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Chapter 15

Roadmap for Action

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> ***If we follow the roadmap of the greatest human achievements in our approach to collaboration and cooperation across industries, disciplines, and even party lines, we can achieve or even exceed global decarbonization goals with geothermal by 2050.***

Perhaps we should tackle the challenge of summarizing hundreds of pages of content in a few paragraphs by exploring the themes - and within each theme - the headlines of this Report. The themes allow us to spot trends (i.e. what path we are likely to take over the coming decades), while the headlines might give us line of sight on where we are headed (i.e. what outcome we are likely to achieve by the end of those decades). So let's roll the themes of the Future of Geothermal Energy in Texas:

Oil and Gas Industry 'Booms' Have Enabled Modern Life, and Provide a Playbook For Building the Future of Geothermal Energy:

Talk with anyone who has found their profession in oil and gas, particularly rig crew members who are often the first to feel the ebb and flow of the industry, and observations are fairly consistent. The oil and gas industry and its workers, buoyed by the resilience and grit that a boom-and-bust industry requires, nearly always turn periods of downturn into periods of determined resurgence, breakthrough technological innovation, and forward movement in the upswings. These shorter-term upswings and downturns, driven largely by geopolitical events, news cycles, even weather, fit into a larger context of the big, world changing shifts and pivots of industry over the past century, the so-called "Booms."

The first Boom to emerge from Texas was the Oil Boom, thrust into existence by the gusher at Spindletop, and pushed the world fully into the Second Industrial Revolution, the age of science and mass production, where the world welcomed inventions such as the Model T and electric lighting. From the first Boom, we got the modern world as we know it today.

The next Boom to emerge from Texas, the Shale Boom, or rise of "unconventionals" in oil and gas vernacular, had every bit of the scale and impact of the Oil Boom,

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propelling the United States into its position as a world leader in the production of gas. For those who doubt the dramatic impact of the Shale Boom on the geopolitical arrangement of the world, consider what the world would look like if the United States was not producing the volumes of gas it does currently, with the ongoing crisis in Ukraine, and resulting global energy market disruptions.

It is the Booms that have produced the major leaps forward, the paradigm shifts, and we may be on the brink of another, driven by the quest for fast global decarbonization. But, if you look closely, the Oil and Shale Booms were not singular technological leaps. They were the result of years of small steps, incremental changes in approach, optimization, iteration, stick-to-itiveness, grit, and determination in the industry. Which brings us to our next Report theme:

We Don't Need a Sexy Moonshot. We Need Fast, Incremental Steps:

In 100 years of small steps, the oil and gas industry has progressed from mining oil from pools on the surface of the Earth, to deep and ultra-deepwater oil and gas exploration. The incrementality, and indeed necessity of the steps in between these two should not be overlooked. To make the jump from land-based drilling to offshore drilling, just as an example, drillers started by building wooden platforms in ten feet (three meters) of water, and caught rides with shrimping boats out to their rigs in the morning. Now, decades later, industry drills the most technically complex wells in the world with price tags in the hundreds of millions, from offshore rigs the size of small cities, in 10,000 feet (3,000 meters) of water. Which brings us to our next Report theme:

We May Be on the Cusp of a Green Drilling Boom:

So that brings us to the third Boom set to emerge from Texas, and it is one that is both upon us, and on us to build: the Heat Boom. Geothermal, particularly Next Generation Geothermal as often referenced in this Report, is in its nascency. Its development stage is much like oil and gas was back in the days of Spindletop, where we aimed to harvest what we could easily access, and what we could see, close to or on the surface. In the geothermal context, queue the pictures of Iceland, the Blue Lagoon, and geysers – and the geothermal power plants that sit beside them. Right now in geothermal, we are harvesting what we can easily access, and what we can see. But there is a geothermal "deepwater" that we refer to in this Report as "geothermal anywhere," and the oil and gas industry is well positioned to go get it. Which brings us to our next Report theme:

Geothermal is No Longer Just About Volcanoes. A New Generation of Technologies and Methods from the Oil and Gas Industry Can Help Us Develop "Geothermal Anywhere.":

While we can't see it bubbling up from the surface of the ground in Texas, or in most places in the world for that matter, geothermal is big, underneath us everywhere, and can serve the needs of Texas and the world, in many ways for thousands of years. Texas, and indeed the world, has enormous geothermal resources, sufficient for many thousands of years of heat and electricity production. In Texas, these are not the traditional geothermal resources you find in Iceland, or along the Ring of Fire - Texas geothermal lies in its sedimentary geology. While we do not yet know how much of this enormous heat resource beneath us can be extracted, or how efficiently we can extract it, this is among the technological challenges that lie ahead of us. Which brings us to our next Report theme:

The Oil and Gas Industry is Well Equipped to Solve Geothermal Challenges and Achieve Fast Global Scale:

The nexus between the oil and gas industry, and the potential for fast, global deployment and scale of geothermal energy, not only in Texas, but everywhere in the world is clear. There are historical aspects of the relationship between the oil and gas industry and environmental and climate groups, local communities, even existing traditional geothermal operators that will require an open minded, inclusive, and reflective approach to the future of geothermal development. This is the concept in the Report we see emerge often of "social license to operate." I touched on these topics in a piece in 2020 entitled "If Oil and Gas Becomes Geothermal, What Does Geothermal Become?" If the oil and gas industry is up to the task of geothermal development at fast global scale, it would be helpful if the rest of the world was onboard with the plan. There is work to be done there.

Yet a conclusion underlying all analyses and major outcomes presented in this Report is that Texas and the oil and gas industry are indeed poised to grab the reins of this unique opportunity and run with it. Which brings us to our next Report theme:

The Oil and Gas Industry is Stepping Up to the Plate:

There are many examples in this Report of oil and gas entities taking on the challenge of developing bespoke technologies for geothermal, making investments, and pursuing geothermal pilot projects. It is a pivotal moment in time for the oil and gas industry, where the world is focused on decarbonization, and where the skilled workforce of the industry are struggling to find paths forward in the future energy mix. Amongst this uncertainty, geothermal is a beacon. Numerous innovations and collaborations are emerging from oil and gas entities making significant effort to modify existing equipment, services, and technologies used in oil and gas to support geothermal development.

Oil and gas industry engagement in the realms of technology transfer, project development, and scale has accelerated rapidly over the past three years. Almost 80 percent of oil and gas entities interviewed for this Report noted that they have a geothermal strategy in place or in development, and almost 70 percent reported that there is no geothermal related technical challenge that the oil and gas industry cannot solve. Further, and interestingly, this historically conservative industry is embracing technologically difficult geothermal concepts at increasing rates, with nearly 100 percent of entities reporting engagement or interest in next generation geothermal concepts like Closed Loop Geothermal Systems. There appears to be a trend in the data outlined in this Report of the oil and gas industry "jumping into the deep end" of the most difficult challenges facing geothermal, which is an intriguing and exciting deviation from business as usual.

Another deviation from business as usual in industry is the origin of geothermal initiatives within oil and gas entities. As the data in this Report suggests, several geothermal initiatives within the oil and gas industry have originated from "top-down" management dictates, while more than half of the recent initiatives came from "grassroots" efforts to diversify and strengthen a company's business portfolio. This is a trend to watch as both internal and external activism becomes a theme in itself in the oil and gas industry. Which brings us to our next Report theme:

Disruptors Gonna Disrupt:

Startups are leading the way with big, bold ideas, and new innovators are entering the space faster than we could incorporate them into this Report. Disruption results in step-changes, which geothermal desperately needs. So charge forward, lead the way, and forget business as usual, disruptors. Which brings us to our next Report theme:

Other Stakeholders Are Also Bucking "Business as Usual," Stepping Up to Support and Drive Geothermal:

Geothermal is experiencing a massive infusion of new voices, faces, entities, and ideas, including new initiatives within government from agencies interested in fast deployment of the resource. A 2023 solicitation for scalable microgrid geothermal systems by the United States military, discussed in this Report, is a prime example. New off-takers are fast emerging - municipalities, utilities, even private landowners. New startups are launching at an accelerating pace, mostly headquartered in Texas and led by oil and gas industry veterans, another new trend. New innovations and ideas are emerging from the oil and gas industry, and the number of entities engaged is quickly growing. New investors are entering the space, eager to support teams, technologies, and scale. These trends combined have created a convergence and are acting as force multipliers on one another.

In the realm of environmental impact, and environmental and climate activism, we are seeing the beginning of a shift in perspective there as well. As the world charges forward with decarbonization and energy transition strategies, it is important to keep eyes wide open on the environmental footprint of the technologies that we are choosing to deploy and scale, and what their life cycle environmental impacts are. Currently, the terms "renewable" and "clean" are being used to describe technologies that require high impact, environmentally destructive mining operations, extensive use of critical and Rare Earth minerals extracted by geopolitical rivals or from unstable regions of the world. Many minerals required for these energy technologies are mined in countries where human rights abuses are rampant, and with little regard to environmental or workplace safety. Further, many of these materials cannot be recycled at the end of their productive lives, creating massive waste streams with toxic by-products that end up in landfills.

