Chapter 5

Leveraging Oil and Gas Technologies, Labor, and Workforce to Advance Geothermal in New Mexico

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Mining, oil, and gas have long shaped New Mexico's economy and society. Turquoise mined from the Cerrillos Hills and Burro Mountains was used for trading long before Europeans arrived. Lead, copper, silver, and gold mines produced a lot of metal during colonial times.[1] In the 1880s, people mined coal; by 1911, they were drilling for oil, and by 1921, for natural gas.[2] Today, New Mexico is vital to the U.S. energy landscape. In 2023, the state was the second-highest producer of crude oil and fifth-highest producer of natural gas.[3,4] The Permian Basin in the southeast of the state and the San Juan Basin in the northwest produce significant amounts of oil and gas and are recognized globally for their advanced subsurface exploration and extraction capabilities.[5]

According to the New Mexico Oil and Gas Association (NMOGA), the oil and gas industry supports approximately 134,000 direct and indirect jobs—roughly 6.4% of the state's 2.1 million residents. It also contributes around $13 billion annually to state and local revenues, equivalent to more than 30% of the state's total public budget.[6] About $7.4 billion—49% of all revenue—goes directly to the state's general operating fund.[7] As of 2022, New Mexico is the leading producer of potash in the country and ranks third in copper production.[8] The state also has significant reserves of coal, uranium, carbon dioxide, and helium.[9]

Despite the economic benefits, New Mexico's reliance on the mining and oil and gas industries has also exposed it to the volatility of resource markets, leading to cycles of booms and busts. This volatility has sparked a growing interest in diversifying the state's energy portfolio, driving the rapid expansion of renewable energy sources since 2015.[10]

Today, geothermal energy is still underdeveloped in the state, with only one active power plant, despite New Mexico being ranked sixth nationwide in estimated geothermal resources.[11] Scaling up would offer a significant opportunity to diversify revenues and capitalize on the state's existing oil and gas expertise, infrastructure, and workforce.[12] Successful geothermal development requires competencies in subsurface exploration, engineering, and natural resources production—skills already prevalent in New Mexico.

LOCATION OF NEW MEXICO OIL AND GAS ASSETS AND GEOMAP HEAT FLOW DATA

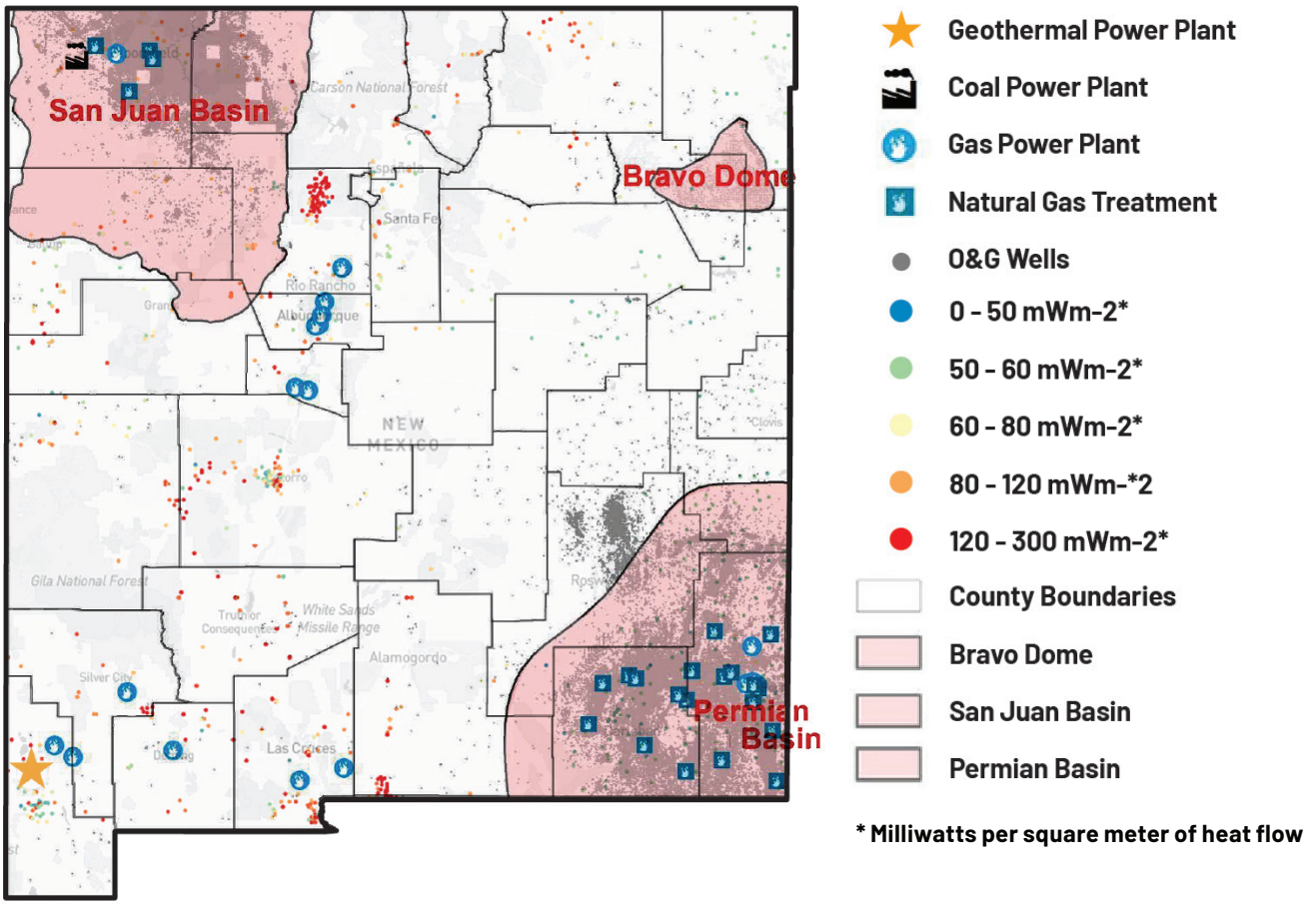

Figure 5.1: New Mexico oil and gas assets: oil and gas wells, natural gas treatment facilities, gas power plants, and main producing basins (Permian, San Juan Basin, and Bravo Dome, compared with the singular geothermal power plant. Sources: Go-Tech, *About Go-Tech*, https://octane.nmt.edu/gotech/Main.aspx; U.S. Energy Information Administration, *New Mexico energy infrastructure data*, https://www.eia.gov/beta/states/states/nm/data/dashboard/energy-infrastructure; U.S. Geological Survey (USGS), *Science data catalog*, https://data.usgs.gov/datacatalog/,.and GeoMap, https://geomap.projectinnerspace.org/map-selection/

New Mexico currently uses 10.7 gigawatts of electrical power each year. Because of its natural geothermal resources, New Mexico also has the technical power potential of 163.32 gigawatts, which means geothermal could enable the state to meet increasing energy demands 16 times over.[13]

This chapter delves into the synergies between geothermal and the oil and gas industry in New Mexico and identifies pathways between them to help ensure New Mexico remains an energy leader in the United States.

BACKGROUND

New Mexico Energy, Minerals, and Natural Resources

Oil and Gas and Mining

New Mexico's oil and gas industry expanded rapidly with the development of commercial oil reserves in the San Juan Basin in 1924.[14] This marked the start of large-scale exploration and production, followed by significant developments in the Permian Basin in the southeast.[15] New Mexico also has a notable history of carbon dioxide (CO_2) production, particularly in the Bravo Dome field in

northeast New Mexico, one of the largest natural CO_2 reservoirs in the United States.[16]

Copper was first used by native people in New Mexico.[17] In 1910, industrial copper production began in Hurley, which has one of the largest pits in the world. Potash mining in the state accounts for 75% of domestic production.[18] Coal mining generated more than $500 million in revenue and 1,200 jobs statewide in 2014.[19] The state used to mine more than one-third of the nation's uranium,[20,21] and it still extracts rare earth minerals and critical minerals.[22]

Existing Subsurface Assets and Geothermal Potential

Mining assets in New Mexico have significant geographic overlap with geothermal resources (see **Figures 5.1** and **5.2**). In New Mexico there is overlap between where the mines are situated and high geothermal gradients, where the temperature increases rapidly as you go deeper into the subsurface.[23] Several minerals, such as epithermal copper and gold, are concentrated through hydrothermal processes because higher temperatures facilitate the movement and displacement of these metals deep within the Earth.[24] Lithium and boron are also often found in geothermal brines. Data sources like GeoMap show that New Mexico has lithium brine in several key areas, including in the Permian Basin. The presence of these minerals in geothermal regions highlights the potential for mineral extraction from geothermal brines. In Southern California, the Salton Sea Geothermal Field and Hell's Kitchen geothermal plant not only supply the region with power to the grid but also produce lithium extracted as a by-product of

