



Minding the Gap



Geothermal Financing at Oil and Gas Scale



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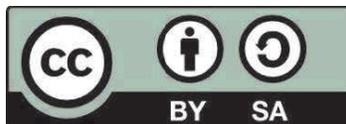


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Executive Summary

This analysis examines how established commercial practices, with an emphasis on the commercial infrastructure that enables the free flow of capital in the oil and gas industry, can be adapted to build a robust and well-functioning financing ecosystem to scale geothermal energy. This work is the result of a three year long discovery process working with more than 100 subject matter experts and entities through workshops, interviews, and research initiatives supported by Project InnerSpace across investment management, oil and gas, geothermal development, insurance, offtake, and policy.

Importantly, geothermal does not need a financing system built from scratch. Over the past century, the oil and gas industry has developed a sophisticated commercial infrastructure that enables capital to flow efficiently into energy projects at scale. This infrastructure includes transaction frameworks, financial instruments, risk classification systems, and regulatory practices that structure how projects are financed, developed, and traded. Many of these institutional mechanisms can be adapted to geothermal at a fraction of the cost and time required to create new systems. Most importantly, adoption of the same financial language that is used in oil and gas can rapidly unlock existing solutions—allowing geothermal projects to be evaluated, financed, and traded within capital markets that already understand these systems.

Barriers that limit capital and insurance market deployment into geothermal at scale can be bucketed into three main categories; 1) **Market related challenges**, 2) **Resource related challenges**, and 3) **Regulatory challenges**.

Market Focused Opportunities

The absence of a common terminology and calibrated frameworks for assigning risk across development phases hampers structured investment, standardized contracting, and project evaluation across equity, debt, insurance, and offtake agreements. Disconnected financial markets, including PPA structures, insurance products, and debt instruments, result in chicken- and-egg dynamics that block project bankability. Limited liquidity in secondary asset sales constrains project development and inhibits investor exits.

Further challenges include commercialization barriers, like the limited track record of large-scale projects, investor perceptions of subsurface uncertainty that may exceed the underlying technical risk, and constrained insurance and capital market capacity. These factors are compounded by regulatory uncertainty and evolving market structures, which together limit the availability of financing instruments and increase the perceived cost of capital. Opportunities to address these challenges will be considered at length in this analysis.

Resource Focused Opportunities

While conventional geothermal projects from traditional geothermal developers like Ormat and Calpine have demonstrated success, albeit with low near stagnant growth over decades of development, next-generation technologies face compounded challenges due to the limited number of mature commercial examples. Perceived geothermal risk leads to an elevated cost of capital compared to other infrastructure asset

classes. Without confidence in predicting flow rates and reservoir longevity, institutional capital has limited ability to price risk with sufficient confidence to commit.

The oil and gas sector offers a strong blueprint for how to address this. Over the past two decades, oil and gas companies conducted extensive, structured experiments in unconventional reservoirs that directly built investor confidence through performance data. We will consider this blueprint fully in the pages below.

Regulatory Focused Opportunities

Information gaps, complex regulatory processes, and redundant, burdensome, unclear, and ill-fitted regulatory structures continue to slow geothermal project development and investment.

Geothermal regulation is inherently complex because it sits at the intersection of energy production, civil infrastructure, and subsurface resource law. Unlike oil and gas, which benefits from more than a century of regulatory development, standardized ownership conventions, and predictable permitting pathways, geothermal projects must navigate fragmented and overlapping jurisdictions. Legal ownership of subsurface heat creates title uncertainty that directly affects project finance. This remains unresolved in many countries and US states. Permitting timelines are often extended, agency roles may be unclear, and the regulatory treatment of geothermal stimulation – particularly in countries that have banned hydraulic fracturing for hydrocarbons – continues to generate legal uncertainty.

These challenges and opportunities for improved regulatory structures and clarity are the subject of a separate body of policy focused work, including Project InnerSpace’s [“Future of Geothermal”](#) report series. This body of work focuses on ecosystem building and deep dive analysis in US states and international ecosystems that are ripe for geothermal development.

The work of our sister organization, InnerSpace Action, focuses on the development and adoption of clarifying and supportive geothermal legislation, including clarification of legal ownership of subsurface heat, and novel funding mechanisms leveraging State resources. Since these regulatory opportunities are the focus of a separate body of work and research, they will not be considered in depth in this analysis.

The Top Opportunities for Unlock

In line with Project InnerSpace’s mission to identify and remove the major barriers that are standing in the way of the exponential growth and development of geothermal energy, we describe and prioritize in the following pages a set of initiatives designed to address market focused and resource focused opportunities, identifying initiatives where philanthropic and catalytic capital is uniquely suited to create meaningful impact.

The top eight opportunities that were identified through our research that, if developed, would support the creation of functioning and efficient capital and insurance markets to scale geothermal are below. The opportunities are listed in order of priority given their interdependence on one another and/or the time required to bring them to fruition. Each of these opportunities represents an area where Project InnerSpace has built partnerships and has committed capital to support as part of our 2026 strategic plan.

What is the Impact of Removing These Barriers on Geothermal Development?

1. A lower cost of capital for geothermal projects through improved market transparency and standardized risk language.
2. A dynamic financing framework designed to align with the capital markets standards established in oil and gas.
3. A functioning insurance market including exploration risk coverage modeled on the Munich Re/KfW program launched in Germany in December 2025.
4. Faster and meaningfully scaled global geothermal development at the pace that is required for relevance.

1. Develop Common Standards

Effective geothermal transactions depend on the ability to impartially assess an asset and its future potential. However, in the absence of a standardized framework or shared language, buyers, sellers, and investors often struggle to agree on the nature and value of geothermal assets. This lack of clarity impedes deal-making, stifles liquidity, and limits the ability of stakeholders with different risk and return profiles to enter or exit investments. A robust classification and reporting system would address these challenges by providing a common foundation for evaluating geothermal projects. Similar systems are well-established in the extractive industries, including frameworks such as PRMS (Petroleum Resources Management System), SRMS (SPE Storage Resources Management System), UN ECE standards, COGEH (Canadian Oil and Gas Evaluation Handbook), JORC (Joint Ore Reserves Committee), and CRIRSCO (Committee for Mineral Reserves International Reporting Standards). These systems support transparency, comparability, and consistency in resource assessment.

Therefore, the most impactful near term opportunity that would create watershed effects to unlock capital for geothermal development is to develop a Geothermal Resources Management System (GRMS) modeled after the Petroleum Resources Management System (PRMS) used in oil and gas, which has supported trillions of dollars of capital to flow toward development of oil and gas projects.

A shared classification framework for geothermal resources and reserves would provide a common language similar to the one the finance community already uses in the oil and gas context, which is required for project valuation, insurance underwriting, standardized contracts, and reserves-based lending.

2. Invest in Demonstrations

Support a portfolio of pilot projects for next-generation geothermal technologies to generate operational performance data and demonstrate commercial viability. Strategic deployments serving data centers, military installations, and industrial facilities can provide early revenue certainty through long-term offtake agreements.

Next generation geothermal pilots in geologically distinct basins will generate the multi-year performance data needed to de-risk investment at scale. In parallel, off-grid development – serving data centers, military

bases, and large industrial facilities – provides a near-term deployment pathway supported by long-term PPAs with creditworthy counterparties, bypassing grid interconnection delays.

3. Develop Familiar Financial Instruments Adapted for Geothermal

Introduce financial structures familiar to capital markets, including reserves-based lending, farm-in/farm-out agreements, joint ventures, and production-linked financing mechanisms. Complementary tools such as government-backed geothermal “Hot Bonds,” early-stage insurance products, and catalytic capital vehicles could reduce the cost of capital, improve project bankability, and attract institutional investors.

4. Develop Standardized Geothermal Contracts and Agreements

Adapt the Association of International Energy Negotiators’ ([AIEN](#)) model contract library – Joint Operating Agreements, Farm-in/Farm-out, Sale and Purchase, Unitisation – to geothermal’s specific characteristics. Standardised contracts reduce legal costs, accelerate deal execution, and make transactions legible to investors unfamiliar with the sector.

5. Facilitate Entry and Exit From Geothermal Assets

Create the conditions for a functioning secondary market: standardized documentation, transparent valuation frameworks, and a marketplace or forum connecting buyers and sellers. A coordinated vehicle for leveraging Advanced Market Commitments made by industry, or a government-backed Advanced Market Commitment for early-stage assets can provide the first-mover demand signal. Over time, this enables diverse investor types – including those requiring exit optionality – to participate in geothermal.

6. Build Partnerships to Support Off-Takers as Early Equity Investors and Guaranteed Off-Take

Bring data centers and large energy consumers in as co-investors or as legally binding guaranteed off-take through portfolio-wide Advanced Market Commitments, anchoring capital structures and aligning buyer and developer interests around long-term thermal performance.

7. Develop Blueprints for Early-Stage Equity Investment

The most acute capital gap in next-generation geothermal development is at the pre-construction phase – typically \$20M per project or more – before construction financing can be secured. A detailed blueprint for a catalytic capital vehicle combining public and private funding under a specialist mandate would provide a replicable deployment model. Preliminary modelling suggests every \$20M of catalytic early-stage equity could unlock ~\$200M in private capital and support ~150 MW of additional capacity.

8. Adopt Oil and Gas Best Regulatory Practices

Introducing tiered permitting (risk-based NEPA/CEQA review), risk-based well standards, like [API RP 53](#), and [API RP 75](#), centralised data portals, and workforce certification frameworks modelled on [SafeLandUSA](#) would reduce permitting delays, regulatory inconsistency, and procedural uncertainty.

Other Supportive Catalytic Work

Further, while this report focuses primarily on what actions we can support now to unlock meaningful capital into geothermal development, as part of our analysis, we looked ahead and asked “if we successfully build what we envision here, what future bottlenecks might constrain success in the future?” The answers to those questions, largely related to **supply chain constraints, entrepreneurship, and targeted research and development**, are the subjects of separate bodies of work ongoing at Project InnerSpace. These initiatives seek to support future bottlenecks with catalytic capital now, so they do not become constraints to growth in the future.

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Chapter 1

The Geothermal Finance Gap: A Comparison with Oil and Gas

Overview:

The challenge and novelty of next-generation geothermal as a business model lies in the fact that it is both more expensive per megawatt-electric to develop than wind and solar, and carries some of the subsurface risks of oil and gas developments.

Recent offtake agreements, such as Fervo and Sage's data-center power deals with Google and Meta signal growing demand for geothermal capital. This demand could expand capital flow from hundreds of millions of dollars per year to multiple billions. **Even so, this remains a fraction of the approximately \$90 billion of upstream CAPEX invested annually in U.S. oil and gas, and the approximately \$600 billion worldwide.**

Ownership structure, immature transaction markets, and low investor awareness could constrain geothermal growth despite increasing offtaker demand. This is particularly true in the case of oil and gas majors, where case for oil and gas technology and business models substantively impacting a growing geothermal industry is compelling, but operators have thus far not meaningfully engaged, with the exception of a handful

of small to mid-sized firms outside of the 'super major' category, due to lack of clarity regarding potential for scale, and profitability. This topic is the subject of a separate forthcoming publication by Project InnerSpace, entitled "**Geothermal Energy at Oil and Gas Scale: A Strategic Investment Case for Oil Majors in Premium Priced Baseload Power.**"

There are over [3,000 active oil and gas operators](#) in Texas alone, with assets owned across a wide spectrum of entity types, including major oil companies, independent producers, private equity, royalty funds, hedge funds, family partnerships, and more. This diversity enables investors with varying risk appetites to participate at every stage of the value chain.

By contrast, the existing geothermal exploration and production industry is characterized by vertically integrated entities undertaking cradle-to-grave projects. For example, in the US, there are approximately 25 geothermal power generation companies, most owning 100% of the working interest in their producing plants. Two are publicly traded - Constellation and Ormat. The balance, including the start-ups, are owned by either private equity or publicly traded exploration

and production and oilfield service companies. This concentrated ownership structure limits the ability of different investor types to choose their preferred risk/return exposure and acts as a structural barrier to capital formation.

Oil and gas assets at every stage of exploration, development, and production are frequently and easily traded, supported by hybrid-online auction houses and investment bank-facilitated M&A processes. In contrast, as previously reported in a 2023 Project InnerSpace publication, [The Future of Geothermal in Texas](#), there were an average of three geothermal asset transactions globally per year between 2017 and 2022. That transaction rate has remained relatively unchanged since, with only a handful of additional transactions each year through 2025. The predominance of private ownership limits price discovery and liquidity, locking up capital and keeping the pool of participants narrow.

