ACTOR NETWORK THEORY APPLICATIONS TO UNITED STATES GEOTHERMAL DEVELOPMENT: PARALLELS FROM THE 1970'S-1980'S TO PRESENT

A Research Paper submitted to the Department of Engineering and Society
Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

By

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April 27, 2023

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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MOTIVATIONS FOR LITHIUM EXTRACTION FROM GEOTHERMAL BRINE

Rapid clean energy scale-up will generate increased demand for critical minerals; thus, new and diverse supply sources are necessary to counter supply strains (International Energy Agency, 2022, p. 14). These strains arise particularly from rapid scaling problems (Olivetti et. al, 2017, p. 229), high geographic reserve location and refining capability concentration (Sun et. al, 2021, p. 12180), mining asset exposure to climate risk (Delevingne et. al, 2020, pp. 2-5), and long project development time (International Energy Agency, 2022, p. 12). Lithium is classified as a critical mineral “hav[ing] a supply chain that is vulnerable to disruption and serv[ing] an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States” (United States Geological Survey, 2022, p. 17). Current and pending mine projects have supply capability covering only half of projected 2030 lithium needs, and “are not ready to support accelerated energy transitions” (International Energy Agency, 2022, p. 11). It is thus in the vested economic and security interests of the United States to jointly propel lithium extraction research and extraction process impact assessment (Hailes, 2022; Parker et. al, 2022).

Primary lithium extraction pathways currently include extraction from hard rock pegmatites, extraction from sedimentary rock such as clays, or evaporation from arid basin brines (Blair et. al, 2022, p. 4). Arid basin brine lithium sourcing faces particular criticism for its heavy water requirements within the internationally recognized wetlands of Chile, Argentina, and Bolivia; its ecological disruption to migratory and native species; and its exploitation of indigenous and local people's land (Blair et. al, 2022, p. 4). Research interest in mineral extraction from underground geothermal reservoirs has persisted since the 1970’s (Hoffmann, 1975, pp. 4-9), but only recently has it evolved into an economically and technically viable scheme (Warren, 2021).

Geothermal brines at high temperatures–on the order of 200-300°C–and high pressures–on the order of 20,000 psig–can dissolve underground minerals present in specific geological regions (Ventura et. al, 2020, p. 5). Engineering advancements saw electricity production from the geothermal fluid heat beginning in the 1960s (McNitt, 1960); however, both mineral extraction and power generation have historically been hindered by severe mineral precipitation and equipment corrosion owing to low brine pH (Burr, 2000, p. 1; Hoffmann, 1975, pp. 9-13). In 1976, there were 52 geothermal wells and 13 deep observation holes drilled between California, Idaho, Nevada, Oregon, and Utah, a 27% increase in total drilled locations from 1975. By 1977, 75% were successful in producing commercial steam, 8 were suspended, and 5 were abandoned (Smith et. al, 1977, p. 256). A comprehensive authority on geothermal technology is available in *Proceedings: Second United Nations symposium on the development and use of geothermal resources*, volumes 1-3 (1975).

Today, most licensed private companies producing geothermally sourced electricity reinject the lithium-rich liquid into the underground reservoirs it came from without extracting the lithium; thus, extractive units could be added to existing infrastructure (*Imperial Valley Geothermal Area*). Figure 1 on page 3 depicts a simplified direct lithium extraction process attached to a geothermal power plant. Evolving research aims to extract target critical minerals before stream reinjection back into their source geothermal reservoirs (Warren, 2021).

