Texas-based startup Sage Geosystems' South Texas geothermal demonstration. Photo credit: Sage Geosystems.

Chapter 9

The Texas Startup and Innovation Ecosystem

J. Beard

Over the past few years, the Texas geothermal startup ecosystem has grown from nonexistence to the largest and fastest growing geothermal ecosystem in the world. The steps that Texas takes next could grow this burgeoning ecosystem into a major player in the State's future economy, and the world's energy mix.

I. Introduction

The Lone Star State, home to nearly 30 million people, is a melting pot of startup companies and legacy industry entities, new ideas and long held traditions, wildcatter culture and "Silicon Hills" buzz, grit and glamor, and a Texas mile of creative energy. Texas and its eccentric and diverse innovation ecosystem has become a magnet for businesses seeking to tap into the talent and energy of the State, with entities like Tesla, Oracle, Caterpillar, and Hewlett Packard joining the dozens of fortune 500 companies who headquarter in the State last year.

Looking to the future of geothermal, Texas' oil and gas industry is perhaps its most valuable asset in achieving fast growth and scale, but rounding the turn in a tight race is the State's burgeoning geothermal startup ecosystem. In this Chapter, we will briefly explore the history of entrepreneurship in the Lone Star State, the Texas innovation ecosystem at large, and the launch and rapid growth of the State's geothermal startup ecosystem. We will end the Chapter with an analysis of data reported by Texas geothermal startups about their greatest barriers to growth, and recommendations on how to keep the geothermal startup ecosystem growing and supported in the Lone Star State.

II. Wildcatting - A Uniquely Texan Brand of Innovation and Entrepreneurship

Texas is well known for its high tech innovations, inventions so ubiquitous that chances are, if you are reading this Report digitally, you are interacting with at least one of them right now. The integrated circuit, which

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led to the invention of the microchip, was invented in 1958 by Nobel Prize recipient Jack Kilby at Texas Instruments. In 1967, another team at Texas Instruments introduced the handheld calculator, which became a staple in the backpacks of generations of high school and college students. 3-D printing emerged from the University of Texas at Austin, invented by graduate student Carl Deckard. Entrepreneur Mary Kay launched her cosmetics business in Dallas and with it a fleet of pink Cadillacs onto suburban streets. The list goes on. Entrepreneurship is just as much a part of the heritage of Texas as the idyllic scenes of the Texas prairie, and ranch life. Brands and products that call Texas home include everything from the trendy, such as Whole Foods Market, and the lithium-ion batteries that are supercharging electric vehicle markets, to staples of office life, like Dell Computers and Liquid Paper's White Out, to libations such as Dr. Pepper, Tito's Homemade Vodka, and Shiner Bock.

The State's energy industry provides perhaps the most powerful example of the innovative and entrepreneurial spirit of Texas. The first oilfield in the State was developed in 1866, and the first refinery in 1898 (Olien, 2022). These developments, along with the oil 'gusher' at Spindletop in 1901, kicked off the Texas oil boom, and a new economy that would enable the world to industrialize. It also led to the launch of legacy oil and gas industry entities, such as the Texas Company (Texaco), Humble Oil and Refining Company (ExxonMobil), Pennzoil, and the M. Guffey Petroleum Company (Gulf Oil Corporation), among others.

The success of the oil and gas industry in Texas, and its skill at growing, innovating, and meeting the energy needs of the world, are due at least in part to the wildcatter culture that emerged from oil and gas explorers as the industry got traction. Wildcatting has been described as a "mythic identity" synonymous with "intrepid, hardworking, hard-playing" laborers who emerged from limited means and "risked everything to accumulate fortunes" (Simek, 2020). It was a wildcatter who discovered the Yates Oil Field, which led to the exploration of the Permian Basin, a massive resource that sustains the prosperity of the Texas oil and gas industry to this day (Simek, 2020).

With a culture of wildcatting in the State, it's no wonder that Texas has produced so many visionary entrepreneurs who have impacted the world - including industry pioneers such as George Mitchell, who pioneered hydraulic fracturing in the Barnett Shale formation of North Texas. Mitchell's initiative and entrepreneurship kicked off the shale boom, rearranged global geopolitics, and has provided a model and playbook for the coming exponential growth of the geothermal industry. His legacy continues to exemplify the outsized impact that Texas has had on the rest of the world. The tenacity of Texans like Mitchell continues in the State's pioneers of today, like Whitney Wolfe Herd (founder and CEO of Bumble), Jeff Bezos (Executive Chairman of Amazon), Vanessa Castagna (former JCPenney chairman and CEO), Michael Dell (Chairman and CEO of Dell Computers), and the late Herb Kelleher (co-founder and CEO of Southwest Airlines).

III. The Texas Innovation Ecosystem of Today

There is currently a robust and thriving ecosystem in Texas built to support startups and entrepreneurs in the State. Based on annual polling from nearly 700 chief executive officers and business owners from around the United States, Texas was identified in 2022 as the number one State for entrepreneurship and startups, and has held this honor for 18 consecutive years (Buss, 2022). Innovation and entrepreneurship ecosystem members in the State are too numerous for individual mention, but include entities such as Capital Factory, DivInc., Sputnik ATX, Texas Venture Labs, MassChallenge Texas, ION, the Austin Technology Incubator, Halliburton Labs, Quake Capital Partners Accelerator, Tech Wildcatters, WIRE accelerator, and many others.

Across the State, there are dozens of startup related programs connected to Texas research institutions, such as the Rice Alliance Clean Energy Accelerator, the Blackstone LaunchPad at the University of Texas at Austin, and the University of Texas at Dallas' Institute for Innovation and Entrepreneurship. Rice's Graduate School of Business took the number one spot in the United States in 2022 in Princeton Review's Best Graduate Programs for Entrepreneurs, while the University of Houston took the number one spot for the Best Undergraduate Programs for Entrepreneurs (PR, 2022). The Rice Business Plan Competition is the world's largest and most well-endowed, with teams competing each year for millions of dollars in cash and prizes.

The more than 200 accelerators, incubators, and entrepreneurship focused entities in Texas, many climate and energy focused, are spread across what the Founder Institute dubs the five Lone Star(tup) Nodes of