Asset Trading Volumes

Oil and gas assets at every stage of exploration, development, and production are frequently and easily traded. In addition to large transactions facilitated by investment banks and broker-dealers, there are hybrid-online auction houses such as [Oil & Gas Clearing House](#), which has conducted on average 1,000 transactions per 16,000 properties across North America over the last 30 years.

In contrast, there have been one to two geothermal asset transactions each year since 2017; the latest, the [acquisition of Calpine](#) by Constellation, can be considered an exception in a market dominated by a private equity buyer or seller. The predominance of private ownership limits price discovery and liquidity. The consequence for the geothermal sector is that investors cannot readily enter and exit assets, capital is locked up, and the pool of participants remains narrow.

Common Language for Transactions and Agreements

Buyers, sellers, and lenders in oil and gas have a common language of reserves and resources, and a comprehensive inventory of contracts for transactions, joint ventures, and related agreements. The parties generally agree on a reduced set of metrics that facilitate rapid decisions on whether to transact, including:

- Acreage;
- Current production;
- Forward commodity prices for future cash flow calculations;
- Proved developed producing reserves and other

Toward Transaction Liquidity in Geothermal: The Oil and Gas Template

The oil and gas transaction process is so efficient that industry players can enter and exit assets at every stage of the value chain and borrow against future production as well as balance sheets. Investors can choose in which segment of the risk-over-return information and value chain they wish to participate, attempt to add or extract value, and be reasonably sure they have a viable exit. It also enables non-industry players to participate when assets are de-risked. For example, shale wells on their hyperbolic decline curves are attractive to pension funds needing to match long-term assets to liabilities.

Beyond attracting investors with different risk-return appetites, confidence in the ability to monetize assets through a liquid transaction market also draws specialized teams. Often undercapitalized, these groups identify highly speculative plays, carry out the intellectual and technical work needed to delineate and commercialize them, and then transfer the assets to better-capitalized entities for further appraisal and development. This cycle of exploration, de-risking, farming out, and development repeats until mature production. Adapting these highly successful oil and gas commercial practices to the geothermal industry could stimulate substantial investment.

reserves categories reported by an independent expert in compliance with an internationally recognised standard

By contrast, the geothermal industry has relied upon bespoke standards and valuations – such as those provided by [GeothermEx](#) for 50 years, which alone has supported the development of 70% of installed global capacity. This dominant position and proprietary valuation methodology does not facilitate the rapid expansion of investment by multiple parties with natural conflicts of interest (such as equity and debt providers and insurers) who are obliged to seek independent valuations.

Public Information

Detailed information on all oil and gas drilling and production is freely available from state databases and can be used to sense-check sellers' claims and third-party reports ([SODIR](#), [ANP](#), [Texas RRC](#)). There is no equivalent public information for geothermal production. This asymmetry materially disadvantages new entrants and prevents the kind of independent verification that institutional capital requires.

Debt Finance

The market for oil and gas debt is highly competitive and sophisticated, with reserves-based lending widely available, as well as the more usual revolving credit, bond, and mezzanine instruments. Proved Developed Producing Reserves are the foundation for lending, with lesser weight for reserves in probable producing, drilled uncompleted wells, and proved undeveloped categories. Forty-eight to sixty-month tenors are common. The structure of these debt instruments may, with modification, benefit geothermal developments, albeit with longer tenors.

In a Nutshell

In summary, the oil and gas transaction process is so efficient that industry players can enter and exit assets at every stage of the value chain and borrow against future production as well as balance sheets. Investors can choose in which segment of the risk-over-return information and value chain they wish to participate, attempt to add or extract value, and be reasonably sure they have a viable exit. It also enables non-industry players to participate when assets are de-risked – for example, shale wells on their hyperbolic decline curves are attractive to pension funds needing to match long-term assets to liabilities.

In addition to attracting investors with varying appetites for risk over reward, the confidence that assets can be readily monetized through a highly liquid transaction market attracts a wide variety of expert teams – often undercapitalised – to seek highly speculative assets and plays; do intellectual work to delineate them and prepare them commercially; and then farm them out to better-capitalised entities to add further information and development. This cycle of exploration, de-risking, farming out, and development repeats until mature production. Adapting these highly successful oil and gas commercial practices to the geothermal industry could stimulate substantial investment.



Chapter 2

Capital and Insurance Market Challenges on the Geothermal Frontier

Our objective in this analysis is to identify, evaluate, and prioritise financial and risk-related barriers to the deployment of geothermal energy globally at scale. This chapter articulates the needs of capital and insurance markets, evaluating the specific challenges that inhibit investment, and offers a structured set of priorities for mitigating those barriers.

Information Required by the Capital and Insurance Markets

There are six categories of information that capital and insurance markets require in order to evaluate and commit to geothermal investments.

1. Financial Information

Geothermal project financing requires a clear understanding of post-tax internal rate of return, capital costs per MWe and MWth, loan terms, and capital structure including debt-to-equity ratios. Key financial risks include interest rates, well underperformance, and long asset-durability questions over lifespans exceeding 20 years.

Operational costs, the structure and security of offtake agreements, and electricity pricing tied to capacity factor and firm power value are crucial inputs. Incentives such as Investment Tax Credits and Production Tax Credits – including transferability provisions – as well as comparisons with alternative power sources through

Levelised Cost of Energy Plus metrics, influence investment attractiveness.

Market dynamics are changing with data centers now valuing baseload power, potentially redefining geothermal's commercial profile. Scale is essential, with large buyers – such as major technology firms – seeking 0.5 GWe or more of contracted supply.

2. Risk Information

Risks span technological maturity, well degradation, exploration uncertainty, and the reliability of reservoir models and design, especially near complex geological features such as magma calderas. Many risks are not well understood pre-operations, including long-term thermal impacts, induced seismicity, and decline rates. There is a recognised need to identify real risks and compartmentalise them through phased development.

Additional risk dimensions include vendor reliability, data availability, geochemistry, and grid integration. Past project data and evidence of successful performance evolution are important for building investor confidence.

3. Resources Information

Resource assessment involves understanding the producible area, reservoir pressure, depth, rock properties such as tensile strength and fracture density,

and stress regimes. Next generation geothermal projects often face more extreme geological conditions, with implications for drilling costs, thermal decline, and reservoir sustainability. Key challenges include heterogeneity in thermal and geomechanical rock properties and principal stress orientation, induced seismicity risks, thermal breakthrough, and subsurface faults – especially in geologically complex areas such as the south-west US. Reliable data on heat extraction rates and reservoir conformance is essential to forecasting thermal performance for offtakers and establishing economic attractiveness.

4. Corporate and Management Information

Investor confidence is influenced by the quality of management and operating teams, along with corporate strength measured by balance sheet and shareholder structure. Strong leadership and demonstrated technical expertise remain key differentiators in a sector where proven operators are scarce.

5. Regulatory Information

Geothermal development is affected by uncertainty around heat and water rights, permitting timelines, and environmental approvals. Regulations often differ from oil and gas in important respects, and permitting delays can materially derail project economics. High per-acre lease costs and unclear ownership frameworks introduce additional risk.

6. Stakeholder Information

Stakeholder concerns encompass community engagement, social licence to operate, public consultations, and the obligation to meet local community needs. International project precedents – including [United Downs](#) and [Eden](#) in the UK, and Iceland's [Krafla Magma Testbed](#) – may offer insights into effective stakeholder engagement, but require transparency and alignment with community interests from the outset.

Key Observation

Across all six categories, a consistent theme emerges: the geothermal sector lacks the standardized, publicly accessible, independently verifiable information that capital and insurance markets require to make confident investment decisions. In oil and gas, this information infrastructure took decades to build through the accumulation of regulatory requirements, industry standards, and market conventions. In geothermal, it remains largely absent – and its absence is itself a primary barrier to investment.

Immaturity of Technical Performance in Asset Classes

Geothermal development faces challenges including a lack of large-scale project demonstrations, technical and budgetary limitations, uncertainty across diverse technologies with varying maturity levels, and insufficient confidence in long-term heat extraction performance, subsurface connectivity, and flow reliability.

- Limited availability of large-scale demonstration projects (e.g., \$500M+) with proven multi-year circulation and heat extraction; current budgets fall significantly short of enabling such validation;
- Technical uncertainty remains around fracture stimulation methods and their applicability to various geothermal settings;
- Varied technological readiness across geothermal types (hydrothermal, EGS, AGS, hybrid systems, and oil and gas well reuse) complicates standardized investment criteria;
- Lack of investor confidence in predicted heat extraction rates and project longevity, especially in novel systems;
- Poorly characterised well-to-well communication over multi-year timescales undermines commercial modelling;
- Unquantified fouling and scaling risks could impair reservoir connectivity and production capacity over time;
- While repurposing oil and gas wells offers theoretical cost savings, few cases demonstrate clear economic viability to date;
- Until next-generation geothermal systems operate commercially for a decade or more, long-term performance and durability concerns will continue to deter investment.

Uncertain Resource Potential

In the realm of geothermal development, particularly with next-generation geothermal systems, a key challenge is the lack of long-term production data to validate reservoir performance predictions. Unlike conventional geothermal projects, there are few benchmarks available, and most existing long-term data come from vertical wells. Notable exceptions include Fervo's Cape project, which provides some insight into horizontally stimulated wells.

This scarcity of empirical data creates significant uncertainty around reservoir behaviour, deterring investment. Current resource estimates rely heavily on physics-based models, which remain difficult to validate without robust production data from horizontal

systems. The variability in predictions from different simulators adds to investor hesitation. **Accelerating the generation of long-term production data through well-designed demonstration projects is critical to building confidence in model outputs and unlocking capital for the sector.**

To address this, coordinated efforts between industry and government are needed, focused on executing high-quality demonstration projects with extensive, structured data collection. The oil and gas sector offers a strong blueprint, having conducted numerous large-scale experiments in unconventional reservoirs over the past two decades. Many of the technologies used in oil and gas – drilling, completions, reservoir simulation – are directly applicable to geothermal, though adaptation for heat rather than fluid recovery is required.

The challenge with geothermal resources is not their size – heat beneath the Earth's surface vastly exceeds global energy needs – but the uncertainty in accessing and delivering this energy. Unlike oil and gas, where reserves are defined by recoverable fluid volumes within geological boundaries, geothermal estimates are based on heat flux, influenced by rock conductivity, fracture networks, and subsurface fluid pathways. Boundaries between geothermal assets are less distinct, raising concerns about inter-site impacts and legal complexities.

Accurately defining geothermal resource potential requires a deeper understanding of heat recovery sustainability and its spatial impacts. This demands expanded geophysical surveying, drilling campaigns to delineate the resources accessible by the project, and advanced modelling of heat transfer processes.

Oil and gas technologies can be adapted to refine geothermal models, particularly in areas such as subsurface thermal simulation, temperature monitoring, and fracture mechanics. Competencies such as in situ stress analysis, thermal conductivity measurement, and advanced reservoir modelling will be critical for reducing uncertainty and supporting the growth of geothermal as a reliable energy source.

Technology Maturity: Next-Generation Geothermal

A significant barrier to the expansion of next-generation geothermal technologies, such as EGS and AGS, is concern over their current level of technical maturity. Many investors are hesitant to commit capital at scale due to a lack of demonstrated performance and limited evidence of consistent financial returns. This perceived immaturity makes it difficult for project developers

to secure funding, particularly from conservative institutional or infrastructure investors.

Historically, EGS projects have relied on vertical wells and 'pump-and-pray' hydraulic stimulation techniques, which have generally delivered disappointing results. These early attempts failed to create reliable, productive reservoirs, further reinforcing skepticism in the financial community. Although horizontal, fracture-stimulated wells offer a promising improvement in reservoir development, the technology has not yet been implemented at sufficient scale to convince the broader market of its commercial viability. As a result, many investors are adopting a cautious, wait-and-see stance.

To overcome this barrier, a focused effort is needed to deliver new demonstration projects in multiple geological settings, designed specifically to produce reliable, long-duration, and ideally open sourced performance data. These projects must be technically rigorous and supported by comprehensive data-gathering programs to validate cost and performance assumptions. Successful demonstrations would help de-risk future investments and set performance benchmarks that could support project finance structures.

