Discussion Paper

Legal Transparency, Financial Governance, and Conciliary Risk Measures for Scalable Geothermal Deployment

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Legal Notice

Key Points

- Policies and regulations are primary enablers of geothermal development due to high uncertainty, capital intensity, and long project timelines, and clear, consistent frameworks reduce risk, unlock investment, and ensure sustainable resource management.

- Core legal pillars for geothermal advancement include resource ownership and access rights; clear, streamlined permitting and licensing; environmental and water-use regulation; reliable offtake and pricing mechanisms for electricity and direct use; and provisions for decommissioning and long-term reservoir management.

- Regulatory certainty is needed to attract investment, but governments often wait for proven projects before reforming regulations; breaking this cycle requires proactive, risk-tolerant governance that establishes fit-for-purpose frameworks before market maturity.

- Regulatory frameworks should be phased, transparent, and adaptive, aligned with the full project lifecycle from exploration to decommissioning, as a lifecycle-based regulation improves clarity, allocates risk appropriately, and strengthens oversight and long-term viability.

- The framework is a practical guide, not a universal template; effective geothermal legislation requires multidisciplinary input across geology, engineering, economics, environmental science, law, and policy that is tailored to national context.

Abstract

The geothermal energy sector is positioned for accelerated growth amid rising demand for low-carbon, secure, and reliable energy systems. As reaffirmed at COP30, global commitments to triple renewable capacity to at least 11 terawatts and to double energy efficiency improvements by 2030 will require substantial expansion of geothermal electricity and direct-use applications. However, despite its capacity to deliver stable baseload energy and long-term resilience, geothermal development remains constrained by regulatory uncertainty, high upfront risk, and policy frameworks that are often designed for more modular renewables, such as wind and solar. This paper offers practical guidance on how to build enabling legal environments by identifying and addressing regulatory uncertainties, streamlining institutional responsibilities, and integrating geothermal-specific provisions into broader energy or environmental legislation through a phased approach aligned with project development stages. Building on the World Bank's geothermal project costs and risk profile, this paper extends risk analysis into the legal and regulatory domain and proposes a phased regulatory model structured around the full project lifecycle – from exploration and resource confirmation to operation, long-term reservoir management, and decommissioning.

Keywords: Geothermal, Market, Energy, Climate, Policy, Regulation, National Strategy, Finance, Risk Mitigation, Technology, Licensing, Project Lifecycle, Decommissioning, Direct Use, Power Generation, Social License to Operate

Introduction

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Geothermal energy, derived from the Earth's internal heat, offers a reliable and sustainable source of power generation and direct uses (IEA 2024). Heat is harnessed primarily by drilling into the ground and transporting it to the surface using working fluids (mainly water and steam). At the surface, heat is converted into electricity through geothermal power plants or used directly for applications such as heating and cooling in buildings and industries through district energy networks or ground-source heat pumps, agriculture, or recreational use.

According to Rystad Energy (2025), geothermal electricity generation accounts for roughly 0.18% of global installed power capacity in 2024, while direct-use applications contribute an additional share equivalent to about 0.19% of global final energy demand. Taken together, geothermal represents a small share of global energy use in 2024, a figure that remains modest given the vast potential. While geothermal projects are underway in over 90 countries, only a handful have consistently expanded their capacity. Recent developments, including escalating energy security concerns, rising demand for cooling and heating, climate change pressures, sustainable investment flows, and technological breakthroughs, are refocusing attention on both geothermal power and direct-use solutions.

For decades, geothermal development was largely confined to regions with abundant high-enthalpy[1] resources, such as those along the Pacific Ring of Fire,[2] Europe, and East Africa. This narrow geographic focus has constrained policy and regulatory research. Today, however, development of widely available, lower-enthalpy geothermal resources is gaining momentum, supported by commercialization of cutting-edge technologies such as binary cycles, advanced geothermal systems, and repurposing of idle oil and gas wells.

