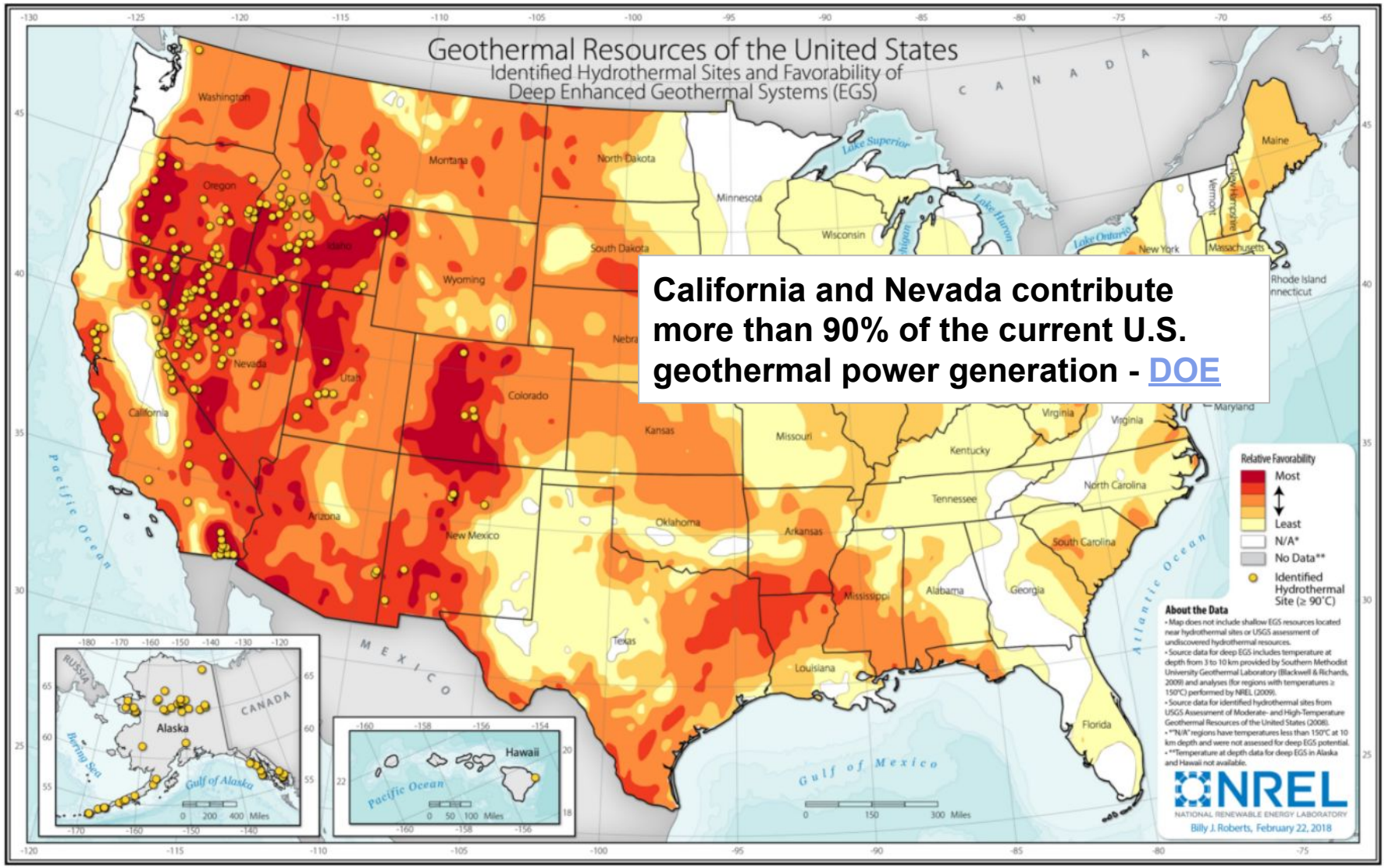
Phase 1) In the **2020**'s expand known existing geothermal resources: heat pumps for buildings, in green houses, hot springs & spas, for clean electricity (Lightning Dock), etc.

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 3 GW.



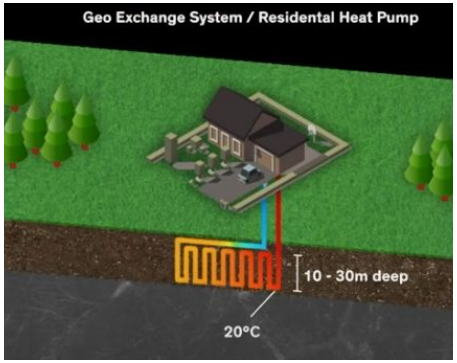
NM Ranks #6 in Geothermal Resources

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



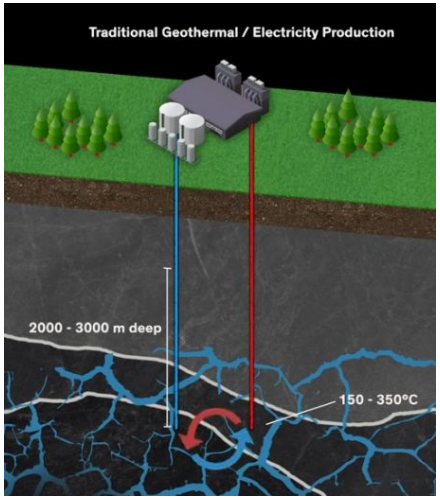
https://www.nrel.gov/gis/geothermal.html

Types of Geothermal by Depth



- **Ground source heat pumps**
  for buildings: 5 feet to 300 feet deep.

- **Hot Springs & direct use**.
  Depths to ~1000 ft.



- **Traditional geothermal electricity** from a hot water aquifer: > 6000 ft. (Lightning Dock)

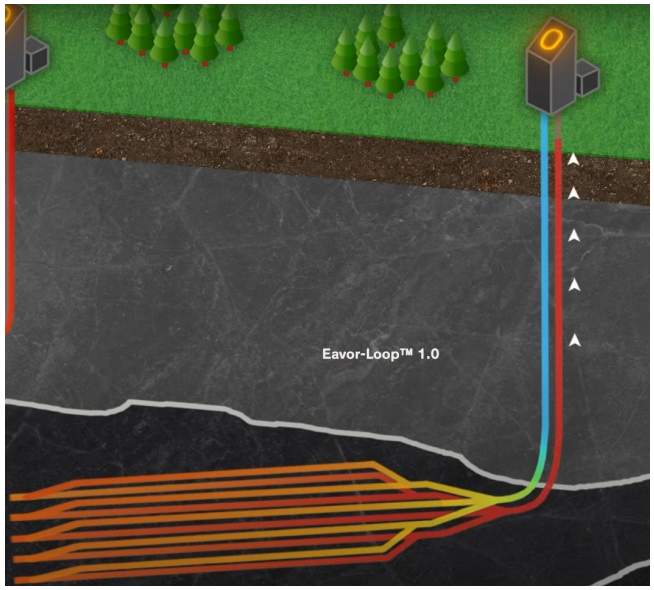
- **Ph2 - Advanced geothermal electricity:**
  closed loop in deep hot rock: > 15,000 ft.