The oil and gas industry offers a valuable template. Over the past two decades, US oil and gas companies have conducted extensive, structured experiments in unconventional reservoirs, providing deep expertise in drilling, well completions, and reservoir simulation. These technologies and methodologies are directly applicable to next-generation geothermal and can significantly accelerate the path to technical validation. Collaborations between geothermal developers, the oil and gas sector, offtakers, and public institutions can leverage these competencies to move the industry closer to commercial maturity and unlock broader investment.

Confidence in Heat Extraction Rate and Thermal Longevity

One of the most critical concerns for investors evaluating next-generation geothermal is the ability to maintain high flow rates and long-term thermal performance. The success of these systems relies on efficiently transferring cold fluid from injection wells through stimulated subsurface fractures to production wells, extracting sufficient heat to generate power or provide thermal energy. Uncertainty in this process – whether due to poor hydraulic connectivity or early thermal short-circuiting – can jeopardise project viability.

Without confidence in predicting flow rates and reservoir longevity, most investors remain cautious, delaying or limiting capital deployment. A failure to sustain adequate flow or heat delivery can lead to early decline in power output, ultimately undermining a project's financial returns. This is especially problematic for large-scale geothermal developments aiming to deliver hundreds of megawatts or more, where high upfront capital must be justified by long-term, stable performance.

Addressing this challenge requires targeted demonstration projects capable of operating at higher reservoir temperatures than current commercial benchmarks, while achieving improved flow rates and demonstrating thermal stability over extended periods – ideally five years or more. These projects must be designed to generate detailed data that will feed into predictive models and reduce uncertainty for future developments.

One promising avenue for improvement is the sequential use of multiple stimulation techniques to create and maintain robust fracture networks. Oil and gas industry practices – particularly those involving fracture-driven interactions – offer a wealth of transferable expertise. Technologies and methodologies from oil and gas, including advanced drilling, well completions, and reservoir simulations, are highly applicable to geothermal and can enhance fracture design and subsurface modelling.

Moreover, specialized engineering competencies are needed, such as discrete fracture network (DFN) modelling, application of image logs to map secondary systems, and real-time supervision of stimulation operations. Laboratory testing on high-temperature fluid-rock interactions and material degradation is also essential to understand long-term performance. Building this foundation of technical evidence is key to establishing investor confidence and enabling large-scale geothermal deployment.

Uncertainty of Scaling Impacts on Long-Term Flow Capacity

Scaling, which is the buildup of mineral deposits in wells, fractures, and surface equipment, is a well-documented challenge in geothermal operations. In both subsurface and surface systems, scale formation can reduce flow efficiency, damage infrastructure, and increase operational costs through cleanouts, chemical inhibition, or equipment replacement.

In the context of Engineered Geothermal Systems

(EGS), this issue presents a significant concern for long-term flow capacity. As flow rates and thermal longevity are critical to the economic viability of geothermal projects, the potential for scale to reduce subsurface permeability or impair well performance creates uncertainty that directly impacts investor confidence. Additionally, ongoing maintenance and treatment costs associated with scale contribute to operating expenses, further complicating the financial outlook for developers and lenders.

To address this challenge, geothermal developers need to validate scale mitigation strategies through both laboratory experiments and long-term field demonstrations. Extended flow tests in high-temperature environments are particularly important for evaluating how scaling evolves over time and for assessing the durability of treatment methods. Developing effective, high-temperature scale inhibitors is essential to maintaining productivity in EGS systems.

The oil and gas industry offers a wealth of relevant expertise in scale prediction, prevention, and remediation. Decades of experience with inorganic scale management in high-pressure, high-temperature wells can be leveraged and adapted for geothermal conditions. This includes the use of predictive modelling, chemical treatment programmes, and mechanical remediation techniques.

By applying these practices and tailoring them to geothermal systems, operators can reduce performance degradation, lower operational risk, and improve the reliability and longevity of geothermal assets.



Chapter 3

Commercialization Challenges as Barriers to Scale

Commercializing geothermal is hindered currently by fragmented terminology, disconnected financial and contract markets, illiquid asset transfer, and constrained access to high-voltage transmission amidst growing competition. Several commercial barriers rise to the fore:

- The geothermal industry lacks proven pathways to scale into a high-volume, low-cost infrastructure sector akin to solar or wind;
- Absence of a common terminology and classification system hampers standardized contracting and project evaluation across equity, debt, insurance, and offtake agreements;
- Disconnected financial markets – PPA structures, insurance products, and debt instruments – result in chicken-and-egg dynamics that block project bankability;
- Limited liquidity in secondary asset sales constrains project development and inhibits investor exits;
- High-voltage transmission access is constrained by both permitting hurdles and limited available capacity in key baseload regions.

Investors' Perception of Risk and Opportunity

Investors perceive geothermal as high-risk due to the high cost of capital, limited willingness to invest at current return expectations, and a lack of standardized, proven technologies, compounded by the need for early-stage de-risking and 'right-risking' frameworks to

enable confidence through Seed to Series C funding and structured debt markets. This results in the following commercial bottlenecks and constraining outcomes:

- Perceived geothermal risk leads to elevated cost of capital compared to other infrastructure asset classes;
- Lack of calibrated frameworks for assigning risk across development phases ('right-risking') hampers structured investment;
- Too few investors are willing to accept the perceived return profile of geothermal projects;
- Early-stage equity markets (seed and Series A) are insufficiently deep to absorb the technical, regulatory, and social risks associated with greenfield development;
- Later-stage investment (Series B, C, and debt) is impeded by the lack of standardized technology solutions and asset class maturity.

High Cost of Capital

While conventional geothermal projects from developers like Ormat and Calpine have been successful, their returns – especially under utility-scale power purchase agreements – are typically lower than those offered by similarly risked oil and gas ventures. This gap in expected returns makes geothermal less attractive to investors, especially when compared to the historical performance and profitability of oil and gas assets.

For next-generation geothermal technologies, the challenge is compounded by the limited number of mature, commercial-scale examples, which leaves investors uncertain about long-term performance and return potential.

This uncertainty translates into poor access to affordable debt financing. When financing is available, it often comes at a high cost, forcing developers to rely on expensive equity, typically at the parent company level. This capital structure is inefficient, especially for later-stage activities like drilling and construction, which are more appropriate for lower-cost debt.

To overcome this challenge, industry and government collaboration is needed to develop a pipeline of demonstration projects that generate sustained production and cost data. These projects would provide the basis for improved cost modelling, better risk allocation, and greater investor confidence.

Oil and gas has long benefited from a mature capital market, built on a track record of performance and well-understood financial structures. Geothermal can leverage similar approaches. The oil and gas industry brings valuable technical capabilities, particularly in subsurface engineering and project execution. But addressing geothermal's unique challenges will also require expertise from other sectors – such as aerospace, chemicals, utilities, and civil engineering. Additionally, IT-driven innovations like AI and digital twins, widely utilized in oil and gas, could significantly enhance geothermal performance monitoring and modelling. A cross-sector, collaborative approach to financing and technology deployment, alongside potential strategic government support, will be critical to unlocking growth.

Market Capacity and Supply Chains

Geothermal development is limited by an immature supply chain, low market volume that deters service company investment, competition with oil and gas for shared resources, inadequate power takeaway infrastructure, and the absence of a robust capital structure to support industry growth across all financing stages.

- The geothermal equipment and services supply chain lacks depth and maturity, limiting scalability;
- Market volumes remain too low to justify oil and gas service firm investment, which increases geothermal project costs;
- Transmission infrastructure ('takeaway capacity') is often unavailable or not prioritised for baseload generation;

- Current financing ecosystem lacks the stage-appropriate capital required for a healthy project pipeline – from Seed through Series A, B, C to debt financing.

Key Observation on Supply Chains

There are few land rigs globally with sufficient capacity to drill the deep horizontal wells (6–7 km) that are increasingly required for next-generation geothermal. This structural constraint limits the industry's ability to scale regardless of capital availability. The surface equipment supply chain is even more constrained, with only a handful of players producing geothermal turbomachinery globally. Until geothermal project volumes are high enough to justify dedicated investment, costs will remain elevated and timelines unpredictable. It is the chicken-and-egg dynamic: without supply chain depth, project costs remain high; without competitive economics, volumes cannot grow to catalyse supply chain investment. **Addressing this requires deliberate intervention – either through financial incentives to expand these supply chains, or through demand signals that make dedicated geothermal capacity commercially viable.**



Chapter 4

Addressing the Challenges: Key Unlocks Toward Terawatt Scale Capitalization

The preceding sections focused on the market, resource, and commercial barriers that are standing in the way of exponentially scaled next-generation geothermal development. **But do not despair - there are solutions that can be immediately brought to bear, including through targeted investment of catalytic capital, to address these barriers.**

This section identifies a set of initiatives designed to close the structural, informational, and contractual gaps that currently limit participation by capital and insurance markets. Addressing these gaps is essential for enabling geothermal energy to scale as a source of reliable, firm power and a foundational component of global electricity markets.

The initiatives described in the pages below are mutually reinforcing, not independent. For example, established standards enables standardized contracts, which in turn enable liquid secondary markets and broader institutional participation, ultimately lowering the cost of capital. Insurance capacity depends on established standards and on performance data from pilot projects.

Eight Key Unlocks to Address Commercial and Financial Barriers

1. Develop a Geothermal Resource Management Standard (GRMS)
2. Finance First-of-a-Kind Pilot Projects
3. Develop Standardized Geothermal Contracts and Agreements
4. Facilitate Entry and Exit From Geothermal Assets
5. Develop and Adapt Familiar Financial Instruments
6. Leverage Offtakers as Equity Investors and Guaranteed Offtake
7. Develop Blueprints for Early-Stage Equity Investment
8. Adopt Best Regulatory Practices from Oil and Gas



Key Unlock #1

Develop a Geothermal Resource Management Standard (GRMS)

Effective geothermal transactions depend on the ability to impartially assess an asset and its future potential. In the absence of a standardized framework or shared language, buyers, sellers, and investors often struggle to agree on the nature and value of geothermal assets.

This lack of clarity impedes deal-making, stifles liquidity, and limits the ability of stakeholders with different risk and return profiles to enter or exit investments. Similar systems are well-established in extractive industries, including [PRMS](#) (petroleum) and [SRMS](#) (storage) discussed above, and [JORC](#) and [CRIRSCO](#) (mineral resource reporting), and can be adapted for geothermal.

Without this shared financial language, capital markets struggle to price risk, which directly contributes to financing barriers.

Key Unlock:

Create an industry-wide system for classifying, reporting, and communicating geothermal resources and reserves – analogous to the PRMS in oil and gas. The GRMS provides the shared language that underpins every other initiative: standardized contracts, independent valuations, insurance underwriting, and reserve-based lending all depend on it.

The adoption and use of reserves standards is strategic to aid in the development and growth of geothermal energy by promoting consistency, reliability, and transparency in estimates and reporting. A framework that defines and distinguishes reserves from resources is key to providing stakeholders with an indication of project maturity, the range of uncertainty in estimates, and which projects can be brought to market versus the barriers that other projects still need to overcome.

The Petroleum Resources Management System (PRMS) – the common global standard for hydrocarbons – provides a good analogy for the establishment of a Geothermal Resources Management System (GRMS) and has an important advantage by being time-tested, as well as widely familiar and accepted by many energy stakeholders, including many new entrants into the geothermal market space.

Impact on Growth

For companies that sell commodities, classifying their resources is fundamental to conducting business and to defining the value of an asset or of a company. A common classification standard brings consistency and better comparability between assets and companies, which is needed by corporate management teams, regulators, and investors to understand the potential of their geothermal resources. That consistency also leads to greater reliability and clearer communication among stakeholders.

Classification standards make technical due diligence faster and more straightforward, as well as aid in comparing opportunities or managing portfolios. All of these factors contribute to greater understanding, transparency, and investment confidence, which creates greater market stability and more favourable conditions for investment in and the growth of geothermal energy. While multiple classification systems do already exist, there is not currently any single universally accepted framework or set of assessment guidelines, and the need to speak the language that financial institutions already use and understand is urgent to support geothermal growth.

Probability of Success

The PRMS already has a high degree of acceptance and familiarity among investors and other energy stakeholders around the world. It benefits from decades of practical application for hydrocarbons, which has helped over time to identify and resolve many questions related to reserves definitions and their proper classification and categorisation. The PRMS includes designations for the commercial maturity of a project (the class), as well as for the uncertainty in a project's estimated resource quantities (the category).