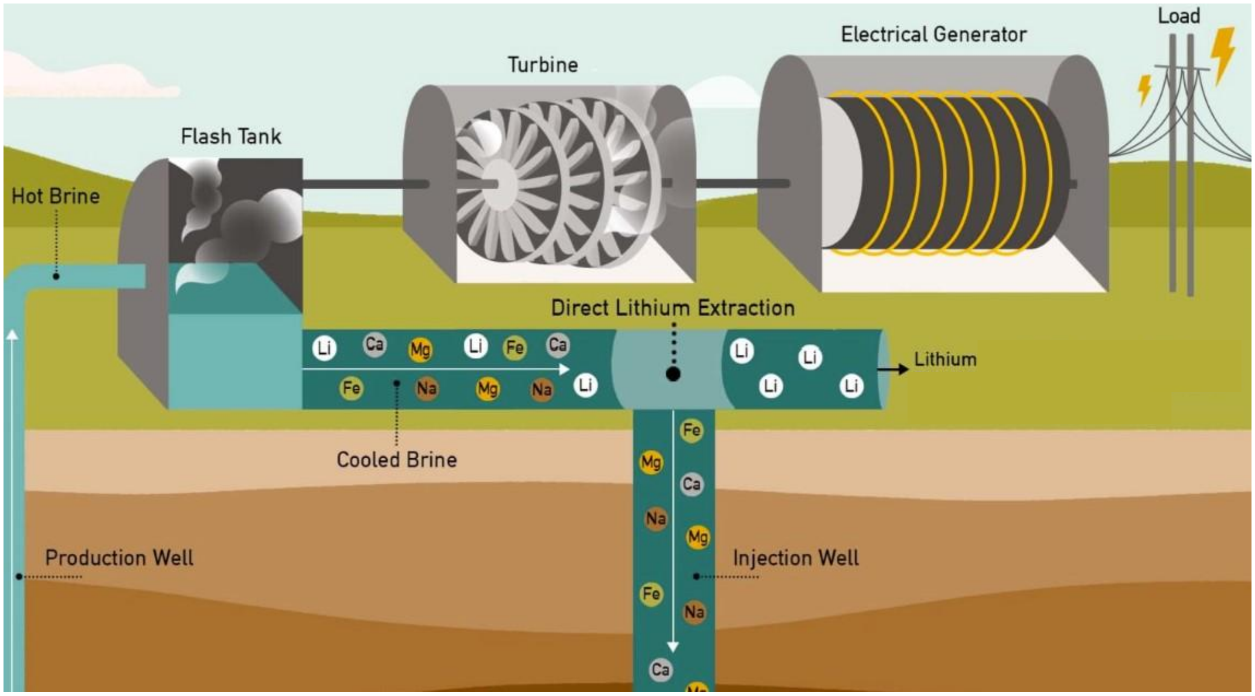

Figure 1: Simplified Direct Lithium Extraction Scheme Attached to Geothermal Power Plant. This figure shows a simplified lithium extraction and electricity generation process from geothermal brine. Hot geothermal brine from an underground source flows to processing units. Steam from the hot brine generates electricity through a turbine and generator. Lithium in the liquid brine phase is separated from other minerals. (Adapted by Madaline Marland (2023) from Jenny Nuss 2021).

University of Virginia professors Gary Koenig, Geoffrey Geise, and Gaurav Giri from the chemical engineering department comprise a team for Targeted Extraction of Lithium with Electroactive Particles for Recovery Technology (TELEPORT). The technical group including Bhargava, Curran, Marland, and Sawyer, in partnership with sorbent research conducted through Project TELEPORT, designed a unit operations scheme utilizing the novel sorbent material. The designed process can produce lithium hydroxide monohydrate ($LiOH \cdot H_2O$) with a purity of 99% (battery-grade) and an overall recovery of 90%, and was designed for addition to existing geothermal power plants.

The overall process design, Figure 2 on page 4, consists of 4 main process blocks: additives mixing, a packed bed reactor network, electrolyzers, and a crystallization unit to achieve the final lithium hydroxide monohydrate product ($LiOH \cdot H_2O$). The additives mixing unit sees the addition of tripotassium citrate monohydrate ($K_3(C_6H_5O_7) \cdot H_2O$), to lower the brine reduction potential such that adsorption in the packed bed reactors is favorable, and ferric chloride ($FeCl_2$), to allow for maximum lithium uptake. In the packed bed reactor network, Iron (III) Phosphate ($FePO_4$) is used to extract lithium (Li^+) using consecutive adsorption and desorption steps. In the electrolyzers, stripped lithium chloride (LiCl) is converted to lithium hydroxide (LiOH) before crystallization into the final lithium hydroxide monohydrate product ($LiOH \cdot H_2O$).

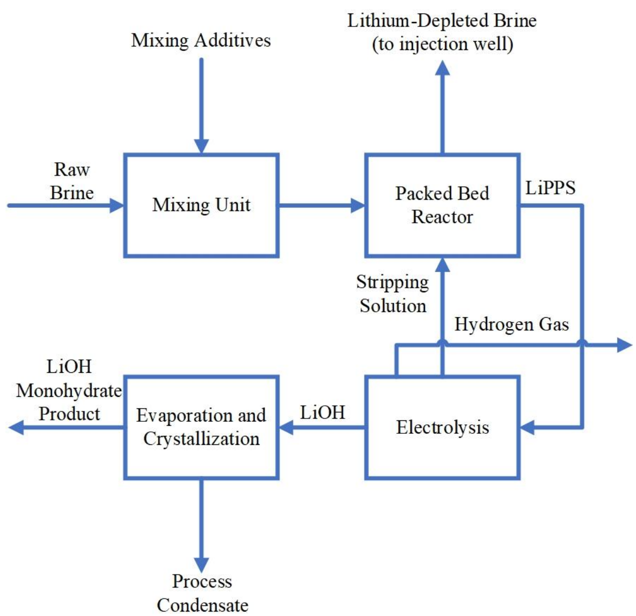

Figure 2: General Block Flow Diagram of Lithium Extraction and Purification. The above figure shows an overview of the designed process for lithium extraction from geothermal brines. The process takes geothermal brine after silica removal pre-treatment and produces battery grade lithium hydroxide monohydrate. (Marland, 2023).