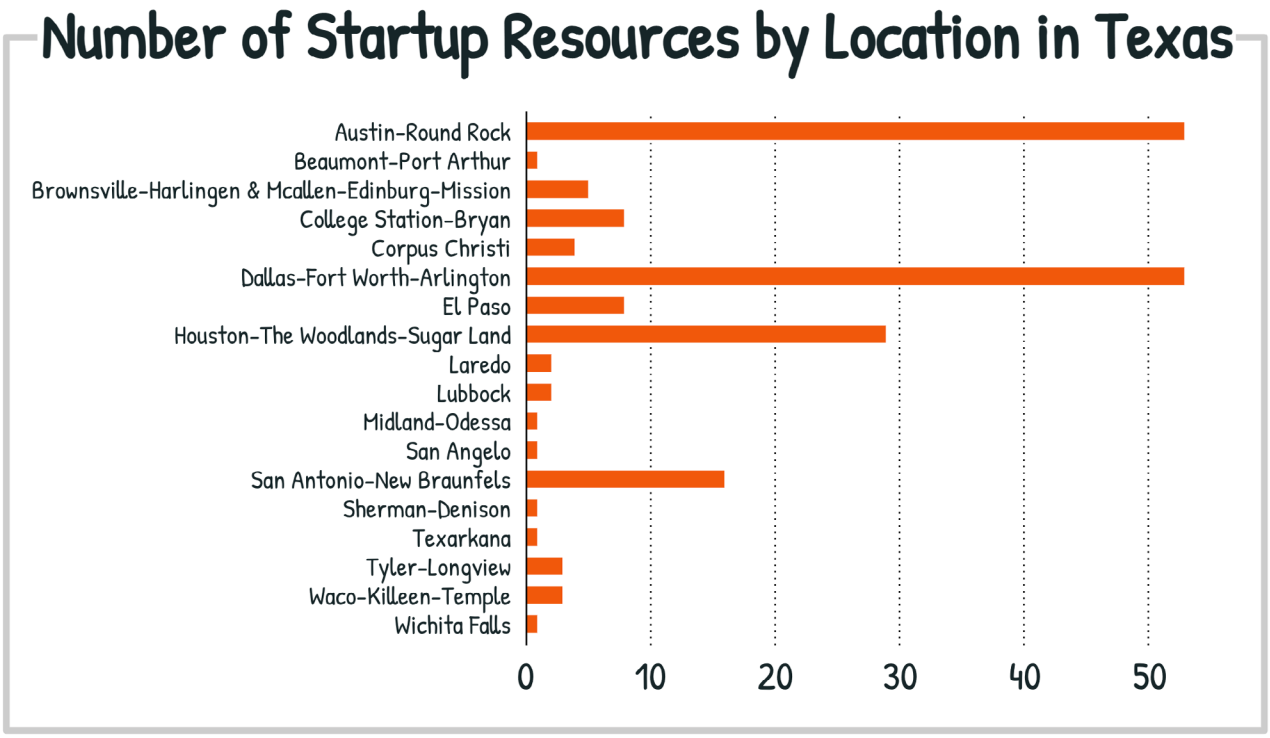

Figure 9.1. Number of entrepreneurial resources by location in Texas.
Source: Adapted from Texas Office of the Governor.

Innovation, including Dallas-Fort Worth, San Antonio, Austin, Houston, and College Station (FI, 2019; Texas EDT, 2017).

Conveniently for entrepreneurs who catch the geothermal bug, these Nodes of Innovation in Texas sit on top of the State's primary geothermal resource corridor (FI, 2022). The alignment of the State's population centers with geothermal resources in Texas is considered in further detail in Chapter 4, The Texas Geothermal Resource: Regions and Geologies Ripe for Development.

Simply put, there is a lot going on in the Texas entrepreneurship and innovation ecosystem, and this serves as the background music, so to speak, for the emergent Texas geothermal startup ecosystem.

IV. The Texas Geothermal Entrepreneurship Organization ("GEO")

In 2018, Chapter author Jamie Beard took a position directing an entrepreneurship program at the University of Texas at Austin ("UT Austin"), with the goal of building enough momentum for geothermal within the institution to apply for a grant, and fund a geothermal focused innovation ecosystem there. She spent her first months at UT Austin mapping the ecosystem, recruiting faculty into the discipline, building momentum for an organized geothermal effort at the University, and searching for a technical leadership team for the future geothermal effort. At this time there was little, if any, funded geothermal research and development ongoing at UT Austin, and no startup activity associated with geothermal. Few faculty members interviewed had given the discipline much thought or attention, and a fair dose of skepticism about the prospects of geothermal overshadowed the occasional glimmer of interest from a faculty member.

During these early days of effort to build the beginnings of the ecosystem, on average, the ratio of faculty disinterest and intrigue in geothermal was about ten to one, with ten expressing little interest or skepticism, and one expressing enthusiasm. But that occasional enthusiastic collaborator over time turned into small groups of actively engaged faculty, as they began to roundtable and discuss the topics with one another. Over the span of a year, majority disinterest gave way to increasing engagement amongst faculty, researchers, students, even alumni, and we worked to map the skillsets and technologies

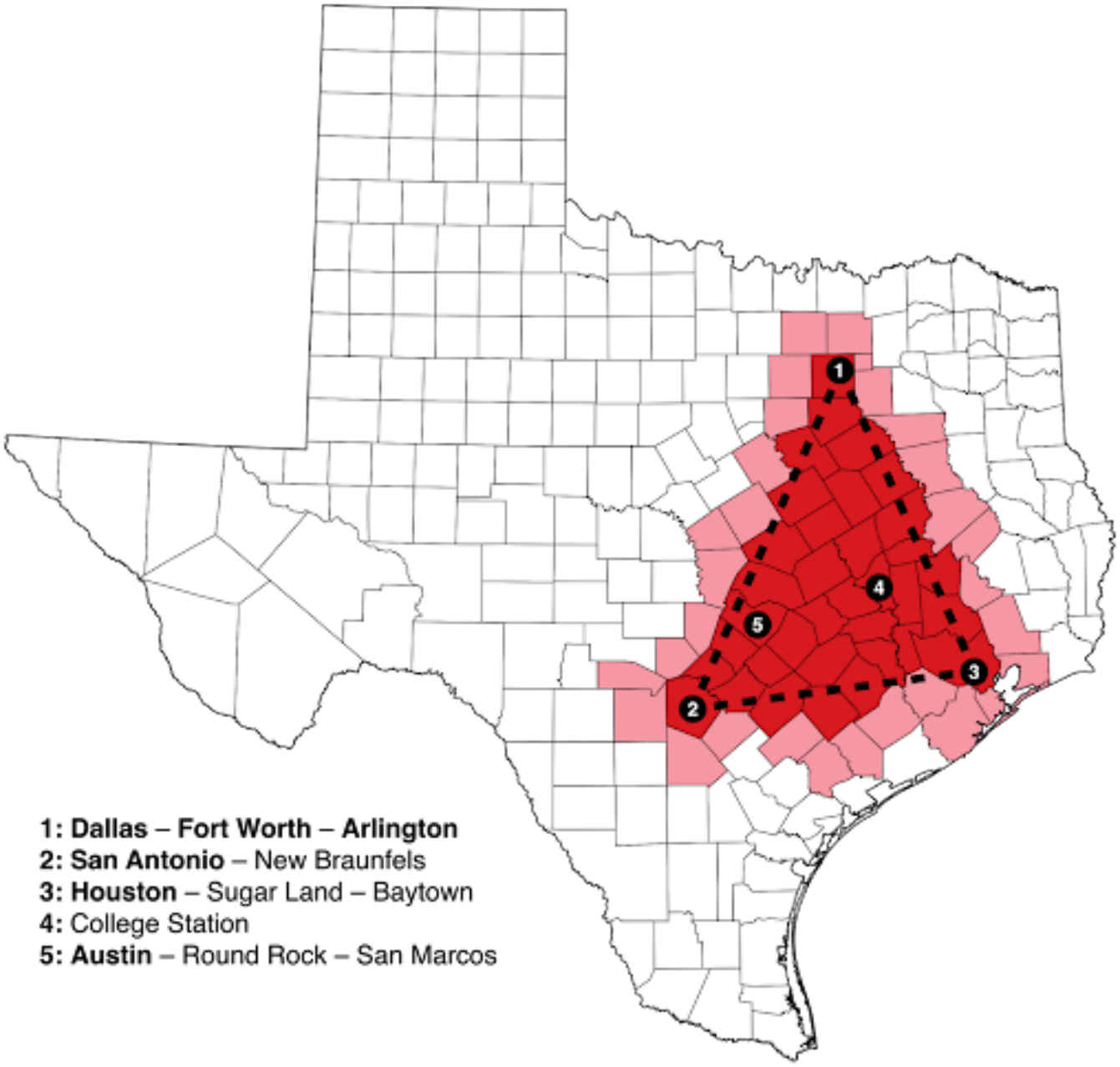

Figure 9.2. Map of the Lone Star(tup) Nodes of Innovation in Texas. *Source: FI, 2022.*

of faculty across schools in search of technologies and entrepreneurs who would be good candidates to launch geothermal focused research and/or startups. The most enthusiastically engaged faculty became de facto recruiters for geothermal themselves within UT Austin, and the most prolific among them became leaders of UT Austin's first organized geothermal effort, the Geothermal Entrepreneurship Organization ("GEO").