The framework is a principles-based system, rather than rules-based, which inherently allows for adaptability to other commodities outside of oil and gas. The Society of Petroleum Engineers International issued a statement in August 2022, allowing for the application of the PRMS to non-hydrocarbons, including geothermal energy – noting the importance of involving appropriate subject matter experts. The PRMS is especially analogous to geothermal energy due to numerous technical and commercial similarities with hydrocarbon reserves and resources. It is also beneficial to recognise that many new entrants to geothermal have an oil and gas background and are already familiar with the PRMS.

The PRMS framework is project-based and allows for application to any size – a project may be defined based on its specific boundary conditions or based on the needs of the transacting parties. As a principles-based system, it is suitable for a wide variety of geothermal applications across the country and on a global scale.

This flexibility means that the GRMS can serve small distributed heat systems and utility-scale next generation systems with the same underlying framework, with project-specific parameters defined

within the structure rather than requiring separate standards.

Given the longstanding use of the PRMS for hydrocarbons, the development of an initial GRMS framework is achievable within one year. After that, revisions will be necessary from time to time as improvements are identified.

Why Standardized Resource Classification Enables Geothermal Finance

Without a shared, accepted language for describing geothermal resources, independent valuations are impossible, due diligence is bespoke and expensive, insurance underwriters cannot build actuarial models, and reserve-based lending cannot be structured.

The classification standards make technical due diligence faster and more straightforward, enable portfolio comparison, and create the conditions for greater market stability and more favorable investment.

Why GRMS Unlocks Everything Else

Without a shared, accepted language for describing geothermal resources, independent valuations are impossible, due diligence is bespoke and expensive, insurance underwriters cannot build actuarial models, and reserve-based lending cannot be structured.

The development of a GRMS was identified in this analysis as the single intervention with the greatest multiplier effect. In fact, [Munich Re](#) has already adopted a GRMS-like framework as the foundation of their geothermal underwriting methodology, demonstrating its real-world uptake at the highest level of the insurance market.

GRMS: The Common Language That Unlocks Geothermal Capital Markets

A core challenge for capital deployment in geothermal is linguistic rather than technical or geological: the industry has not yet adopted the financial language that institutional capital understands and trusts.

In the oil and gas industry, the Petroleum Resources Management System (PRMS) is built for the boardroom, producing outputs like “proved reserves” and project maturity designations that go directly into financial models and loan documents. The construct is unambiguous - if a resource is not economically recoverable, it is not a reserve - giving investors a clear, explicit signal rather than a diluted mix of economics and policy criteria. Banks, insurers, and the SEC already operate within the PRMS framework in the oil and gas context, therefore a GRMS would result in geothermal projects being assessed immediately, without requiring capital markets to adopt an entirely new classification system. This dramatically lowers the cost of capital and speeds support to geothermal at scale, by leveraging an existing ecosystem of trust rather than building a parallel one from scratch.

Adapting the PRMS into geothermal within a GRMS framework will generate a technology-agnostic system, capable of classifying conventional hydrothermal projects, next generation projects, and newly emerging technologies under a single framework, removing the friction of technology-specific standards.

Crucially, a PRMS-based standard unlocks reserves-based lending, the scalable debt mechanism that financed the growth of every major energy industry, moving geothermal beyond its current dependence on venture and concessionary capital. The framework is already proven to be extensible, having been adapted for CO² storage and water resources, with geothermal requiring the natural addition of thermal capacity classifications rather than a ground-up rebuild.

With GRMS, we lay the financial infrastructure for geothermal at scale, the equivalent of GAAP for accounting, that gives the financial world the confidence to engage at scale. With a GRMS in place, multiple downstream financing mechanisms become feasible:



Agreed upon definitions of reserves, resources, and project maturity stages required for **standardized contracts** to function. Without GRMS, contract terms cannot be consistently interpreted across counterparties;



Insurance underwriting, which depends on a shared risk language;



Unlock of private equity investment, reserve-based lending and project finance, which require independently auditable asset valuations. Lenders cannot underwrite against reserves they cannot classify;



With GRMS in place, the **Securities and Exchange Commission** can require geothermal companies to comply with its reserves reporting rules, greatly increasing investor confidence;



Unlock of secondary market liquidity, which requires buyers and sellers to agree on what they are transacting. A common resource classification system is the prerequisite for price discovery.



Why Standards Come First: A Note on Downstream Dependencies

The order of operations in removing the barriers considered in this analysis matters. Foundational standards and data infrastructure must come before financial instruments, because financial instruments cannot be properly structured without them.

This is therefore why the development of standards, out of all of the solutions presented in this analysis, was prioritized as the most important and urgent action to take to address the full suite of barriers discussed in this work.

- Standardized contracts require agreed definitions of reserves, resources, and project maturity stages to function. Without GRMS, contract terms cannot be consistently interpreted across counterparties. Every contractual innovation, including Joint Operating Agreements, Farm-in/Farm-out, and reserve-based lending structures, requires the GRMS as its definitional foundation.
- Insurance underwriting depends on a shared risk language. The estimated \$10 billion cumulative U.S. insurance market opportunity modeled in a research analysis funded by Project InnerSpace and performed by InnSure, is contingent on the GRMS providing the actuarial foundation insurers need.
- Reserve-based lending and project finance require independently auditable asset valuations. Lenders cannot underwrite against reserves they cannot classify. The GRMS transforms physical subsurface data into a standardized financial asset that can serve as loan collateral.
- Secondary market liquidity requires buyers and sellers to agree on what they are transacting. A common resource classification system is the prerequisite for price discovery. Without it, every transaction requires bespoke valuation, restricting the market to participants willing to bear high due diligence costs.
- Pilot project investment benefits from the GRMS because performance data from pilots can only build investor confidence if it is collected, reported, and compared using a common standard. The GRMS provides the reporting framework that makes pilot data legible across the investment community.
- Early-stage equity investment relies on GRMS-based reserves classification for eligibility criteria, enabling governance of catalytic capital vehicles with commercial discipline.



Key Unlock #2

Finance Next-Generation Pilot Projects

Key Unlock:

Next generation pilot projects in geologically distinct basins will generate the multi-year performance data needed to de-risk investment at scale. In parallel, off-grid development – serving data centers, military bases, and large industrial facilities – provides a near-term deployment pathway supported by long-term PPAs with creditworthy counterparties, bypassing grid interconnection delays.

Pilot Projects in Multiple Basins

The lack of proven long-term performance data for next-generation technology creates significant investor uncertainty. Large-scale funded pilot projects or drilling campaigns can demonstrate the technical and economic viability of these systems, mitigating risk and attracting private sector capital. Successful demonstration projects will generate valuable real-world data on long-term heat extraction rates, fracture conductivity, and other critical parameters. This information will build confidence among investors, insurers, and lenders, facilitating the scaling up of next-generation geothermal deployment.

The oil and gas industry possesses extensive experience in drilling, hydraulic fracturing, and

reservoir management – skills directly transferable to next-generation geothermal development. By partnering with these companies, governments and private industry consortia alike can accelerate project timelines and minimise costs compared to starting from scratch. The technical challenges associated with next-generation geothermal are comparable to those faced by the oil and gas industry in shale and tight formation development, allowing for a relatively smooth technology transfer process. The oil and gas industry also has a proven track record of rapid innovation and ‘fail-fast’ experimentation, particularly when supported by federal funding initiatives.

Impact on Growth

Once proof-of-concept is achieved through pilot projects, next-generation geothermal technologies can be readily scaled up using the same pad development model employed in shale and tight oil operations. The oil and gas sector offers a compelling blueprint. Over the past two decades, oil and gas companies conducted extensive, structured experiments in unconventional reservoirs that directly built investor confidence through performance data in consortia like [HTFS](#), and [DeepStar](#) for deepwater.

Next generation geothermal systems can be deployed modularly, allowing for incremental capacity additions as demand increases – reducing upfront capital costs and minimising financial risk. Oil and gas companies

have extensive infrastructure networks (pipelines, transportation) that can be adapted for geothermal energy production and transmission, further streamlining deployment.

Strategic Collaborations

The U.S. is in a unique position to lead de-risking at scale due to a combination of high quality geothermal resources, oil and gas legacy infrastructure, a burgeoning startup and innovation ecosystem. By aligning demonstration funding, risk reduction efforts, and financing mechanisms, key uncertainty pain points – particularly those related to technical performance, cost profiles, and scalability, can be overcome.

Demonstration projects funded by investors, public entities, or through industry consortia and/or public private partnerships, can generate the critical data needed to reduce perceived technical and financial risk, thereby enabling institutional capital to assess projects for debt financing. For example, in the US, joint demonstration efforts between private industry and the Department of Energy, the Department of War, and even the Department of Commerce, can generate the critical data needed to reduce perceived technical and financial risk.

Prioritize Financing of Off-Grid Projects:

Off-grid geothermal projects – those on military bases or on data center campuses – can provide dedicated power to consumers struggling to find adequate supply. Producers may be able to realize more investable project economics by not having to compete with grid electricity prices. Long-term PPAs may become more straightforward due to being executed directly between producers and on-site consumers. Although the development and operation of an off-grid geothermal project is the same as a ‘normal’ plant, the reduction or elimination of transmission for on-site consumption may reduce costs, regulatory and environmental issues, and overall project complexity. On-site consumption is also an opportunity to match geothermal resources (site-specific) with consumers that can operate anywhere (not site-specific).

On-site consumption of geothermal energy enables more favourable pricing for the producer and better economics for the associated investor because the electricity price is not necessarily tied to prices for grid-based power. Data centers may be willing to pay a premium for a dedicated power supply – one that is not shared with the general public and subject to typical grid fluctuations – while geothermal-based power helps them meet their renewable energy goals. PPAs can be

negotiated directly between the supplier and end-user, enabling more transparent and efficient agreements with less uncertainty and fewer variables.

Data center opportunity: The demand for electricity for the AI industry is greater than the grid can supply. Funding may not be a barrier to scalability given the abundance of capex available for data centers. This model is largely compatible with existing geothermal development practices, requiring only modest adjustments for on-site consumption and reliability. The policy environment is now actively reinforcing the case for dedicated, off-grid supply: the [White House Ratepayer Protection Pledge \(2026\)](#) discourages data centers from drawing incremental grid power in ways that raise consumer electricity bills. Off-grid geothermal is not merely a commercially attractive option for hyperscalers – it is the structurally compliant answer to that policy directive, providing genuinely additional, ratepayer-neutral power that cannot be challenged as a cost burden on the broader grid. Data centers that can point to a dedicated behind-the-meter geothermal supply are therefore better positioned on both energy security and regulatory grounds than those relying on grid interconnection alone. The mechanism by which these commitments can be structured as legally binding, bankable instruments – and aggregated across a portfolio of projects to attract institutional debt capital – is discussed below in Key Unlock #6.

Military base opportunity: For consumers that want the security of being independent from the public grid – such as [military bases](#), healthcare facilities, or other essential services – the off-grid model is a strong match. Federal installations have the authority to sign long-dated agreements with creditworthy terms, providing exactly the revenue certainty that project finance lenders require. Any construction related to on-site consumer facilities can be coordinated to occur simultaneously with geothermal plant construction, reducing overall timelines. On-site consumption negates issues associated with grid interconnection – including permitting delays, environmental surveys, construction time – and is especially suited for stranded geothermal resources. The development timeline for a geothermal project itself is independent of whether electricity will be sold to the grid or consumed on-site, removing a major source of delay.



Key Unlock #3

Develop Standardized Geothermal Contracts and Agreements

Key Unlock

Adapt the Association of International Energy Negotiators' ([AIEN](#)) model contract library – Joint Operating Agreements, Farm-in/Farm-out, Sale and Purchase, Unitisation – to geothermal's specific characteristics. Standardized contracts reduce legal costs, accelerate deal execution, and make transactions legible to investors unfamiliar with the sector.

The geothermal sector suffers from inconsistent and bespoke contractual frameworks – a significant barrier to investment and project development. Each geothermal project often relies on bespoke agreements that vary widely in structure, terminology, and risk allocation. This lack of uniformity increases legal costs, lengthens negotiation timelines, and creates uncertainty for both investors and developers.

Developing a suite of standardized geothermal contracts modeled after templates developed by the Association of International Petroleum Negotiators, now the [Association of International Energy Negotiators](#)

([AIEN](#)), was identified in this analysis as one of the highest impact actions that would remove financial and commercial barriers in next-generation geothermal financing.