LOCATION OF NEW MEXICO MINING ASSETS AND GEOMAP HEAT FLOW

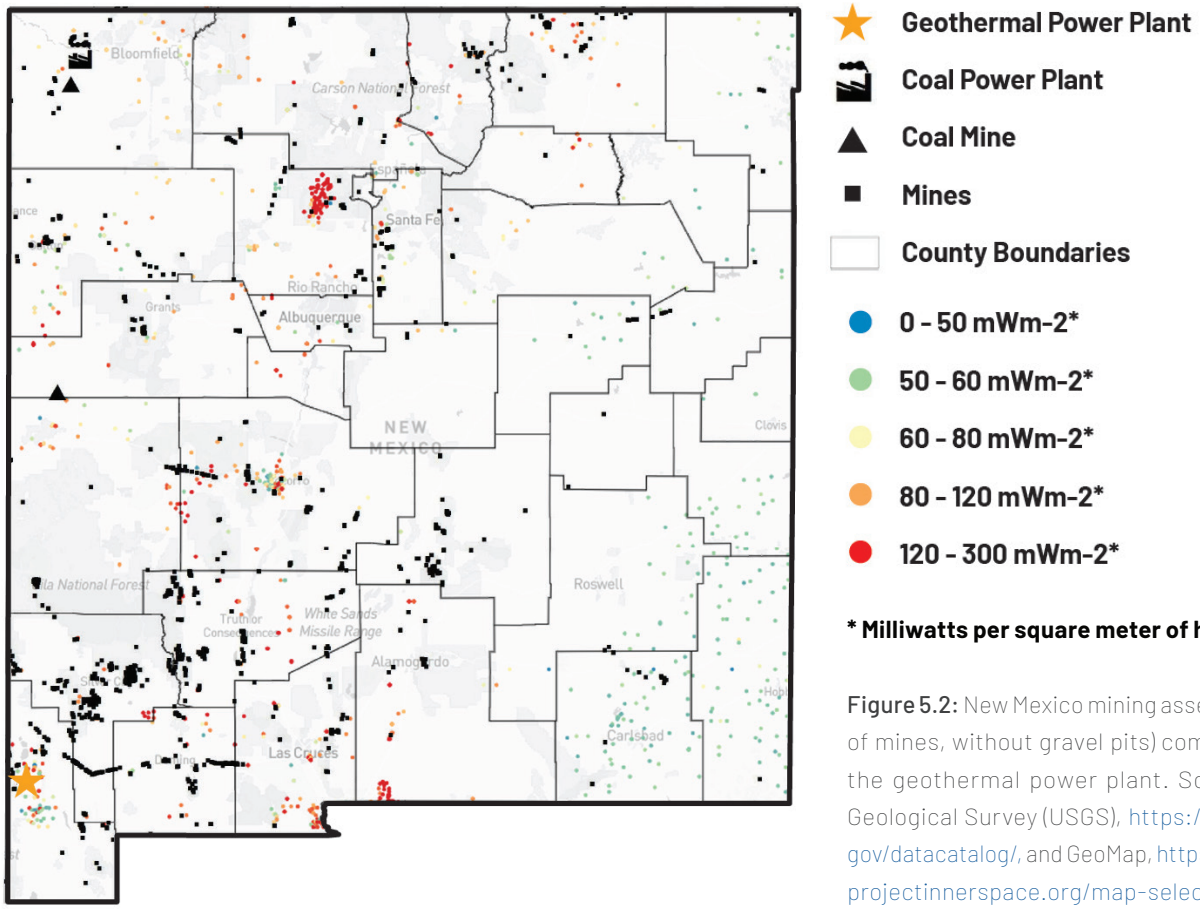

Figure 5.2: New Mexico mining assets (all types of mines, without gravel pits) compared with the geothermal power plant. Source: U.S. Geological Survey (USGS), https://data.usgs.gov/datacatalog/, and GeoMap, https://geomap.projectinnerspace.org/map-selection//

geothermal operations; the lithium can then be used in battery-grade products.[25,26]

Oil and gas assets, on the other hand, are typically located in sedimentary basins with lower heat gradients, which generally has made them less conducive to geothermal energy production. That said, advancements in technology and direct-use applications can harness lower temperatures, depending on the end uses, energy needs, and project design. (See more in Chapter 4.[27]) Although geographic overlap may not indicate a strong correlation between geothermal power generation potential and the Permian and San Juan oil and gas basins, the workforce, technologies, and infrastructure do.

ENGAGEMENT AND INTEREST IN GEOTHERMAL DEVELOPMENT IN THE OIL AND GAS AND MINING INDUSTRY

We conducted an in-depth review of 392 entities in New Mexico to assess their current engagement and interest in geothermal development. Respondents fell into eight categories (**see Figure 5.3**):

- Local operators (e.g., companies, small businesses, or individuals involved in resource extraction or energy development)
- Drilling companies (companies specializing in the physical drilling process)
- Service companies (a company that provides specialized products, equipment, and expertise to support exploration and production)
- Multistate operators (e.g., energy or resource companies, often with larger capital and infrastructure capabilities)
- Mining companies
- Geothermal firms (those focused on geothermal energy exploration, development, and production)
- Utilities
- Trade organizations

Local operators make up the largest portion of the entities reviewed (44%). While these firms often have deep localized expertise, many of them are small to midsized and may lack the capital resources or be hesitant to assume the risks associated with geothermal energy. These companies might represent the majority of companies by number, but larger companies typically account for the bulk of energy production in the state. Nonetheless, the significant number of local operators signals substantial potential for expansion of geothermal, especially if targeted support, incentives, or partnerships can help them enter geothermal development.

Drilling companies—which represent 22% of the entities studied—have the potential to repurpose existing drilling expertise and infrastructure for geothermal exploration. Appropriate training and investment could enable these companies to play a critical role in advancing geothermal development.

Service companies, which provide essential support activities such as equipment maintenance and logistics, account for just 14% of the entities reviewed, which underscores the opportunity for them to expand their operations into the geothermal sector and grow their business.

Multistate operators, primarily focused on fossil fuels, and often based outside New Mexico or even outside the United States, account for 8% of the entities but represent a large part of the oil and gas and mining activity.

Mining companies make up 7% of entities, largely because only major players were identified. As in the oil and gas industry, there are numerous small, local mining operators with limited assets, but just a few large, multistate operators hold significant assets within the state.

Geothermal firms and **utilities** each made up only 2% of the entities in the review. Oil and gas **trade organizations** made up 1% percent of entities but represented numerous other entities in the oil and gas industry (such as local operators).

The recent surge in New Mexico oil production, driven by unconventional drilling in the Delaware Basin, has been led by larger companies such as Chevron,[28] Devon Energy,[29] ExxonMobil,[30] and Occidental,[31] all

NEW MEXICO OIL, GAS, AND MINING INDUSTRY INVOLVEMENT IN GEOTHERMAL

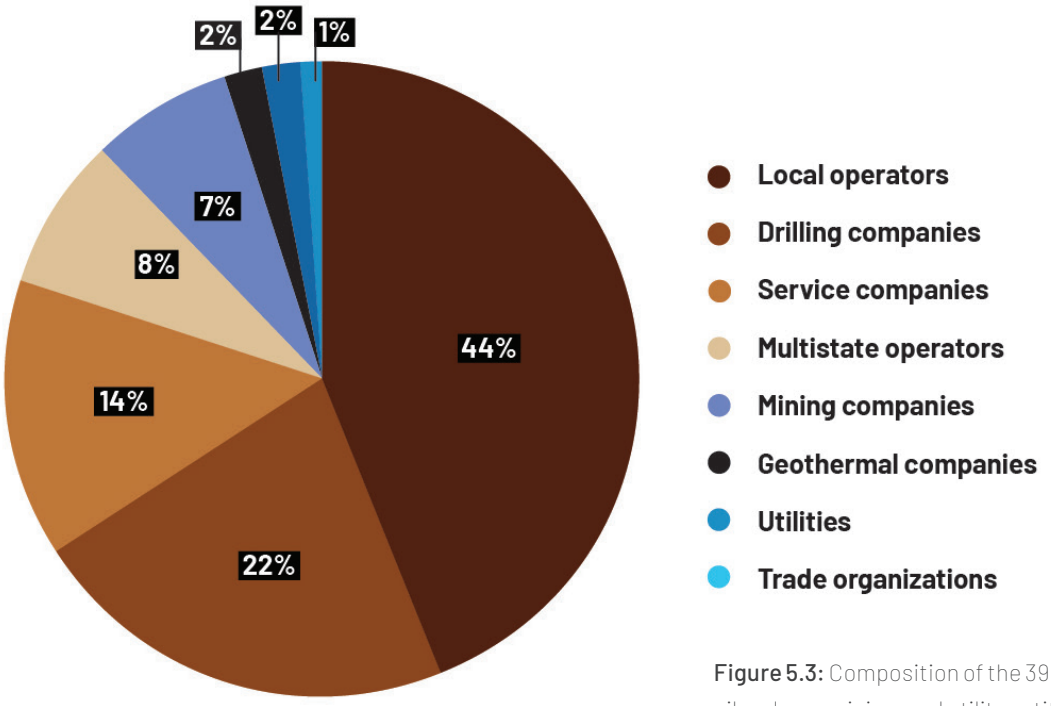

Figure 5.3: Composition of the 392 New Mexico oil and gas, mining, and utility entities identified during our research.

of which have shown some interest in geothermal. This underscores the importance of leveraging multistate operators to drive investments in geothermal energy and support long-term sector growth in New Mexico.

ENGAGEMENT IN GEOTHERMAL ENERGY

To understand the current level of interest and engagement in geothermal development in New Mexico, we conducted discussions, surveys, and a comprehensive literature and web review (**Figure 5.4**).

Geothermal Companies and Oil and Gas Trade Organizations (10 out of 10; 100% interest)

Geothermal-specific companies and oil and gas trade organizations active in New Mexico (e.g., NMOGA, Independent Petroleum Association of New Mexico, Geothermal Rising) of course show 100% interest in geothermal development, but their small total numbers (seven for geothermal and three for oil and gas organizations) indicate a limited presence in the state.

Multistate Operators (17 out of 33; 52% interest)

With more than half of large operators expressing interest, this group represents a significant potential driver for geothermal development. These entities likely see geothermal as complementary to their energy portfolios, particularly as they develop low-carbon energy sources. The nearly equal proportion of those that didn't express the same interest (16 of 33) suggests room for outreach and incentives.

Utilities (2 out of 7; 29% interest)

Utilities exhibit a moderate interest level, reflecting cautious but growing engagement in geothermal energy. Their critical role in energy marketing and distribution makes their involvement essential, but the relatively low

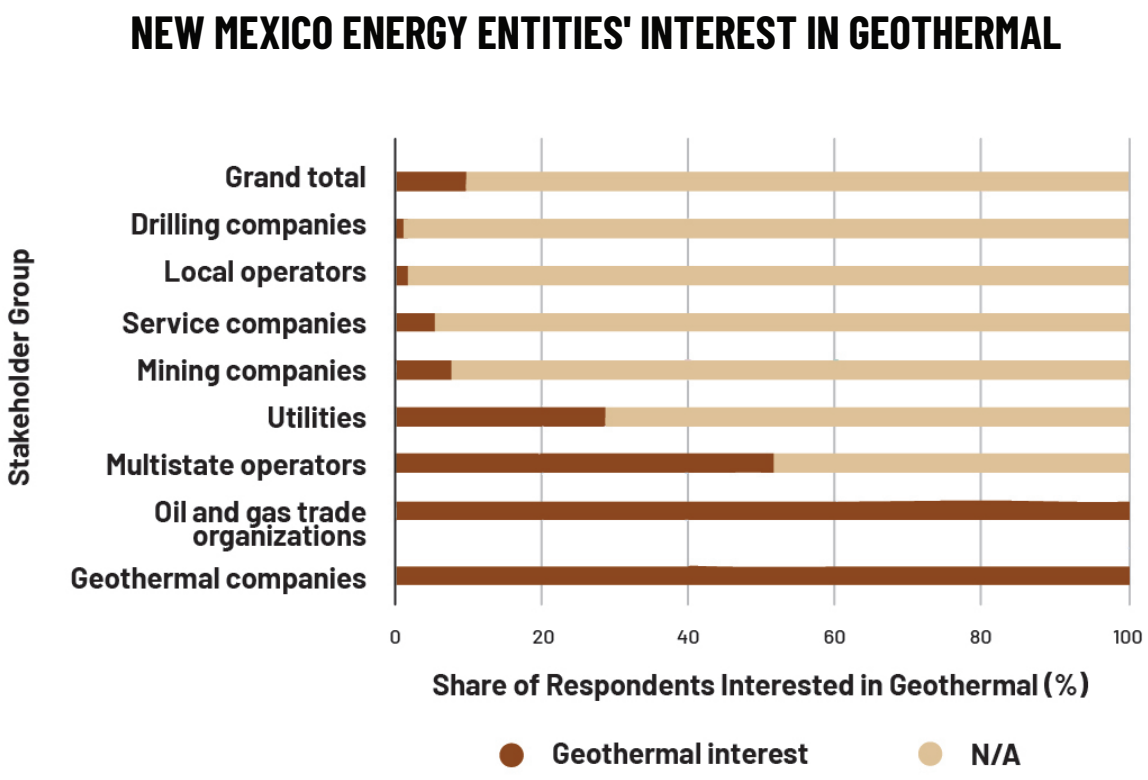

Figure 5.4: Current levels of engagement with and interest in geothermal development from New Mexico's energy stakeholder sectors. N/A (not available) indicates either a negative response or that no information was available. Sources: MIT Center for Energy and Environmental Policy Research. (2022). *The Roosevelt Project: Accelerating an equitable clean energy transition in New Mexico*. Massachusetts Institute of Technology. https://ceepr.mit.edu/wp-content/uploads/2022/12/2022-The-Roosevelt-Project-New-Mexico-Case-Study.pdf; New Mexico Energy, Minerals and Natural Resources Department.(n.d.). *OCD permitting: Operator search*. https://wwwapps.emnrd.nm.gov/OCD/OCDPermitting/Operators/Search/OperatorSearch.aspx