The GEO leadership team included purposefully diverse skill sets, all experts in entrepreneurship, geophysics, and petroleum engineering, and with the exception of one team member, all new to geothermal. The team members were full of fresh ideas, energy, and enthusiasm for solving geothermal challenges, and were spread out purposefully across multiple schools at UT Austin, to amplify our interdisciplinary approach to the geothermal ecosystem we set out to build. GEO leaders included Chapter author, legendary entrepreneur and inventor of the ethernet Dr. Bob Metcalfe, former Air Force Major General and geophysicist Dr. Ken Wisian, and veteran oil and gas industry drilling expert and Professor of Petroleum Engineering Dr. Eric van Oort. After some months of planning and waiting, a funding opportunity announcement from the U.S. Department of Energy ("DOE") was published that fit closely enough with our goals, and we went for it.

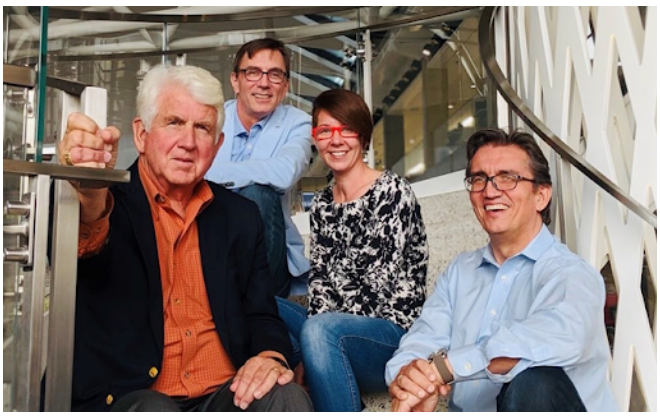

Figure 9.3. The GEO leadership team, including from the left, Dr. Robert (Bob) Metcalfe, Professor of Entrepreneurship and Innovation (now emeritus), Dr. Ken Wisian, Associate Director of the Bureau of Economic Geology, Jamie Beard (Chapter author), Executive Director of GEO, and Dr. Eric van Oort, Professor of Petroleum Engineering in the Hildebrand School of Petroleum and Geosystems Engineering. *Source: Texas GEO, 2022.*

In 2019, the DOE granted the UT Austin Cockrell School of Engineering a $1 million grant to launch GEO, a unique, first of its kind program aimed at building a research, development, and innovation ecosystem within a leading petroleum engineering and geoscience research institution, with legacy oil and gas expertise. Further goals of GEO were outreach and engagement with the oil and gas industry about geothermal related challenges, and recruitment of faculty, students, oil and gas industry veterans, and even oil and gas entities themselves to engage in geothermal ventures, inquiries, and development (Texas GEO, 2022).

The program was funded under the DOE Geothermal Technologies Office Efficient Drilling for Geothermal Energy ("EDGE") funding opportunity announcement. GEO was funded under topic area three of EDGE, which focused on "exploring innovative approaches and models to accelerate the transfer of geothermal drilling and related technologies from the laboratory into the real world" (DOE, 2018).

GEO's primary mission was creation of a self-sustaining innovation ecosystem for geothermal, focused on the number one petroleum and geosystems engineering department in the world, the Hildebrand Department of Petroleum and Geosystems Engineering. The approach was based on the hunch that faculty and researchers within petroleum and geosystems engineering departments would have ample excitement, enthusiasm, and spot-on skill sets and technologies in development to dive head first into geothermal challenges, with fast, breakthrough impact (UT News, 2019).

As we got GEO off the ground and built momentum, though we experienced increasing energy and excitement coming from faculty, students, alumni, and even increasingly oil and gas entities, there was no public facing representation of the innovation, ideas, and traction that we were seeing day to day in talking with ecosystem stakeholders. The team decided to launch a blog, called HeatBeat, as an avenue to publish stories, interviews, opinions, and debates to spread the word about what we were finding with a larger community. We hoped the blog would challenge the often sleepy and underwhelming geothermal narrative with new voices, new ideas, and new entrants to the geothermal scene, who were willing to question the status quo. The message was that something new, cutting-edge, and potentially very big for geothermal was happening down

in Texas. HeatBeat became the place we would point media, industry, donors, venture capitalists, students, and others who were excited about this new Texas-based geothermal traction and wanted to dig in further.

Next we discovered that although there were plenty of faculty, researchers, and by this time participants within oil and gas entities interested in contributing to the geothermal conversation, individuals were having difficulty gaining acceptance into journals and conference proceedings, both within the geothermal and oil and gas conference and journal scene. It turned out that geothermal conversations led by oil and gas didn't have a clear home at that time, with new oil and gas entrants viewed as outsiders in geothermal circles, and also as outsiders within oil and gas due to the subject matter. We needed a high visibility public platform for engaged voices to discuss, debate, and get their ideas out into the world, so in 2020, we launched the PIVOT - From Hydrocarbons to Heat conference ("PIVOT"), and the inaugural PIVOT2020 lit a fire under an already excited and growing ecosystem. At this time, the world was in the midst of the global COVID-19 pandemic, so PIVOT was born as an all virtual conference, and it quickly grew. In its second year, PIVOT had become the largest geothermal gathering in the world, with thousands attending from more than 100 countries globally. More than 60 percent of attendees hail from the oil and gas industry (PIVOT, 2022).

A central component in growing PIVOT was assuring the conference was free to attend. Removing this barrier allowed new entrants, students, researchers, and even the general public a low risk and near effortless avenue to engage with geothermal. The first year, PIVOT2020, required a massive effort from a small and dedicated group of "do-it-yourself" volunteers. By the second year, we had fundraised sufficiently to transition the conference into professional production.

By the end of the two year DOE grant period in 2021, UT Austin had become the epicenter of geothermal research and development in Texas, with faculty members engaging in geothermal research, and geothermal focused research consortia launched across two schools (BEG, 2022). At least two faculty members launched geothermal startups, with others engaging as advisors to geothermal startups and industry entities interested in engaging in the space (Bedrock, 2022; HeatBeat, 2020). UT Austin now has established geothermal curricula, and is a recognized entity and source of experts in the next generation geothermal space. Further, GEO's work at UT Austin resonated throughout surrounding research institutions in Texas, and amongst alumni, several of which became inspired to begin geothermal research and development at their institutions, or launch geothermal startups of their own. Sage Geosystems, a leading startup in next generation geothermal, is an example of one such entity, founded by UT Austin alumni and former Shell Chief Scientist, Lance Cook.

In sum, a relatively small grant and a two year sprint catalyzed far reaching impact, a new and self-sustaining geothermal innovation ecosystem in the heart of oil and gas country, and a small army, ever increasing in size, of geothermal startups launching into the field, with headquarters and/or operations in Texas. If we wish to keep the fire under geothermal burning bright, we need constant infusion of innovation, ideas, and new entrepreneurs. As such, the GEO model can, and should be, replicated across research institutions globally with legacy expertise in petroleum engineering and geoscience, creating new self-sustaining innovation ecosystems for geothermal, everywhere. In sum, geothermal would benefit immensely from a fleet of geothermal innovation ecosystem builders at institutions and entities globally.

The GEO model is as follows: 1) conduct a full survey of faculty, capabilities, technology readiness levels of commercializable and high-impact geothermal applicable technologies, and create a list of interested and entrepreneurial faculty and postdocs; 2) give seed grants and support to the top motivated faculty who have an "on the bench" technology that can be adapted for geothermal applications quickly with minimal investment, or to new research ideas that could quickly develop into high impact commercializable technologies applicable to geothermal; 3) nurture those faculty members and postdocs through the process of starting a venture, and assist them in obtaining funding to spin out entities from their research and development activities.

This was not always a smooth process as we got GEO off the ground, and we often built the airplane as we were flying it. Below are a few notes on lessons learned in building GEO, and best practices for those interested in building their own geothermal innovation ecosystems in entities and institutions that may not have significant existing geothermal expertise or engagement.