AIEN contracts have long provided oil and gas with adaptable, internationally recognized templates that streamline negotiations, reduce legal complexity, and align interests across stakeholders. Geothermal lacks a comparable baseline. Therefore, adaptation of AIEN methodologies – Joint Operating Agreements, Farm-out Agreements, and Unitization Agreements for geothermal development, while introducing geothermal-specific contracts such as standardized Power Purchase Agreements, Resource Lease Agreements, Risk-Sharing Agreements, and permitting frameworks, is low hanging fruit and uniquely suited for catalytic capital support.

Impact on Growth

From a technoeconomic perspective, the absence of standardized contracts in geothermal leads to higher legal costs, longer negotiations, and lower project

bankability. Custom contracts for each deal increase transaction times by 3–6 months, with legal expenses adding \$250,000–\$500,000 per project depending on complexity. Investors are often discouraged by the lack of standardized risk-sharing models and revenue allocation frameworks.

In oil and gas, standardized AIPN/AIEN contracts lower transaction costs, accelerate due diligence, and provide a predictable structure for stakeholders – especially financiers and insurers. Adapting this proven approach to geothermal would provide transactional clarity, reduce soft costs, and promote uniformity in how subsurface resources are accessed, developed, and monetized.

Adopting standard contracts could reduce geothermal legal and structuring costs by 40–60% per project and potentially shorten deal closure times by 4–5 months. This accelerates financial close and commissioning timelines, improving IRR profiles and increasing project appeal for equity and debt providers. Within four years, widespread use of these contracts could reduce industry-wide legal costs by over \$100 million annually.

Standardized contracts would simplify the legal process, saving both time and money – especially in early-stage projects where resources are limited. They would make deals more understandable and transparent for investors unfamiliar with geothermal, enabling faster financial close and improving project IRR. They would enhance the ability to replicate successful project structures, reducing the learning curve and enabling faster industry scaling.

Pathways to Catalysis

The adaptation of AIEN templates to geothermal is relatively straightforward. Many of the legal constructs – joint development, production sharing, royalty schemes, and operating committee frameworks – already apply conceptually to geothermal. However, geothermal introduces unique considerations that require modular contract architecture: resource risk (temperature and flow rate decline), regulatory complexity due to overlapping environmental, water, and land-use statutes, and novel technologies like closed-loop geothermal systems.

These differences necessitate modular contract architecture where geothermal-specific clauses are integrated into a general AIEN-style structure. Legal advisors familiar with AIEN templates will require relatively minimal onboarding to pivot toward geothermal-specific content, especially when working collaboratively with technical geothermal experts and policymakers. Implementing a suite of templates tailored to geothermal's unique features would require collaboration between legal experts, developers, and financiers – but many of the contractual concepts from oil and gas are directly transferable and need only modest adaptation.

Standardized contracts are highly scalable across multiple contexts. Conventional hydrothermal, EGS, and AGS systems can all adopt core templates with minor amendments. International geothermal markets – Kenya, Indonesia, Germany – could adapt these templates to align with local laws while retaining the foundational structure, making geothermal more investable globally. Utilities, developers, insurers, and investors all benefit from a uniform legal framework, facilitating portfolio investment models, M&A, and secondary market development.

Creating and disseminating standardized geothermal contracts would increase efficiency, reduce costs, and improve investor confidence – critical factors in accelerating deployment. It would also provide the legal and financial foundation necessary to support a growing and increasingly sophisticated geothermal industry.

A minimum viable product suite of contracts could be deployed within 6 months following a phased development model. A full-featured national adoption program – including regulator alignment, integration into public procurement frameworks, and widespread legal training – could be completed within 12 months.



Key Unlock #4

Facilitate Entry and Exit From Geothermal Assets

Key Unlock:

Create the conditions for a functioning secondary market: standardized documentation, transparent valuation frameworks, and a marketplace or forum connecting buyers and sellers. An industry consortium or government-backed Advanced Market Commitment for early-stage assets can provide the first-mover demand signal. Over time, this enables diverse investor types – including those requiring exit optionality – to participate in geothermal.

This chapter explores how to create a robust, liquid geothermal market by improving mechanisms for investor entry and exit, thereby unlocking capital at various stages of project development. Drawing lessons from the oil and gas industry – where mergers, acquisitions, and asset transfers are routine – the geothermal sector can benefit from standardized financial practices, data platforms, and deal structures that lower friction for investment and asset transactions.

Key elements of this approach include enabling diverse forms of capital to participate through specialized financial instruments, streamlining project ownership

transfers via transparent M&A processes, and improving risk-adjusted returns by creating more predictable pathways for divestment. A major limitation in the current geothermal landscape is the lack of a liquid market where assets can be bought, sold, or transferred easily. This deters investors, particularly those with shorter investment horizons or less tolerance for early-stage risk.

Impact on Growth

A more dynamic and liquid geothermal market offers key technoeconomic advantages that improve project viability and speed up development. Easier investor entry and exit attracts a broader range of capital sources – each with different risk appetites and timelines – allowing better alignment between funding and project stage. Clear divestment and acquisition paths foster a more active M&A environment, helping companies optimise portfolios and recycle capital. This liquidity lowers capital costs, reduces perceived risk, and enables faster project financing and execution.

Market dynamism also drives innovation, as competitive pressure promotes adoption of efficient technologies and strategic investors bring expertise and best practices. Industry consortia or government-backed

Advanced Market Commitments (AMCs) further support early-stage projects by guaranteeing purchases – especially for those under \$10 million – reducing revenue risk and sending strong market signals. Together, these elements create a more bankable, competitive, and scalable geothermal sector.

Advanced Market Commitments

AMCs for early-stage, lower-value projects (e.g., under \$10 million) can significantly enhance investor confidence, stimulate market activity, and encourage the formation of a specialized geothermal finance ecosystem. By guaranteeing offtake or revenue floors, AMCs reduce early-stage risk and improve bankability – key advantages for geothermal’s capital-intensive early phases. AMCs have been successfully used in other sectors to stimulate markets by ensuring early demand and demonstrating public sector commitment. They signal market viability and build investor confidence in a way that regulatory guidance alone cannot.

A NAPE-Style Transactional Marketplace

Building a transactional marketplace or forum for geothermal – similar to the [North America Prospect Expo \(NAPE\)](#) used in the oil and gas industry – could further improve liquidity. Such a platform would allow developers, buyers, and investors to connect, share standardized asset data, and execute transactions more efficiently. The presence of standardized legal and technical documentation, along with transparent valuation methodologies, would help streamline due diligence and lower transaction costs. Together, AMCs and a transactional forum would create the infrastructure necessary for a dynamic geothermal finance market.

Pathways to Catalysis

The geothermal sector can draw on extensive oil and gas industry experience in market development, financing, and risk management. Standardized contracts and data-sharing – common in oil and gas – can reduce friction and build trust through consistent PPAs, drilling contracts, and data protocols. Financial tools like project finance loans, royalty structures, and carried interest models could be adapted to geothermal to attract diverse capital and spread risk. Advanced Market Commitments offer another useful model proven across multiple sectors, from vaccines to renewable energy.

This framework supports national scalability by addressing data and regulatory barriers. Centralized, standardized data platforms can improve transparency,

cut due diligence time, and boost investor confidence by enabling better risk assessment. Streamlined and harmonized permitting across states reduces bureaucratic delays, lowers costs, and enables developers to replicate projects efficiently. Together, these measures create a foundation for scalable, cross-jurisdictional geothermal growth.

Facilitating easier entry and exit for investors and developers can significantly reduce geothermal project timelines. Efficient mechanisms for project transfers – such as streamlined M&A processes – allow stalled or under-resourced projects to be acquired and advanced by new parties without starting from scratch. By reducing friction in ownership transitions, this approach ensures that promising geothermal projects are not delayed due to changes in strategic focus, financial limitations, or organizational capacity.



Key Unlock #5

Developing and Adapting Financial Instruments

Key Unlock

Develop several financial instruments – some adapted from oil and gas, some novel – were identified in this analysis as capable of materially improving geothermal project bankability. They are most effective in combination. They collectively address the actual and perceived risk borne by capital markets by using trusted structures, transferring risk to insurers, or mobilising State support.

A coordinated suite of financial and risk mitigation measures can significantly accelerate geothermal development by improving bankability, reducing capital costs, and expanding investor participation. When deployed together, these mechanisms address core barriers across the project lifecycle – particularly for high-demand, site-flexible consumers such as data centers. Aligning geothermal project finance structures with those used in oil and gas introduces proven tools like joint ventures, production-based financing, and structured debt.

To complement this foundation, government-backed instruments absorb portions of performance risk.

Insurance companies as early-stage equity investors further strengthen the capital structure. In parallel, government-backed insurance covering reservoir temperature decline reduces a key technical risk, especially critical for next-generation geothermal.

The following pages identify five financial instruments that, if developed and adopted to support next-generation geothermal, would have an outsized impact on growth and capital availability in the sector.

1. Oil and Gas-Aligned Finance Structures

Introduce reserves-based lending, joint ventures, and production-based financing, instruments familiar to institutional capital, that distribute risk across development stages:

Geothermal energy has strong potential as a stable and reliable power source, but it remains underdeveloped due to high upfront costs, technical uncertainty, and limited financial frameworks to manage early-stage risks. In contrast, the oil and gas industry has long used financing tools that could be applied to geothermal – debt financing tied to future revenues, joint ventures that share risk, and production-based financing aligned with output.

Adapting these models can make geothermal projects more attractive to investors. Debt backed by projected energy sales, joint ventures with experienced firms, and use of federal incentives like ITCs and PTCs can improve project economics. Success will also depend on solid cost estimates, defined revenue models such as PPAs, and effective risk mitigation for drilling and resource variability.

By applying oil and gas financial strategies to geothermal development, the industry can open new investment channels and accelerate project timelines. Some examples include:

Reserves-Based Lending (RBL):

Adapt proven oil and gas project finance models, such as reserve-based lending and farm-in/farm-out agreements, to increase geothermal project bankability. In RBL, debt is secured against the projected revenue stream from proven reserves, with the loan facility size calibrated to a conservative forecast of future production. This will require a GRMS reserves classification and a bankable offtake agreement, providing the revenue certainty against which the loan is sized.

Farm-in / Farm-out:

Under a farm-in arrangement, a developer retains a royalty interest while selling a working interest to a better-capitalized partner that funds drilling. This structure enabled the US shale revolution – thousands of small operators de-risked acreage and attracted capital by farming out working interests before drilling. An equivalent structure for geothermal, made possible by a GRMS valuation and AIEN-based contracts, could catalyze a similarly distributed exploration effort.

Joint Ventures:

Joint ventures can distribute risk, increase financial clarity, and make geothermal more appealing to institutional and infrastructure investors familiar with the hydrocarbon sector. By embedding these models into geothermal deals, developers can better secure funding at earlier stages and move toward more predictable capital flows. Pilot projects also play a key role by creating replicable models and building stakeholder confidence.

2. Separating Hydrothermal, EGS and AGS Risk Profiles

A prerequisite for effective project finance is the creation of a standardized geothermal risk profiling framework that separates the distinct risk characteristics of hydrothermal, engineered open-loop (EGS), and closed-loop (AGS) geothermal projects. The current tendency to group these technologies under a single risk category undermines investment clarity, obscures important technical differences, and leads to inefficient capital deployment.

Next Generation geothermal projects are by definition in the exploration to early appraisal stage. They have a variety of threat types that each have wide uncertainties. Geoscientists, engineers, investors, and insurance underwriters need to distinguish and separately assess geological risks, drilling risks, economic risks, and commercial risks. These need to be clearly defined, planned for, and accurately communicated so that risks and investment decisions can be carefully managed.

The ‘geothermal anywhere’ mantra will require geothermal exploration into frontier regions labeled ‘high risk’ and high uncertainty by strategists and insurers. This is emphasized by geological and drilling challenges not anticipated in recent hydrothermal, engineered open-loop reservoir (fracture-stimulated EGS), and engineered closed-loop reservoir (AGS) projects in well-understood regions. A systematic and globally standardized framework is required to construct and compare risk profiles for geology, drilling, economics, and commercial viability risks in hydrothermal, engineered open-loop reservoir, and engineered closed-loop reservoir scenarios.