interest level indicates potential barriers (e.g., perceived risks, upfront costs, technological unfamiliarity) that need to be addressed. Discussions revealed that larger utilities (e.g., Public Service Company of New Mexico [PNM], El Paso Electric, Xcel Energy) are more interested in geothermal energy's potential for long-term energy storage in various geothermal energy systems. This capability could help balance the intermittent nature of solar and wind power, both of which have been extensively developed in New Mexico. Developing a 5 gigawatt geothermal goal for the state that includes geothermal energy storage (GES) could help drive interest in geothermal by utilities, as it makes renewables less intermittent.

Smaller utilities and cooperatives, on the other hand, expressed less interest than the larger ones. As described in Chapter 4, rural electric co-ops can include ground source heat pumps as a way to meet the state's clean energy goals. This may be an area to increase co-ops engagement in the sector.

Mining Companies (2 out of 26; 8% interest)

Mining companies show limited interest in geothermal energy. Given the geographical and operational overlap between mining and geothermal resources, this low level of interest highlights a missed opportunity. Greater outreach and tailored solutions—such as utilizing geothermal heat for mineral processing and exploring opportunities for recovery of minerals like lithium and other critical elements from geothermal brines—could significantly enhance mining companies' engagement and interest.

Service Companies (3 out of 56; 5% interest)

Service companies, which provide essential support to energy operations, show very low interest in geothermal development. Most of the companies that aren't interested in geothermal are small, while larger, multinational service companies and manufacturers do express interest. Smaller companies could expand their expertise to cater to geothermal projects, but their low engagement suggests a lack of awareness, a lack of demand within the sector, or a high level of risk associated with diversifying.

Local Operators (3 out of 173; 2% interest)

Local operators represent the largest group in terms of total number (173) but show minimal interest in geothermal development, which highlights a significant gap in potential. These entities generally lack the capital resources to explore geothermal. Most are small, family-owned businesses with existing assets in oil and gas that continue to make profits doing "business as usual" and thereby avoid the risks associated with venturing into a new industry. However, some of these companies are willing to attempt smaller projects that larger companies won't touch, so this attitude could change based on the profitability of oil and gas, financial risks, and the availability of geothermal resources close to companies' existing operations.

Drilling Companies (1 out of 87; 1% interest)

Although drilling companies have technical expertise that is highly relevant to geothermal development, their engagement remains minimal. This finding is not unexpected, as drilling companies typically don't initiate projects themselves; rather, they provide contracted services to entities that fund and manage the projects. The lack of interest may stem from limited demand and the nature of New Mexico's drilling sector, which is largely composed of small, independent operators that might lack the resources, market knowledge, or incentive to assume the risks associated with diversifying into geothermal development. Furthermore, with steady demand and active projects in the oil and gas sector, these firms face little immediate pressure to pursue opportunities in other industries. If the policies suggested in Chapter 7 are adopted, then New Mexico is likely to drill significantly more wells, offering potential opportunities for these companies.

Overall, only 10% of the 392 entities reviewed have shown interest in geothermal development. These groups—geothermal-specific companies, trade organizations, and larger energy operators—are leading the effort by actively exploring options to repurpose New Mexico oil, gas, and mining assets, technologies, skills, and workforce for geothermal development. The lack of engagement in the state from other critical sectors highlights substantial untapped potential and indicates that policy could help further engage these groups.

INITIATIVES SUPPORTING GEOTHERMAL EXPANSION IN NEW MEXICO

Several initiatives, including some originating from the oil and gas industry, are actively advancing geothermal energy development in New Mexico. Next, we describe a few key initiatives that we consider significant.

Outreach and Engagement

There is a growing wave of outreach and engagement among leaders and energy experts focused on advancing geothermal energy in New Mexico. Numerous geothermal-focused events took place in 2024, including the Advancing Geothermal Development in New Mexico workshop at New Mexico Tech (NMT), the Building an Advanced Energy Ecosystem in New Mexico conference, and the New Mexico Energy Initiatives workshop at NMT. In the first half of 2025 NM Tech hosted a geothermal meeting and the New Mexico Energy Summit hosted a geothermal panel.

These gatherings provided critical platforms for stakeholders to discuss the untapped potential of geothermal energy in New Mexico, share technological advancements, and address barriers to development. (Policy recommendation #14 in this report encourages the adoption of geothermal-specific apprenticeships and workforce training; see Chapter 7.)

At the Advancing Geothermal Workshop at NMT, 47 of the 175 registrants (27%) were from industry (**Figure 5.5**). Among the industry groups present, 60% were from the oil and gas sector, demonstrating the industry's

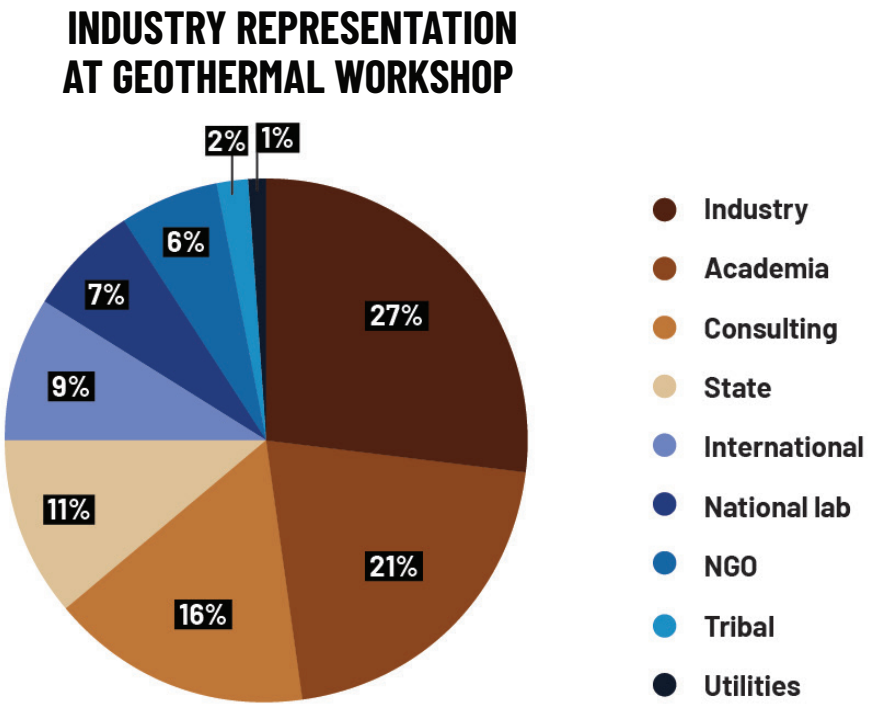

Figure 5.5: Demographics and industry representation at the Advancing Geothermal Development workshop at New Mexico Tech, with a focus on oil and gas.

growing recognition of geothermal energy's potential—and its alignment with their sector's expertise and infrastructure.

Private Sector Efforts in Next-Generation Geothermal

A handful of companies are currently pursuing geothermal development in New Mexico, with new interest entering the state from additional organizations.

Engineered Geothermal Systems (EGS)

One stakeholder that focuses on the use of EGS for utility-scale thermal and electric power generation projects has increased its presence in the state and is leveraging advanced commercial technologies, such as high-tech drill bits and other emerging drilling innovations. The company views New Mexico as a "logical leader in the next-generation geothermal industry," citing the state's resources, access to world-class universities and national laboratories, and large and experienced subsurface engineering and operations workforce.

In 2023, Fervo achieved a major milestone with an EGS by completing a successful 30-day production test at its Project Red site in Nevada.[32] The test demonstrated sustained power output of 3.5 megawatts, validating the commercial viability of an EGS and marking the first time that horizontal drilling and fiber-optic sensing—techniques borrowed from oil and gas—have been successfully applied at this scale in the geothermal sector. While Fervo is currently focused on Utah and Nevada, the company's breakthroughs reveal real potential for EGS applications in New Mexico's geothermal-rich regions.

Advanced Geothermal Systems (AGS)

AGS consists of a circuit of wellbores containing a fluid that is heated via the hot surface of the wellbore pipes, rather than through direct contact with the hot rocks. This system could play a key role in expanding New Mexico's geothermal footprint, and private sector efforts related to AGS are gaining momentum. Companies such as XGS Energy are working with closed-loop technologies to unlock the state's massive geothermal potential, and thermally conductive materials developed by XGS have been reported to increase heat recovery by between approximately 30% and 50% relative to conventional approaches.[33] These materials may offer deployment advantages in various regions of the state because they're less dependent on local water resources and geological conditions. These systems also reduce exploration risks, improve energy output efficiency, and enable development in regions previously considered unusable for traditional geothermal approaches.

SMALL MODULAR HEAT EXCHANGE UNIT

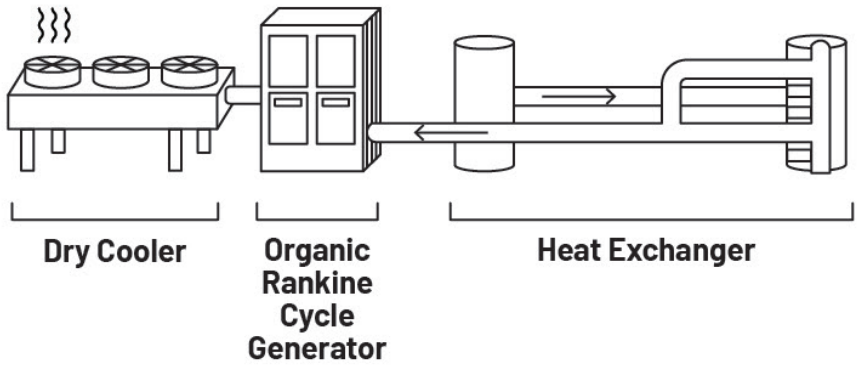

Figure 5.6: A small, modular unit manufactured by Gradient Geothermal at an active geothermal power plant in Nevada. Source: Adapted from Gradient Geothermal. HXC Geothermal System. https://www.gradientgeothermal.com/#HXC

Geothermal Energy Storage (GES)

Geothermal energy storage (GES) is an emerging form of next-generation technology that captures and stores energy using the natural heat and pressure in deep underground rock formations. Fluid is injected into a well during periods of low electricity demand or high renewable generation. The high-pressure reservoir acts like a subsurface battery, storing energy. When energy is needed, the fluid is released and flows back to the surface at high velocity, converting the pressure into mechanical energy that can be used for power generation. Unlike traditional geothermal systems that rely solely on high-temperature hydrothermal reservoirs, GES systems use deep wells in sedimentary basins.