Geochemical data focused on well sites in the Salton Sea Known Geothermal Resource Area (KGRA) of California (*Imperial Valley Geothermal Area*) in accordance with Project

TELEPORT guidelines. Professor Eric Anderson, Department of Chemical Engineering, provided additional advisement.

Classification of geothermal resource ownership and jurisdiction is legally complicated. Lands containing geothermal resources can be divided between a surface and a mineral estate. Legal disputes often trace estate lease agreements back decades, in some cases to the late 1950s and early 1960s when geothermal exploitation in the American West began (Kennecott Corp. v. Union Oil Co., 1987). Geothermal resource water rights remain undecided between estate parties and are often reliant on the phase and source of geothermal water present or if the resource is located on federal, state, or private land (Silver & Comeau, 1979, p. 446). 1977 analysis by NASA's Jet Propulsion Laboratory writes:

> [Geothermal development] requires an interrelationship among explorer, developer, and user that has not previously been required. This requirement emerges not only because of technical factors in extraction and use but also because of an increasing awareness by local governments and private citizens of the consequences of major development activities [...] As is becoming typical in our country, industry, government, and concerned citizens square off in an advocacy proceeding with their own experts who attempt to discredit either the research tool, the procedure, or the interpretation of the results. There should be no expectation that geothermal energy development will foster a different environment. (Citron, 1977, p. 38-39)

Increasing competition and marketability for mineral extraction process knowledge, geochemical data, and mineral technologies disincentivizes collaboration between actors within a complicated geo-political and technical regulatory space (Williams, 2022).

The following STS work will apply an Actor Network Theory (ANT) framework (Latour, 1991; Latour, 1992; Callon, 1986; Law, 1986) to study changes in American mineral property management, land management policy, and natural resource law from the 1970's to the 1980s. By grouping specific organizations into three categories of macro-actors–federal, state, and private–larger socio-political trends may be observed than by relational study between individual actors, Figure 3 on page 6. These macro-actor categories exist as a function of actor organizational structure but more broadly, exist as a function of motivational and framing similarity. The following STS work is completed to elucidate framing and power dynamic shifts among American technical and political mineral interests. Parallels between 1970s developmental motivations and present developmental motivations may thus inform future geothermal project framing. The chosen STS topic is tightly coupled to the technical topic in that both focus on a specific sub-industry but differ in the applied lens.

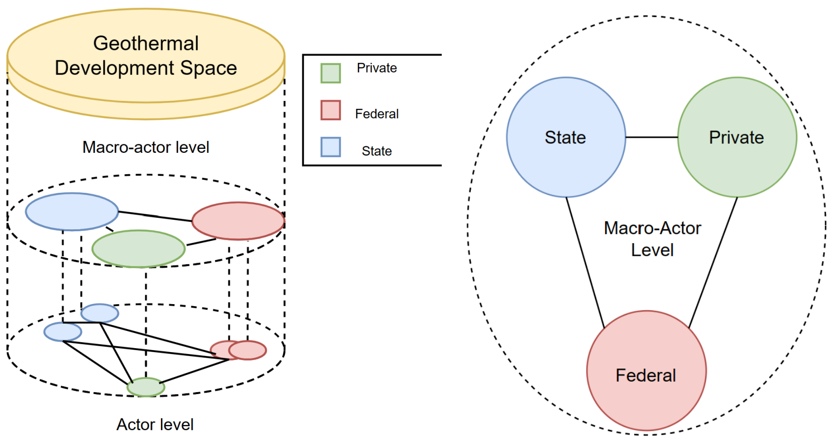

Figure 3: Actor Network Theory Applications to the Geothermal Development Space. The above figure visualizes multiple levels of actors within the geothermal development space. On the left schematic, the actor level corresponds to organizations, companies, and agencies and the macro-actor level categorizes these actors as federal, state, or private. On the right schematic, an overhead view of the macro-actor level shows federal, private, and state macro-actors with circle spacing representing framing proximity. In the early geothermal resource development era, state and private actors shared common framing in the absence of federal involvement (Marland, 2023).