A logical framework that ties into the GRMS would make it easy for geothermal project stakeholders to profile the categories of threats and uncertainties. Refining the risk evaluation method of hydrothermal, engineered open-loop reservoir, and engineered closed-loop reservoir scenarios can draw on parallels from conventional petroleum, low-permeability petroleum, and SAGD petroleum reservoirs and operations.

There is no need to reinvent a risk profiling method – an adaptation of petroleum reservoir engineering types and exploration and production risk evaluations would only take a few months if time can be dedicated by the appropriate experts.

Once in place, the risk profiling framework will improve bankability, reduce uncertainty, and support policy and market interventions tailored to the actual risk profile of geothermal technologies – thereby unlocking investment and accelerating deployment across the entire sector.

3. Hot Bonds – Government-Backed Geothermal Debt

Hot Bonds are tax-exempt municipal bonds designed to attract capital for early-stage geothermal projects, modeled after Green Bonds but focused specifically on geothermal development. Issued by state or municipal governments, they would target private investors and utilities to fund geothermal power, district heating, and new technologies – particularly in resource-rich but undercapitalized regions. The tax-exempt status offers investors federal (and possibly state/local) income tax relief, making the bonds more attractive. Local government partnerships could reduce investor risk through guarantees or matched funding, while aligning projects with state energy goals and qualifying them for incentives.

Structured as long-term, low-interest debt instruments, Hot Bonds link investment returns to geothermal energy output. They aim to reduce early-stage capital burdens and provide a scalable, tax-efficient investment mechanism for impact investors, pension funds, and others seeking stable returns tied to energy expansion.

Hot Bonds could significantly accelerate the growth of the geothermal sector. With better economics in resource-rich areas – near-field or in the western US – these bonds could help create a critical mass of funding for the earliest next-generation geothermal projects, catalyzing faster and more efficient market entry.

One of the core advantages of Hot Bonds is that they could support a techno-economic evaluation framework to assess geothermal projects on a per-project basis. Investors would be able to see the returns based on specific project data, such as resource temperature, depth, and the cost of drilling, which would provide more granular risk assessment tools.

With the backing of both public and private entities, Hot Bonds could scale rapidly, particularly in areas with established geothermal resources but low utilization. Regions such as Nevada, California, and Utah could serve as early adopters, where large-scale geothermal plants and next generation projects can be rapidly deployed with the help of bond funding.

By providing capital to support both exploratory and commercial-scale geothermal projects, Hot Bonds could significantly shorten the time required for new geothermal projects to reach deployment. The ability to raise capital for exploration, drilling, and infrastructure development would cut the typical timelines for geothermal project development.

4. Insurance-Funded Investment Tax Credit Equity

Insurers advance early-stage equity equivalent to the projected ITC, reducing developers' upfront equity burden and improving returns for co-investors.

An innovative financing model in which insurance companies function as cornerstone investors in geothermal projects by advancing the value of the US Investment Tax Credit (ITC) at the start of the equity-raising process could be developed. Under current rules, the ITC – created under the Inflation Reduction Act – is only disbursed once the geothermal project is placed into service, meaning it cannot be used to offset initial capital needs. If insurers were willing to underwrite the risk of non-payment, they could inject funds equivalent to the expected ITC at the outset of construction. In exchange, developers and other equity investors would pay an insurance premium.

This early injection of capital reduces the amount of equity required from traditional investors and enhances the return on equity by reducing upfront exposure. For the insurance company, this represents a structured, risk-based investment aligned with the government's incentive policy – creating an opportunity to expand their portfolio into energy infrastructure. While this approach is not standard in the oil and gas industry, it is well within the norms of creative dealmaking familiar to experienced energy finance professionals and legal advisors.

Allowing insurance companies to provide capital equivalent to the forecasted ITC value offers a strong techno-economic rationale. It directly addresses one of geothermal's biggest financial barriers: the high cost and limited availability of early-stage equity. By accelerating access to expected public incentives, insurance-backed ITC financing would de-risk the project's early phase and improve the project's overall financial profile. This not only makes geothermal investments more attractive to private equity but could also lower the weighted average cost of capital across the development lifecycle.

The business model relies on the insurer's ability to accurately assess and price the risk of non-payment or delay in the ITC. In return for bearing this risk, the insurer receives an agreed premium – compensating them for bridging the timing mismatch between capital need and credit disbursement. This effectively converts a back-ended subsidy into front-loaded project equity, unlocking earlier construction timelines and broader investor participation.

Project InnerSpace Insurance Market Funded Research – The InnSure Analysis

In 2023, Project InnerSpace funded research into the geothermal insurance industry, to explore barriers to insurer participation in the geothermal industry. The research concluded that the barriers are structural, not technical. For instance, there is no common language, no aggregated data, and no first mover. Building meaningful insurer participation requires sustained engagement, patient capital to seed the capacity stack, and material progress on data standards (principally a GRMS). See more details about this research in the Appendix.

Modelling 60 GW of US geothermal development by 2050 – consistent with [DOE's Enhanced Geothermal Shot](#) trajectory – reveals a substantial insurance market opportunity:

- \$10 billion+ in cumulative gross written premiums from the US geothermal insurance market over the period to 2050.
- ~\$400 million in annual gross written premiums at peak market maturity – a scale sufficient to represent a genuine, standalone business line for a major insurer.
- ~10% of project value is the current estimated insurance cost today, with a trajectory to approximately 7% as the market matures and actuarial data accumulates – a material burden that better-structured products can reduce.
- Primary coverage lines include: exploration risk (temperature and resource discovery); construction risk; temperature decline performance risk; and long-term production insurance – broadly analogous to the coverage lines that already exist in oil and gas.

These figures demonstrate that the geothermal insurance opportunity is not marginal or speculative – it is a concrete, sizeable business opportunity for insurers willing to be early movers. The challenge is the absence of a first mover: no single insurer is willing to build the actuarial capacity, the underwriting frameworks, or the specialist claims-handling infrastructure required unless there is a credible volume of insurable projects. The ITC equity mechanism addresses exactly this problem by creating a structured, IRS-backed revenue stream that insurers can underwrite with confidence.

While not a standard practice in oil and gas, the strategy of early capitalization through creative deal structuring is familiar territory for energy sector financiers. Oil and gas dealmakers are experienced in allocating risk and reward through complex layered agreements, including royalty streams, prepaid offtake, and insurance wrappers. Legal and financial advisors accustomed to structuring exploration-phase oil and gas deals can bring their tools and frameworks into geothermal, customizing risk-sharing models to accommodate the timing and requirements of the ITC. Although geothermal does not currently share the same scale or liquidity as hydrocarbons, its policy-supported revenue structures make it an appealing candidate for this type of innovative financing model.

Once proven viable, this model could be quickly scaled. The key enablers are the development of standardized insurance contracts and strong working relationships between geothermal developers, equity investors, and insurers. In the US, given the uniformity of the ITC framework across the US, the approach is geographically flexible and could apply equally to small distributed systems and large utility-scale projects. To scale successfully, this model will require building trust and familiarity within the insurance industry and among developers – tailored outreach and pilot deals will be essential to demonstrate feasibility and financial performance.

Implementation of this strategy could occur within a 12-24-month window, depending on regulatory clarity and insurer engagement. Initial pilots would likely focus on one or two well-structured projects with willing developers and equity partners. During this time, insurance products would need to be designed, tested, and approved – requiring collaboration with underwriters, tax counsel, and industry players. Once validated, the model could expand quickly, particularly if supported by a federal or state-level signal recognizing the role of insurance in advancing ITC-backed energy projects.

5. Government-Backed Exploration and Performance Insurance

The specific risk preventing offtakers and project finance lenders from committing to next-generation projects is long-term reservoir performance uncertainty.

Next-generation geothermal projects face a critical technoeconomic challenge: uncertainty around long-term temperature decline. Unlike hydrothermal systems with decades of operational data, next-generation geothermal systems lack a track record to validate temperature behaviour over time. This uncertainty deters investors, complicates Power Purchase Agreements, and makes projects largely uninsurable by private markets. Due to a lack of data and high uncertainties, insurance companies shy away from such risks. In addition, there are only a small number of such projects, so it does not yet represent a viable business model for insurance companies.

As we will see below, countries like [Germany](#), [Türkiye](#) and [Indonesia](#) are leading with novel government backed insurance schemes, improving investor confidence and making financing more feasible. While implementation is complex – requiring flexibility across technologies, long lead times, and substantial public funding – a well-structured scheme could be adapted across project types and scaled over time.

Creating a project portfolio for next-generation geothermal technologies requires addressing the fundamental challenge of risk distribution. In a dysfunctional market where insurers are absent and investors wary, building such a portfolio purely with private capital is improbable. A financing PPP, in which the government co-invests, requires the public sector to offer either high returns or guarantee losses – neither of which is efficient nor sustainable.

Conversely, an insurance-based PPP enables more targeted and cost-effective risk-sharing. Government-backed insurance lowers the perceived risk of early-stage investment, allowing more capital to flow into FOAK projects. Insurers – more experienced in underwriting and risk assessment than public agencies – can take the lead in determining which projects are insurable and under what terms. This model provides multiple advantages:

- Lower upfront public funding due to premium-based cost recovery.

- More sophisticated, market-aligned risk assessment.
- Portfolio-wide de-risking that reduces investor hesitation across multiple basins.
- The German geothermal insurance scheme – where Munich Re underwrites and the state backs 70% of losses – offers a successful precedent. For the US, adapting this model could enable efficient deployment of government resources to crowd in private capital at scale.

For next-generation geothermal projects, the temperature decline over time is a challenge. There is no track record or long-time data available to evaluate a decline of temperature. General temperature gradients are usually available from oil and gas wells, but temperature behaviour over time for next-generation projects with significant heat extraction is unknown. Government-backed insurance of the temperature gradient and its decline over time could help attract investors by mitigating a significant risk.

The German Proof Point – Munich Re / KfW / December 2025

Munich Re / KfW / German Federal Government, December 2025

In December 2025, Munich Re and KfW, backed by the German federal government, launched the first government-backed geothermal exploration insurance programme in Europe – targeting 65 projects and €2–3 billion in investment over four years.

This demonstrates exactly what Project InnerSpace identified as the viable path forward: a government-backed first-mover facility that absorbs structural risk, establishes underwriting precedents, and seeds the commercial market capacity that private insurers can then build upon. Munich Re's adoption of GRMS as the foundation of their underwriting methodology directly aligns with the data infrastructure Project InnerSpace is funding – and is the strongest possible validation that the GRMS-to-insurance pipeline identified in this report is real, not theoretical.

Challenges persist, particularly regarding the appropriate duration of such insurance coverage and

the precise design of its terms. An alternative is a guarantee scheme, whereby public funds secure private investments – yet, given that temperature decline is not the sole significant risk, it is uncertain whether a stand-alone guarantee scheme would be sufficient to meet the requirements of investors or lenders.

Key outstanding questions include:

- At what level of degradation should the insurance be triggered?
- How can the policy accommodate the wide variety of technologies and differing performance requirements?
- How can over-insurance be avoided, ensuring that typical entrepreneurial risks are not unduly socialized?
- Should the mechanism take the form of an insurance product, or would a guarantee scheme aimed at securing bank or investor financing be more appropriate?

While establishing such a PPP is complex and time-intensive, once in place its structure is highly adaptable to varying technologies, regional conditions, and risk categories. As geothermal technology advances and project archetypes diversify, underwriting criteria, premium pricing, and coverage types can be adjusted accordingly. Unlike rigid grant structures, an insurance-based PPP can evolve organically – adapting to operator feedback, market shifts, and technical validation data. While implementation is the bottleneck, adaptation becomes progressively easier over time, particularly with government and insurance sector buy-in.

The PPP insurance model is inherently scalable. Once risk pools and underwriting methodologies are established, the scheme can grow with project volume. Scalability is constrained primarily by the size of the public capital backstop and the long-term guarantee obligations for risks like temperature decline or subpar well performance.

However, premiums paid by developers can be pooled into a revolving fund, reducing the need for constant capital injections. With sufficient political support and technical governance, the insurance pool can become self-sustaining over time.

Realistically, designing and launching an effective geothermal insurance PPP will require 2–4 years. Challenges include aligning stakeholders, developing underwriting standards, securing initial capital, and creating legal and governance structures. This is slower than traditional grant-making, but the long-term benefits – market catalyzation, reduced government exposure, scalable replication – justify the lead time. Once implemented, the time from concept to project deployment will decrease markedly due to reduced investor hesitation and faster financial closure.