Sage Geosystems—a pioneer in the GES space—applies their oil field experience and techniques to offer easily dispatchable firm power. The Department of Defense (DOD) recently identified Sage as a company whose novel technology will be critical for advancing energy resilience across U.S. military installations.[34] Considering that 5% of New Mexico land is occupied by DOD facilities[35] and intermittent renewables account for 46% of the state's electricity grid (see Chapter 2), GES systems present a unique pathway for New Mexico in next-generation geothermal opportunities.

Coproduced Geothermal from Oil and Gas

Coproduced geothermal resources represent a growing area of development. Traditionally used for direct applications like heating, agriculture, fisheries, and mineral recovery, low-temperature resources are increasingly used for power generation under the right conditions. Coproduced resources leverage hot fluids generated as by-products of oil, gas, and mineral extraction to produce heat or electricity, offering a dual benefit: reduced reliance on foreign energy sources and extended economic life of oil and gas fields.[36] In 2024, Colorado-based Gradient Geothermal highlighted an innovative approach involving small, modular power units at well sites or central facilities (see **Figure 5.6**). These systems extract heat from produced fluids to generate emissions-free electricity, which can be used on-site or supplied to the grid.[37] Gradient has deployed this technology in oil fields in several states to power on-site operations.[38] Leveraging existing oil and gas assets reduces the need for new drilling and exploration and minimizes upfront costs and environmental impacts. This approach not only facilitates cleaner energy but also provides oil and gas operators with a viable pathway to optimize energy use and decrease their carbon footprints, all of which are applicable to New Mexico's current oil and gas operations.

Exploration

New Mexico's rich geothermal resources and supportive policy environment make it an attractive destination for national and international exploration companies specializing in geothermal energy. TLS Geothermics recently expressed interest in New Mexico, expanding on previous work using proprietary geoscience-driven machine-learning tools. The company's approach is

inspired by advanced techniques from the oil and gas industry that emphasize predictive modeling rather than reliance on surface manifestations.[39] Other groups with similar novel computational techniques, such as EnviTrace in Santa Fe,[40] could play a pivotal role in next-generation geothermal exploration.

PARTNERSHIPS

Geothermal stakeholders are increasingly forming partnerships in the global energy system to advance their projects. In the private sector, for example, Wells2Watts (an initiative led by Baker Hughes) repurposes inactive oil and gas wells into geothermal assets through closed-loop systems.[41] At the federal level, the Geothermal Energy from Oil and Gas Demonstrated Engineering (GEODE) consortium—funded by the U.S. Department of Energy and led by Project InnerSpace and the Society of Petroleum Engineers—brings together subject-matter experts from the oil and gas and geothermal industries to leverage best practices and knowledge to help expand the use of geothermal technology.[42] In New Mexico and Texas, the Permian Energy Development Lab, a consortium dedicated to energy innovation in the Permian Basin, has partnered with subsurface energy technology company Teverra to develop projects in geothermal energy and other advanced energy fields.[43] The Tribal Energy Consortium, an organization with members representing 20 Tribes in seven western states, is also working to connect Tribal entities interested in geothermal.[44]

TECHNOLOGY TRANSFER

Over the past 20 years, drilling for oil and gas has shifted toward unconventional resources that are harder to access, particularly in the Permian Basin of New Mexico and Texas. These resources require advanced drilling technology such as directional drilling, insulated drill pipe, and advanced casing methods. The importance of hydraulic fracturing, or fracking, can't be understated for enabling access to much larger areas within geological formations with greater precision.

Today, significant geothermal potential exists in hot, dry rock at greater depths and in more complex geologic settings. The oil and gas industry's proven ability to drill faster, to drill horizontal wells, and to surgically target and develop fractures to increase permeability is instrumental for the geothermal industry.[45] Horizontal wells are used in an increasing number of new geothermal technologies to maximize heat extraction, including in an EGS and an AGS, as well as in enhanced geothermal reservoir recovery systems.[46] A pilot project in Utah recently successfully demonstrated the stimulation of a well to increase permeability in tight, deep reservoirs.[47] Oil and gas equipment such as seismometers, distributed acoustic sensing, and reservoir tracers have proven invaluable for characterizing the success of unconventional geothermal operations.[48] For New Mexico to unlock its full geothermal potential, these technologies must be deployed at scale.

INFRASTRUCTURE REUSE

The reuse of oil, gas, and mining infrastructure presents a transformative opportunity to accelerate geothermal energy deployment. Add to all this, there are various ways that existing infrastructure can be repurposed to help reduce project costs, minimize environmental impacts, and fast-track the expansion of the geothermal sector.

Coproduction (Mining)

As mentioned earlier, one of the simplest ways to increase the efficiency of existing oil and gas wells and mines is by using the heat from the resource itself. Heat from mining operations can be used in other parts of a mining operation. For instance, the Lihir gold mine in Papua New Guinea generates several megawatts of electrical energy from a geothermal system within the ore body.[49] Though mines in New Mexico don't currently intersect at such high temperatures, there is potential for thermal and electrical energy generation at depths of 3,000 meters in much of the Rio Grande rift and southwest New Mexico,[50] areas with active mining operations (**Figure 5.8**).

Coproduction (Oil and Gas)

In oil- and gas-producing regions, water in host reservoir rocks is partially or fully artesian and flows to the surface during hydrocarbon production.[51] In the San Juan and Permian Basins, almost seven barrels of water are produced on average for every barrel of oil.[52,53] With this amount of liquid, any fluids at or close to the lower-end temperature for geothermal energy—100°C (212°F)—can be used to coproduce direct thermal energy or binary-cycle electric energy through a small wellhead unit.[54] The energy generated from each well would vary according to flow rate, fluid composition, system design,

and fluid temperature. However, given that wells that produce less than 10 barrels of oil a day—known as *stripper wells*—have produced more than 20% of New Mexico's crude oil in certain years,[55] we shouldn't overlook the potential impact of having many small energy producers. The Department of Energy is currently exploring this potential at several sites nationwide through the Wells of Opportunity program.[56]

Abandoned Mines

Repurposing abandoned mines, particularly those in high geothermal gradient regions, for geothermal energy storage and heating applications[57] can transform liabilities into assets and minimize costs. (This approach could also have several challenges, depending on a mine's location.) Abandoned mines can provide subsurface access to geothermal reservoir analogs, especially in regions where hydrothermal activity aligns with extracted mineral deposits. This access has offered valuable insights for scientific studies.[58] In New Mexico, when a mine reaches the end of its production life, it enters the Abandoned Mine Land (AML) program or the Mining Act Reclamation Program (MARP), in which mine lands are recontoured, hazardous openings are sealed, or disturbed areas are revegetated so the site can once again be a self-sustaining ecosystem.[59,60] Programs

OIL AND GAS WELL CONVERSION OPPORTUNITIES

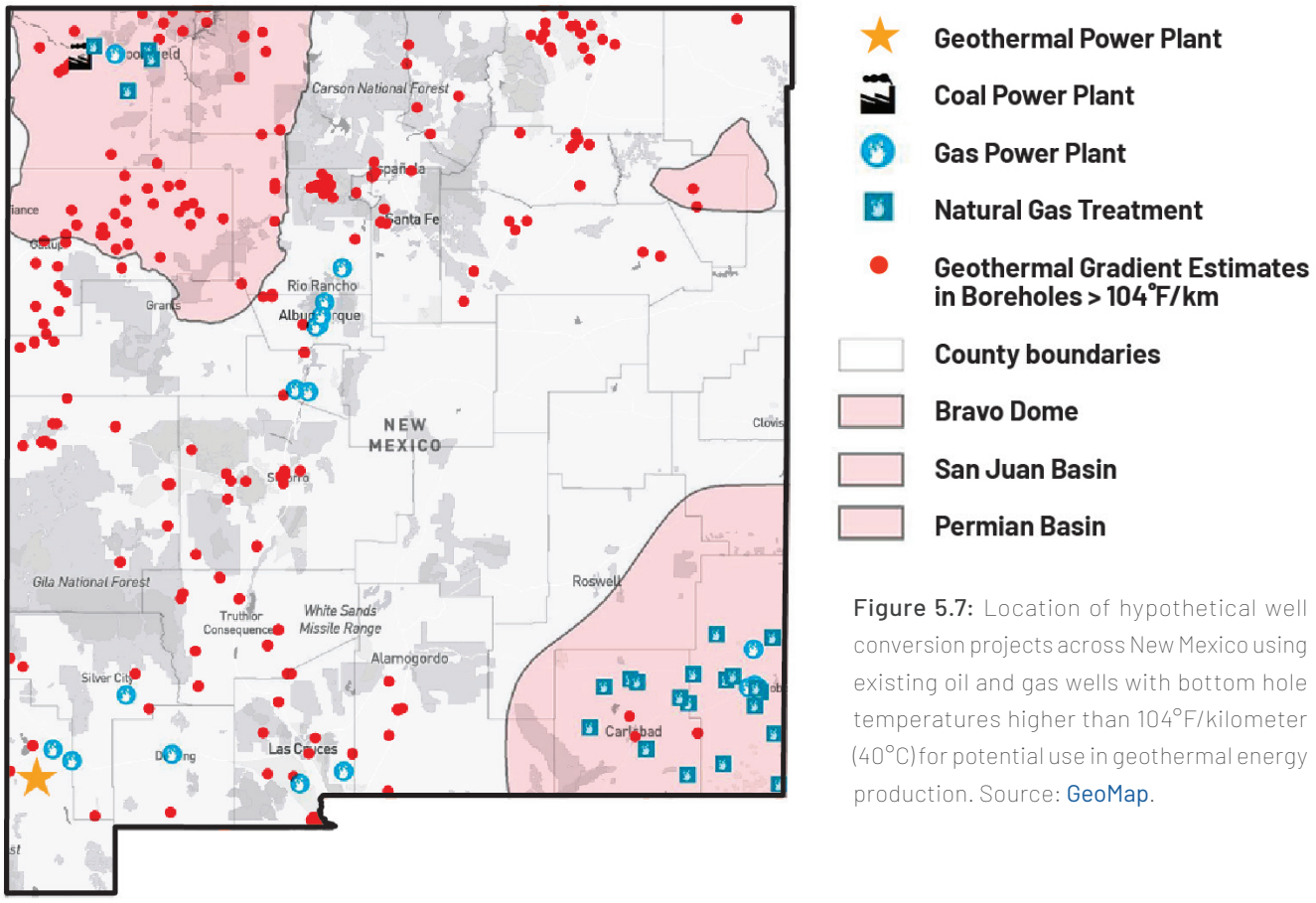

Figure 5.7: Location of hypothetical well conversion projects across New Mexico using existing oil and gas wells with bottom hole temperatures higher than 104°F/kilometer (40°C) for potential use in geothermal energy production. Source: GeoMap.

like these are vital to restoring New Mexico's natural ecology, but before a mine site is locked into AML or MARP, the mine's geological setting should be studied to determine whether there's a geothermal system below that could help support the state's energy transition.