- **Cast a wide net with your technology and capability survey, but not too wide**: We focused on all faculty, in every relevant department and school, which was a significant time commitment. Ultimately, if you plan a handful of presentations at department meetings and faculty lunches as a starting point, the most enthusiastic faculty will come to you.
- **Resist allowing your initiative to become centered around a single school, program, or faculty member**: Institutional settings are fraught with silos, turf competitions, and academics battling each other for spotlight and recognition. Avoid these dynamics by involving as diverse a group as possible, being inclusive of multiple disciplines, departments, and schools. Letting "1,000 flowers bloom" in your ecosystem is a way to keep the playing field open to new entrants and innovators who may be intimidated if one program or outspoken academic is the only face of your program.
- **Bust the Silos**: Geothermal needs all types of expertise, including business, finance, marketing, communications, policy, legal, geoscience, and all types of engineering, including mechanical, civil, electrical, chemical, computer, and petroleum/geosystems. If you are able to house your program in a portion of your institution that sits across the various silos, like the Office of the President, Provost, or Vice-President of Research, it will allow you more movement across and through the silos that are so prevalent in large academic institutions.
- **Disperse Seed Grants Freely and Fast**: Seed grants are an excellent vehicle to use to amplify the excitement of faculty members who have interest and ideas about how they can adapt existing research and/or technologies to apply in the geothermal context. Small grants of $25,000 or $50,000 are typically enough to support the work of a student to push inquiries forward. Raise seed grants from corporate or philanthropic sponsors, and grant them early and often to supercharge your ecosystem.
- **Hire an Entrepreneur in Residence ("EIR")**: In hindsight, this would have been an excellent way to provide faculty and students with the extra attention they needed prior to being ready to plug into an accelerator or incubator program in GEO, and it is the way we have chosen to move forward as we expand GEO into other research institutions in the coming year. An EIR can assist with basic skills, such as building an initial pitch deck, business plan, and answer questions about entity formation, freeing program leaders to focus on stakeholder outreach, discussions with department chairs, fundraising, deploying seed grants, etc.
- **Don't Reinvent the Wheel**: Leverage the parts of your innovation ecosystem that are already in place by plugging your teams and entrepreneurs into existing incubators and accelerators after you've been successful at recruiting them into geothermal and helping them refine their idea. Every piece of the ecosystem that you do not have to build from scratch will allow you to focus on the primary objective, which is to nurture and seed interest in geothermal across as many disciplines and minds as possible within your institution.

As an illustration of how your growing geothermal ecosystem can be quickly plugged into existing programs, in the Texas ecosystem, Rice University now has multiple geothermal startups in their accelerator program (Franklin, 2022), and multiple others sit at incubators, co-working spaces, and accelerators in Austin and Houston. Further, Houston's Greentown Labs has begun hosting geothermal focused networking events. This is an efficient and desired outcome that allows ecosystem builders the bandwidth to focus on recruiting and priming the innovation pipeline, while handing the task of growing and mentoring entities off to programs already in place that are designed to do that work.

While walking the full course with emerging teams, from idea, to pitching, to funding, to piloting, was helpful for the Chapter's author in developing an understanding of the novel challenges that the geothermal ecosystem would face, it is an unnecessary component of building a robust and flourishing geothermal innovation ecosystem. Presently, what geothermal needs most urgently is fresh ideas, bold and energetic entrepreneurs, and oil and gas thought leaders to try their hand in geothermal. Geothermal ecosystem builders at research institutions globally can fulfill that critical need.

The ultimate goal of a geothermal innovation ecosystem is organic, self-sustaining growth. This occurred at UT Austin to such an extent that this Chapter's author was able to step out and launch new initiatives, while

the ecosystem continues to grow and flourish. At the beginning of the process of building UT Austin's ecosystem, teams had to be actively recruited, and forward momentum required an active, and at times, heavy push. Initial recruitment efforts of targeted subject matter experts were often unsuccessful at first, and even in the second or third attempts. However now, more often than not, new startups and teams emerging from the Texas ecosystem approach the author of this Chapter to introduce themselves, saying that they had been inspired by PIVOT, or another startup making headlines, or were recruited by colleagues, researchers, or friends who had launched a startup, etc. The ecosystem is now catalyzed, self-sustaining, and flourishing. It is a geothermal innovation engine. Let's keep that going. Pick a place to build your own ecosystem, and dive in.

V. The Geothermal Renaissance - Geothermal Startups and the Innovation Ecosystem

Leading GEO, then becoming the host of PIVOT and leader of Project InnerSpace has introduced the author of this Chapter to emerging geothermal startups from all over the world. Many are based in Texas, but not all. Some have emerged from oil and gas from epicenters of industry globally, such as Calgary, Oklahoma City, Aberdeen, and others.

A few have launched elsewhere in the world, and are considering moves to Texas due to the growing ecosystem and investor pool in the State. A list of geothermal focused or adjacent startups in this quickly growing innovation ecosystem is captured in Appendix B of this Chapter. This ecosystem has raised just over a billion dollars to date, with roughly three-quarters of these funds raised in the past three years.

Below is an illustration of the years the startups in Appendix B were founded. As one can see, the ecosystem has experienced substantial growth over the past several years, which appears to be accelerating. Keep in mind that this represents startups that have made it onto this Chapter author's radar globally, including entities who are headquartered and have operations in Texas, but also entities who do not. As you'll see in the next illustration, the Texas startup ecosystem accounts for most of the growth of this ecosystem over the past three years.

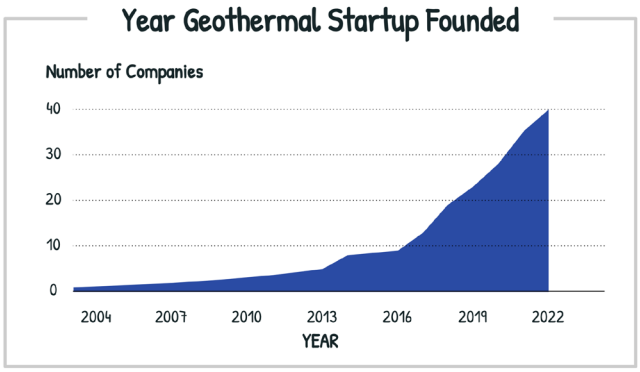

Figure 9.4. Trend of geothermal companies founded globally between 2002 and 2022. *Source: Future of Geothermal Energy in Texas, 2023.*

Over the past three years, nine of the 11 geothermal startups with headquarters in Texas launched. This positions the Texas ecosystem as the driver behind the sharp global growth of the ecosystem. The Texas geothermal startup ecosystem is also quickly gaining on all other states in the number of geothermal startups headquartered in the State, with 11 entities in Texas alone, and 16 entities in all other states combined.

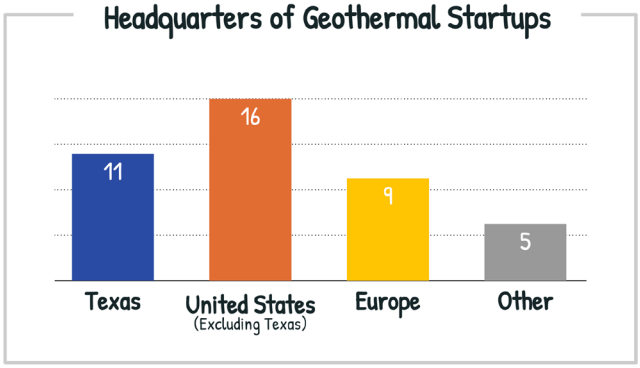

Figure 9.5. Location of geothermal startup headquarters between 2016 and 2022. *Source: Future of Geothermal Energy in Texas, 2023.*

For this Chapter, a subset of geothermal startups in the global ecosystem were interviewed to gain an understanding of what technology areas the ecosystem was focusing on, and what technology challenges the ecosystem views as the most significant facing both geothermal as a whole, and their entities in particular. In the first inquiry, we asked the startups what technology area they were pursuing in geothermal, giving them the choice of Engineered (Enhanced) Geothermal Systems, Advanced Geothermal Systems (which we defined as Closed Loop Geothermal Systems), both of these system

types, which was defined to include Hybrid Geothermal System concepts, or other, which was defined to include endeavors such as tool development or services that could apply broadly across all geothermal technologies.