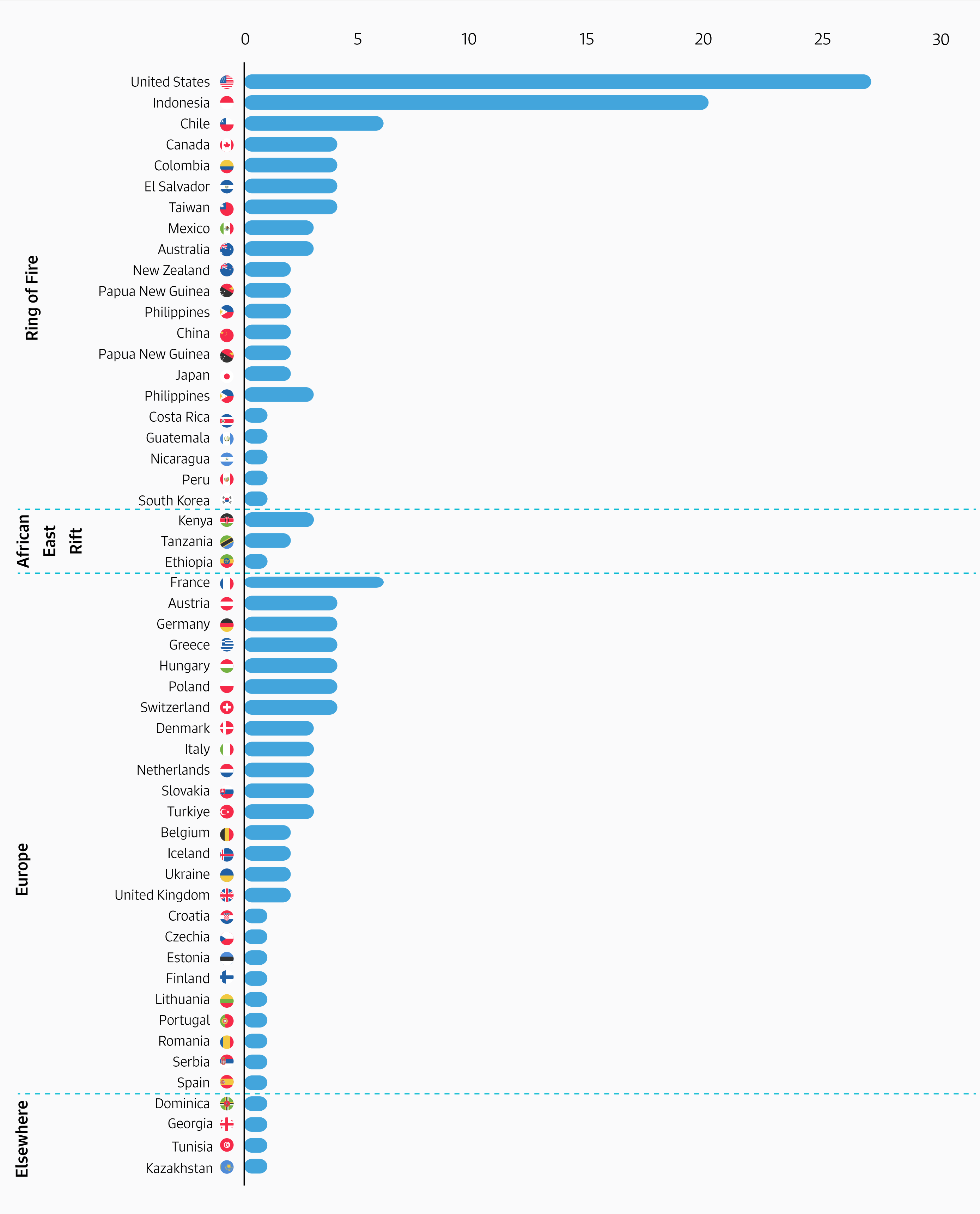
This shift underscores the urgency of establishing or modernizing geothermal governance. Since the turn of the century, national energy laws and policies have evolved from their traditional focus on fuels to regulating the full energy lifecycle while integrating energy justice principles and climate goals. However, in many jurisdictions, geothermal development lacks clear policy direction and suffers from fragmented institutional structures, opaque permitting processes, and inconsistent license terms.

While more than 130 national policies worldwide now include geothermal-specific provisions (Rystad Energy 2025), their depth and coherence vary significantly (see Figure 1). Countries such as Canada, Mexico, and Nicaragua have established robust permitting and classification systems, but many others still rely on outdated or generalized mining laws. Even where roadmaps exist, such as the U.S. Department of Energy's FORGE initiative, targeted efforts to de-risk and incentivize investment are not universally adopted.

1 Enthalpy refers to the total heat content of geothermal fluids under specific pressures and temperature conditions.

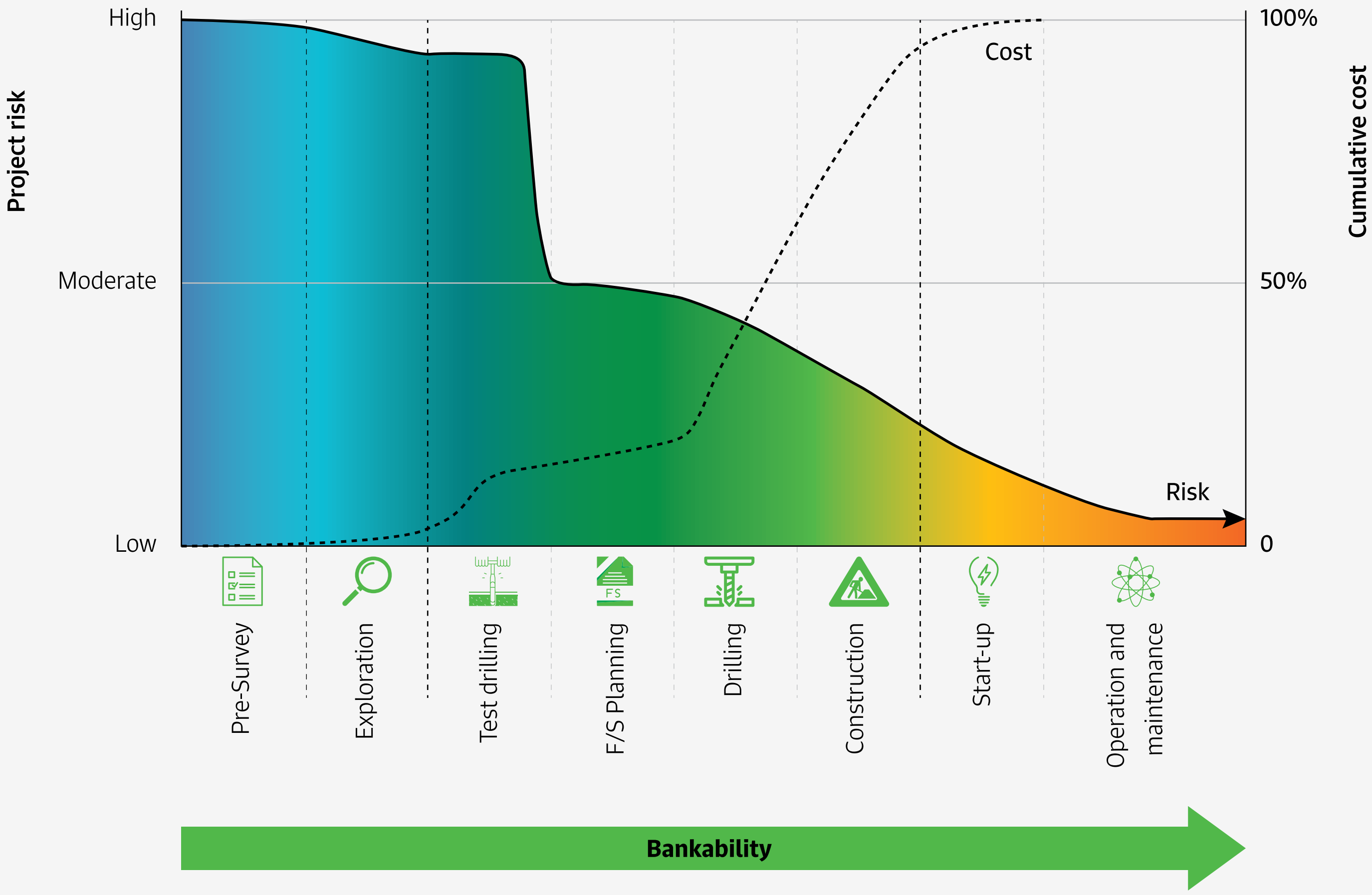
2 The Ring of Fire is "a string of volcanoes and sites of seismic activity, or earthquakes, around the edges of the Pacific Ocean" (National Geographic Society n.d.). It covers the western flanks of North America and South America, and the eastern parts of Asia.