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

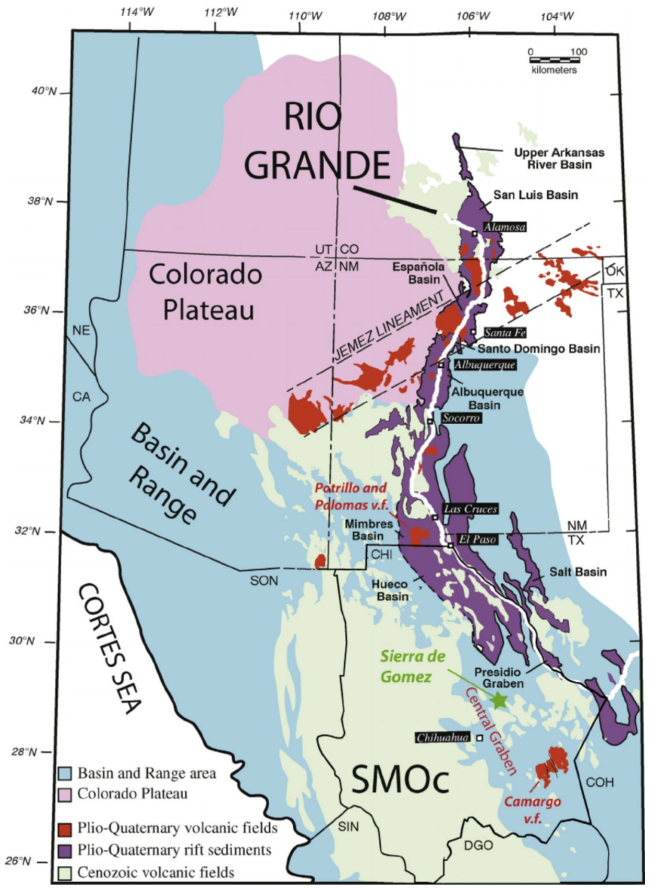
Phase 2: Adv. Geothermal Electricity

- **Advanced geothermal (AGT)** electricity, closed loop in deep hot rock: >15,000 ft.
- 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.

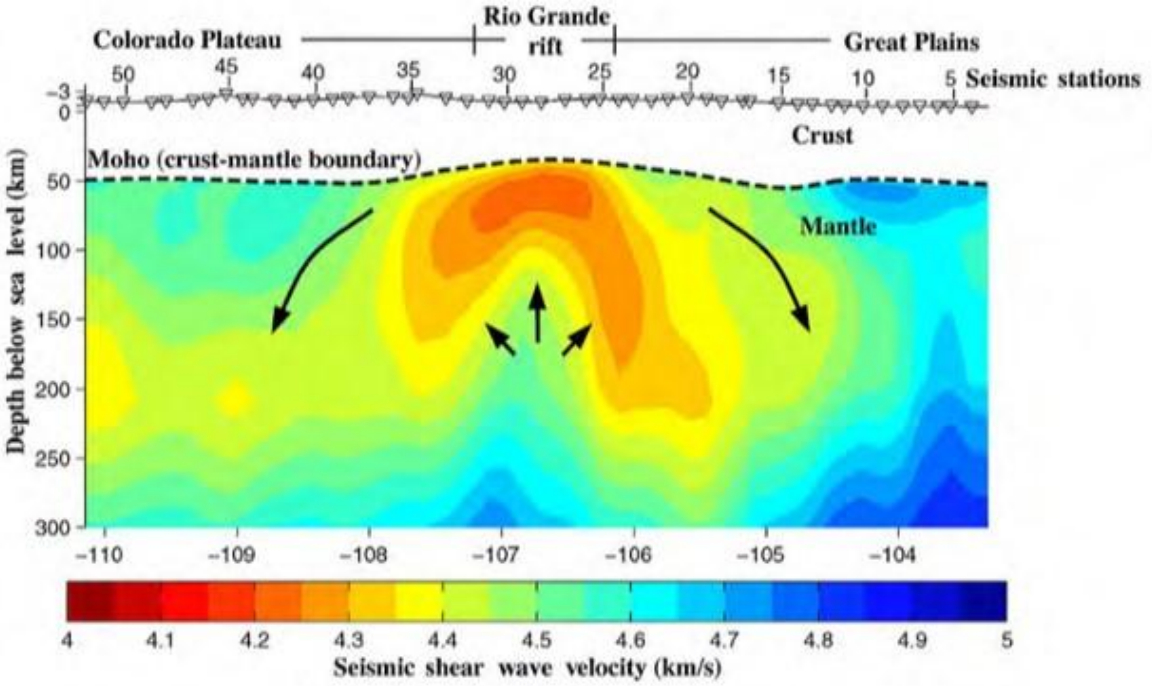
Closed loop geothermal electricity generation