Orphaned Wells

In 2023, New Mexico had 74,099 wells that weren't in operation and an estimated 1,700 unused and unplugged wells (orphan wells) that were environmental hazards and required remediation or plugging.[61,62] After 20 to 25 years, most oil and gas wells in tight formations, such as those in the Permian Basin, yield less than 6% of their initial produced volume.[63] Coal bed methane wells in the San Juan Basin tend to produce for between 20 and 30 years,[64] whereas geothermal wells can last for close to 100 years.[65] Some of the first geothermal wells ever drilled in the United States—such as MAGMA-1 in California at the Geysers—have been operating since 1955.[66]

Repurposing an abandoned, orphaned, or nonproductive well for geothermal use can significantly extend its lifetime and justify the large capital cost of drilling to reenter or deepen it. Reusing an existing well or well system could potentially replace up to 69% of a geothermal project's capital expenditures,[67] which occur during the drilling and exploration phases. (A company would save the median cost of $20,000 to decommission and plug a well).[68] This approach would also help reduce potential methane emissions from an improper plugging job.[69]

But there are challenges associated with converting plugged wells. Geothermal wells often need to go deeper than even the deepest oil and gas wells. Geothermal also uses a larger wellbore diameter than is typically used in oil and gas drilling.[70] Additionally, geothermal energy production may require multiple wells to establish a system for cycling water to the hot rock. The well's location would need to have suitable viable heat in the subsurface, and electricity transmission costs would need to be reasonable; many oil and gas wells, however, are located off the grid in remote areas. (**See Figure 5.7**.)

Current research around the world focuses on these challenges[71,72] due to the potential cost savings.[73] New Mexico is already pursuing this opportunity with the recent passing of HB 361, which authorizes the conversion of depleted oil or gas wells into a facility that provides energy storage or develops geothermal energy (see Chapter 7).[74]

Road and Structure Reuse

A final benefit exists in the use of surface infrastructure already in place from mining and oil and gas—that is, roads, mining platforms, wellpads, and operation centers. Geothermal operations can also, at times, repurpose pipelines, drill rigs, and large mining equipment. Along with the advantages of reducing the need to alter new terrain, use of existing infrastructure could enable developers to save on up-front costs and permitting time.[75]

SCIENTIFIC AND OPERATIONAL EXPERTISE

Proper geothermal project development requires extensive exploration to characterize the subsurface geology. This exploration typically involves structural geology, lithology, geochemistry, geophysics, and other methods that are integrated to characterize a potential reservoir. A major contributor to this knowledge base comes from existing oil and gas and mining operations, including lithologic data from mine shafts and well logs; geochemical data from produced fluids and ores; direct measurements of geophysical properties such as resistivity and density (which geophysics would otherwise have to infer); high-resolution seismic data; and direct temperature measurements. Oil and gas companies retain such data, which can be repurposed for geothermal exploration, reducing up-front risks as a result. Similarly, mining companies' knowledge of subsurface conditions, which is generally gained during exploration and planning, can be applied to identify viable geothermal resources. The data may be limited to shallower depths than the geothermal project will reach, but it is a solid start.

Oil and gas industry involvement in geothermal can lead to accelerated learning curves and substantial cost reductions.[76] One report specific to Texas found that 70% of entities interviewed in the oil and gas sector view any technical challenge posed by geothermal energy as solvable.[77] The large amount of geographic overlap of oil and gas companies from Texas in New Mexico is a good sign.

WATER RESOURCE MANAGEMENT

New Mexico is prone to droughts.[78] Given the high volumes of water extracted with each barrel of oil or million cubic feet of natural gas noted earlier, recycling produced water reduces reliance on the limited groundwater resources in the semi-arid areas of New Mexico. Produced water can be—and has been—used in new hydrofracturing projects and as a drilling fluid, and it has been reinjected for enhanced oil recovery as well. There are few restrictions in place for reinjecting produced water in energy operations, and this will be a critical skill to transfer for future geothermal operations in similar areas.[79]

Geothermal projects require water for drilling, operation, and potential well stimulation. It is feasible, if not imperative, for future projects look to existing produced fluids from oil and gas and any nearby mining operations to help meet these water needs.[80] Oil and gas operations are also required to monitor wastewater, sample fluid chemistry, eliminate spills,[81] and adjust fluid chemistry. New Mexico's Geothermal Resources Development Act[82] holds geothermal projects to the same standards, so the oil and gas industry is well positioned to transfer knowledge to geothermal development.

AVERAGE WEEKLY WAGES IN PRIVATE SECTOR IN NEW MEXICO (2023)

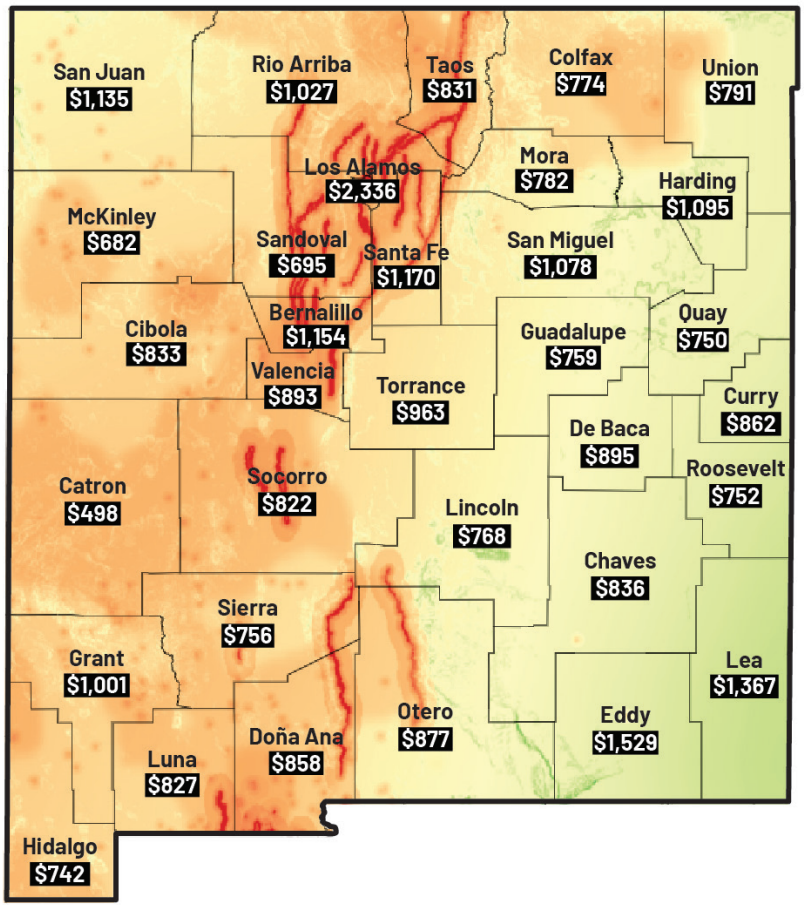

Figure 5.8: Map of the average weekly wage in the private sector in New Mexico in the fourth quarter of 2023. Adapted from Doran, M, Quarterly census of employment and wages, fourth quarter 2023. *Labor Market Review*. https://www.dws.state.nm.us/Portals/0/DM/LMI/QCEW_4thqtr_2023.pdf, and GeoMap.

WORKFORCE DEVELOPMENT

Current Workforce Trend and Wages

In New Mexico,the mining, quarrying, and oil and gas extraction sector accounted for 23,563 direct jobs in the fourth quarter of 2023.[83] Of these, 66.4% were in support activities, 20.2% in oil and gas extraction, and 13.4% in mining.[84]

Figure 5.8 shows that the state's highest average weekly wages are concentrated counties with either significant mining, oil, and gas production activities, such as Lea, Eddy, Grant, and San Juan, or counties associated with government, national labs, and urbanized economies, such as Santa Fe, Los Alamos, and Bernalillo.[85] This indicates salary disparities: Wealthier counties benefit from extractive industries, research facilities, or urban centers, while poorer rural areas lack infrastructure and income from energy resources. Interestingly, geothermal resource potential aligns with some of these lower-income counties, particularly in the south and southwest parts of the state, along the Rio Grande rift. Expanding geothermal energy in these regions could promote economic development.