Figure 1. Number of overarching and geothermal-related policies and regulations issued by governments.



Source: Authors' analysis, based on Rystad Energy (2025).

Figure 2. Geothermal project costs and risk profile at various development phases.



Source: Modified from Gehringer and Loksha (2012).

Compounding these governance challenges is the high degree of technical uncertainty in early-stage geothermal development. Developers face numerous risks throughout the project lifecycle, particularly during exploration and drilling (see Figure 2). Chief among these is exploration risk (also known as geological risk), which refers to uncertainty about whether a geothermal resource has sufficient heat, flow, and permeability to be economically viable. This risk is highest in early exploration stages (Gehringer and Loksha 2012).

Closely tied to exploration risk are economic risks, which can magnify its impact. Unlike other renewables, geothermal requires high upfront capital investment before commercial viability can be confirmed. The time to value creation spans multiple development phases over several years, and geothermal projects are characterized by long lead times and high upfront risk (Gehringer and Loksha 2012), discouraging private sector interest without clear risk mitigation tools or policy incentives. These long lead times, coupled with early-phase uncertainty, make it difficult to secure financing, particularly in emerging markets.

Legal and regulatory risks are equally limiting, especially for emerging markets. Inconsistent policies, unclear permitting procedures, and institutional fragmentation create uncertainty that deters investment. A cross-country assessment found that regulatory instability is a major barrier to market entry, often comparable in impact to exploration risk (Seyidov 2019). These barriers often stem from overlapping agency mandates, resulting in project delays and additional costs. For example, geothermal projects on federal lands in the U.S. historically took up to 10 years to secure necessary permits due to multi-agency approval requirements (Robins et al. 2021). However, recent measures by the U.S. Department of the Interior (2025a) aim to accelerate reviews and approvals to less than a month.

Existing literature offers valuable insights into the legal regulatory landscape at national, regional, and international levels. Contributions have analyzed EU member state legislation (Dumas et al. 2020) and non-EU states (Hámor-Vidó et al. 2024). Interdisciplinary studies have concluded that while many aspects of the geothermal value chain are covered by EU law, additional measures are needed to address conflicts between different uses of underground resources (Hámor-Vidó et al. 2024). Reports have also provided overviews of legal and regulatory frameworks for Eastern Africa (IRENA 2020a) and for Latin America and the Caribbean (GIZ 2024).

The literature has also provided sector-specific approaches, including the impact of regulatory and policy frameworks on geothermal research and development investment (Manzella et al. 2018) and regulatory aspects of the life cycle assessment (LCA)of power plants (Tomasini Montenegro et al. 2017; Parisi et al. 2020).

International agencies, multilateral institutions, and governmental authorities have identified legal and regulatory barriers to scaling up geothermal resources (IEA 2024). Academic and institutional literature has examined good regulatory practices from a general perspective (Berman et al. 2018), as well as specific issues such as data management (de Wit and Hallgrimsdottir 2023), district heating (Kępińska, Tomaszewska, and Pająk 2016), and the social license to operate (Barich and Stoklosa 2021; ESMAP 2024). In 2025, leading law firms also published an online guide analyzing regulatory frameworks in 15 countries (Elements by BBA//Fjeldco 2025).

While extensive, the literature remains fragmented across jurisdictions and project phases, lacking a comprehensive framework that systematically addresses regulatory requirements across the entire geothermal project lifecycle. Existing works tend to focus on discrete topics or country-specific analyses, offering limited guidance on designing coherent, phased legal and regulatory architectures that reduce risk in nascent markets. As the role of geothermal in the energy transition becomes more pronounced, addressing regulatory gaps – including subsurface rights, access and land use, monitoring and liability rules, and financial de-risking schemes – will be essential (Garabetian, Bogi and Dumas 2019; ESMAP 2024).

Building on existing literature and best practices, we propose regulatory and policy considerations across each phase of the geothermal project costs and risk profile of Gehringer and Loksha (2012). The framework aims to bolster investor confidence, create a level playing field, and reduce uncertainty by aligning legal instruments with the technical and financial characteristics of each development stage. The objective of this framework is to assist policymakers in clarifying the dynamics of geothermal projects, thereby facilitating their effective integration into energy policies and regulations and minimizing potential barriers.

The scope of this article encompasses legal and regulatory issues relating to deep geothermal resources and commercial-scale projects, excluding shallow resources, ground source heat pumps for residential buildings, and by-products such as geologic hydrogen, carbon sequestration, and critical minerals. While these emerging byproducts help the economics of geothermal projects and generate revenue streams, they warrant further assessment in a separate publication. The focus in this paper is on power generation and direct uses, with emphasis on new market entrants and emerging markets. It offers practical guidance on how to build such enabling legal environments by identifying and addressing regulatory uncertainties, streamlining institutional responsibilities, and integrating geothermal-specific provisions into broader energy or environmental legislation through a phased approach aligned with project development stages.