Rio Grande rift heat source

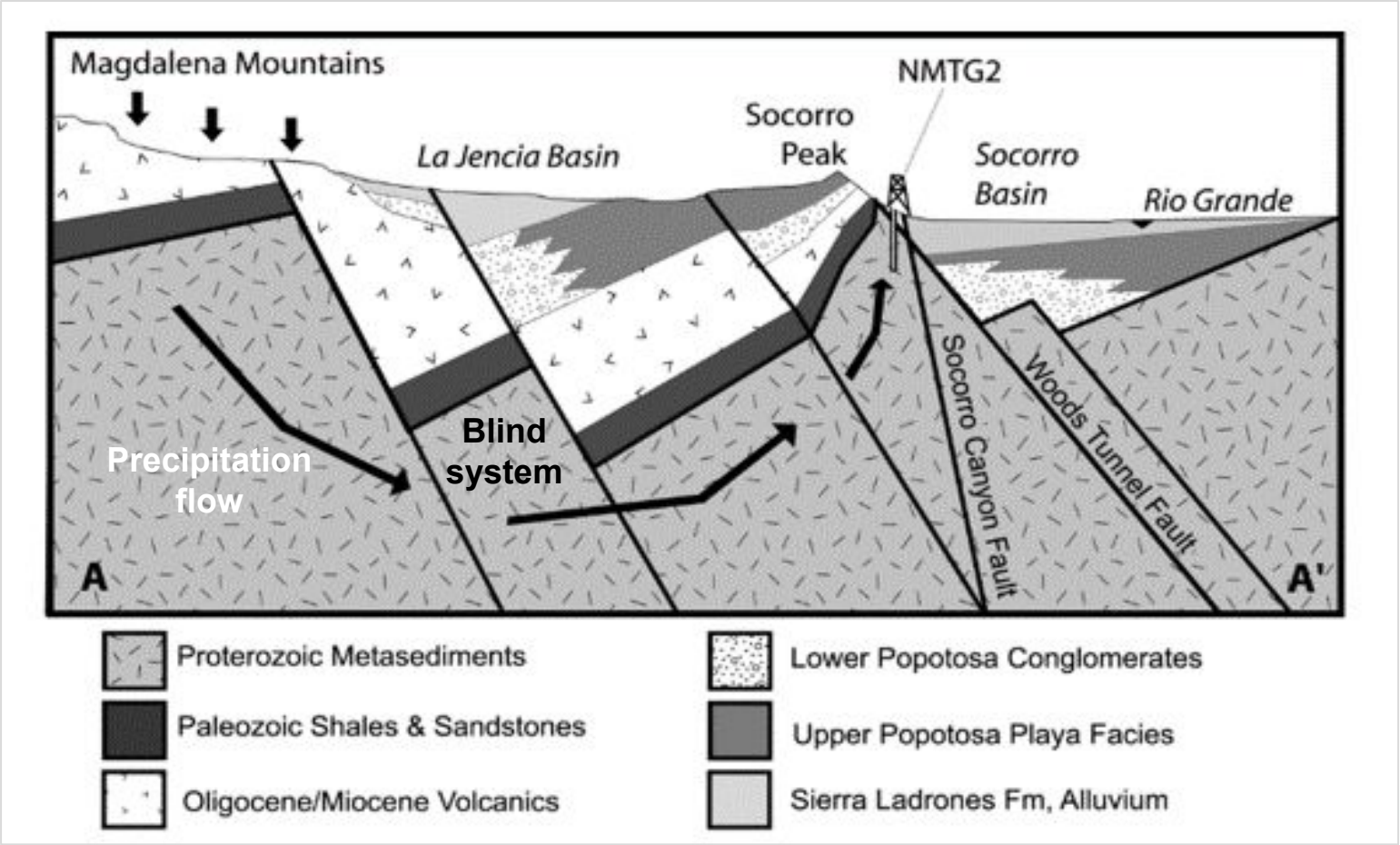


Interpreted cross sectional view



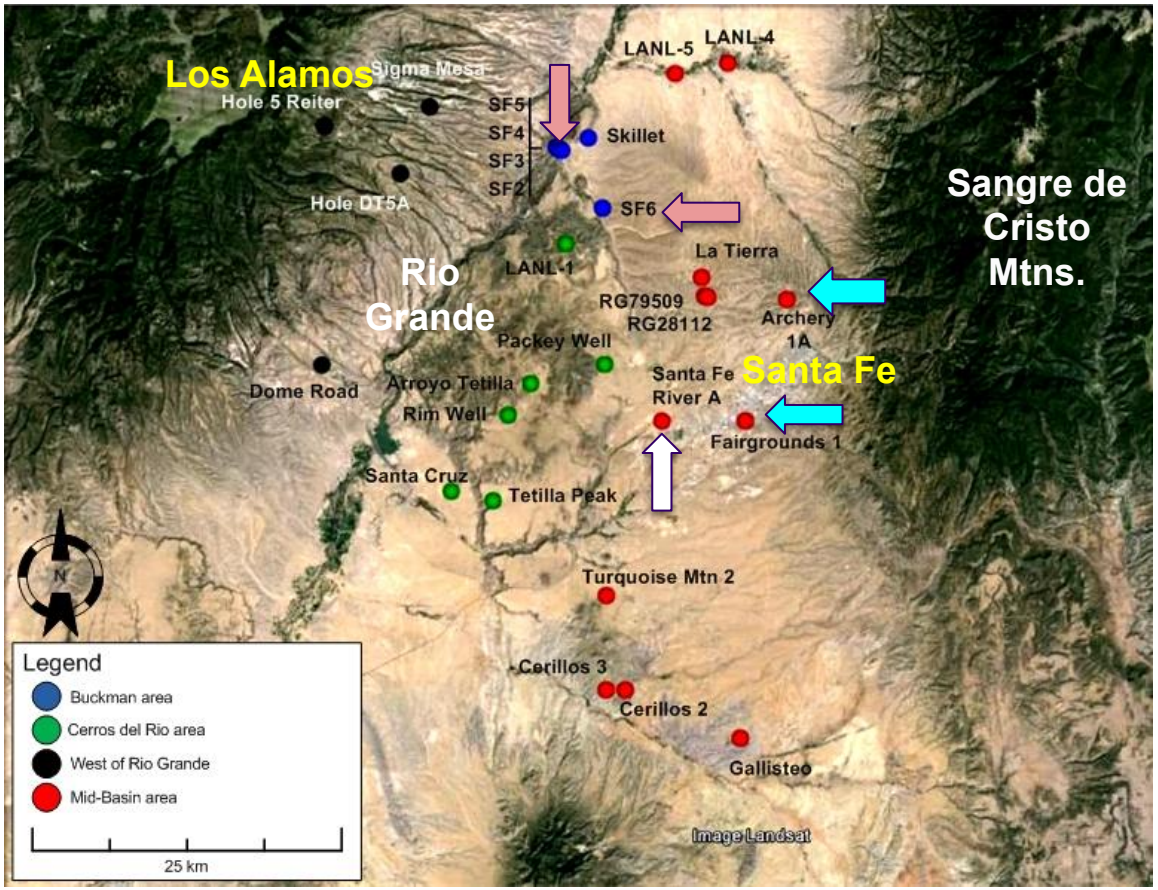
- Extension associated with the Rio Grande rift causes thinning of the crust, upwelling of hot mantle, and elevation of subsurface temperatures along the Rio Grande corridor.
- Thinning also occurs in the Basin and Range of SW NM.

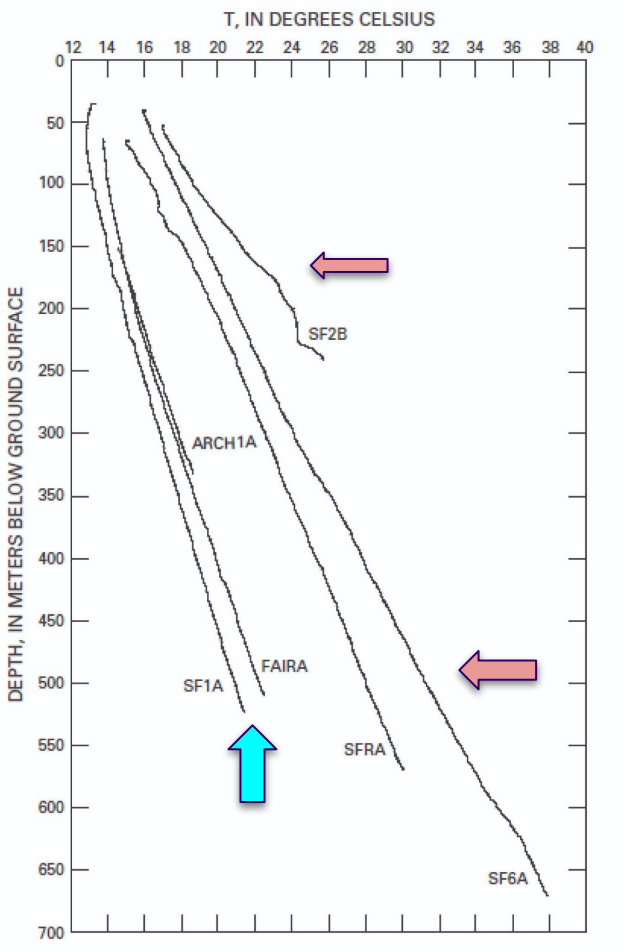
Gravity-driven system, Socorro



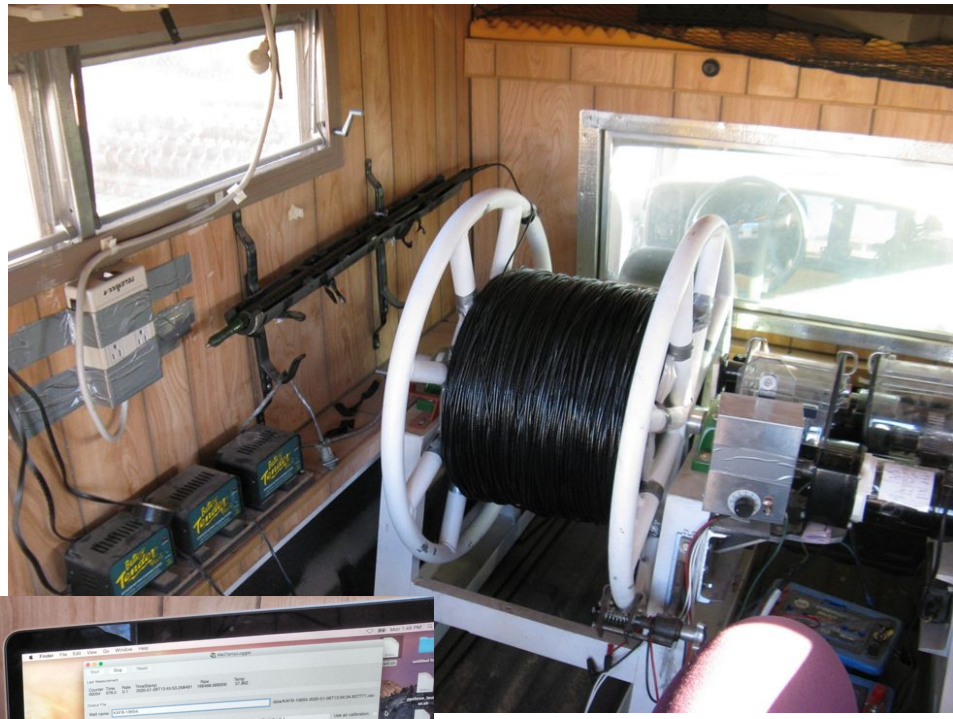
- Precipitation percolates into the subsurface, where it is heated by elevated temperatures associated with the Rio Grande rift extension.
- Heated groundwater moves back up to the surface along rift-related faults.