EXAMINING SHIFTING POWER DYNAMICS BETWEEN FEDERAL, STATE, AND PRIVATE ACTORS THROUGH CHRONOLOGICAL CASE STUDY

Early geothermal mineral projects within the United States were predominantly centered in the Western states and on privately owned lands: in California particularly, but also Nevada, Oregon, Idaho, Wyoming, Montana, and Alaska, and secondarily Utah, New Mexico, and Colorado (Brooks, 1966, p. 521; Koenig, 1970, pp. 1-2). McNitt details geothermal development in California from 1955 to 1962 (1963). Geothermal energy development occurred almost exclusively on privately owned lands (Sullivan et. al, 1974, p. 4) because the statutory framework for geothermal exploration on federally owned land was insufficient. George Cameron Coggins, University of Kansas law professor and author of the seminal *Federal Public Land and Resources Law*, wrote:

> [In 1960] state law and professional discretion provided the answers to many legal questions: federal law was absent or indistinct; most land agencies had traditions emphasizing independent managerial judgment [...] Federal land management in 1960 had little relationship to federal law [...] The extent of change between 1960 and 1980 could not have been anticipated. (1981, p. 475)

Several prior works including those by Randall (1964), Brooks (1966, pp. 521-524), and Bjorge (1974, pp. 5-6) further review of federal geothermal resource management policy basis before 1970. Before the implementation of federal law allowing leasing of federal land in 1974, 90% of the leased land in the Imperial Valley Known Geothermal Resource Area (KGRA) of California was privately owned (Sullivan et. al, 1974, p. 4), and 75% of that was leased by just four companies: Standard Oil of California, Union Oil Company, Southern Pacific Land Company, and the two Magma subsidiaries (Sullivan et. al, 1974, p. 10).

In the absence of federal influence, state and private actors acted independently from federal interests in framing early geothermal project development procedural structure.

California, the first state to see geothermal resource development, passed the Geothermal Resource Act of 1967; other Western states subsequently passed similar legislation (Bloomquist, 2003, p. 53). Geothermal leases between 1960 and 1970 stabilized from their origin in oil and natural gas lease language to a distinct form with shocking homogeneity between private actors (Sullivan, 1974, p. 32). Sullivan writes:

> Such similarity appears to derive from the fact that the interests of the potential developers are so uniform --- given the nature of the industry and that of the resource --- that the document language used to secure and protect these interests was bound to become rather identical as time and experience affected the leasing process. (1974, p. 33)

Geothermal leasing language homogeneity among private actors demonstrates their framing similarity as a macro-actor grouping despite competition between individual actors.

1970'S: FEDERAL GEOTHERMAL RESOURCE MANAGEMENT AUTHORITY EXPANDS

Beginning in the 87th Congress with S.3075, the federal government sought to provide a statutory framework for geothermal steam and mineral exploration on public lands. Legislation in the 89th Congress, S.1674 and H.R.7334, was passed by Congress but failed by presidential veto (112 Cong. Rec. 28863, 1966). The bills would have authorized the Secretary of Interior to lease federal and public land for geothermal steam and associated mineral exploration similar to provisions for oil and gas under the Mineral Leasing Act (Disposition of Geothermal Steam, 1966). President Lyndon Johnson's veto wrote the bill opposed "prudence and reason" in allowing unfair grandfather rights, that the holders of mineral leases would automatically become entitled to geothermal leases; allowing for land leases large enough for a single developer to monopolize the geothermal rights of an entire state; allowing for royalties to be paid only for steam sold or utilized, thus encouraging steam waste; failing to provide a clear structure for government lease renegotiation; allowing for perpetual leases if geothermal steam is produced commercially; and allowing 20 years of development time for projects to begin production (112 Cong. Rec. 28863, 1966).

Though the President directed a new bill that accounted for the "pitfalls" of the prior version to be passed in the next year, it was not until four years later that legislation was ultimately passed. The accompanying House Committee on Interior and Insular Affairs report to S.368, which eventually became the Geothermal Steam Act of 1970, writes, "One reason for the lack of development of geothermal steam potential of the United States can be directly attributed to the absence of reliable statutory authority to permit its development on public lands" (H.R. Rep No. 91-1544 at 4, 1970). That federal regulatory framework took years to establish demonstrates framing competition between actors operating within the federal macro-actor group; consequently, geothermal development progress was slowed.