While slightly more startups reported engagement in Advanced Geothermal System development over those who reported engagement in Engineered Geothermal Systems (39 percent and 23 percent, respectively), 15 percent reported that they were pursuing both or hybrid concepts, or had not yet definitely ruled out one or the other in their development strategies. Interestingly, this data is not entirely consistent with the data emerging out of the oil and gas industry, as presented in Chapter 6, Oil and Gas Industry Engagement in Geothermal: The Data of this Report, where oil and gas entities reported 87 percent engagement in Next Generation Engineered Geothermal Systems, and 93 percent engagement in Advanced Geothermal Systems. This may be explained by an "all of the above" strategy on behalf of oil and gas entities to engage in all technology types, and wait to see how field trials progress before down-selecting into a specialty, an approach that would be difficult for startups, who are limited by both funding and bandwidth, to execute.

An unrelated, but potentially important observation that may help in interpreting the data emerging from the geothermal startup ecosystem: if you look at the startup table in Appendix B, a large majority of startups (29 of 43 entities) identify currently as "developers/operators," as opposed to tool, equipment or service providers. This designation has puzzled a number of venture capitalists in private conversations with the Chapter author, as a good number of the companies who identify as developers/operators would be better suited in terms of business model as technology and/or service providers. The question often comes up, "why are these companies trying to go out and develop projects on their own," and the simple answer to that question is because there is no entity currently out there willing to fill that role. Ideally, and perhaps in the near term, oil and gas entities themselves will be willing to step into that role as geothermal developer/operator, allowing the geothermal startup ecosystem to focus on their specialities and technology development.

Indeed, during pitches early in the fundraising journeys of geothermal startups who began as technology developers and service providers, venture capitalists would often raise the question of the size of the addressable market for their technology and/or service, and teams were not able to address those questions sufficiently with the funding entities. We are building the tools, services, and market for next generation geothermal in parallel with one another, and often makes for difficult conversations with funding entities. Due to these dynamics, many startups have managed this issue by switching their business model to become operators/developers over the past few years in order to command more control over the project development pipeline for the purpose of fundraising.

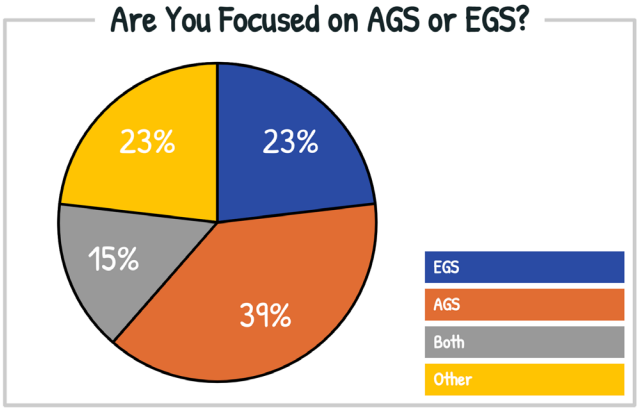

Figure 9.6. Technology focus area of geothermal startups around the globe between 2002 and 2022. *Source: Future of Geothermal Energy in Texas, 2023.*

This is an example of a funding pain point that exists within the geothermal startup ecosystem currently, and is one of many. It is also an example of how ill-suited venture capital ("VC") is for geothermal currently, with VC entities struggling to understand the funding needs of the community, the likely trajectory of the next generation geothermal market, the risks associated with novel "first of a kind" projects, the culture and approaches of the teams emerging from Texas, the incremental nature of forward movement in the drilling industry vs. the "moonshot" approach of Silicon Valley, and the types of teams and expertise who are most likely to be successful in the geothermal space. These themes will be explored further below.

In the next inquiry, we asked the startups if they were focused on Direct Use heat concepts, or power production concepts, giving them the choice of heat, power, both, or not applicable, which was defined as concepts or business models that applied broadly enough across all geothermal concepts as to make this distinction meaningless.

Responses were split fairly evenly between these four responses, with power inching out heat and both by 31 percent, 23 percent, and 23 percent, respectively. Entities who responded not applicable tended to be technology and/or service providers.

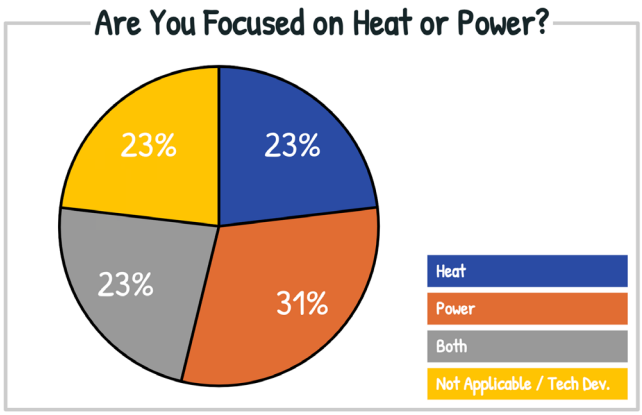

Figure 9.7. Technology focus area of geothermal startups around the globe between 2002 and 2022. *Source: Future of Geothermal Energy in Texas, 2023.*

Half of entities who indicated that they are pursuing power production concepts noted that they would pursue markets for waste heat emerging from their geothermal power operations should those markets become apparent, or if there were off-takers nearby. At least two entities who reported that they are pursuing both have built production of both heat and power into their business model as a central component, and reported that co-locating power production pilots with off-takers for heat was a priority.

VI. Nurturing the Geothermal Startup Ecosystem in Texas and Globally

As mentioned above, several ecosystem pain points have emerged over the past few years, as an accelerating number of entities, often led by veteran oil and gas industry teams with decades of collective operational and project development experience in industry, progress from concept to pilot in a matter of months. Field iteration and "learning while doing" was an essential component of the success and speed of the national gas shale boom in the early 2000s, and it is sure to have a similar impact on geothermal - but teams have to be adequately funded to pursue field deployments. These teams on several occasions have sought to raise $30 to 50 million USD for semi-commercial first of a kind geothermal pilots as their seed round, an approach that VCs have largely failed to support.

Many of the challenges associated with first of a kind geothermal project finance are associated with risk management/mitigation – and first of a kind projects have two types of risk, subsurface and technological, making them unique from a risk perspective. An excellent report was published recently, which explores the first of a kind problem in the broader context of climate finance, and was inspired in part by the challenges encountered by several geothermal teams attempting to raise funding for their projects (Khatcherian, 2022).

Private equity has also been slow to engage due to these risks, telling teams seeking to deploy first of a kind projects to "come back after your first project is in the ground." As of the publication date of this Report, we are on the cusp of the public announcement of at least two private equity engagements in next generation geothermal concepts, but these deals have been slow moving, difficult to close, and are not near the prolific level of engagement and funding that is needed to support geothermal into exponential growth.

Insurance has been raised as a likely missing link in the project finance/funding equation for first of a kind projects, but geothermal is not currently a large enough market to engage existing climate risk/insurance entities at any serious level, and there are unique risk profiles requiring subject matter expertise that current entities lack, which dissuades engagement. While there are a small handful of entities globally who have begun to engage in this space, it is an area in need of fast attention and brain power. This Chapter author's entity, Project InnerSpace, recently funded an initiative to build a bespoke insurance product for novel next generation geothermal projects as a stop gap measure to assist in getting teams into the field and engaged in pilots while new finance and funding mechanisms are built to serve geothermal over the coming years.