The paper is structured into four more sections. Section 2 aligns legal and regulatory design with the geothermal project lifecycle. Section 3 examines financial and risk mitigation considerations for geothermal development. Section 4 contains practical drafting notes for statutes, regulations, and permits. Section 5 concludes.

Aligning Legal Frameworks with the Geothermal Project Lifecycle

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The geothermal project costs and risk profile developed by Gehringer and Loksha (2012) (see Figure 2) serve as a foundational model for designing a comprehensive legal framework for geothermal development, addressing the perspectives of regulators and developers alike.

This alignment ensures that laws, regulations, permits, incentives, and responsibilities are tailored to the challenges at each stage. Geothermal projects are customarily divided into four main phases (see Figure 3): exploration and resource assessment; field development and surface facilities construction; operational; decommissioning and post-operational management. Each phase presents regulatory considerations for both power generation and direct-use applications. This article is structured around the regulatory requirements for each phase and those applicable across multiple phases.

1. **Exploration and resource assessment:** This phase is extremely high risk. To support this phase, policies and legal frameworks must address key issues such as data collection, access and ownership, risk mitigation mechanisms, permitting frameworks, and local community engagement. Case studies from New Zealand, Indonesia, the Netherlands, and France provide valuable insights into regulatory approaches that reduce risk and improve bankability.

2. **Field development and surface facilities construction:** This phase involves land use and social acceptance, streamlined permitting, taxation and royalties, monitoring, and environmental incentives. It also requires coordination on well drilling approvals, water rights, reinjection obligations, rights of way, and permits for building or heat networks. Case studies from Kenya and the U.S. provide examples of effective regulatory practices.

3. **Operational:** During the operational phase, regulatory considerations include offtakes and pricing mechanisms, approval for expansions, legal recognition of direct-use agreements, and third-party access. Case studies from the UK, the Netherlands, and Indonesia provide insights into successful frameworks.

4. **Decommissioning and post-operational management:** This phase addresses license termination, stranded assets and liability transfers, environmental restoration, abandoned well management, and reservoir longevity plans. Although full decommissioning is relatively uncommon due to the long productive lifespan of most reservoirs, it occurs where resource performance declines, where facilities are upgraded, or where concessions expire.

The following sections offer general guidance on creating regulatory frameworks from inception to decommissioning. The proposed framework is primarily intended for medium- to large-scale geothermal power generation and direct-use projects, and it could be scaled proportionately for small-scale applications. On a different note, it is worth noting that financing geothermal projects, while addressed as a standalone topic in this paper, is intrinsically linked to regulatory certainty and risk mitigation at each phase of development.

Figure 3. Geothermal project cycle key phases and the underlying regulatory requirements.

Exploration and resource assessment phase

- Ownership and access to resources
- Data access and resource information
- Land use and social acceptance
- Exploitation and appraisal permitting framework

Field development and construction phase

- Exploitation and development permitting framework
- Geothermal reservoir longevity plans
- Monitoring and surveillance

Operational phase

- Operational permits
- Offtake and pricing mechanisms
- Taxation and royalties
- Regulatory oversight and tariff approval

Post operational management and decommissioning

- Termination and revision of licenses
- Asset decommissioning
- Environmental restoration
- Decommissioning permits

Source: Authors' analysis, based on Gehringer and Loksha (2012) and Elements by BBA//Fjeldco (2025).

2.1 Exploration and Resource Assessment Phase

This phase focuses on progressively reducing geological uncertainty and establishing regulatory and financial viability. Key regulatory elements include establishing clear ownership and access rights, implementing robust data access systems, developing comprehensive permitting frameworks, and adhering to international standards for resource assessment and environmental protection.

2.1.1 Ownership and Access to Underground Geothermal Resources

A foundational element of any geothermal legal framework is the precise definition of resource ownership and the right to access. Geothermal projects rely heavily on subsurface information, especially in the early stages. Without (i) clarity on who owns geothermal resources, (ii) whether they fall under water, mining, or energy laws, and (iii) under what conditions they can be accessed, developers face a high-risk and ambiguous legal environment.

Ownership can relate to groundwater, thermal water, minerals, and other substances, varying by country. The exploration and utilization of geothermal resources must consider constitutional and legal provisions related to land ownership and sub-surface resources.

The question of ownership and right of use is crucial, especially when projects are developed by private entities. Developers need a clear understanding of their rights to access, explore, use, and manage geothermal resources. Unclear ownership interests can impact the ability to attract and maintain private sector financing (Eckstein 2025). Ownership and rights of use are also crucial for cascaded use of geothermal resources,[3] as developers need to secure their rights on the resource and clearly understand the scope of such rights.

In most countries, ownership is vested in the state, and exploration or exploitation activities require authorization through a license, permit, or concession. A common exception applies to shallow use with heat pumps, which is often exempt from full licensing, although simplified permitting still applies.

It should be noted that in a few countries (e.g., Iceland) private landowners hold titles to geothermal resources under their land but are restricted from utilizing such resources without a specific license.[4] Table 1 demonstrates the legal status of geothermal resource ownership in selected emerging and mature markets into three distinct legal models:

- **Type I** – Full State Ownership: Geothermal resources are vested entirely in the state, independent of surface land ownership.
- **Type II** – State Ownership with Simplified Permitting for Shallow Use: The state retains ownership of geothermal resources, but shallow direct-use developments may proceed with a simplified permitting regime.
- **Type III** – Hybrid Regimes: Ownership varies by jurisdiction, land type, or resource classification.