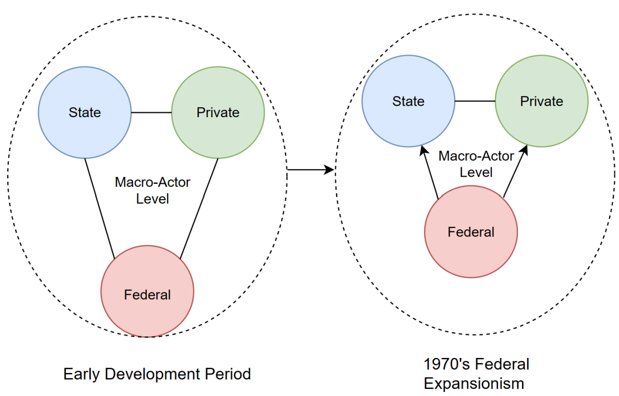

Figure 4. Shifts in Federal Macro-Actor Behavior. This figure shows changes from the early geothermal development period, in which state and private actors had similar framing in the absence of federal regulation, to the 1970s, when the federal government began to pass geothermal development regulations. The arrows indicate exertion from the federal government on state and private problem framing (Marland, 2023).

1970: Federal Geothermal Steam Act of 1970 and Increasing Political Motivation for Geothermal Development

It was not until the Geothermal Steam Act of 1970, 30 U. S. C. § 1001 *et seq*, that the Secretary of Interior was authorized to lease public and federal lands. Its inaccurate name contributes to legal imprecision today as the law encompasses both geothermal *minerals* and steam regulation. The act defines geothermal resources to include:

> i. all products of geothermal processes, embracing indigenous steam, hot water, and hot brines
>
> ii. steam and other gases, hot water and brines resulting from water, gas, or other fluids artificially introduced into geothermal formations
>
> iii. heat or other associated energy found in geothermal formations
>
> iv. any byproduct derived from them

As the legal definition of "geothermal resource" includes hot water and steam, the Geothermal Steam Act prompts dispute with state water laws if the geothermal water is supplied by state-owned groundwater tributaries (Silver & Comeau, 1979, p. 446). The Geothermal Steam Act of 1970 thus demonstrates growing federal dominion over geothermal resource management without internal federal coordination or coordination with state powers.

30 U.S.C. § 1020(b), provides:

> Geothermal resources in lands the surface of which has passed from Federal ownership but in which the minerals have been reserved to the United States shall not be developed or produced except under geothermal leases made pursuant to this chapter. If the Secretary of the Interior finds that such development is imminent, or that production from a well heretofore drilled on such lands is imminent, he shall so report to the Attorney General, and the Attorney General is authorized and directed to institute an appropriate proceeding in the United States district court of the district in which such lands are located, to quiet the title of the United States in such resources, and if the court determines that the reservation of

> minerals to the United States in the lands involved included the geothermal resources, to enjoin their production [...] (Section § 21(b))

Coal and mineral estates on patented lands were entitled to the federal government under the Stock-Raising Homestead Act. The House Committee on Interior and Insular Affairs failed to resolve ambiguity as to whether the Geothermal Steam Act entitled the federal government to geothermal resources under patented lands (Brojge, 1974, pg. 9). The Geothermal Steam Act relied on the courts to decide if "the reservation of minerals to the United States in the lands involved [include] the geothermal resources". This legal ambiguity became the driving force for the later landmark case United States vs. Union Oil Company (1977), though the case itself still did not ultimately provide a precise legal definition for geothermal resources.

1971-1973: Increased Political Motivation for Geothermal Development

Political motivation for achieving energy independence increased further within American national politics following the 1973 global oil crisis (*Oil Embargo, 1973–1974*). Energy imperialism cultivated a pervasive attitude that the United States was entitled to the vast mineral reserves within its borders (Outer Continental Shelf Lands Act Amendment, 1978) and that movement toward exploitation was unjustifiably slow (Gedicks, 1977). In 1975, a partnership between the National Science Foundation, acting under its Research Applied to National Needs (RANN) program, and the University of Southern California Law Center began to investigate legal structures surrounding geothermal brine extraction to address "a situation where capital [...] is not likely to be ventured adequately so long as the law leaves unsettled, or perhaps settles unsatisfactorily, many key questions" (Stone et al., 1975, p. 1).

Hoffmann of the California Institute of Technology Environmental Quality Laboratory wrote in 1975 "much of the current research effort may simply be a duplication of research already completed but not disseminated" (p. 13) and emphasizes that "valuable engineering and physical chemistry data remains in closed files" (p. 15). As natural resource law emerged as a distinct branch of legal study, pedagogical natural resource casebooks of this time mirrored the lack of federal regulatory structure in devoting much of their text to the acquisition of private resource rights on public lands (Blumm & Decker, 2006, p. 15).