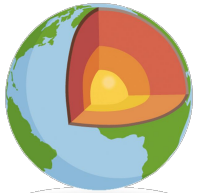
Temperature data from Santa Fe





Temperature measurement



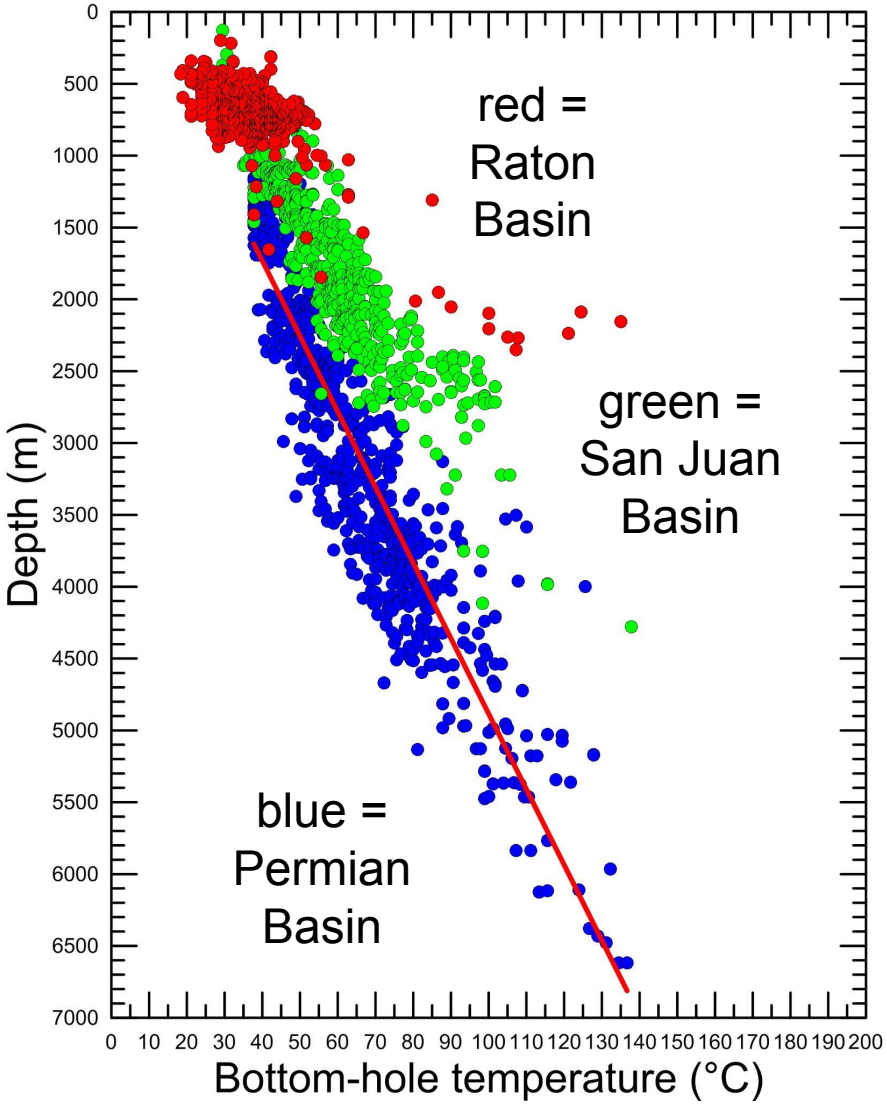


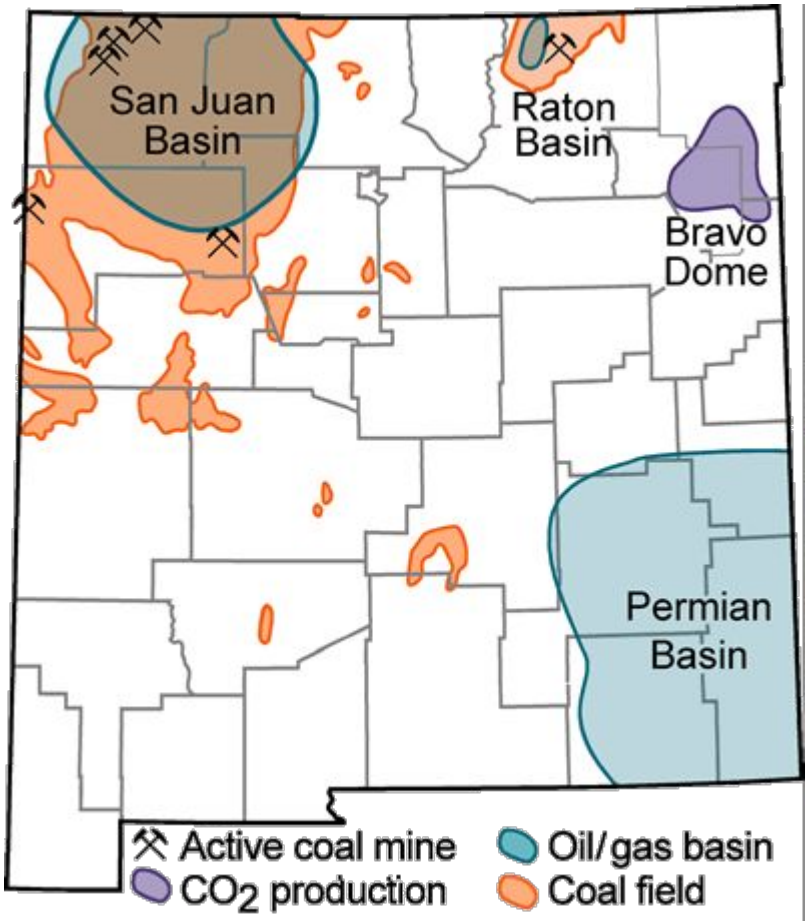
Geothermal Research at NMT

Previous and current research (w/ Mark Person)

- Geothermal database (DOE: 2010-2014)
- Truth or Consequences (2013)
- Play Fairway, SW NM (DOE with LANL 2016-2017)
- Mesilla Basin (USGS: 2019)
- Buckman well field, Santa Fe (SAGE: 2019)
- Rincon (NSF: 2019 to present)
- Thermal structure of the San Juan Basin (DOE, just awarded to Luke Martin)

Temperatures in NM basins





Eavor NM Test Well in 2022

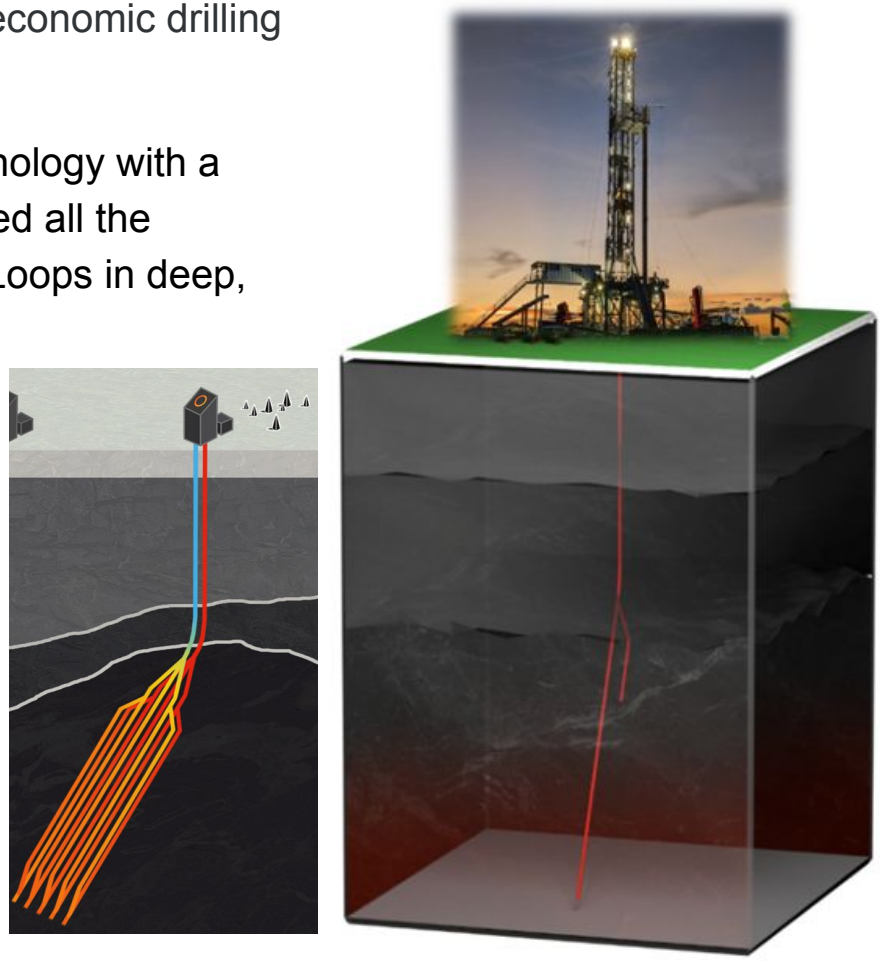
Eavor drilled (Aug-Dec ’22) the deepest and hottest directional geothermal well in history: Eavor-Deep™ at Lightning Dock, NM