If we wish to support the emerging geothermal startup ecosystem into a global powerhouse capable of driving prosperity and growth, we need to listen to and quickly address the needs and pain points of the ecosystem before those pain points cause a loss of momentum. As is explored in other Chapters of this Report, there are roles for all types of stakeholders to play in supporting

this ecosystem, including policy-makers, the oil and gas industry, advocacy groups, funding entities, governments, and others. All stakeholders should quickly dig in and play a role in removing the barriers to growth that stand in the way of the growth of the ecosystem currently.

As part of our interview process of startups for this Chapter, we polled entities about technology gaps, pain points, how they would deploy funding if they had it to achieve maximum impact, and what they most need from the oil and gas industry. Startup responses were aggregated so the results remain anonymous to encourage direct discussions and open discourse. We summarize the data received below.

A. What Technology Gaps Could Hold You Back?

The startups interviewed for this Chapter were asked what technology gaps in geothermal are likely to hold them back if not addressed. The question was asked in the context of problems that the startups themselves were not seeking to address, but that had the ability to hold them back if some other entity was unable to address them. Responses varied widely across entities, with little consensus.

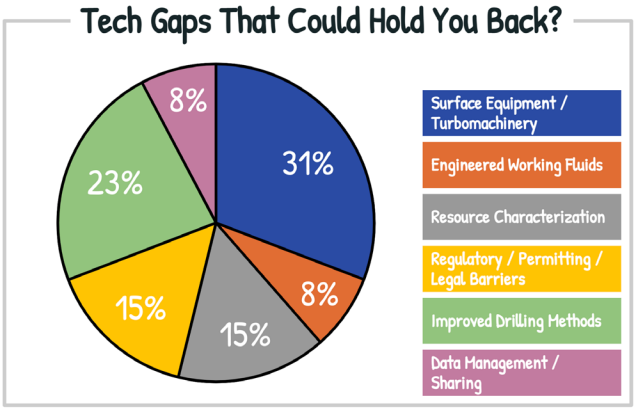

Figure 9.8. Responses from interview participants identifying technology gaps that, if not addressed, could hold their entities back. *Source: Future of Geothermal Energy in Texas, 2023.*

The largest majority of entities at 31 percent reported that surface equipment/turbomachinery is a technology gap that could have impactful and potentially negative outcomes on their own efforts if not addressed by others. This data is consistent with the perspectives emerging from oil and gas entities polled in Chapter 6, who also reported that lack of innovation in surface equipment is a technical challenge that stands as an impediment to the growth and advancement of geothermal. Faster drilling methods, regulatory barriers, and resource characterization rounded out the next three most popular responses, at 23 percent, 15 percent, and 15 percent, respectively. Advancement of Engineered Working Fluids and the need for data sharing and management across industry each garnered 8 percent.

B. What Challenges Keep You Up At Night?

Teams were asked what their biggest pain points were in terms of traction, funding, or other perceived risks. Entities' responses were telling, and echo some of the themes explored in earlier parts of this Chapter, particularly with regard to funding. Many of these pain points involve issues that the teams themselves cannot solve or personally influence, but that will have an outsized impact on their ability to succeed. Responses included:

- **"Green" investors tend to avoid oil and gas technologies and teams**. One team noted that they lost a potential investment due to the fact that their technology could theoretically be applied in the oil and gas context, despite the fact that the team had no intention of pursuing that application or market.
- **Venture capital is largely unfamiliar with geothermal**. Teams reported spending most of their pitch time with VCs explaining basic attributes of geothermal, or dispelling disinformation or misunderstandings within venture capital teams about geothermal before getting to their specific technology or pitch. "We are spending our valuable time educating venture capitalists about the opportunity generally, and then they don't invest" noted one entity. Another team remarked, "we stopped talking to VCs a long time ago."
- **There is bias in the funding ecosystem, and the teams feel it**. One entity recalled a venture capital team cutting a meeting with their team short after addressing their concept, which involved a partnership with an oil and gas entity, in a condescending manner. The founder remarked that "anti-oil and gas bias is rampant, and it's demoralizing."
- **Funding for pilot projects is needed now**. One team noted that investors want data to gauge the potential success of the pilot, but that pilots are the avenue to collect such data, stating "we can't learn until we get

into the field." Another noted "We just need to deploy. It will cause an avalanche of funding if we get the first project in the ground. That's the unconventionals playbook."

- **New financing mechanisms are needed for first of a kind deployments**. All teams interviewed expressed this as a concern on some level. Some described the need for oil and gas project finance to engage, since they more fully understand the risks associated with subsurface projects. Another team noted, "we aren't sexy enough for VCs - they want moonshots - we want to build power plants."
- **The "F" word is off limits**. At least two teams pursuing Engineered Geothermal or Hybrid Geothermal Systems remarked that discussions about frac'ing with venture capital teams can be tensioned, or fraught with misunderstanding. One team noted, "You can't talk about frac'ing with climate impact funds, no matter how big or positive the impact, or how different the technology is in the geothermal context. They don't want to have anything to do with it."[1]

C. What Do You Need From Oil and Gas?

When teams were asked what they most need from the oil and gas industry to help them succeed, responses fell into three broad categories. The first is support for pilot projects and first of a kind deployments, noting that many oil and gas entities expect to see the outcome of pilot projects before they will invest. But as we saw reflected in the comments above, funding for first of a kind pilot projects is a significant barrier for startups. To borrow venture capital vernacular, we have here a valley of death. "There is a chicken and egg problem with oil and gas," one team noted. "They want to see field data, but don't want to fund us to deploy so we can get them the field data."

The second category of need lies in the scale, global footprint, and experience in large-scale project execution and management of oil and gas. At least two entities described oil and gas as the key to their concepts achieving fast global scale after a pilot proves successful, with one entity remarking "we are running the sprint now, but once our concept is proven in the field, it would make sense for us to get acquired [by an oil and gas entity] at that juncture."

The third category of need is access to the vast amounts of subsurface data within oil and gas entities for the purpose of pre-project risk assessment and subsurface characterization. Several entities expressed the view that if the oil and gas industry utilized their data for the purpose of geothermal exploration, the outcome would be a product far superior to anything in existence today. "They have a lot of very high quality data that could be really helpful to us if we had it," noted one entity. Another entity noted that they developed a partnership with an oil and gas entity specifically for this purpose.

D. How Would You Utilize $100 Million in Funding?

When the startups were asked how they would utilize $100 million in funding if they had it, the results were largely consistent with the data emerging from prior interview questions, with 69 percent of entities describing some variation of field deployment.

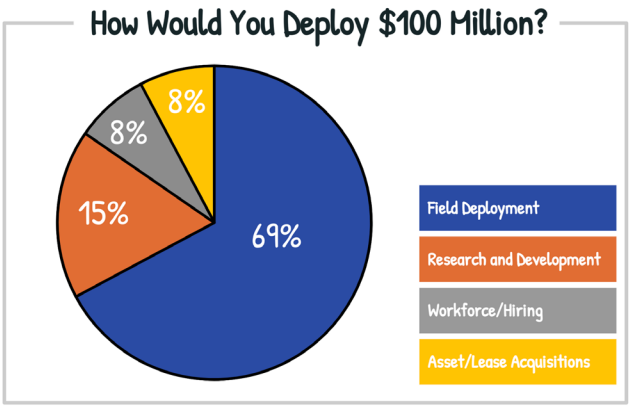

Figure 9.9. Responses from interview participants identifying how they would deploy $100 million dollars in funding. *Source: Future of Geothermal Energy in Texas, 2023.*

At least two entities expressed the desire to deploy pilots with significant investment in instrumentation on the pilot well, to learn from and analyze the resulting data, and to re-deploy further iterations based on that data. "We need to data mine our test wells, but the cost of that level of data acquisition is likely beyond what most startups can raise for their pilots." noted one entity. "The data, if we could afford to pull out all the stops to capture it, would be invaluable," noted another.