1977: United States v. Union Oil Company

Union Oil Company of California was producing geothermal steam and associated geothermal resources through a land lease from parties originally granted land patent under the Stock-Raising Homestead Act. The United States Attorney General sought to test ambiguity within Section § 21(b) of the Geothermal Steam Act in bringing a quiet title action to reclaim ownership of the produced geothermal steam and resources (Bjorge, 1974, p. 9) . The United States District Court for the Northern District of California sided in favor of Union Oil Company before the decision was reversed by the United States Court of Appeals for the Ninth Circuit. The upper court held that the Geothermal Steam Act (Geothermal Steam Act, 1970) did not reserve Union Oil Company the geothermal resources beneath patented lands issued under the Stock-Raising Homestead Act of 1916.

A thorough legal refute of the upper court's decision is available by Bjorge (1974). Commentary in the subsequent Geothermal Kinetics Inc., v. Union Oil Company decision by the Court of Appeal of California, First Appellate District, Division Three states, "the basis for the holding is partly the Congressional intent to retain government control over energy resources" (p. 5). United States v. Union Oil Company demonstrates tension between federal, state, and private macro-actors in which the federal level exerted power over private and state macro-actors.

1977: Geothermal Kinetics Inc., v. Union Oil Company

The matter of geothermal resources belonging to the surface estate or mineral estate was determined in favor of the mineral estate in Geothermal Kinetics v. Union Oil Company, 1977. This decision is distinct from the prior United States v. Union Oil Company which decided geothermal resources were not included in the mineral estate because the land was under federal patent. Geothermal Kinetics Inc., v. Union Oil Company demonstrates tension between private actors and grants greater authority to the owner or lessee of the mineral estate than the surface estate.

A 1979 publication reviewing legal issues related to Texas geothermal resource development wrote, "The question of rights to and ownership of a geothermal resource is not certain. The courts of Texas have not directly addressed the question of whether a geothermal resource belongs to the surface estate or to the mineral estate" (RPC Inc., 1979, p. 1) and concluded "Lawsuits can be expected either before or shortly after the first commercial development of geopressured geothermal resources" (p. 1). That this publication was written two years after the 1977 *Geothermal Kinetics* decision with Department of Energy grant support highlights the era's level of discordance between federal and state actors. Bloomquist (1986) wrote of the time:

> The legal and institutional framework developed by the states and the federal government often differed substantially in format, content, and direction. Too often the legal and institutional framework established left as many questions unanswered as answered, and in some cases, the framework has proven to be more of an obstacle to development than an aid. (p. 88)

Bloomquist provides a further review of state-level geothermal resource management laws passed from the 1970s to early 1980s (1986, pp. 89-91).

1980s: RAMPANT PRIVATE SPECULATION AND STATE LEVEL PUSHBACK TO FEDERAL EXPANSIONISM

The 1980s marked a shift in macro-actor relations surrounding geothermal project development. The Sagebrush Rebellion, emerging in 1979 with a Nevada law claiming "unappropriated" federally controlled land within the state, was a movement by Western states to curtail federal land management expansionism and return land control to private or state actors (Leshy, 1980, p. 317).

1987: Kennecott Corp v. Union Oil Company

The legal embroilment of Kennecott Corporation versus Union Oil Company represents private venture speculative collapse of geothermal operations as an early-stage technology. The following timeline summarizes the opinion of the Court of Appeal of California, Fourth Appellate District.

The Imperial Irrigation District (IID), a public water utility, owned land in the Salton Sea Known Geothermal Resource Area (KGRA) of California. In 1961, the IID leased 280 acres to individuals comprising the O'Neill Group "for drilling, extracting, and processing all steam and thermal energy" and associated mineral elements. The O'Neill Group, as lessee, was entitled to quitclaim upon payment of $100 and terminate all business relations *excepting accumulated damages and outstanding payments*. The O'Neill Group and Shell Oil Company then conducted geothermal operations on the land and disposed of waste residues via brine ponds. Hazardous materials resulting from geothermal operations were meant to be stored in these brine ponds; thus, preventing flow into the Salton Sea.

In 1966, the O'Neill Group transferred its entire leasehold interest to Imperial Thermal Products (ITP), which operated the existing well operations until 1972. In 1972, ITP leased its interests to Southern Pacific Land Company (Southern) entitling Southern as lessee upon 60 days notice to the IID and ITP to quitclaim and *surrender Southern of all obligations to ITP*. In 1973, Southern leased ⅓ of its interests to Mono Power Company (Mono) entitling Mono to quitclaim and be *relieved of all obligations* upon 90 days notice. Southern also at this time leased another ⅓ interest to Phillips Petroleum Company (Phillips).