Resource Assessment Frameworks

Regarding resource assessment, various methods are used to evaluate the potential of geothermal systems, ranging from volumetric calculations to advanced numerical simulations. The United Nations Framework Classification (UNFC), developed by the United Nations Economic Commission for Europe, is the most widely recognized classification framework. It encompasses specifications for classifying geothermal resources based on their maturity, economic feasibility, and environmental considerations (United Nations Economic Commission for Europe and Ad Hoc Committee of the International Geothermal Association 2022), allowing a meaningful comparison of geothermal resource estimates with other energy resources (IEA 2021). Countries like Australia and New Zealand have integrated the UNFC into their regulatory frameworks (Falcone et al. 2025).

The Society of Petroleum Engineers (SPE) is working to adapt its Petroleum Resources Management System (PRMS) to include geothermal energy. Recognizing similarities in subsurface fluid behavior and extraction between geothermal and petroleum systems, SPE sees potential in applying PRMS principles to geothermal projects. This extension aims to standardize resource classification and improve communication and investment planning. Though still in development, the effort reflects a broader move to integrate geothermal into established resource management frameworks (Society of Petroleum Engineers 2022).

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3 Cascaded use of a geothermal resource means using the same geothermal fluid for several purposes, often by different users, to expand offtake options and improve project economics.

4 Under Icelandic law, the ownership of resources in the ground is attached to private land, while on public land, resources in the ground are the property of the State of Iceland, unless other persons can prove their ownership.

Table 1. Legal status of geothermal resource ownership in selected countries.

	Country	Legal status of ownership	Legal source
Type I	Indonesia	All natural resources, including geothermal, are owned and controlled by the state for the welfare of the people.	Constitution of Indonesia
	Philippines	Geothermal resources are considered natural resources and are owned by the state.	Constitution of the Philippines
	El Salvador	The subsoil belongs to the state. The state may grant concessions to entities or individuals for exploitation.	Constitution of El Salvador
	Türkiye	All geothermal resources belong to the state, independent of land ownership.	Law on Geothermal Resources and Natural Mineral Waters No. 5686, Arts. 4–5
Type II	Chile	Geothermal energy belongs to the state but may be explored/extracted by concession holders. Shallow direct-use developments may proceed without concession.	Law N°19.657
	France	Mineral and fossil substances subject to the mining regime do not belong to the surface owner – they are administered by the state. Simplified permitting regime for shallow resources	French Mining Code, Article L100-3, L112-2
Type III	U.S	Federal: On federal lands, geothermal resources are owned by the U.S. government. State: Rules differ – in some states, geothermal follows the surface estate (e.g., Nevada, Oregon, Texas, Utah), while in others, it is attached to the mineral estate (such as California and Nebraska, though New Mexico excludes it). In certain jurisdictions, it is reserved to the state (for example, Alaska), whereas in Wyoming, geothermal resources are governed under water law. States like Idaho and Montana treat geothermal energy as a sui generis resource category.	Federal: Property clause of the Constitution and the Geothermal Steam Act of 1970

Sources: (Elements by BBA//Fjeldco 2025); GIZ (2024); Eckstein (2025).

2.1.2 Data Access and Resource Information

Accurate and accessible resource data is crucial during exploration and early development, when uncertainty and risk are highest. Information on geothermal resources – geological data, characteristics, and fluid composition – is key to development. Mapping geothermal potential at the regional or country level is a critical step in enabling resource utilization. The quality of available data, coupled with information on potential markets, determines project feasibility.

Governments are essential in making geothermal resource information accessible. At a minimum, stakeholders should maintain public records, including surface manifestation data (temperature, chemical composition), seismic data, and data from shallow and deep drilling (stratigraphy, temperature, pressure, permeability). Information on groundwater resources is also essential, as it helps avoid contamination and can serve as a thermal source for heat pump systems (see Table 2). Water-stressed regions face considerable challenges. For example, Saudi Arabia's stringent groundwater regulations may constrain shallow geothermal applications in the region (Aldubayan and Al-Suwailem 2025).

License holders are typically required to provide results of geological, geochemical, geophysical, and hydrogeological studies, as well as drilling and reservoir tests, technical specifications of wells, and reinjection plans. From a developer's perspective, all reporting should be conducted on a confidential basis, with public authorities adhering to strict confidentiality duties regarding commercially sensitive information.

Policymakers face the challenge of balancing proprietary information protection with data transparency. For example, Indonesia vests ownership of geothermal data in the government and requires prior consent for transfer, grounded in Law 21 of 2014 and Government Regulation 7 of 2017 (Baker McKenzie 2018; Government of Indonesia 2014).

The World Bank and the National Renewable Energy Laboratory (NREL) guidance emphasize the importance of standardized reporting formats and periodic publication in reducing exploration risk premiums (World Bank 2014; IEA 2024).

Geothermal hackathons, such as the SPE Europe Energy GeoHackathon (SPE Geo Hackathon 2025), foster innovation by developing AI-driven models to interpret geological data and characterize geothermal resources. Table 2 categorizes data sharing policies into two principal models.

- **Type I – Competitive selection based on pre-disclosed data:** Governments identify and designate resource-rich areas based on available technical data, then award development rights through competitive processes; and
- **Type II – Open-access public data repositories:** Governments maintain centralized geological databases or online platforms that provide free or low-cost access to exploration data, including geological, geophysical, and drilling information.

Table 2. Data sharing policies in well-established geothermal markets for power generation and direct use applications.