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

“This well showcased Eavor’s proprietary drilling technology with a **standard oil industry rig and crew**, and demonstrated all the components required to construct commercial Eavor-Loops in deep, hot rock. **Achieved 18,000 ft depth & 250°C temps.**

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

Eavor claims a path to “**sub-$60/MWh costs**”.



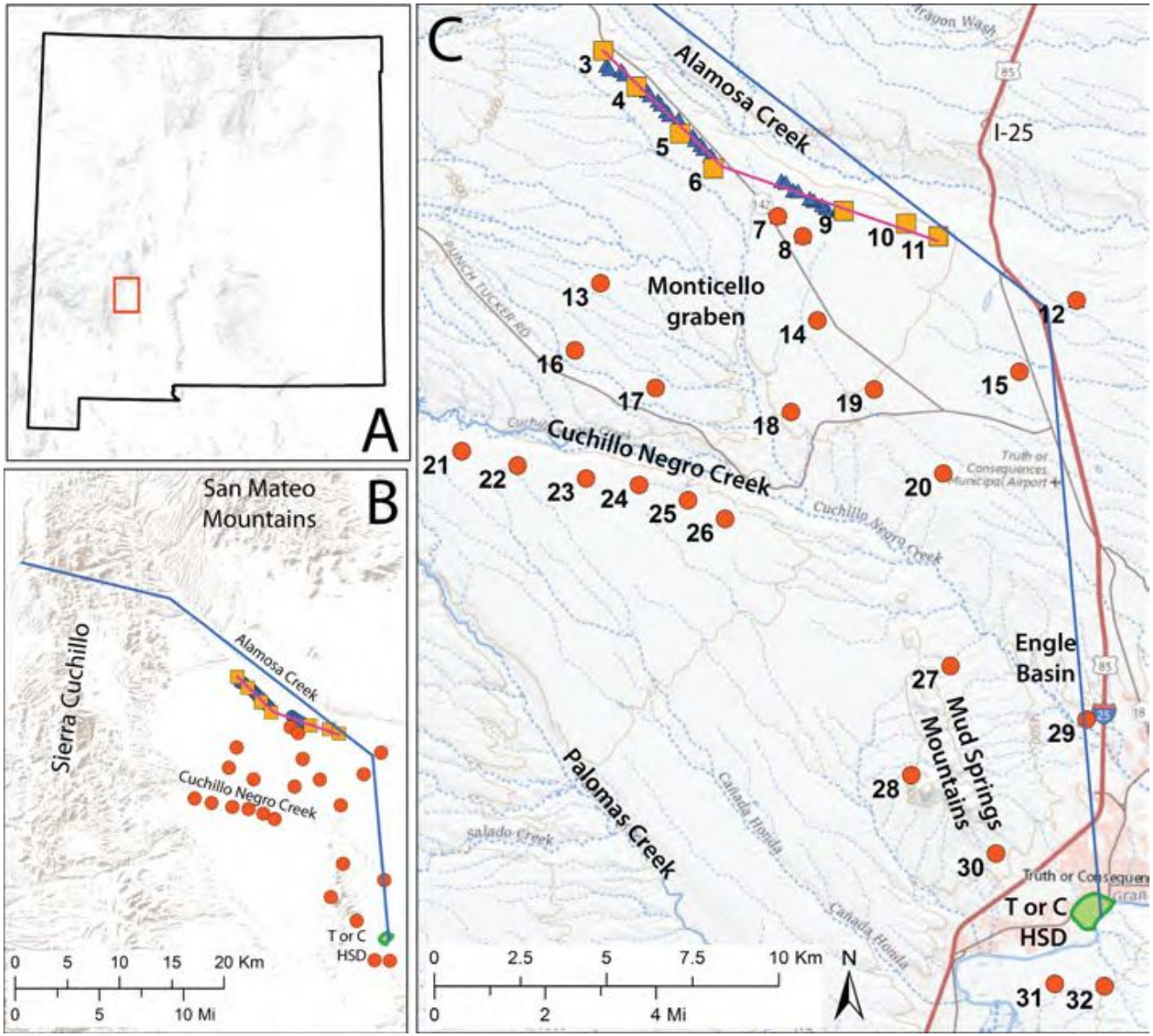
Eavor was granted the construction and deployment of a **20MW** geothermal extraction system as part of **Nevada’s** energy strategy. - NV Energy Dec 2022

https://www.eavor.com/press-releases/eavor-to-drill-the-deepest-and-hottest-directional-geothermal-well-in-history-eavor-deep/
https://www.eavor.com/blog/nevada-is-making-space-for-dispatchable-green-energy-amidst-energy-instability-in-the-southern-american-states/