In 1976, the California Regional Water Quality Control Board (CRWQCB) found ITP in violation of waste disposal regulations and ordered brine pond maintenance such that waste residues would not leak into the Salton Sea, or relocation of the existing brine ponds to approved locations. ITP, Southern, Mono, and Phillips equally shared the cost of this maintenance. In December 1976, Phillips surrendered its ⅓ total interest, assigning half to Southern and half to ITP. In 1978, Union Oil Company (Union) became the designated operator of the leased land with 50% interest; Mono and Southern each had 25% interest. In 1980, ITP sold to Black Bear Mining Company all of its lessee interests; however, in the sale, ITP *indemnified Black Bear Mining Company of any brine pond liability*.

Opinion by Judge J. Butler states, "In May of 1981, the pot began to boil". The CRWQCB submitted a proposed order finding ITP, Union, Southern, and Mono as responsible for the hazardous waste generation and prohibiting further pond usage based on evidenced Salton Sea contamination. Union, acting on behalf of itself, Mono, and Southern, surrendered its interests the following day to avoid brine pond cleanup liability. On June 9th, 1981, ITP responded to the notice of surrender by declaring it invalid. On June 17th, 1981, Union appealed to the CRWQCB to release the ITP lessees of brine cleanup liability. ITP responded that the CRWQCB had no jurisdiction to decide the bearers of waste disposal cost. On July 13th, 1981, Union, Mono, and Southern surrendered their land interests per the 60 day notice lease terms. On August 6th, 1981, ITP issued notice to Union that the surrender was ineffective and that Union, Southern, and Mono were responsible for brine cleanup. ITP assigned to Bear Creek all of its lease interests; Bear Creek merged with Kennecott in 1982.

ITP only stood to benefit from the California Water Quality Control Board lacking the jurisdiction to hold it accountable for proper waste management; however, under a macro-actor lens, the action demonstrates pushback from private actors to governmental oversight. ITP had been engaging in geothermal operations in the area since at least 1963 (Palmer et. al, 1975, p. 28), before the passage of the California Geothermal Resource Act in 1967 and the federal Geothermal Steam Act of 1970. Early development within the region occurred before regulatory framework establishment; thus, lease terms were "constrained only by the laws of contract" and "the parties of the leases [...] set the tenor of the legal environment within which development [occurred]" (Sullivan et. al, 1974, pg. 4).

In April 1983, ITP filed for declaratory relief with the United States District Court for the Central District of California for Union, Southern, and Mono to be held wholly or partially responsible for brine pond cleanup. On May 25, 1984, the court held ITP solely responsible for brine cleanup. Union, realizing it was not liable to cleanup expenses, then asserted to the State Lands Commission that ITP's rejection of lease surrender meant Union still held interest. The 1972 lease agreement from ITP to Southern stated that ITP retained mineral rights and as the brine pond waste resulted from mineral development, Union and lessees could retain lease interest without cleanup liability. Kennecott, previously ITP, filed to quiet title and declare Union, Southern, and Mono free from any interest on the land. The court sided with Kennecott in quieting the title, denying Union, Southern, and Mono any reasserted interest.

The speculative collapse of Imperial Valley geothermal lease participation demonstrates the fragility of geothermal operations in the 1980's during which exploration was still in an early technological stage. Analysis of geothermal lease patterns in the Imperial Valley from 1958 to 1972 found:

> In a large number of cases the lessee has never taken possession of the land despite leases which have been in effect for up to 10 years. The lease document has served, then, in certain cases as a means of gaining competitive position --- and denying that position to other companies --- for possible future development. (Sullivan et. al, 1974, p. 4)

An important and common feature of geothermal leases was a rental fee provision in which lessees, in failing to begin geothermal resource production within their allotted development period, could pay a nominal rental fee to their lessers to extend their lease term, renewable indefinitely (Root, 1976, p. 665; Sullivan, 1974, p. 5). This allowed highly speculative activity in which lessees to secure lands "for which they have neither the capital nor the intent for actual production" (Sullivan et. al, 1974, p. 6) and allow speculators to "secure the rights to certain properties and, at a future time, assign the lease at a profit to another firm which is capable or desirous of reaching a productive stage on that land" (Sullivan et. al, 1974, p. 6) or wait until development was deemed profitable. Of the 584 publicly available geothermal leases for the Imperial Valley between 1958 and 1972, only 4.4% requested drilling permits (Sullivan et. al, 1974, p. 7).