	Country	Data access policies	Description
Type I	Philippines	Open and competitive selection process for pre-determined areas (PDAs)	Geothermal services contracts relating to pre-determined areas are awarded through a competitive process. PDAs refer to areas with potential through sufficient available technical data, as may be determined by the Renewable Energy Management Bureau and approved by the Department of Energy Secretary.
Type II	Netherlands	Geological databases based on the Mining Act	Data is made available on databases such as the National Key Registry of the Subsurface (Bassiregistratie or BRO) and the clearing house for data on the shallow and deep geology of the Netherlands (DINOloket). Data availability is said to have contributed to reducing resource risk for operators and is considered, together with other policies, an enabling factor for the development of geothermal direct-use projects.
	Indonesia	MEMR One Map Indonesia (online platform)	The Ministry of Energy and Mineral Resources (MEMR) launched an online platform in 2017, ESDM One Map Indonesia, which provides access to energy and mineral resource data and information. This presents a variety of geospatial information obtained from different sectors of MEMR. The available information includes maps and geospatial data concerning geothermal resources throughout Indonesia.
	United States	U.S. Department of Energy and U.S. Geological Survey	The U.S. Department of Energy's Geothermal Data Repository and the National Geothermal Data System compile and share geological, geophysical, and well data from federal and state programs. These platforms ensure standardized reporting, enhance data transparency, and reduce exploration risk by providing open public access to geothermal information across jurisdictions.

Sources: Department of Energy (DOE) Philippines (2024); NLOG (2023); Setyowati et al. (2018), U.S. Department of Energy (n.d).

2.1.3 Exploration and Appraisal Permitting Framework

The permitting framework applicable to the exploration and resource assessment phase represents the first formal legal interface between the developer and the state. It sets the procedural and substantive requirements that govern early-stage access, testing, and reporting obligations. While permitting continues across later phases, this early framework is unique in that it must balance regulatory oversight with flexibility, allowing developers to reduce geological uncertainty while ensuring that exploration activities remain environmentally and socially responsible. Predictable, transparent, and appropriately sequenced permitting and regulatory arrangements are important to reduce uncertainty and facilitate private investment during the early stages of geothermal development (World Bank 2016a; ESMAP / The World Bank 2021; Gehringer and Loksha 2012).

To achieve this balance, the framework should be structured around two sub-stages: (i) surface exploration and pre-feasibility, and (ii) appraisal and confirmation drilling. Each sub-stage requires separate approvals and screening levels that reflect the differing risks, technical complexities, and environmental footprints of the activities undertaken. Clear delineation of these sub-stages ensures predictability for investors and reduces overlaps among competent authorities (see Table 3).

Sub-Stage 1: Surface Exploration and Pre-Feasibility

This sub-stage encompasses non-intrusive and shallow activities to assess geothermal potential prior to deep drilling, including geological and geochemical surveys, geophysical imaging, and shallow temperature-gradient hole (TGH) drilling. The principal regulatory objective is to facilitate low-impact data collection while protecting environmental and land-use interests.

During this phase, drilling shallow boreholes such as TGHs can be authorized under a simplified notification model, referred to as a “casual subsurface authorization.” This allows developers to submit a concise technical notification outlining borehole specifications, environmental screening, and safety measures. A comparable model exists in the Netherlands, where the Dutch Mining Act permits geothermal reconnaissance drilling up to 500 meters under a notification regime rather than a full exploration license.

Emphasis should be placed on data transparency and coordination. Where activities intersect groundwater zones or protected aquifers, developers must obtain clearance from the competent water or environmental authority. The Netherlands’ system further integrates public data repositories such as DINOloket and BRO, ensuring exploration information is systematically stored and accessible (NLOG 2023).

Environmental review during this sub-stage is generally limited to screening or preliminary assessment, including baseline monitoring for noise, dust, induced seismicity, water quality, and biodiversity impacts. Complete Environment and Social Impact Assessment (ESIA) procedures are rarely triggered unless statutory thresholds are exceeded, reflecting the principle that regulatory effort should correspond to environmental and social risk.

Sub-Stage 2: Appraisal and Confirmation Drilling

Following successful pre-feasibility results, this sub-stage authorizes intrusive operations to validate the geothermal resource, including drilling slim-hole or full-diameter wells, as well as conducting flow, injectivity, and interference tests and implementing well-integrity and safety measures.

The key permitting instrument is the drilling and well-design approvalz, supported by a comprehensive drilling plan covering casing programs, cementing and blowout prevention, expected depths and pressures, HSSE guidelines, and well-abandonment contingencies. In the U.S., comparable approvals are required under the Geothermal Steam Act and Nevada’s NRS §534A. Similar requirements exist under New Zealand’s national code of practice and the Netherlands’ Mining Regulation.

Environmental obligations intensify at this sub-stage. Regulators typically require baseline environmental screening before drilling, followed by periodic monitoring covering water quality, air emissions, induced seismicity, and surface stability. In the EU, deep drilling is classified under Annex II of the Environmental Impact Assessment Directive, requiring case-by-case screening. In jurisdictions aligned with World Bank and IFC standards, ESIAs are required proportionate to the project’s potential risk (IFC 2012).

Parallel permits may include reinjection or discharge authorizations specifying injection depth, maximum pressure, chemical composition monitoring, and mechanical integrity testing.

Table 3. Benchmark schedule of permitting requirements, exploration, and resource assessment phase.

Sub-stage	Permit or authorization	Core requirements	Competent authority / oversight	Indicative duration
Surface exploration and pre-feasibility	Exploration permit or registration	Land access consent, shallow drilling, environmental screening, and mandatory data reporting	Geological survey or Ministry of Energy / Environment (e.g., Germany, Iceland, Kenya)	15-30 days
	Casual subsurface authorization	Defines exploration area and borehole limits, safety provisions, and reporting obligations	Water Resources or Environmental Authority (e.g., France, Netherlands)	Up to 60 days
Appraisal and confirmation drilling	Drilling and well-design approval	Casing and blowout program, HSE plan, abandonment procedure	Energy or mining authority (e.g., Türkiye, Kenya)	30-60 days
	Reinjection / discharge permit	Fluid management plan, injection parameters, and monitoring program	Environmental or water authority (e.g., Indonesia, France)	30 days
	Environmental Screening / EIA	Site-specific review of air, noise, and induced seismicity	Environmental authority (e.g., France, Indonesia, Kenya)	Case-dependent (screening up to 90 days)

Sources: Authors' analysis based on de Wit and Hallgrímsdóttir (2023); French Mining Code (décret n°78-498, 2015/2020); Dutch Mining Act (Mijnbouwwet, Arts. 1, 6, 145, 2022); Türkiye Geothermal Law No. 5686; Indonesia MEMR Reg. No. 7/2017; Kenya Energy Act 2019.