Key Unlock #6

Offtakers as Early Equity Investors and Guaranteed Offtake

Key Unlock

Bring data centers and large energy consumers in as co-investors or as legally bound guaranteed off-take through portfolio-wide Advanced Market Commitments, anchoring capital structures and aligning buyer and developer interests around long-term thermal performance.

Off-Takers as Equity Investors

Engaging offtakers as early equity investors in high-risk geothermal power projects can significantly accelerate sector growth. This model helps offset the substantial upfront risks of exploration and drilling by bringing in capital from the entities that will eventually purchase the power. This reduces financial pressure on developers, shortens project timelines, and supports broader geothermal deployment, ensuring such expenses are not passed to taxpayers.

Offtaker participation aligns buyer and developer interests, fostering long-term partnerships and

building investor confidence. Their involvement can attract additional investment and contribute to a more resilient, diversified energy system. Offtaker equity provides critical early capital for resource assessment and advanced design, lowering costs and improving project viability. Their investment signals confidence, improving terms from other financiers and boosting key project metrics like NPV and IRR.

Offtakers might take on the risk of investing in a geothermal project for several reasons:

- By participating as equity investors, offtakers can influence project design, timelines, and operational priorities to better align with their energy needs and business goals.
- Equity participation ensures the offtaker has priority access to the plant's output, addressing concerns about energy availability or competition for grid capacity.
- Becoming an early investor in a renewable project signals leadership in energy innovation, improving the offtaker's brand image among stakeholders and the sector, paving the way for future opportunities.



- Governments often provide tax credits, grants, or subsidies for renewable energy development. Offtakers can benefit directly or indirectly from these incentives, improving the financial justification for their equity investment.

This model requires offtakers to expand beyond PPAs into equity roles, involving changes in corporate strategy and legal structures. Although complex, it can be achieved with appropriate policy support. The [2024 Glencore-Merafe-Pele solar deal](#) in South Africa shows that direct offtaker investment can work in practice – a creditworthy offtaker co-invested in upstream generation to secure supply at contracted prices.

Large corporates and utilities are well-positioned for this model; smaller offtakers may face capital or risk limits. Pooling offtaker investments or involving intermediaries can help distribute risk. Governments may also de-risk early-stage efforts, especially in regions seeking new power or job creation. The data center sector in particular – given the scale of capital flowing into AI infrastructure – represents a transformative pool of potential offtaker-investors. We see early signs of offtaker interest in equity investments in the geothermal space in [Google's investment](#) in Fervo Energy's E round in 2025, though this investment came at a later stage than we propose would have the highest impact in this chapter.

Upfront capital from offtakers accelerates early activities like site work and drilling, reducing delays from financing gaps. Their vested interest improves decision-making and execution speed, helping projects reach the market faster. This model has direct analogues in oil and gas joint ventures where downstream players co-invest in upstream development to secure supply.

Off-Takers as Guaranteed Off-Take

Advanced Market Commitments (AMCs) have emerged as a promising mechanism to incentivize innovation and investment in nascent technologies, particularly in the context of first-of-a-kind pilots. These commitments, often championed by technology majors, involve a guarantee of a market for certain products or services upon successful development and deployment. This model can bridge the gap between technological innovation and commercial viability, particularly in industries facing high upfront costs and substantial risks associated with developing new technologies.

One of the primary advantages of AMCs lies in their ability to mitigate the financial risks that accompany first-of-a-kind projects. By pledging to purchase a set volume of geothermal power at a specific price, technology majors – many of whom now seek several hundred megawatts of contracted supply per campus – can create a predictable revenue stream, bolstering

investor confidence and encouraging participants throughout the supply chain.

The policy environment is now actively reinforcing this logic: the [White House Ratepayer Protection Pledge \(2026\)](#) discourages data centers from drawing incremental grid power in ways that raise consumer electricity bills, creating a structural incentive for hyperscalers to secure genuinely additional, off-grid or dedicated supply. A legally binding take-or-pay AMC with a geothermal developer – particularly for a behind-the-meter project as described in Key Unlock #2 – is one of the cleanest mechanisms available to demonstrate additionality and ratepayer neutrality. For many data centers, some form of dedicated supply commitment may therefore evolve from a commercial preference into a compliance necessity.

However, for an AMC to be impactful in the next generation geothermal space, it must be a legally binding agreement that appears as a contingent liability on the balance sheet of the offtaker. This is not a novel requirement: the take-or-pay obligation has underpinned project finance in oil and gas, LNG, and pipeline infrastructure for decades, obligating the buyer to pay for a contracted volume whether or not they draw it, and simultaneously creating a receivable on the developer's balance sheet against which a lender can advance debt.

It is precisely this balance-sheet reality – on both sides of the transaction – that transforms a well-intentioned public commitment into a bankable instrument. The sector has already seen the cost of “toothless” commitments: vaguely worded pledges that could not be leveraged into a financial mechanism and did little to assist developers in raising capital for infrastructure projects.

The second dimension of making AMCs work at scale is portfolio aggregation. An offtaker's commitment for hundreds of megawatts of geothermal power, while commercially meaningful, is unlikely on its own to attract institutional debt capital at favorable terms. But if a consortium of creditworthy hyperscalers each makes legally binding take-or-pay commitments across a portfolio of geothermal projects, those cashflow obligations can be pooled into a Special Purpose Vehicle and used to back a bond issuance or a reserves-based lending facility – connecting directly to the Hot Bond structure described in Key Unlock #5. The portfolio approach also provides the risk diversification that

single-project finance cannot: not every well in a multi-project pool will underperform simultaneously, allowing a lender to underwrite the blended cashflow of the portfolio rather than the binary risk of a single reservoir.

The implication for strategy is clear: rather than pursuing bilateral developer-to-offtaker AMCs one project at a time, the priority should be convening a consortium of creditworthy offtakers willing to make portfolio-wide commitments, then engineering the legal and financial wrapper around that pool that allows institutional capital to flow in at scale.



Key Unlock #7

Develop Blueprints for Early-Stage Equity Investment

Key Unlock

The most acute capital gap in next-generation geothermal development is at the pre-construction phase – typically \$20M per project or more – before construction financing can be secured. A detailed blueprint for a catalytic capital vehicle combining public and private funding under a specialist mandate would provide a replicable deployment model. Preliminary modelling suggests every \$20M of catalytic early-stage equity could unlock ~\$200M in private capital and support ~150 MW of additional capacity.

Bridging the Pre-Construction Capital Gap

Access to risk-tolerant capital for early-stage development remains one of the most critical challenges in scaling geothermal energy. Pre-construction phases – which include resource delineation, permitting, drilling, and offtake negotiation – typically require more than \$20M per project and are often too early for traditional infrastructure finance or institutional capital.

Without targeted funding at this stage, many otherwise viable geothermal opportunities are unable to progress

to construction readiness. Government, philanthropic, or industry consortia funding for geothermal de-risking can deliver substantial technoeconomic benefits by addressing key financial and developmental challenges. One of the most significant impacts is the reduction of early-stage financing barriers. Pre-construction activities such as exploration, permitting, and design are capital-intensive and risky, often deterring private investors. Direct public investment in these phases helps unlock projects that might otherwise stall due to funding gaps.

By absorbing some of the upfront risk, de-risking support also enhances the overall viability of geothermal projects – making them more attractive to private investors who are generally more willing to participate in lower-risk, post-development phases. The funding acts as a catalyst, crowding in private capital that might otherwise remain on the sidelines. Government involvement can also stimulate innovation – targeted support for emerging geothermal technologies and advanced drilling techniques encourages experimentation, accelerates deployment, and ultimately drives down costs.

Beyond grants and first-loss loans, a broader suite of financial tools can further incentivise geothermal development. Tax credits for geothermal project

investments can lower upfront costs for developers, while production tax credits tied to electricity output provide long-term revenue certainty, supporting larger-scale investment. Government loan guarantees can also play a pivotal role by reducing perceived risk for lenders, thereby easing access to construction financing and improving overall project bankability.

The PPP Insurance Portfolio Approach

An alternative to direct capital injection is the creation of a public-private partnership to catalyse a functioning portfolio of first-of-a-kind next generation geothermal projects, focusing on risk-sharing through insurance mechanisms rather than direct public financing. In early-stage, high-risk markets like EGS, where commercial insurance is currently unavailable or dysfunctional, a government-backed insurance PPP can unlock private capital by mitigating exploration, temperature decline, and long-term performance risks.

If implemented strategically, this PPP model could jump-start the US geothermal industry by building a diversified, de-risked project portfolio across multiple basins, thereby proving out the bankability of geothermal technologies and scaling the sector over time. The approach aligns with investor expectations for structured de-risking, can be implemented with less capital than traditional grants, and generates a premium-based cost recovery mechanism that reduces the ongoing public funding burden.

Convening of Finance Actors

A collaborative initiative that brings together all key finance actors - lenders, investors, developers, and government offices to develop a comprehensive financial package tailored specifically for geothermal projects is required. This approach aims to address financing challenges by creating standardized documentation, risk mitigation strategies, and streamlined approval processes, ultimately accelerating geothermal deployment.

A broad initiative, possibly led by private sector energy consumers, such as hyperscalers, offers strong technoeconomic advantages by bringing together a diverse range of finance stakeholders. This collaborative structure enables a comprehensive understanding of geothermal project risks, financing requirements, and market dynamics – leading to better-informed investment decisions and more effective financial strategies. By developing standardized documentation, risk assessment frameworks, and due diligence procedures, the initiative can simplify the financing process, reduce transaction costs, and accelerate

project timelines. The shared approach builds transparency and trust, increasing investor confidence and attracting a wider array of capital sources.

Blueprint Design and Leverage Ratios

A comprehensive analysis of catalytic capital mechanisms can demonstrate how targeted equity at the pre-construction phase can unlock significantly larger pools of private investment. Drawing lessons from oil and gas finance, venture syndication, and impact investment structures, this approach can provide a blueprint for how early-stage equity could be efficiently deployed by a specialist investment vehicle. Such a vehicle could operate under public-private partnership principles and use commercial discipline to allocate capital, targeting projects that show both technical promise and scalable business models.

Key financial stakeholders – including project developers, equity sponsors, insurers, and potential offtakers – have indicated that a consistent source of catalytic capital would improve deal flow, de-risk pipelines, and standardize diligence procedures. **Preliminary modelling suggests every \$20M of catalytic early-stage equity could unlock approximately \$200M in private capital and support approximately 150 MW of additional capacity – a 10x leverage ratio reflecting the confidence effect of specialist public capital.**

The core deliverable will be a blueprint for designing and implementing this funding mechanism, including governance, eligibility criteria aligned with GRMS reserves classification, equity structures (convertible instruments, royalty interests, co-investment rights), and scaling pathways. Rather than advocating for a specific policy intervention, the analysis would equip stakeholders with a clear, actionable model that aligns market-based incentives with public interest goals – and can be implemented without legislative change.

Scalability

This model is built for international scalability, with mechanisms in place to ensure efficient and equitable deployment of government support across a broad range of geothermal projects. A standardized application process with clear eligibility requirements enables consistent and transparent allocation of funding, allowing developers to access resources without unnecessary administrative barriers. A project prioritization framework can be implemented to evaluate proposals based on factors such as potential energy output, resource quality, and geographic impact – ensuring that public funds are directed toward the most promising and strategically valuable projects.



Key Unlock #8

Adopt Oil and Gas Best Regulatory Practices

Key Unlock

Introducing tiered permitting (risk-based NEPA/CEQA review), risk-based well standards ([API RP 53](#), [RP 75](#)), centralized data portals, and workforce certification frameworks modelled on [SafeLandUSA](#) would reduce permitting delays, regulatory inconsistency, and procedural uncertainty.

Adopting Oil and Gas Best Regulatory Practices

Some degree of regulation will be necessary for the orderly implementation of geothermal energy projects. Some will oppose regulations, but including the voices of those affected by them to the extent possible will result in greater public acceptance. Likely models for regulations include the SEC (Securities and Exchange Commission) and COGEH.

Geothermal projects will inevitably be regulated by local, state, provincial, and federal governmental authorities. Proper regulatory practices must be based on clear definitions (as in [PRMS](#) or [COGEH](#)) and on clear, preferably concise, reporting requirements as in US Securities and Exchange Commission regulations.