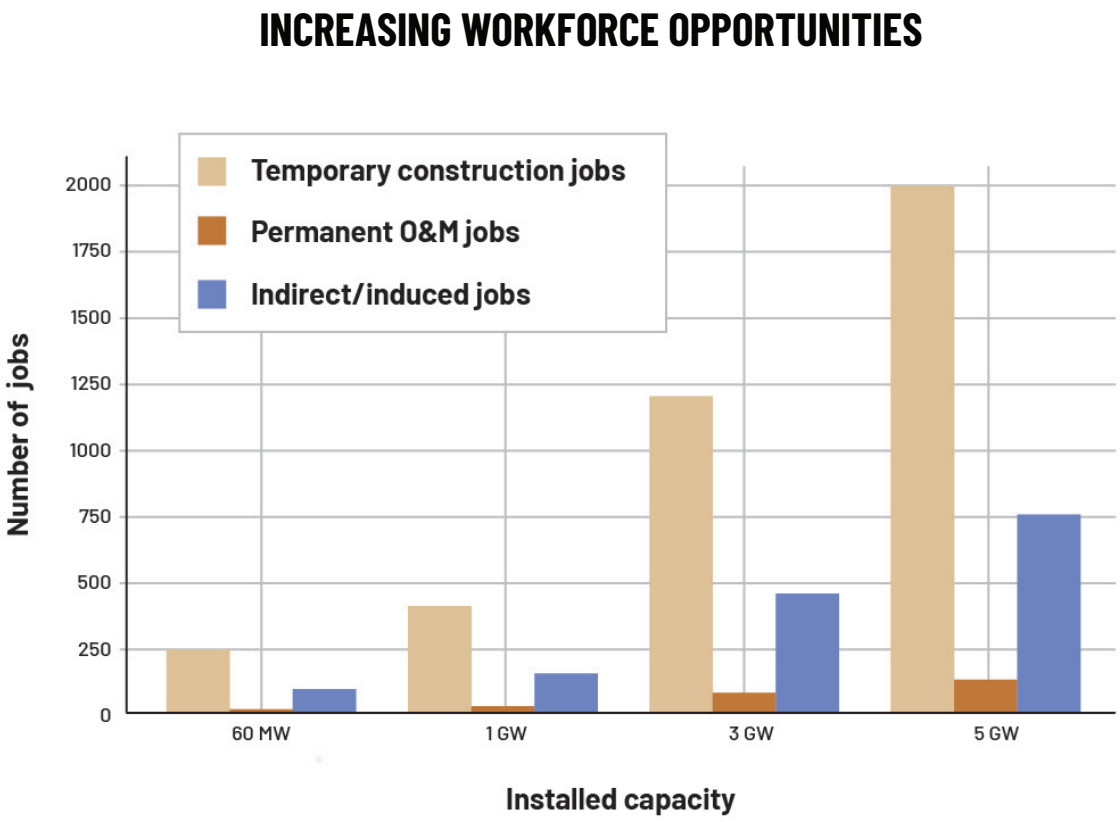

Figure 5.9: Employment impacts of geothermal energy expansion in New Mexico under various capacity growth scenarios and reasonable jobs creation ratios by 2040. GW = gigawatts; MW = megawatts. Sources: Hanna, R., Heptonstall, P., & Gross, R. (2024). Job creation in a low carbon transition to renewables and energy efficiency: A review of international evidence. Sustainability Science, 19(1), 125–150. https://doi.org/10.1007/s11625-023-01440-y; Research and Analysis Bureau. (n.d.). Nevada labor market information: Quarterly census of employment and wages (QCEW). State of Nevada Department of Employment, Training & Rehabilitation. https://nevadaworkforce.com/QCEW/index; Fendt, L. (2022, December 14). The push for a greener New Mexico–from immigrant oil workers. Searchlight New Mexico. https://searchlightnm.org/the-push-for-a-greener-new-mexico-from-immigrant-oil-workers/

Job Creation Benefits

To assess the potential for job creation from geothermal energy development in New Mexico, we developed four scenarios. Three are based on targeted development goals (reaching 1 gigawatts, 3 gigawatts, and 5 gigawatts of installed capacity by 2040),[86] while the fourth is a more conservative scenario based on current development trends and growth rates. We should note that data shows New Mexico has the technical potential of at least 163 gigawatts of geothermal.[87] Gigawatt-scale geothermal is increasingly viable, as Fervo Energy is demonstrating up to 2 gigawatts, proving the scale is technically and commercially achievable.[88] These data points show that it's possible (particularly if many of the policies suggested in Chapter 7 are implemented) that the state could surpass a 5 gigawatt goal. (A growth rate refers to the percentage increase in a given value—such as installed geothermal capacity—over time, typically calculated on an annual basis.) To model future capacity, we applied a standard exponential growth formula:

$$C(t) = C_0*(1+r)^{t-1}$$

Where:

$C(t)$ = installed capacity at year (t)
C_0 = 15 MW (initial geothermal capacity in 2024)[89]
r = annual growth rate
t = number of years since the starting point

We calculated the needed growth rate for the four scenarios in New Mexico to be:

- To reach **1 gigawatt by 2040**, an annual growth rate of approximately **33%** of geothermal capacity is needed.
- To reach **3 gigawatts by 2040,** an annual growth rate of approximately **43%** is needed.
- To reach **5 gigawatts by 2040**, an annual growth rate of approximately **49%** is needed.
- A fourth scenario assumes a conservative **10% annual growth rate**, resulting in **only 60 megawatts added by 2040.**

Building on these scenarios, we estimated the potential for geothermal-related job creation in New Mexico (see **Figure 5.9**). We applied conservative full-time-equivalent job creation rates per megawatts based on what we found in our research:

- 4 jobs per megawatt for direct temporary construction jobs[90]
- 0.25 jobs per megawatt for direct permanent operations and maintenance jobs[91]
- 1.5 jobs per megawatt for indirect/induced jobs per megawatt[92]

These results—based on idealized, incremental capacity additions to the grid—are reasonable assumptions for modeling purposes, but they don't account for real-world constraints. We should also note that a skilled geothermal workforce will likely earn higher wages than those in most other occupations.[93]

Depending on the scale of deployment, geothermal could support thousands of jobs statewide by 2040. Under a 5 gigawatt growth scenario, geothermal development could create nearly 2,000 construction jobs, 750 indirect and induced jobs, and more than 125 permanent operations and maintenance jobs.

Job Quality and Longevity

The simulation referenced (**Figure 5.9**) uses a direct correlation between megawatts of geothermal capacity and job creation. (While this correlation may hold in some cases, we recognize the limitations.) Comparing New Mexico's oil and gas production with employment trends in the mining, quarrying, and oil and gas extraction sectors however, shows a clear decoupling between output and workforce size. This suggests that productivity gains, automation, and capital-intensive extraction methods have enabled significant increases in output without a proportional rise in labor demand. Another consideration is that much of the workforce could be transitory and live out of state (e.g., living in Texas, for work in the Permian Basin).

Rural New Mexico communities that have relied on oil and gas jobs for their livelihood and dealt with a lot of employment instability are looking for more stable, sustainable jobs with fewer associated risks.[94] A 2021 medical study found that New Mexico's oil and gas industry

RELEVANT SKILLS

Figure 5.10: The Congressional Research Service estimates that 61% of the oil and gas workforce is in "high-relevance occupations" that directly translate to the geothermal industry. Source: CRS: https://www.congress.gov/crs-product/R47405

has the second-highest mortality rate among all oil and gas workers in the country—and the second highest of all industries in New Mexico, after construction.[95] The leading causes of death included vehicle accidents and cardiovascular incidents, both of which are avoidable with proper work practices and training.

Historical trends based on the evolution of employment in extractive industries[96] suggests that increased geothermal capacity will not necessarily result in exponential job growth in New Mexico. However, unlike the cyclical nature of the oil and gas industry, geothermal development offers the potential for long-lasting, stable jobs in operations, maintenance, and indirect support services. A recent National Renewable Energy Laboratory study in California estimates that natural gas could create 0.13 jobs per thousand homes powered; the numbers of jobs per thousand are only 0.10 and 0.13 for wind and solar, respectively. For geothermal, however, that number increases to 0.40 jobs per thousand homes powered.[97]

Currently, approximately 61% of the state's oil and gas workforce is employed in "high-relevance occupations" that align closely with roles needed in the geothermal industry, highlighting strong potential for New Mexico's oil and gas workforce to find new roles.[98] State institutions are supporting this shift. The New Mexico Energy, Minerals, and Natural Resources Department is offering free training on heat pumps and zero-energy buildings,[99] and New Mexico Tech has launched a geothermal certificate program to help build a skilled local labor force for the state's clean energy future.[100]

CONCLUSION

New Mexico has a significant opportunity to create more jobs, economic development, and state and local revenue by using its existing oil and gas know-how to tap into its substantial geothermal resources. Our modeling shows that nearly 3,000 jobs would be added to the state if it produced just 5 gigawatts of its massive geothermal potential. Adding geothermal energy to New Mexico's

employment portfolio would leverage skill sets and expertise from local workers in the mining and oil and gas sectors, provide additional employment cushions to two sectors notorious for boom-and-bust cycles, offer an avenue for the state to diversify its revenue stream, and greatly improve economic and employment outlooks in parts of the state that are lagging.

Geothermal energy has garnered strong interest, yet only 14% of the 2024 New Mexico Tech Advancing Geothermal Development Workshop's industry participants—and just 10% of overall industry stakeholders surveyed in this analysis—are actively exploring geothermal opportunities or developing projects in New Mexico. This lack of exploration demonstrates that critical challenges persist, despite the state's unique combination of abundant geothermal resources, extensive oil and gas infrastructure, and a skilled workforce. As outlined in Chapter 7, "Policy and Regulatory Pathways to Catalyze Geothermal in New Mexico," other incentives may be needed to help harness the potential of geothermal.

The future of New Mexico's geothermal landscape will be characterized by two contrasting groups of oil and gas and mining stakeholders: small, independent businesses with limited assets and larger companies with substantial resources. These groups face distinct challenges that hinder their expansion into geothermal activities.

BARRIERS TO STAKEHOLDER ENGAGEMENT

Large energy companies that could be leading the development face challenges such as the following:

- **Permitting complexity:** A lack of clear permitting processes discourages investment. Streamlining regulations and providing clearer guidance are critical steps to address this issue.
- **High up-front costs and risks:** Exploration and drilling require significant financial investment, posing substantial risks. State-backed loan guarantees, tax credits, or other financing mechanisms could attract developers and reduce financial obstacles. Repurposing existing infrastructure for geothermal use can also reduce costs and financial risk. Finally, pilot projects could help highlight the state's potential for other investors.
- **Land access issues:** Many promising geothermal resources are located on remote, Tribal, or federally controlled lands, distinct from areas with current and historical oil and gas development. Partnerships with federal agencies and infrastructure improvements are essential to unlocking these resources for potential exploration by stakeholders with the capital to finance such ventures.

Small businesses and independent operators face additional challenges:

- **Awareness:** Many small operators or independent service companies lack knowledge about New Mexico's geothermal potential and the economic benefits of diversifying their portfolio. Outreach programs can highlight geothermal benefits, high-paying job opportunities, and compatibility with existing skill sets in drilling and services.
- **Training and workforce development:** Specialized training programs that focus on the nuances of geothermal technologies can help small businesses repurpose their expertise for this sector.
- **Cost and risks:** Access to industry-standard data, software, analytical tools, and technologies is often cost-prohibitive, creating a significant barrier for new entrants and smaller organizations. Additionally, the financial and operational risks associated with diversifying into emerging sectors like geothermal energy are difficult for many small businesses to absorb.
- **Cultural and industry mindset:** A "business as usual" mentality within the traditional oil and gas sector hinders innovation. Advocacy campaigns that showcase successful geothermal projects and targeted engagement efforts can drive a cultural shift and inspire broader participation.