In Nevada and California, Underground Injection Control programs regulate these activities (NDEP 2017).

To minimize procedural overlap, surface-use and access permissions can be consolidated into the drilling authorization, as practiced in the U.S. In several advanced markets, categorical exclusions or fast-track mechanisms have been introduced for low-impact confirmation activities, reserving full NEPA review for projects of potentially significant impact (U.S. Department of the Interior 2025b). Table 3 categorizes permitting requirements into two distinct regulatory models:

- **Type I – Surface exploration and pre-feasibility:** Non-intrusive and shallow activities designed to assess geothermal potential prior to the authorization of any deep drilling, including geological and geochemical surveys, geophysical imaging, and shallow TGH drilling.
- **Type II – Appraisal and confirmation drilling:** Intrusive operations designed to validate the existence and productivity of the geothermal resource, including drilling slim-hole or full-diameter wells.

2.2 Surface Construction and Field Development Phase

This phase marks the transition from subsurface validation to full-scale infrastructure development, requiring coordination of multiple regulatory domains, including construction, environmental management, surface access, land use, and operational safety. Key regulatory elements include establishing comprehensive exploitation and development permitting frameworks, addressing land use and social acceptance considerations, implementing provisions for direct-use and cascaded use applications, establishing robust monitoring and surveillance systems, and developing geothermal reservoir longevity plans to ensure sustainable resource management.

2.2.1 Land Use and Social Acceptance

Geothermal resource ownership and extraction rights define who legally controls the subsurface resource. In contrast, land use and social acceptance concern how the project affects the surface environment and local communities. These considerations supplement formal ESIA[5] processes through community engagement and evaluation of social license to operate.

5 ESIA is a structured process that identifies and evaluates the potential environmental and social impacts of a project prior to its commencement and throughout the lifecycle of geothermal projects. The World Bank's Environmental and Social Framework is one of the well-renowned guidelines adopted by the geothermal industry and a prerequisite for financing geothermal developments. It integrates environmental, health, and social considerations into project planning to support sustainable development and regulatory compliance.

Geothermal projects, particularly in remote areas, often entail supporting infrastructure such as roads and water supply systems. These land use changes can generate significant socioeconomic benefits for surrounding communities, including improved mobility, access to healthcare and education, and employment opportunities (ESMAP 2024).

Project infrastructure is often shared with local communities as part of engagement strategies. Developers frequently allocate funding toward community assets such as schools and clinics to strengthen social acceptance and secure a social license to operate (ESMAP 2024).

Developers must balance community needs with what they can realistically deliver. While developers cannot replace governments in providing core services, they depend on community support and consent (Karytsas, Polyzou, and Karytsas 2019).

Policy mechanisms can be a crucial factor in enhancing social acceptance. Table 4 categorises these mechanisms into three distinct regulatory approaches and presents notable examples from Indonesia, Kenya, and Türkiye:

- **Type I – Mandatory CSR programs:** Developers must budget annually for community development coordinated with regional governments (Indonesia).
- **Type II – Constitutional benefit-sharing:** Profits, training, employment, and technology transfer are shared with host communities based on constitutional principles (Kenya).
- **Type III – Revenue-sharing mechanisms:** A portion of annual administrative fees (e.g., 1% of gross revenue) is transferred directly to host municipalities (Türkiye).

A distinguishing feature of geothermal energy is its potential for direct-use applications. Communities near geothermal developments may utilize residual heat for agriculture, demonstrating measurable socioeconomic benefits, including enhanced food security. For example, geothermal heat can create optimal conditions for crop production in greenhouses, improving yields and reducing losses (IRENA 2022). These direct-use applications contribute to social acceptance by delivering visible, practical benefits, particularly when aligned with community needs in food security, employment, and local enterprise development.

Table 4. Social license to operate in selected countries.

Country	Source	Mechanism	Impact on Social acceptance
Indonesia	Investment Law No. 25/2007 (Art. 15); Geothermal Law No. 21/2014; Gov. Reg. No. 7/2017	Mandatory corporate social responsibility and community development programs are budgeted annually and coordinated with regional governments.	This structure ensures early-stage community engagement, particularly during construction. It embeds community benefits into budgeting, enabling developers to deliver infrastructure, training, and livelihood support that mitigate social risk and enhance acceptance.
Kenya	Constitution of Kenya (2010, Arts. 202 and 66); National Energy Policy (2018); Natural Resources (Benefit Sharing) Bill (2022, pending)	Benefits sharing principles based on the constitution, which support the expectation that the benefits geothermal projects generate should be shared equally. However, the Formal benefits sharing framework is pending	These principles support the expectation that the benefits that geothermal projects generate, such as profits, training, employment, and technology transfer, should be shared equally. KenGen reserves 10% of its jobs for locals and promotes gender equity in employment and education. The Geothermal Development Company's long-term Community Engagement Strategy (2023–2032) institutionalizes local involvement during early project phases.
Türkiye	Law No. 5686/2007 (as amended)	Geothermal licenses are required to pay an annual administrative fee equal to 1% of their gross revenue, and 20% of this fee must be transferred to the local municipality where the project is located.	Direct fiscal benefit for host communities, incentivizes local support, aligns local government interests with project success, and supports smoother implementation during construction.

Sources: Investment Law No. 25/2007 (Indonesia); Geothermal Law No. 21/2014 (Indonesia); Government Regulation No. 7/2017 (Indonesia); Constitution of Kenya (2010); National Energy Policy (2018); Natural Resources (Benefit Sharing) Bill, No. 6 of 2022 (Kenya, pending); Law No. 5686/2007 (Türkiye).