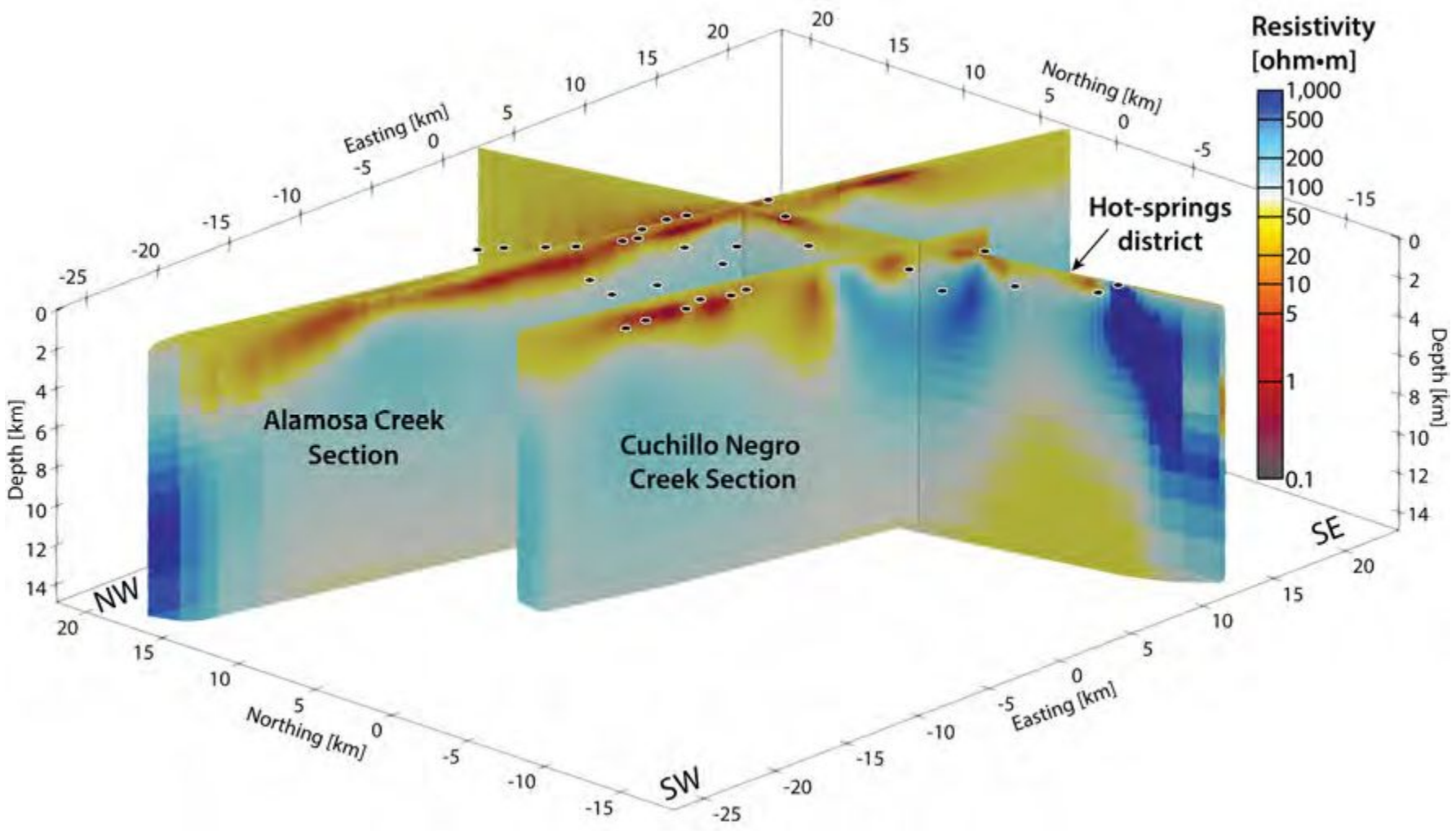
Truth or Consequences survey

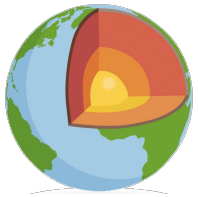
Future plans:

Geophysical studies to identify blind geothermal systems and brackish water resources.



Magnetotelluric results





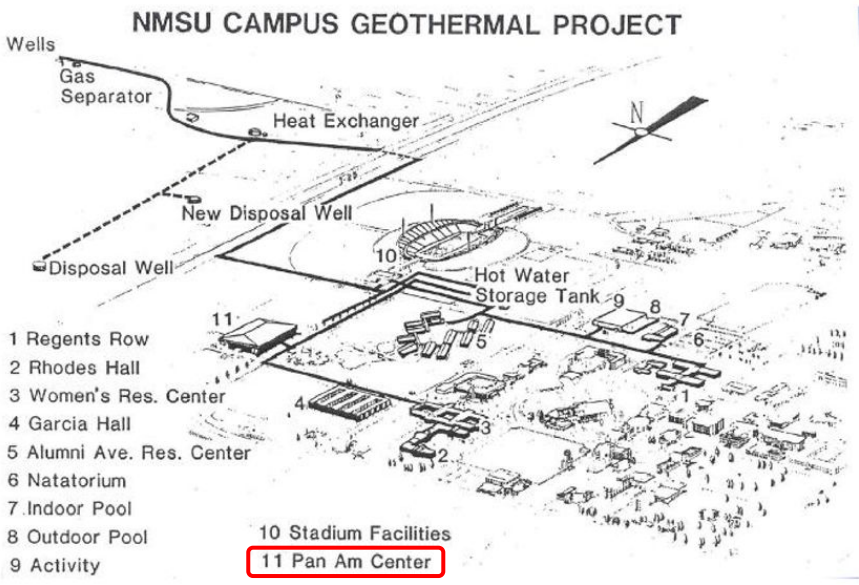
Geothermal Center of Excellence

- **$400,000 funding** appropriated in 2023 (HB2 Sec 5-234 on p227)
  - NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY - **For innovation and expansion of geothermal energy.**

- Preliminary plan for 2023:
  - **Upgrade & organize the geothermal database**
    - Translate the 2010-14 DOE-funded NM geothermal database to the web for public access.
  - **A workshop & gathering in late summer 2023**
    - Plan a workshop with university, community college, national lab and industry representatives (EnviTrace, Alma Energy, Tetra Corp). The workshop will be used to establish a **consortium** and identify future research directions.
  - **Design a geothermal demonstration at NMSU link**

NMSU Geothermal Project

(1979 to 2015)



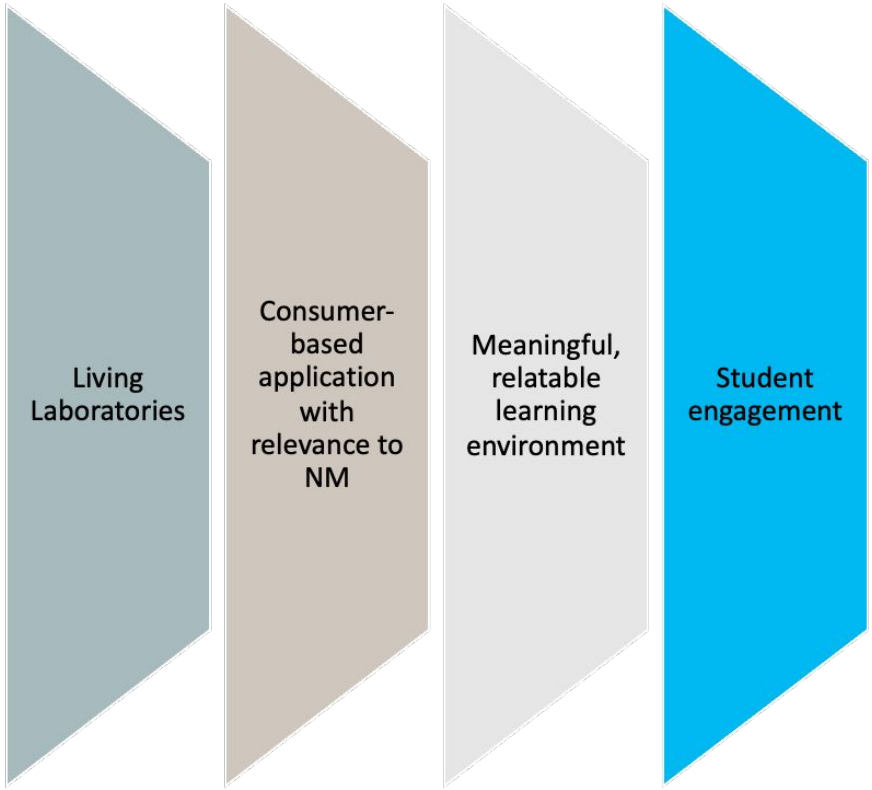
- Between 1973 and 1979, NMSU experienced a >400% increase in the cost of natural gas. (similar to cost trends in 2022).
- **An appropriation from the New Mexico Legislature provided funds for the design and construction of the NMSU Campus Geothermal Project** [1]
- NMSU Geothermal Projects provided 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

Education and Workforce

Advancing Adoption in NM



- Create relevant, real-world opportunities for students
- Involve students at demonstration sites for integration and scale of geothermal-based technologies
- Focus demonstrations to advance adoption based on geographic and topographic regions of the state
- Integrate Environmental and Energy Justice as attributes for scale and adoption of geothermal technologies (ground-source heat pumps, lower energy burden)

Project Innerspace

Where to Find the Energy to Save the World

Jamie Beard is pouring everything into a singular vision: Tap into the awesome potential of geothermal power in Texas, and beyond. She has no time to lose.