By comparison, geothermal is a standout, and we are seeing a steady trend in the past few years of environment and climate groups not only engaging in the details of the supply chains and carbon footprints of traditional renewables, but also in the benefits and attributes of geothermal energy. All energy technologies have an environmental impact, and we need to take a levelheaded, fact-based approach to how we deploy technologies over

the coming decades to assure that we do not repeat the environmental impacts of our past energy sources, with the energy sources of our future. Which brings us to our next Report theme:

Aggressive Targets, a Bold Vision, and Interdisciplinary Collaboration Directed at Geothermal Will Drive Down Cost, and Drive Up Scale:

Cost is a central challenge that has constrained geothermal development historically and is a recurring theme across Chapters. But while cost challenges associated with geothermal are today's reality, as technology and methods transfer from oil and gas optimizes systems, and risk is mitigated, successful business models will emerge. As the Report concluded, all geothermal concepts, including Next Generation, scalable geothermal concepts like Engineered Geothermal Systems and Advanced Geothermal Systems will benefit significantly from oil and gas technology and knowledge transfer, providing quick wins and achievable learnings projected to deliver 20 to 43 percent in cost savings, depending on the type of geothermal technology. And these cost reduction estimates do not consider the impact of new innovations and technology breakthroughs.

Cost reduction, increased efficiency, and optimization of scalable geothermal systems stands as a "grand challenge" for Texas to aim for by the end of this decade. There are strong parallels here with the trajectory of the oil and gas industry historically. As the utilization of oil and gas scaled, the business model became successful, and that business model has dominated the world's energy production for a century. There is no reason to reinvent the wheel to build our clean energy future. We have the playbook - we just need to apply it to grow and scale geothermal. But industry cannot do this alone, which brings us to our final Report theme:

An 'Apollo' Style Mobilization of Stakeholders Could Drive Sufficient Global Scale for Geothermal to Supply a Majority of Global Demand for Electricity and Heat by 2050:

The final recurring theme is the need for robust, focused engagement from governments and world leaders to realize the targets identified in this Report. Geothermal will benefit from a laser focus on how policy incentives and market shaping can help build this new global industry with a firm root in the State of Texas. Ultimately, the development of geothermal systems at scale - the coming Heat Boom - is likely to follow closely in parallel with the Shale Boom. As Texas is a world leader in unconventional oil and gas production, it is positioned to become the world leader in the production of the scalable geothermal systems of the future. It will take time and significant investment, but as this Report concludes, the potential for Texas to become the global geothermal epicenter is exceptional.

Which brings us to the subject of global impact. From this Report emerges disruptive and globally significant headlines, like the possibility that Texas could fully decarbonize its grid, utilizing existing oil and gas technologies and capacity, in only four years of drilling geothermal wells in the State. **In another ground-breaking estimate, a strenuous "all hands on deck" development scenario where 1.4 million geothermal wells are drilled globally between 2030 and 2050, would result in 77 percent of global projected electricity demand being supplied by geothermal by 2050. Drilling another 600,000 geothermal wells globally in that same period for heat production could supply more than 100 percent of global projected heat demand by 2050. This is a pathway to decarbonization that, while aggressive and extraordinary in its scale, is perhaps more realistic than any other path to decarbonization in existence currently.**

In oil and gas, we've followed the trajectory of industry from Spindletop at the turn of the century, to the Deepwater exploration and production of today. Similarly, we will follow the trajectory of geothermal development near volcanos of today, to the sedimentary development in Texas prairies of the near future, to SuperHot development anywhere in the world in the further out future. There will be steps in between, as there always have been, in ways of learning and progress of the industry - but our Heat Boom, Green Drilling Boom - whatever you want to call it, is here and it is up to us to build. We can get there. The oil and gas industry has achieved this speed and scale before, with rapid global impact. **If we follow the roadmap of the greatest human achievements in our approach to collaboration and cooperation across industries, disciplines, and even party lines, we can achieve or even exceed global decarbonization goals with geothermal by 2050.**

So let's go.

Since we began with a geothermal pun in the introduction of this Report, perhaps we should end with one that seems fitting:

Well, well, well Texas, what do we have here... 🔥

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. 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 have 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.