[1]An excellent piece of scholarship recently published that considers perception spillovers and their impact on next generation energy technology acceptance. This is likely a dynamic at play in the challenges startups are facing with funding entities in the cleantech and climate space (Westlake, et al., 2023).

Another entity remarked that $100 million would afford them the opportunity to deploy multiple iterations of the same design, which would result in an optimized system after multiple wells. This comment is consistent with the responses amongst oil and gas entities who were asked this same question in Chapter 6, Oil and Gas Industry Engagement in Geothermal: The Data of this Report. Another entity interested in deployment stated that they would try their hand at a coal plant to geothermal conversion with the funds, also consistent with oil and gas entity data from Chapter 6.

Entities who expressed interest in investing in research and development noted that $100 million may be enough to solve entire and difficult problem sets in geothermal, which may require materials science advances. Two examples given by entities for research and development investments were next generation drilling technologies, and high temperature electronics. High temperature electronics, noted one entity, could enable an entirely new set of capabilities and technology transfer from oil and gas into geothermal, including rotary steerables, and powerful telemetry equipment.

The entities who expressed interest in workforce development and hiring worried that skilled workforce availability was likely to become an impediment to their growth and expansion in the coming years. They remarked that workforce training and certification programs would be very helpful in priming the pipeline of workers ready to pursue careers in geothermal. Finally, the entities expressing an interest in asset acquisition focused on lease acquisition, noting that a significant portion of the projected future value of their entity would likely be related to their portfolio of leaseholds, and where those leases stand in the very long and burdensome federal geothermal permitting timeline. "When oil and gas finally is ready to pull the trigger on projects, we will have a portfolio of leases nearing the end of their permitting process and ready to be launched," one entity noted.

VII. Conclusion

This Chapter is a long and varied journey through Texas' history of wildcatting, energy innovation, and modern day entrepreneurship, which are all characteristics that have provided fertile ground for the emergent and thriving geothermal startup ecosystem. The next challenge for Texas, now that an organically growing and self-sustaining geothermal startup system—the fastest growing in the world—now calls the State home, is to find pathways to support the ecosystem by removing barriers to growth.

A few themes emerge from this Chapter. The first is the failure of traditional funding mechanisms such as venture capital and private equity to support and sustain the funding needs of the geothermal startup community. As we explored, a unique mixture of subsurface and technology risk, as well as unfamiliarity with the resource generally has largely constrained the needed flow of capital into the ecosystem. In addition to these factors, bias and a difference in cultures between silicon valley based funding entities and largely oil and gas industry veteran teams from Texas may play a more significant role in forming these impediments than we as an ecosystem are willing to admit. Silicon Valley seeks to fund the 'moonshots' of 'visionaries,' and oil and gas teams who show up to pitches in buttoned up suits to talk low and slow about conservative approaches, incremental steps, and IRR doesn't translate. I've been present in several of these pitches, and the dynamics are to be frank, cringe.

The reality is, we don't need shiny big talkers and slick pitch decks to build geothermal plants. We need teams who have the professional and operational experience to go out and successfully drill and develop projects. In geothermal, we need to build a new definition of what a successful entrepreneur, and what a backable team looks like, because it is highly likely given the skill sets needed that it will not follow the Silicon Valley playbook. There are a few geothermal startups out there who have been successful at merging these two cultures within their executive teams - marrying veteran oil and gas expertise with edgy pitch decks and VC savvy executives. Those teams may have a strategic advantage moving forward, particularly in fundraising efforts. Ideally, oil and gas private equity, or high net worth individuals who amassed their fortunes in oil and gas will be willing to step in over the coming years to support these oil and gas teams who are struggling to make it through a difficult to address funding valley of death.

Incremental steps may sound underwhelming in pitch decks, but that is what we need to prove scalable geothermal concepts in the field. We don't need to fund the sexiest sounding concepts. We need to fund concepts that seem the most obvious, and even boring,

and iterate on incremental successes. It's a different approach than venture capital is accustomed to, but it is one entirely familiar to the oil and gas industry. Our ability as a community to raise the profile of geothermal over the coming years within the oil and gas industry sufficiently to result in significant investment commitments may be determinative of whether geothermal becomes a substantial player in our global energy future, or fails to launch due to insufficient flow of capital.

Over the past few years, the Texas geothermal startup ecosystem has grown from nonexistence to the largest and fastest growing geothermal ecosystem in the world. The steps that Texas takes in the coming years, including its resident oil and gas industry, could grow and support this burgeoning ecosystem into a major player in the State's future economy, and the world's energy mix. Let's not miss this opportunity for the State of Texas, and the world.

Conflict of Interest Disclosure

Jamie Beard serves as Executive Director of Project InnerSpace, a 501(c)(3) organization that works on issues within the subject matter of this manuscript, and is compensated for this work. She further serves in a non-compensated role as a founding member of the board of the Texas Geothermal Industry Alliance. Outside of these roles, Jamie Beard certifies that she has no affiliations, including but not limited to board memberships, stock ownership and/or equity interest, in any organization or entity with a financial interest in the contents of this manuscript, and has no personal or familial relationship with anyone having such an affiliation or financial interest.

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Chapter 9 Appendix A

The authors of the Future of Geothermal Energy in Texas report are grateful for the participation and insight provided by the following individuals. Thank you for taking the time to share your knowledge and experiences about the geothermal startup ecosystem in Texas and from around the globe. Data collected from all participants has been aggregated and anonymized to capture and disseminate trends, views, and perspectives.

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- Spencer Bohlander, Chief Executive Officer, Icarus Energy
- John Clegg and Team, Chief Technology Officer, Hephae Energy Technologies
- Karl Farrow and Team, Chief Executive Officer, CeraPhi Energy
- Cameron Grant and Team, Chief Commercial Officer, STRYDE
- Kathy Hannun, President, Dandelion Energy
- Sarah Jewett, Director of Strategy, Fervo Energy
- Kirsten Marcia, Chief Executive Officer, DEEP Earth Energy
- Niall McCorack and Team, Chief Executive Officer, CausewayGT
- Johanna Ostrum, Chief Operating Officer, Transitional Energy
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- Cindy Taff and Team, Chief Executive Officer, Sage Geosystems

Chapter 9 Appendix B - Geothermal Startups

Table 9.1. The past few years have seen a dramatic increase in the number of geothermal startups launched. Members of the geothermal startup ecosystem are in various stages of fundraising, research, demonstration, and deployment. *Source: Future of Geothermal Energy in Texas, 2023.*