CHAPTER REFERENCES

1 Anderson, E. C. (1957). *The metal resources of New Mexico and their economic features through 1954*. Bulletin 39. State Bureau of Mines and Mineral Resources, New Mexico Institute of Mining & Technology. https://geoinfo.nmt.edu/publications/monographs/bulletins/downloads/39/Bulletin039_nc.pdf

2 Broadhead, R. (2017). *Memoir 50A: Energy and mineral resources of New Mexico: Petroleum geology*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/monographs/memoirs/50/A/

3 New Mexico Oil and Gas Association. (n.d.). *About us*. Retrieved December 3, 2024, from https://www.nmoga.org/about_us

4 U.S. Energy Information Administration. (2024, December 10). Five states drove record U.S. natural gas production in 2023. *Today in Energy*. https://www.eia.gov/todayinenergy/detail.php?id=63964

5 Brister, B. S., & Price, L. G. (Eds.). (2002). *New Mexico's energy, present and future: Policy, production, economics, and the environment*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/guides/decisionmakers/2002/dmfg2002_complete.pdf

6 New Mexico Oil and Gas Association. (n.d.). *About us*. Retrieved December 3, 2024, from https://www.nmoga.org/about_us

7 New Mexico Oil and Gas Association. (n.d.). *Drilling down on dollars: The role of oil and gas in New Mexico's budget*. Retrieved April 17, 2025, from https://www.nmoga.org/industry_impact

8 Fonquergne, J.-L., Bayle, S., Lopez-Ferber, M., Fraval, E., Bonnet, H., Chomet, K., & Frimpong, G. (2025). *New Mexico energy landscape: Overview and analysis 2025*. Petroleum Recovery Research Center and the New Mexico Initiatives at New Mexico Institute of Mining and Technology. https://nm-secm.org/new-mexico-energy-landscape-overview-and-analysis-2025

9 Fonquergne, J.-L., Bayle, S., Lopez-Ferber, M., Fraval, E., Bonnet, H., Chomet, K., & Frimpong, G. (2025). *New Mexico energy landscape: Overview and analysis 2025*. Petroleum Recovery Research Center and the New Mexico Initiatives at New Mexico Institute of Mining and Technology. https://nm-secm.org/new-mexico-energy-landscape-overview-and-analysis-2025

10 Fonquergne, J.-L., Bayle, S., Lopez-Ferber, M., Fraval, E., Bonnet, H., Chomet, K., & Frimpong, G. (2025). *New Mexico energy landscape: Overview and analysis 2025*. Petroleum Recovery Research Center and the New Mexico Initiatives at New Mexico Institute of Mining and Technology. https://nm-secm.org/new-mexico-energy-landscape-overview-and-analysis-2025

11 Kelley, S., & Solomon, T. (2023). *Developing New Mexico's geothermal heat and electricity*. New Mexico Legislature. https://www.nmlegis.gov/handouts/ALFC%20071823%20Item%2011%20-%20Geothermal%20Electricity.pdf

12 Beard, J. C., & Jones, B. A. (Eds.). (2023). The *future of geothermal in Texas: The coming century of growth and prosperity in the Lone Star State*. Project InnerSpace. https://energy.utexas.edu/research/geothermal-texas

13 GeoMap; https://geomap.projectinnerspace.org/map-selection/

14 MIT Center for Energy and Environmental Policy Research. (2022). *The Roosevelt Project: Accelerating an equitable clean energy transition in New Mexico*. Massachusetts Institute of Technology. https://ceepr.mit.edu/wp-content/uploads/2022/12/2022-The-Roosevelt-Project-New-Mexico-Case-Study.pdf

15 MIT Center for Energy and Environmental Policy Research. (2022). *The Roosevelt Project: Accelerating an equitable clean energy transition in New Mexico*. Massachusetts Institute of Technology. https://ceepr.mit.edu/wp-content/uploads/2022/12/2022-The-Roosevelt-Project-New-Mexico-Case-Study.pdf

16 MIT Center for Energy and Environmental Policy Research. (2022). The Roosevelt Project: Accelerating an equitable clean energy transition in New Mexico. Massachusetts Institute of Technology. https://ceepr.mit.edu/wp-content/uploads/2022/12/2022-The-Roosevelt-Project-New-Mexico-Case-Study.pdf

17 McLemore, V. T. (1996). Copper in New Mexico. *New Mexico Geology, 18(2)*, 25–36. https://doi.org/10.58799/nmg-v18n2.25

18 Bureau of Land Management. (n.d.). *Potash*. Retrieved April 17, 2025, from https://www.blm.gov/programs/energy-and-minerals/mining-and-minerals/nonenergy-leasable-materials/potash

19 New Mexico Energy, Minerals, and Natural Resources Department. (n.d.). *FAQ–Coal Mine Reclamation Program*. Retrieved April 17, 2025, from https://www.emnrd.nm.gov/mmd/coal-mine-reclamation-program/faq-coal-mine-reclamation-program/#:~:text=Over%2014%20million%20tons%20of,in%20New%20Mexico%20and%20Arizona

20 McLemore, V. T. (2020, January 27). *Uranium resources in New Mexico*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/resources/uranium/nmresources.html

21 McLemore, V. T. (2020, January 27). *Uranium resources in New Mexico*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/resources/uranium/nmresources.html

22 MIT Center for Energy and Environmental Policy Research. (2022). *The Roosevelt Project: Accelerating an equitable clean energy transition in New Mexico*. Massachusetts Institute of Technology. https://ceepr.mit.edu/wp-content/uploads/2022/12/2022-The-Roosevelt-Project-New-Mexico-Case-Study.pdf

23 Williams-Jones, A. E., Samson, I. M., & Olivo, G. R. (2000). The genesis of hydrothermal fluorite-REE deposits in the Gallinas Mountains, New Mexico. *Economic Geology, 95*(2), 327–341. https://doi.org/10.2113/gsecongeo.95.2.327

24 McLemore, V. T. (2015). Rare earth elements (REE) deposits in New Mexico: Update. *New Mexico Geology, 37(3), 59–69*.

25 Advanced Energy Economy. (n.d.). *Advanced Energy success stories*. https://info.aee.net/hubfs/California%20Hudson%20Ranch%20and%20Hells%20Kitchen.pdf?hsLang=en

26 NS Energy. (2024, August 14). *Hell's Kitchen Lithium and Power Project*, US. https://www.nsenergybusiness.com/projects/hells-kitchen-lithium-and-power-project-us/

27 Geothermal Technologies Office. (2013). *Low-temperature and co-produced resources*. U.S. Department of Energy. https://www1.eere.energy.gov/geothermal/pdfs/lowtemp_factsheet.pdf
28 Chevron. (2023, September 5). *Geothermal collab heats up renewable energy projects*. https://www.chevron.com/newsroom/2023/q3/geothermal-collab-heats-up-renewable-energy-projects
29 Devon Energy. (2023, April 18). *Fervo Energy announces investment from US oil and gas leader Devon Energy* [Press release]. https://www.devonenergy.com/news/2023/Fervo-Energy-Announces-Investment-From-US-Oil-and-Gas-Leader-Devon-Energy
30 German, B. (2024, March 19). *Exclusive: Exxon CEO says company is "keeping a very close eye" on geothermal*. Axios. https://www.axios.com/2024/03/19/exxon-mobil-woods-geothermal
31 Occidental Petroleum Corporation. (2024, June 4). *Occidental and BHE Renewables form joint venture to commercialize TerraLithium extraction technology* [Press release]. https://www.oxy.com/news/news-releases/occidental-and-bhe-renewables-form-joint-venture-to-commercialize-terralithium-extraction-technology/
32 Fervo Energy. (2023, July 18). *Fervo Energy announces technology breakthrough in next-generation geothermal* [Press release]. https://fervoenergy.com/fervo-energy-announces-technology-breakthrough-in-next-generation-geothermal/
33 Jacobs, T. (2024, February 5). Hot rock slurry: Developer of emerging geothermal tech readies for field tests. *Journal of Petroleum Technology*. https://jpt.spe.org/hot-rock-slurry-developer-of-emerging-geothermal-tech-readies-for-field-tests
34 Defense Innovation Unit. (2024, April 16). *Three additional next generation geothermal technology companies advancing DoD energy resilience* [Press release]. https://www.diu.mil/latest/three-additional-next-generation-geothermal-technology-companies-advancing
35 Sicard, S. (2022, August 15). How much land does the military really own? *Military Times*. https://www.militarytimes.com/off-duty/military-culture/2022/08/15/how-much-land-does-the-military-really-own/
36 Geothermal Technologies Office. (2013). *Low-temperature and co-produced resources*. U.S. Department of Energy. https://www1.eere.energy.gov/geothermal/pdfs/lowtemp_factsheet.pdf
37 Gradient Geothermal. (n.d.). *Gradient Geothermal*. Retrieved April 17, 2025, from https://www.gradientgeothermal.com/
38 Gradient Geothermal. (n.d.). *Gradient Geothermal*. Retrieved April 17, 2025, from https://www.gradientgeothermal.com/
39 TLS Geothermics. (n.d.). *TLS Geothermics*. Retrieved April 17, 2025, from https://www.tls-geothermics.com/
40 GeoML. (n.d.). *GeoML*. Retrieved April 17, 2025, from https://geo-ml.com/index.html
41 Baker Hughes. (2024, April 8). *Discovering geothermal ground truths through Wells2Watts*. https://www.bakerhughes.com/company/energy-forward/discovering-geothermal-ground-truths-through-wells2watts
42 Geothermal Energy from Oil and Gas Demonstrated Engineering (GEODE). (n.d.). *GEODE*. Retrieved April 17, 2025, from https://www.geode.energy/
43 Cariaga, C. (2024, March 19). *Teverra and Permian Basin research consortium partner for geothermal, advanced energy*. Think GeoEnergy. https://www.thinkgeoenergy.com/teverra-and-permian-basin-research-consortium-partner-for-geothermal-advanced-energy/
44 Tribal Energy Consortium. (n.d.). *Tribal Energy Consortium*. Retrieved April 17, 2025, from https://www.ndnenergy.org/
45 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges
46 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges

47 U.S. Department of Energy. (n.d.). *Wells of Opportunity*. https://www.energy.gov/eere/geothermal/wells-opportunity#:~:text=A%20key%20step%20to%20unlocking,of%20Opportunity%20(WOO)%20initiative

48 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges

49 Melaku, M. (2005, April 24–29). *Geothermal development at Lihir–An overview*. World Geothermal Congress, Antalya, Turkey.