That Union, Southern, and Mono wanted to reassert lease interest during a legal conflict with their lessor, ITP, indicates similar motivations between the organizations despite their competition: motivated by the same drive for profit, psychological pressures to retain business holdings in the area, or some combination, actors within a single macro-actor category vied dominance over another.

PARALLELS TO CURRENT GEOTHERMAL DEVELOPMENT AND FUTURE TAKEAWAYS

In the early development period, state and private actors developed framing independent of federal actors in the absence of federal regulatory structure. In the 1970s, increasing federal dominion in natural resource and land management led to discontinuities between state and federal policy. In the 1980s, federal expansionism exerted sufficient force on state and private framing such that state and private actors began to resist federal expansionism. The 1980's also marked rampant private speculation which capitalized on discordance in geothermal leasing regulations.

White et. al in a post-audit of geothermal development in Imperial County, California writes, "Interestingly, just as the Energy Crisis spurred interest in geothermal energy development in the mid-1970s, concern over a potential climate change crisis has spurred renewed interest in action now" (2014, p. 187). This is reflected in the Geothermal Technologies Program Annual Budget, which beginning in the 2010s began to mirror funding patterns from the 1970s and 1980s, Figure 5 on page 19.

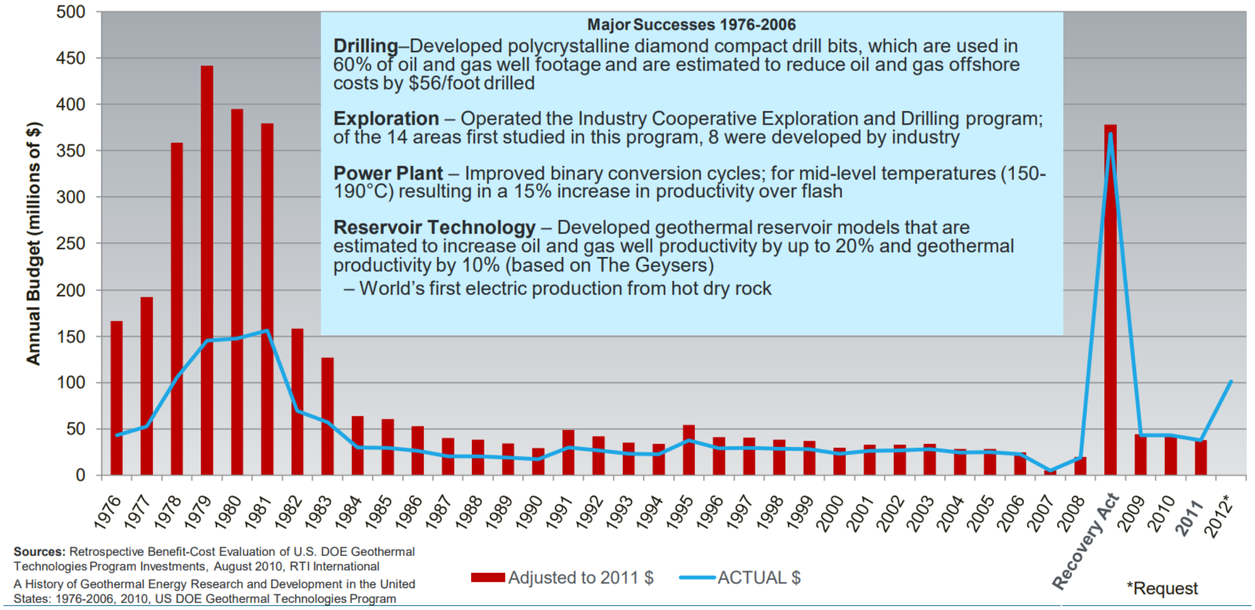

Figure 5. Annual Budget for the Geothermal Technologies Program 1976-2012. This graph shows the annual budget for the Department of Energy Geothermal Technologies Program (GTP) from 1976 to 2012, adjusted to 2011 dollars (Milliken, 2011).

In 2023, the Biden administration sought an 85% increase to the Geothermal Technologies Program budget from the previous fiscal year for a total annual budget of $203 million. Despite renewed federal geothermal development interest, consistent and responsive federal funding and policy development are needed to correct prior years during which federal funding "cyclical[ly] surged and retreated" (Neves et. al, 2021, p. 3). Coordination between actors, but more critically between macro-actors, is essential for sustainable and rapid development of geothermally derived mineral extraction processes. Groups seeking to understand and influence future geothermally derived mineral extraction efforts should caution against historical failings.

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