WIRED

*Project Innerspace: We are working with **Jackson Grimes**, Project Mgr & **Trent McFayden**, Dir. of Strategic Initiatives*

- Project InnerSpace is a 501(c)3 non-profit focused on **expanding the use of geothermal energy globally**. InnerSpace aims to make the production of clean, always on geothermal energy possible anywhere in the world by 2030.
- **Project Innerspace's Mission:** "To enable geothermal anywhere in the world. Fast." This organization is engaging the oil and gas community to facilitate this goal.
- **Phase I of InnerSpace** will produce high resolution geothermal prospecting maps to provide information about the quality and depth of geothermal resources within a 100km radius of the world's major population centers.
- **Phase II of InnerSpace** will fund ten teams to drill and develop 'first of their kind' power or heat producing geothermal projects in strategic locations globally.

https://www.projectinnerspace.org https://www.wired.com/story/where-to-find-the-energy-to-save-the-world-geothermal-texas/

Geothermal in New Mexico Today

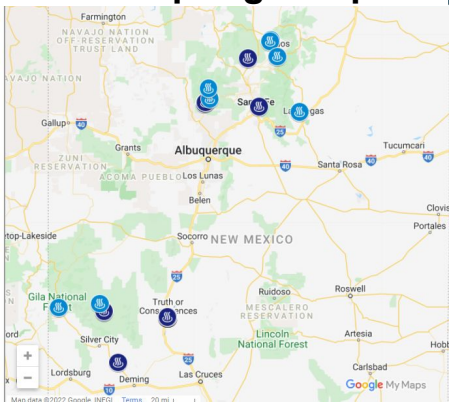
Phase 1 geothermal businesses

- **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.

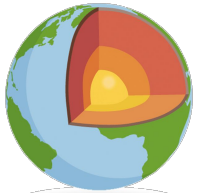
Hot Springs map



- **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

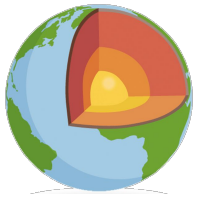


Some GT Development Opportunities

For phase 1

- Revive 1980's **NMSU geothermal projects**
- **San Juan Basin** thermal characterization

- **Zia Pueblo** DOE study 2012-2013
- **Mesa del Sol** integrated cascading community GT development
- **Expand Lightning Dock** geothermal electric plant
- Low grade heat (129°F-180°F) for **drying chile, onions**, etc
- Revisit 1980's **Jemez Springs** attempt to develop hydrothermal



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.

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.

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

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

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

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

Sage Geosystems - **USA**

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

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

Office in Albuquerque, NM.

Over $500M in GT Federal Funds

Some require state matching funds.

Zach Millimet of Sen. Heinrich's office

- **I**nfrastructure **I**nvestment and **J**obs **A**ct:
  - **$500M** for "Clean Energy Demonstrations on Current & Former **Mine Land**". Up to five projects (incl **geothermal**). Through 2026.
  - **$84M** for **enhanced geothermal** energy; 1st round closed June 16, 2023. A 2nd round is likely but tbd.
- The Department of Energy (DOE):
  - Enhanced Geothermal Earthshot: cut EGS costs 90% by 2035, to $45 per MWh
  - $23M "Onsite Energy Technical Assistance Partnerships" including **geothermal**. Applications were due April 21, 2023.
  - Geothermal Technologies Office - funding opportunities
    - The **Fall 2023 Geothermal Collegiate Competition** opens Aug 1, 2023.

⇨ Leveraging federal funding will require **added resources in EMNRD**

IRA funding opportunities https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf

Jobs in a Geothermal Power Plant

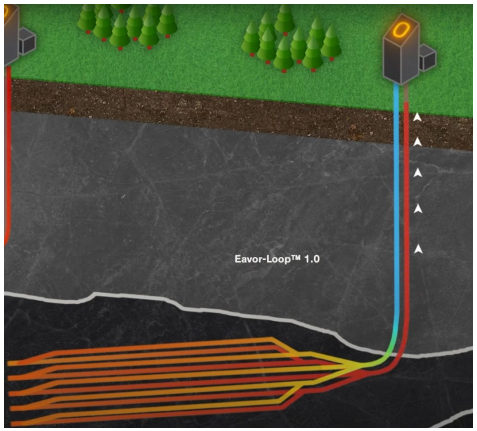
GEA
GEOTHERMAL ENERGY ASSOCIATION

Table 2: Jobs Involved in Geothermal Development (50 MW)	
Stage of Development	**No. of jobs**
Start-up	10 – 13
Exploration	11 – 22
Drilling	91 – 116
Plant Design and Construction (EPC)	383 – 489
Operation and Maintenance	10 – 25
Power Plant System Manufacturing	192 – 197
Total	**697 – 862**
Source: GEA	

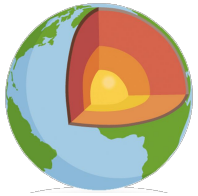
- Per the Geothermal Energy Association, a 50 MW geothermal power plant would employ about **36 workers** during normal operation, including operators, support and repair services.
  For 3,180 MW of geothermal needing 64 plants, **~2300** workers.
- For the design-through-construction phase, add another **687-837 construction jobs** per plant.
- This is **potentially tens of thousands of workers** during **construction** and **~two thousand in ongoing operations**.

http://www.geo-energy.org/pdf/reports/GreenJobs_Through_Geothermal_Energy_Final_Oct2010.pdf
https://spectrum.ieee.org/automation-is-engineering-the-jobs-out-of-power-plants

Summary

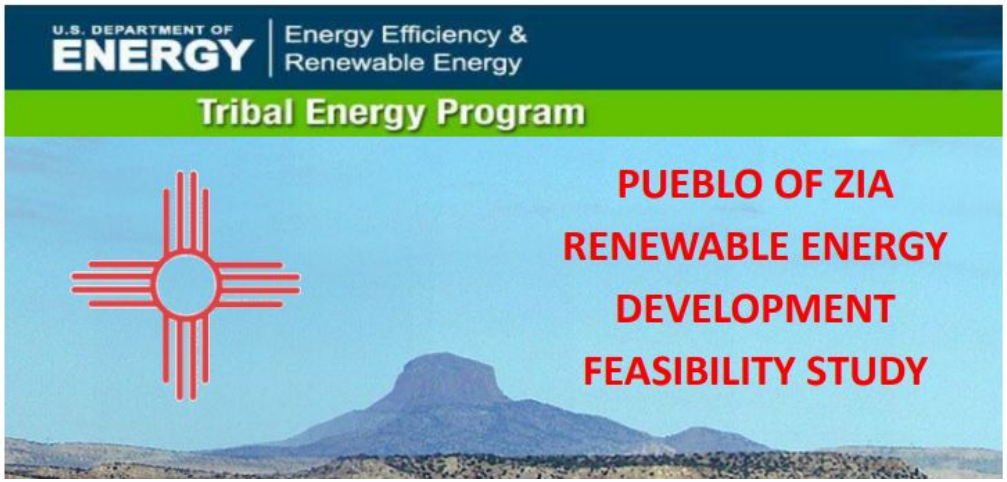


- New Mexico is #6 in geothermal resource potential
- Clean energy for heat & dispatchable electricity
- A worthy investment for economic development
- A rapidly evolving R&D and investment landscape
- Leverages skills & rigs from the oil industry
- Over $500M in federal funding available for research and development

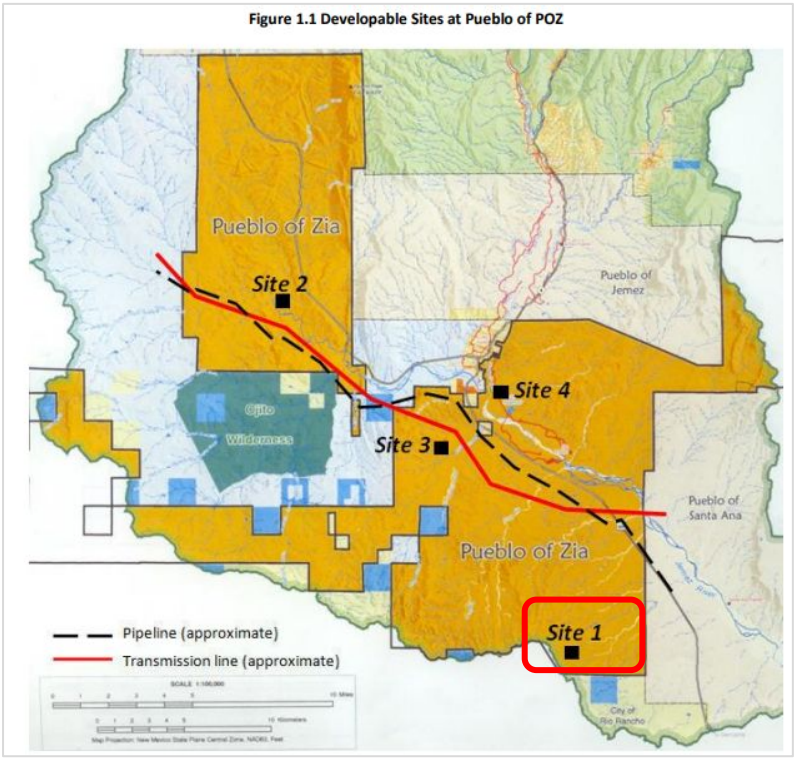


Backup

Zia Pueblo 2012-13 Geothermal Study



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 ***to demo four cascading benefits of geothermal development.***