50 Stanford University. (n.d.). *Stanford Temperature Model*. Retrieved April 17, 2025, from https://stm.stanford.edu/

51 Brister, B. S., & Price, L. G. (Eds.). (2002). *New Mexico's energy, present and future: Policy, production, economics, and the environment*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/guides/decisionmakers/2002/dmfg2002_complete.pdf

52 Brister, B. S., & Price, L. G. (Eds.). (2002). *New Mexico's energy, present and future: Policy, production, economics, and the environment*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/guides/decisionmakers/2002/dmfg2002_complete.pdf

53 Bennett, K. (2023, August). Permian embraces produced water recycling. *The American Oil & Gas Reporter*. https://www.aogr.com/magazine/frac-facts/permian-embraces-produced-water-recycling#:~:text=In%20general%2C%20Permian%20Basin%20wells,high%20as%2012%20to%20one

54 Witcher, J. C. (2006, summer). Geothermal energy in New Mexico. *New Mexico Earth Matters*. https://geoinfo.nmt.edu/publications/periodicals/earthmatters/6/n2/em_v6_n2.pdf

55 Broadhead, R. F. (1990). Oil and gas discovery wells drilled in New Mexico in 1989. *New Mexico Geology, 12*(4), 83–89. https://doi.org/10.58799/nmg-v12n4.83

56 U.S. Department of Energy. (n.d.). *Wells of Opportunity*. https://www.energy.gov/eere/geothermal/wells-opportunity#:~:text=A%20key%20step%20to%20unlocking,of%20Opportunity%20(WOO)%20initiative

57 Ramos, E. P., Breede, K., & Falcone, G. (2015). Geothermal heat recovery from abandoned mines: A systematic review of projects implemented worldwide and a methodology for screening new projects. *Environmental Earth Sciences, 73*, 6783–6795. https://link.springer.com/article/10.1007/s12665-015-4285-y

58 Ray, M. (2023, October 26). *Geothermal research at SURF takes leap forward with DOE Energy Earthshots initiative*. Stanford Underground Research Facility. https://sanfordlab.org/news/geothermal-research-surf-takes-leap-forward-doe-energy-earthshots-initiative

59 New Mexico Energy, Minerals and Natural Resources Department. (n.d.). *Award winning work*. https://www.emnrd.nm.gov/mmd/abandoned-mine-land-program/projects/award-winning-work/

60 Mining and Minerals Division. (2022). *Guidance for revegetation of Part 5 existing mines and Part 6 new mines*. New Mexico Energy, Minerals and Natural Resources Department. https://www.emnrd.nm.gov/mmd/wp-content/uploads/sites/5/2022-1219-MMD-MARP-Revegetation-Guidelines-FINAL.pdf

61 New Mexico Oil Conservation Division. (n.d.). *OCD Permitting – Inactive Wells*. New Mexico Energy, Minerals and Natural Resources Department. https://wwwapps.emnrd.nm.gov/OCD/OCDPermitting/Reporting/Compliance/InactiveWells.aspx

62 Fuge, D. (2023, December 1). *Orphan well plugging & site remediation update*. New Mexico Energy, Minerals, and Natural Resources Department. https://www.nmlegis.gov/handouts/RHMC%20120123%20Item%202%20EMNRD%20OCD%20-%20Orphan%20Well%20%26%20Financial%20Assurance.pdf

63 Higgins, B., Pratson, L., & Patiño-Echeverri, D. (2024). Techno-economic assessment of repurposing oil and gas wells for enhanced geothermal systems: A New Mexico, USA feasibility study. *Energy Conversion and Management: X*, *24*, 100811. https://doi.org/10.1016/j.ecmx.2024.100811

64 Brister, B. S., & Price, L. G. (Eds.). (2002). *New Mexico's energy, present and future: Policy, production, economics, and the environment*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/guides/decisionmakers/2002/dmfg2002_complete.pdf

65 Soltani, M., Kashkooli, F. M., Souri, M., Rafiei, B., Jabarifar, M., Gharali, K., & Nathwani, J. S. (2021). Environmental,

economic, and social impacts of geothermal energy systems. *Renewable and Sustainable Energy Reviews, 140*, 110750. https://doi.org/10.1016/j.rser.2021.110750

66 Calpine Corporation. (n.d.) *The Geysers: A very special place*. Retrieved April 17, 2025, from https://geysers.com/history11

67 Higgins, B., Pratson, L., & Patiño-Echeverri, D. (2024). Techno-economic assessment of repurposing oil and gas wells for enhanced geothermal systems: A New Mexico, USA feasibility study. *Energy Conversion and Management: X, 24*, 100811. https://doi.org/10.1016/j.ecmx.2024.100811

68 Raimi, D., Krupnick, A. J., Shah, J.-S., & Thompson, A. (2021). Decommissioning orphaned and abandoned oil and gas wells: New estimates and cost drivers. *Environmental Science & Technology, 55*(15), 10224–10230. https://doi.org/10.1021/acs.est.1c02234

69 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges

70 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges

71 Zolfagharroshan, M., Xu, M., Boutot, J., Zueter, A. F., Tareen, M. S. K., Kang, M., & Sasmito, A. P. (2024). Assessment of geothermal energy potential from abandoned oil and gas wells in Alberta, Canada. *Applied Energy, 375*, 124103. https://www.sciencedirect.com/science/article/pii/S0306261924014867?via%3Dihub

72 Koltzer, N., Schoenherr, J., Sporleder, M., Niederau, J., & Wellmann, F. (2024). Repurposing idle wells in the North German Basin as deep borehole heat exchangers. *Geothermal Energy*, 12, 35. https://link.springer.com/content/pdf/10.1186/s40517-024-00315-4.pdf?utm_source=chatgpt.com

73 Higgins, B., Pratson, L., & Patiño-Echeverri, D. (2024). Techno-economic assessment of repurposing oil and gas wells for enhanced geothermal systems: *A New Mexico, USA feasibility study. Energy Conversion and Management: X, 24*, 100811. https://doi.org/10.1016/j.ecmx.2024.100811

74 New Mexico Legislature. (2025) EMNRD Conversion of Certain Wells. https://www.nmlegis.gov/Legislation/Legislation?chamber=H&legtype=B&legno=361&year=25

75 Brister, B. S., & Price, L. G. (Eds.). (2002). *New Mexico's energy, present and future: Policy, production, economics, and the environment*. New Mexico Bureau of Geology and Mineral Resources. https://geoinfo.nmt.edu/publications/guides/decisionmakers/2002/dmfg2002_complete.pdf

76 International Energy Agency. (2023). *The future of geothermal energy*. https://iea.blob.core.windows.net/assets/b5b73936-ee21-4e38-843b-8ba7430fbe92/TheFutureofGeothermal.pdf#page=68

77 Beard, J. C., & Jones, B. A. (Eds.). (2023). *The future of geothermal in Texas*. Project InnerSpace. https://energy.utexas.edu/research/geothermal-texas

78 Sullivan Graham, E. J., Jakle, A. C., & Martin, F. D. (2015). Reuse of oil and gas produced water in southeastern New Mexico: Resource assessment, treatment processes, and policy. *Water International, 40*(5–6), 809–823. https://doi.org/10.1080/02508060.2015.1096126

79 New Mexico Environment Department Eastern Research Group, Inc. (2024). *New Mexico strategic water supply feasibility study*. New Mexico Environment Department. https://www.env.nm.gov/wp-content/uploads/2024/11/NMED-Revised-Draft-Feasibility-Study-112224.pdf

80 New Mexico Environment Department Eastern Research Group, Inc. (2024). *New Mexico strategic water supply feasibility study*. New Mexico Environment Department. https://www.env.nm.gov/wp-content/uploads/2024/11/NMED-Revised-Draft-Feasibility-Study-112224.pdf

81 Sullivan Graham, E. J., Jakle, A. C., & Martin, F. D. (2015). Reuse of oil and gas produced water in southeastern New Mexico: Resource assessment, treatment processes, and policy. *Water International, 40*(5–6), 809–823. https://doi.org/10.1080/02508060.2015.1096126

82 New Mexico Energy, Minerals and Natural Resources Department. (n.d.). Geothermal Resources Development Act–Sections 71-9-1 to 71-9-11 NMSA 1978. Retrieved April 17, 2025, from https://www.emnrd.nm.gov/ecmd/wp-content/uploads/sites/3/GeothermalResourcesDevelopmentAct.pdf

83 Doran, M. (2024, May). Quarterly census of employment and wages, fourth quarter 2023. *Labor Market Review*. https://www.dws.state.nm.us/Portals/0/DM/LMI/QCEW_4thqtr_2023.pdf

84 Doran, M. (2024, May). Quarterly census of employment and wages, fourth quarter 2023. *Labor Market Review*. https://www.dws.state.nm.us/Portals/0/DM/LMI/QCEW_4thqtr_2023.pdf

85 U.S. Energy Information Administration. (2024, June 20). *New Mexico state profile and energy estimates: Profile analysis*. https://www.eia.gov/state/analysis.php?sid=NM#:~:text=Renewable%20energy%20is%20the%20largest,34%25%20of%20the%20state's%20generation

86 Doran, M. (2024, May). Quarterly census of employment and wages, fourth quarter 2023. Labor Market Review. https://www.dws.state.nm.us/Portals/0/DM/LMI/QCEW_4thqtr_2023.pdf

87 Project InnerSpace. (n.d.). GeoMap. Retrieved April 18, 2025, from https://geomap.projectinnerspace.org/geomap/

88 DiGangi, D. (2024, October 21). *Interior approves 2-GW Fervo Energy geothermal project in Utah*. Utility Dive. https://www.utilitydive.com/news/interior-geothermal-fervo-energy-categorical-exclusion-nepa/730413/

89 Kelley, S., & Solomon, T. (2023). *Developing New Mexico's geothermal heat and electricity. New Mexico Legislature*. https://www.nmlegis.gov/handouts/ALFC%20071823%20Item%2011%20-%20Geothermal%20Electricity.pdf

90 Jennejohn, D. (2010). *Green jobs through geothermal energy*. Geothermal Energy Association. https://geothermal.org/sites/default/files/2021-02/Green_Jobs_Through_Geothermal_Energy.pdf

91 Matek, B., & Gawell, K. (2014). *The economic costs and benefits of geothermal power.* Geothermal Energy Association. https://geothermal.org/sites/default/files/2021-02/Economic_Cost_and%20Benefits_0.pdf

92 Hanna, R., Heptonstall, P., & Gross, R. (2024). Job creation in a low carbon transition to renewables and energy efficiency: A review of international evidence. *Sustainability Science, 19*(1), 125–150. https://doi.org/10.1007/s11625-023-01440-y

93 Research and Analysis Bureau. (n.d.). *Nevada labor market information: Quarterly census of employment and wages (QCEW)*. State of Nevada Department of Employment, Training & Rehabilitation. Retrieved April 18, 2025, from https://nevadaworkforce.com/QCEW/index

94 Fendt, L. (2022, December 14). *The push for a greener New Mexico–from immigrant oil workers*. Searchlight New Mexico. https://searchlightnm.org/the-push-for-a-greener-new-mexico-from-immigrant-oil-workers/

95 Faturos, A., Bodor, G., Proe, L., & Lathrop, S. (2021). Occupational mortality in the New Mexico oil and gas industry. *Journal of Forensic Sciences, 66*(6), 2283–2288. https://doi.org/10.1111/1556-4029.14831

96 New Mexico Jobs. (n.d.). *New Mexico jobs*. https://www.jobs.state.nm.us/vosnet/Default.aspx?plang=

97 Higgins, B., Pratson, L., & Patiño-Echeverri, D. (2024). Techno-economic assessment of repurposing oil and gas wells for enhanced geothermal systems: A New Mexico, USA feasibility study. *Energy Conversion and Management: X, 24*, 100811. https://doi.org/10.1016/j.ecmx.2024.100811

98 Smith, M. (2023). *Oil and gas technology and geothermal energy development*. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R47405#:~:text=The%20geothermal%20power%20and%20O&G,faces%20a%20number%20of%20challenges

99 New Mexico Energy, Minerals and Natural Resources Department. (n.d.). *Sustainable education for advanced buildings (SEAB)-Energy Conservation Code Training for professionals.* Retrieved April 18, 2025, from https://www.emnrd.nm.gov/ecmd/seab/

100 New Mexico Tech. (n.d.). *Geothermal energy certificate*. Retrieved April 18, 2025, from https://www.nmt.edu/academics/petreng/Geothermal.php