Adopting proven regulatory practices from the oil and gas sector can streamline geothermal development by reducing permitting delays, clarifying agency roles, and improving investor confidence. The oil and gas industry has established risk-based permitting frameworks, clear well classifications, and efficient processes for exploratory and production phases – elements largely missing in geothermal regulation. While project managers may resist new regulations in areas where they do not currently exist, some regulations are in the public interest and benefit project stakeholders by promoting uniformity.

Well-defined and systematic regulations will minimize misunderstandings between operators and governments, and improve public trust in geothermal.

Specific regulatory practices to adopt:

- Safety Management Systems: Apply API RP 75 for risk-based safety plans and audits – critical for next-generation geothermal projects.
- Well Control Standards: Use API RP 53 for blowout prevention and equipment checks to boost safety in high-pressure drilling.
- Data Transparency: Launch a federal geothermal data portal for public access, including well logs, output, and permitting data.
- Tiered Permitting: Apply risk-based NEPA review to fast-track low-impact geothermal projects while maintaining robust review for higher-impact developments.
- Workforce Certification: Develop geothermal training modelled on SafeLandUSA – standardize safety and field qualifications across the sector.

Establishing a regulatory framework modeled on the US Securities and Exchange Commission or COGEH requirements can be completed in a year or two if professional staff assists volunteer committees. In the case of the SEC, modernized regulations for oil and gas were established in about 18 months. Appropriate regulations, developed jointly with people with varying degrees of support or even opposition, provide an opportunity to serve all in the interest of this affordable and reliable source of energy.



Conclusion

Forward to Terawatt Scale Development

The geothermal sector sits at an inflection point: offtake demand is accelerating, next-generation technologies are maturing, and institutional capital is actively looking for firm, dispatchable power at scale.

Oil and gas attracts institutional capital with a shared language of standardization that allows buyers, sellers, lenders, and insurers to transact with confidence. Geothermal can do the same in quick order by leveraging what the financial community has already come to rely on in the oil and gas context.

With a functioning language of standardization in place - a Geothermal Resource Management System - every subsequent initiative detailed in this analysis becomes viable. Reserves-based lending, the debt mechanism that financed the shale revolution, requires auditable reserves classifications. Farm-in and farm-out structures that distribute exploration risk across multiple capital providers require agreed definitions of resource maturity. Insurance products that can price and transfer reservoir risk require actuarial models built on comparable, standardized data. Secondary markets that allow investors to enter and exit positions require a common valuation framework.

The development of a GRMS is a foundational act of market-building - the equivalent of laying the pipeline before expecting the capital to flow. The industry, the

investors, and the technology are ready. The standard is what must come next.

The leverage for the actions outlined in this analysis is compelling. Every \$20 million of catalytic early-stage equity, structured around GRMS based classifications, is estimated to unlock \$200 million in private capital - a 10X multiplier that reflects what market confidence built on standardized information can achieve. A functioning insurance market, currently absent, is projected to generate over \$10 billion in cumulative premiums by 2050. The cost of capital for geothermal will fall materially as transparency improves and institutional investors can benchmark projects with the same tools they apply to the rest of their energy portfolios.

The financial community already knows how to speak the language of massive, globally scaled subsurface energy asset development - we simply now must apply that language to scale geothermal.



Appendix:

The InnSure Analysis – Building the Geothermal Insurance Market

Insuring First-of-a-Kind Geothermal Projects

In oil and gas, a mature insurance ecosystem – spanning exploration risk, construction, equipment, liability, and long-term production performance – underpins the confidence of lenders, equity investors, and offtakers at every stage of the project lifecycle. For the nascent next-generation geothermal sector, particularly for first-of-a-kind projects, this ecosystem does not yet exist in any meaningful form.

In 2023, Project InnerSpace provided a research grant to insurance think-tank InnSure to identify the structural reasons for this gap, and to map potential pathways for its development. InnSure interviewed dozens of expert stakeholders spanning geothermal engineering, oil and gas, specialist insurers, and project finance as part of this research.

The interviews confirmed that the barriers to insurer participation are structural, not technical. The insurance industry does not differentiate between geothermal projects or companies, lacks the knowledge to translate

project details into underwriting risks, and views the industry as too small to justify dedicated capabilities.

The market sizing was concrete: modelling 60 GW of geothermal production by 2050, InnSure projected cumulative insurance premiums exceeding \$10 billion, with annual gross written premiums peaking at around \$400 million. Insurance costs were estimated at approximately 10% of project value today, declining to around 7% as the market matures – a significant cost burden that better-designed products and clearer risk standards could materially reduce.

Primary coverage lines include exploration risk, construction risk, temperature decline performance risk, and long-term production insurance – broadly analogous to coverage lines that already exist in oil and gas.

The Path Forward

The analysis identified the need to both accelerate industry engagement and proactively build capabilities

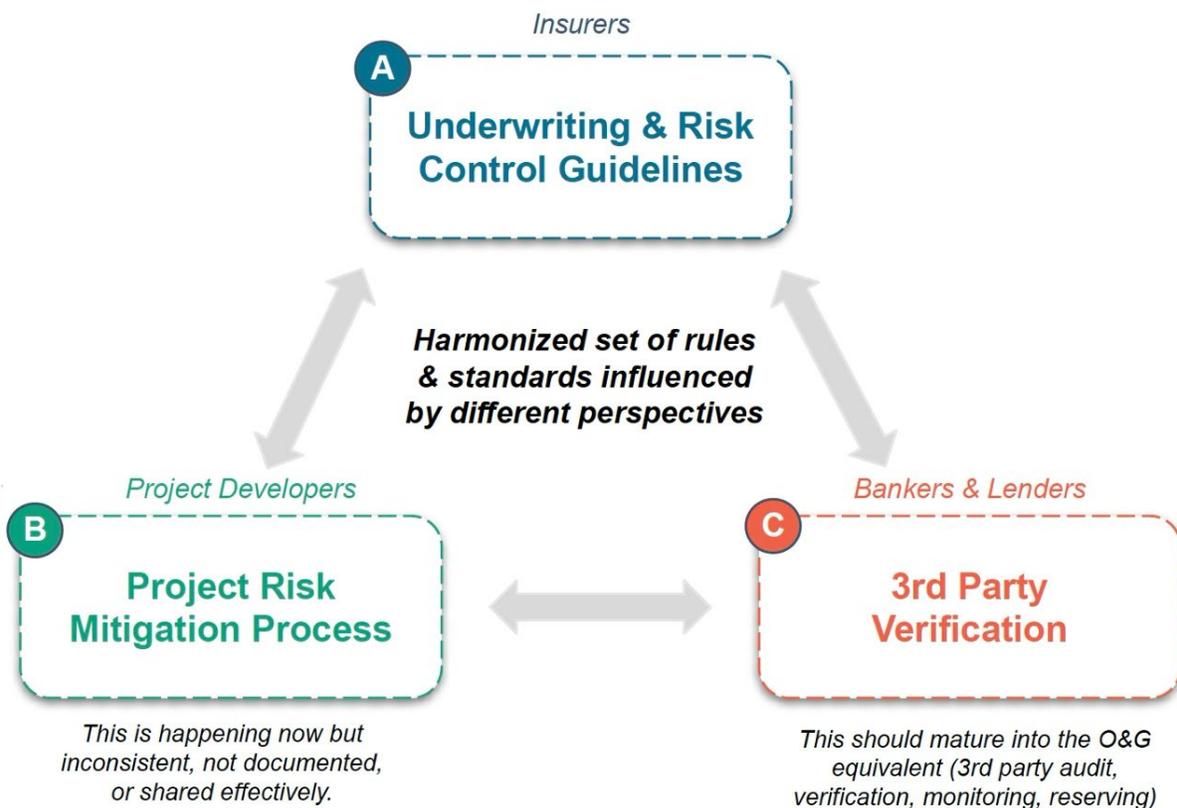
where they do not exist — particularly in data standards, audit and verification, and risk control and engineering, which are foundational to risk assessment, management, and transfer.

The ecosystem needs a common vernacular serving similar but distinct roles for insurers, project developers, and bankers and lenders: underwriting and risk control guidelines, project risk mitigation processes, and third-party verification frameworks respectively. Project risk mitigation is already happening but remains inconsistent, undocumented, and not shared effectively.

The finding directly anticipated the central argument of this report — that the GRMS is the foundational enabler for unlocking both capital and insurance markets.

The research concluded that the insurance capacity stack must evolve over time from philanthropic and public sources toward a market-based blend requiring education of insurance and geothermal players; creation of standards and third-party verification; identification of forward-thinking capacity; proxy-brokering for commercial players; and sharing of risk returns and actuarial loss data.

Since this research was performed, the most important real-world validation of this thesis has come from Germany, which launched the first government-backed geothermal exploration insurance program in Europe. This intellectual framework aligns closely with what InnSure identified as the viable path forward: a government-backed first-mover facility that absorbs structural risk, establishes underwriting precedents, and seeds the commercial market capacity that private insurers can then build upon.



References

1. Upstream Oil and Gas Investment Outlook 2024. International Energy Forum (IEF)([2024](#)).
2. Texas Independent Producers and Royalty Owners Association (TIPRO). TIPRO([link](#)).
3. Geothermal Texas. University of Texas at Austin Energy Institute([link](#)).
4. Oil and Gas Clearinghouse. OGClearinghouse([link](#)).
5. Constellation Completes Calpine Transaction, Powering America's Clean Energy Future. Constellation Energy([2026](#)).
6. Reflecting on 50 Years of Geothermal Innovations. SLB([2023](#)).
7. Norwegian Offshore Directorate Fact Pages. Norwegian Offshore Directorate(SODIR)([link](#)).
8. Open Data – ANP Brazil. Agência Nacional do Petróleo (ANP)([link](#)).
9. Production Data Application – Texas RRC. Railroad Commission of Texas([link](#)).
10. Community Engagement – Geothermal Engineering Ltd. Geothermal Engineering Ltd (GEL)([link](#)).
11. Eden Geothermal Community Fund. Eden Geothermal([link](#)).
12. The Krafla Magma Testbed Symposium. KMT([link](#)).
13. Petroleum Resources Management System Version 1.03. Society of Petroleum Engineers (SPE)([2018](#)).
14. CO2 Storage Resources Management System(SRMS). Society of Petroleum Engineers (SPE)([2025](#)).
15. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code). JORC([2012](#)).
16. CRIRSCO International Reporting Template. CRIRSCO([2024](#)).
17. Munich Re and KfW: New Exploration Risk Cover for Geothermal System Operators. Munich Re([2025](#)).
18. Learnings from the Hydraulic Fracturing Test Site(HFTS)#1, Midland Basin, West Texas – A Geomechanics Perspective (URTEC-1570). URTEC([2019](#)).
19. The DeepStar Project. DeepStar([link](#)).

References

20. Powering the AI Revolution. Project InnerSpace ([link](#)).
21. Department of Defense Expands Geothermal Initiative to Support Mission. Defense Innovation Unit (DIU) ([link](#)).
22. Model Contracts. Association of International Energy Negotiators (AIEN) ([link](#)).
23. NAPE Expo. NAPE ([link](#)).
24. Green Bond Principles. International Capital Market Association (ICMA) ([2025](#)).
25. DOE Launches New Energy Earthshot to Slash Cost of Geothermal Power. U.S. Department of Energy ([link](#)).
26. Geothermal Energy Power and Heat Generation in Türkiye – Minimising Exploration Risk. AFRY ([link](#)).
27. Geothermal Resource Risk Mitigation (GREM). PT Sarana Multi Infrastruktur (PTSMI) ([link](#)).
28. Ratepayer Protection Pledge. The White House ([2026](#)).
29. Glencore Agrees Solar Plant Deal with Pele Green Energy. Reuters ([2024](#)).
30. API STD 53: Well Control Equipment Systems for Drilling Wells. American Petroleum Institute (API) ([link](#)).
31. API RP 75: Safety and Environmental Management System for Offshore Operations and Assets. American Petroleum Institute (API) ([link](#)).
32. SafeLand ([link](#)).
33. COGE Handbook. Society of Petroleum Evaluation Engineers Canada (SPEE Canada) ([link](#)).
34. Act 152: An Act Relating to Hydraulic Fracturing Wells for Natural Gas and Oil Production. Vermont Legislature ([2012](#)).
35. High-Volume Hydraulic Fracturing in New York State. New York State Department of Environmental Conservation ([2015](#)).



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