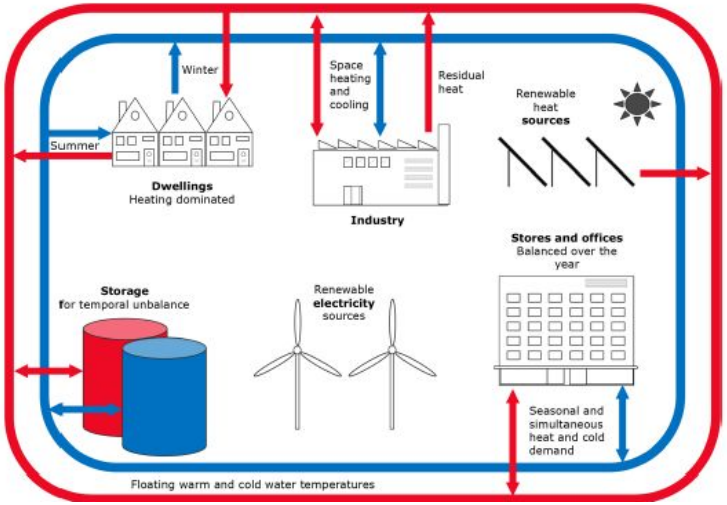
Mesa del Sol is a development south of the Albuquerque Airport

- **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**



Project Innerspace

Geothermal entrepreneur **Jamie Beard** of Project Innerspace was profiled in this May 4, 2023 cover story in Wired magazine.

https://www.wired.com/story/where-to-find-the-energy-to-save-the-world-geothermal-texas/

Geothermal Research at Sandia Labs

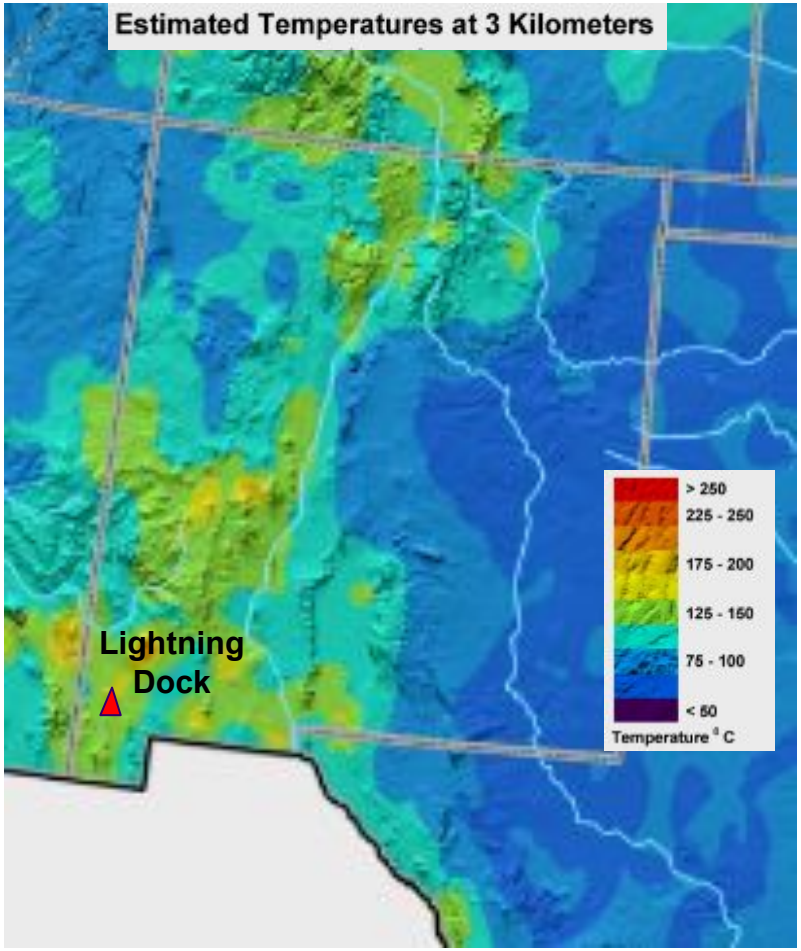
Sandia's work in subsurface access, monitoring, and modification of the subsurface is aimed at the development of enabling technologies and reducing the cost and risk associated with drilling in harsh, subterranean environments.
A large portion of the cost and risk of generating electricity from geothermal 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.

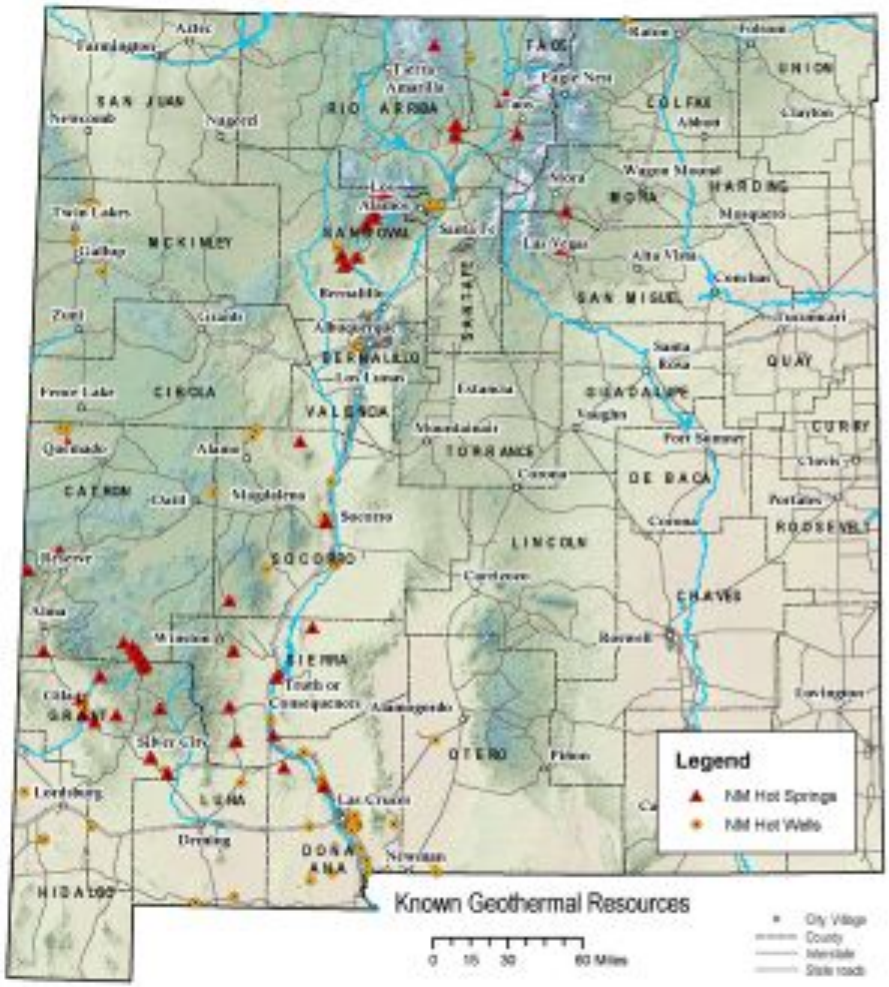
Sandia National Laboratories

- 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/

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 Rio Grande rift/Basin and Range.

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