Company Name	Category	Country	HQ State/ Province	Project Location(s)	Year Founded	Type of Geothermal/ Technology/ Service	Development Stage	Funds Raised (USD)	Funding Type	Funding Stage	Website
Altarock	Developer/ Operator	United States	Washington	Oregon	2007	Superhot Rock	Demonstration/ Pilot	$36,500,000	Traditional VC	Series C	altarockenergy.com
Baseload Capital	Developer/ Operator	Sweden	Stockholm	Utah, Colorado, Nevada & California	2019	Hydrothermal	Early Deployment	N/A	PE/Corporate	Series B	baseloadcap.com
Bedrock Energy	Tools/Equipment Provider	United States	California	Texas, Alberta	2022	Direct Use	Demonstration/ Pilot	$6,000,000	Climate Impact VC/Traditional VC	Seed	bedrockenergy.com
Canopus Drilling Solutions	Tools/Equipment Provider	Netherlands	Holland	Europe	2018	Drilling	Research	$3,100,000	Climate Impact VC	Seed	canopusdrillingsolutions.com
CausewayGT	Developer/ Operator	Ireland	Ireland	Texas, Ireland, Northern Ireland	2020	Direct Use	Early Deployment	Fundraising	Climate Impact VC/Corporate	Seed	causewaygt.com
Celsius Energy	Developer/ Operator	France	Hauts-de-Seine	France, Massachusetts	2018	Direct Use	Demonstration/ Pilot	N/A	Corporate	Series A	celsiusenergy.com
CeraPhi Energy	Developer/ Operator	United Kingdom	England	United Kingdom	2020	Well Reuse	Demonstration/ Pilot	$3,000,000	Privately Funded	Seed	ceraphi.com
Controlled Thermal Resources	Developer/ Operator	Australia	Queensland	California	2013	Hydrothermal/ Lithium	Demonstration/ Pilot	$37,000,000	PE/Corporate	Series B	cthermal.com
Criterion Energy Partners	Developer/ Operator	United States	Texas	Texas, Utah, Nevada	2021	Blind/ Sedimentary Geothermal	Demonstration/ Pilot	Fundraising	Government/ Corporate	Series A	criterionep.com
Crust Harvest	Developer/ Operator	Norway	Stavanger	Norway	2022	Hydrothermal	Research	N/A	Privately Funded	Seed	crustharvest.com
Dandelion Energy	Service Provider	United States	New York	Northeast United States	2017	Direct Use	Deployment	$134,500,000	Traditional VC	Series B	dandelionenergy.com
DEEP Corp	Developer/ Operator	Canada	Saskatchewan	Saskatchewan	2010	Blind/ Sedimentary Geothermal	Demonstration/ Pilot	$53,500,000	PE/Government	Series B	deepcorp.ca
DeepPower	Tools/Equipment Provider	United States	Utah	Utah	2022	Drilling	Research	N/A	Traditional VC	Series A	deeppower.com
Earthbridge Energy	Developer/ Operator	United States	Texas	N/A	2021	Storage/ Sedimentary Geothermal	Research	Fundraising	Climate Impact VC/Corporate	Seed	earthbridgeenergy.com
Eavor	Developer/ Operator	Canada	Alberta	Global	2017	Closed Loop	Early Deployment	$100,000,000	Climate Impact VC/Corporate	Series B	eavor.com
Eden GeoPower	Service Provider	United States	Massachusetts	N/A	2020	EGS	Research	$3,796,672	Government	Series C	edengeopower.com
Eden Geothermal Ltd	Developer/ Operator	United Kingdom	England	United Kingdom	2019	Direct Use	Demonstration/ Pilot	$22,200,000	PE/Government	Series A	edengeothermal.com
EnhancedGEO	Developer/ Operator	United States	Florida	N/A	2022	EGS	Fundraising	N/A	Privately Funded	Seed	enhancedgeo.com
Fervo Energy	Developer/ Operator	United States	Texas	Nevada, Utah	2017	EGS	Deployment	$184,915,000	Climate Impact VC	Series C	fervoenergy.com
GA Drilling	Tools/Equipment Provider	Slovakia	Slovakia	Global	2013	Drilling	Demonstration/ Pilot	$36,900,000	Traditional VC	Series A	gadrilling.com
Geothermal Engineering (GEL)	Developer/ Operator	United Kingdom	England	United Kingdom	2008	EGS	Early Deployment	$19,000,000	PE/Government	Series A	geothermalengineering.co.uk
GeoGen Technologies	Developer/ Operator	Canada	Alberta	N/A	2021	Well Reuse	Research	N/A	Privately Funded	Seed	geogen.com
Geothermal Technologies	Developer/ Operator	United States	Maryland	Colorado	2018	EGS	Demonstration/ Pilot	$25,000,000	Traditional VC	Series A	geothermal.tech
Geothermal Wells (GTW)	Developer/ Operator	United States	Texas	N/A	2022	Well Reuse	Research	Fundraising	Privately Funded	Seed	geothermalwellsllc.com
Geothermic Solutions	Tools/Equipment Provider	United States	California	USA	2014	Superhot Rock/ Closed Loop	Demonstration/ Pilot	$22,500,000	Traditional VC	Series A	geothermicsolution.com
GeoX Energy	Developer/ Operator	United States	California	Global	2019	Superhot Rock	Demonstration/ Pilot	$11,000,000	Corporate	Seed	geoxenergy.com
Greenfire Energy	Developer/ Operator	United States	California	California	2014	Closed Loop	Demonstration/ Pilot	$22,700,000	Government/ Corporate	Series A	greenfireenergy.com

Table 9.1. (Continued)

Company Name	Category	Country	HQ State/ Province	Project Location(s)	Year Founded	Type of Geothermal/ Technology/ Service	Development Stage	Funds Raised (USD)	Funding Type	Funding Stage	Website
Hephae Energy Technology	Tools/Equipment Provider	United States	Texas	N/A	2021	Drilling	Research	$3,100,000	Climate Impact VC/Corporate	Seed	hephaeet.com
HyperSciences	Tools/Equipment Provider	United States	Washington	N/A	2014	Drilling	Early Deployment	$15,000,000	Corporate/ Crowdfunded	Series B	hypersciences.com
Icarus Energy	Developer/ Operator	United States	Texas	Texas, California, Australia	2021	Closed Loop	Demonstration/ Pilot	Fundraising	Privately Funded	Seed	icarus.how
ICE Thermal Harvesting	Developer/ Operator	United States	Texas	California	2021	Well Reuse	Demonstration/ Pilot	$1,700,000	Government	Govt Funded	ice-th.com
Lilac Solutions	Developer/ Operator	United States	California	California	2018	Hydrothermal	Early Deployment	$150,000,000	Climate Impact VC/Corporate	Series B	lilacsolutions.com
OGL Geothermal	Developer/ Operator	United Kingdom	England	N/A	2021	Blind/ Sedimentary Geothermal	Demonstration/ Pilot	Fundraising	Climate Impact VC	Seed	ogl-geothermal.com
Particle Drilling	Tools/Equipment Provider	United States	Texas	N/A	2003	Drilling	Early Deployment	$80,000,000	PE/Corporate	Series B	particledrilling.com
Qheat	Developer/ Operator	Finland	Finland	Finland	2018	Direct Use	Early Deployment	$5,800,000	Traditional VC/ Government	Series A	qheat.fi
Quaise	Developer/ Operator	United States	Massachusetts	N/A	2018	Drilling	Demonstration/ Pilot	$75,000,000	Climate Impact VC/Corporate	Series A	www.quaise.energy
Sage Geosystems	Developer/ Operator	United States	Texas	Texas	2020	Blind/ Sedimentary Geothermal/ Storage	Early Deployment	$25,000,000	Climate Impact VC/Corporate	Series A	sagegeosystems.com
Strada Global	Tools/Equipment Provider	United Kingdom	England	N/A	2019	Drilling	Research	$2,500,000	Traditional VC	Seed	stradaglobal.com
STRYDE	Tools/Equipment Provider	United States	Texas	Global	2019	Geothermal Services	Deployment	N/A	Corporate	Series A	strydefurther.com
TERRACOH	Developer/ operator	United States	Minnesota	N/A	2016	Hydrothermal/ CCUS	Demonstration/ Pilot	$2,500,000	PE/Government	Series B	terracoh-age.com
Transitional Energy	Developer/ Operator	United States	Colorado	Nevada	2020	Well Reuse	Early Deployment	$4,329,000	Government	Series A	transitionalenergy.us
Upflow	Service Provider	New Zealand	New Zealand	New Zealand	2017	Geothermal Services	Deployment	N/A	Government/ Corporate	Series A	upflow.nz
Viridly	Developer/ Operator	United States	Texas	N/A	2022	Direct Use	Research	Fundraising	Privately Funded	Seed	https://www.linkedin.com/company/viridly/about/
Zanskar Geothermal and Minerals	Service Provider	United States	Utah	N/A	2018	Geothermal Services	Research	$15,000,000	Climate Impact VC	Series A	zanskar.com
Total								**$1,101,540,672**			