In most jurisdictions, geothermal legislation is primarily oriented towards electricity generation, resulting in gaps in the regulatory framework for direct-use applications (ESMAP 2024). Accordingly, the definition of geothermal uses should be sufficiently comprehensive to accommodate both direct-use projects and cascaded utilization.

2.2.2 Exploitation and Development Permitting Framework

In this phase, the permitting framework must coordinate construction, environmental management, surface access, land use, and operational safety under a coherent, time-bound procedure. The World Bank notes that "this stage requires the most complex interaction between surface and subsurface governance systems, as construction and commissioning activities physically manifest prior regulatory decisions" (World Bank 2014, 60-61).

Permits are primarily construction- and land-based, extending to permanent surface infrastructure. The framework should identify competent authorities, define coordination mechanisms, and specify approval sequencing. In advanced jurisdictions, a single-window permitting approach consolidates applications within a single administrative channel. For example, Iceland's National Energy and Environment Agency (NEEA) integrates environmental and operational licensing under a unified procedure (NEEA 2023).

Two primary sub-stages can be distinguished within this phase: (i) surface works and plant construction, and (ii) field commissioning and integration.

Sub-Stage 1: Surface Works and Plant Construction

This sub-stage authorizes the establishment of geothermal surface facilities, including well pads, pipelines, separators, cooling units, and power plants. Developers must comply with land-use plans, zoning laws, and environmental and social obligations, and must obtain construction permits, environmental and building consents, and water-use authorizations, as applicable (see Table 5).

Baseline environmental approvals from earlier phases are typically updated to reflect construction-related impacts. In the EU, this sub-stage triggers full ESIA obligations under Annex I of Directive 2011/92/EU for geothermal plants with a thermal capacity exceeding 20 Mwe (European Parliament and Council of the European Union 2011). In Kenya and Indonesia, developers must submit ESIA reports including construction-phase management plans and stakeholder consultation results (ESMAP 2023).

Surface construction demands clear rights to occupy and modify land, derived from surface leases, easements, or temporary occupation licenses. In the U.S., surface rights on public lands are administered under the Geothermal Steam Act and the Federal Land Policy and Management Act (U.S. Department of the Interior 2024a).

Sub-Stage 2: Field Commissioning and Integration

This sub-stage involves integrating wells, surface pipelines, and plant systems for operational readiness testing. Key authorizations include commissioning approvals, operational readiness certificates, and reinjection and emission permits. Regulators may impose verification conditions to confirm compliance with approved design standards.

In the Netherlands, the State Supervision of Mines issues operational certification once compliance with the approved plan and successful flow and reinjection tests are demonstrated (NLOG 2023). New Zealand's Resource Management Act (1991) requires final inspection and confirmation of discharge consents and water management obligations before transitioning to operations.

Environmental monitoring and post-construction audits form part of legal obligations, with authorities requiring continuous reporting on well integrity, noise, and emission control. These obligations ensure that "construction and commissioning do not compromise the long-term sustainability of the geothermal field" (IFC 2012, 9-12). Table 5 categories permitting requirements into these two sub-stages:

- **Sub-stage 1 – Surface works and plant construction:** Authorizes the establishment of geothermal surface facilities, including well pads, pipelines, and power plants, requiring construction permits, environmental consents, and water-use authorizations.

- **Sub-stage 2 – Field commissioning and integration:** Involves integrating wells and plant systems for operational readiness, requiring commissioning approvals, operational certificates, and reinjection or emission permits where applicable.

Table 5. Benchmark schedule of permitting requirements, surface construction, and field development phase.

Sub-stage	Permit or authorization	Core requirements	Competent Authority / oversight	Indicative duration
Surface works and plant construction	Construction and building permit	Engineering design, structural safety, and environmental management plan	Ministry of Energy / Municipal Authority (e.g., Türkiye, Kenya, Indonesia)	30-60 days
	Surface use or land lease authorization	Land access rights, footprint definition, and restoration commitments	Land Administration / Environment Authority (e.g., France, Germany, Kenya)	30-45 days
	ESIA Approval	Comprehensive environmental and community impact review	Environmental authority (e.g., Indonesia, Kenya, France)	60-120 days
Field commissioning and integration	Operational readiness or commissioning certificate	Verification of design compliance, safety inspection, and system integrity	Energy or industrial safety authority (e.g., Türkiye, Iceland)	30 days
	Reinjection and discharge permit	Fluid reinjection standards, effluent composition limits, and monitoring obligations	Water or environmental authority (e.g., France, Indonesia)	30-45 days

Sources: Authors' analysis based on Türkiye Geothermal Law No. 5686; Indonesia MEMR Reg. No. 7/2017; Kenya Energy Act (2019) and EMCA (1999); French Environmental Code (2023); German Federal Mining Act (2023); National Energy Authority (Orkustofnun) (2023).

To promote consistency and improve understanding of various geothermal technologies, the International Association of Drilling Contractors (IADC) has released an initial draft of the Geothermal Well Classification to standardize relevant terminology and concepts. One purpose of this is to provide a clear context to distinguish well types, act as a communication tool to bridge the gap between drilling and non-drilling professionals, present the complexities and unique challenges of geothermal well drilling in a clear and accessible manner, and identify gaps in the supply chain that may hinder geothermal project development (IADC 2025).

2.2.3 Geothermal Reservoir Longevity Plans

Effective reservoir management is essential for sustaining geothermal productivity. Reinjection of fluids is the primary mechanism for maintaining pressure, stabilizing temperature, and mitigating land subsidence.

A well-known example is the Geysers field in California, where steam pressure declined sharply during the 1980s due to limited reinjection. Treated municipal wastewater for reinjection successfully restored pressure (Duffield and Sass 2003). Similarly, in New Zealand's Wairakei and Tauhara fields, subsidence exceeding 15 meters prompted aggressive reinjection programs (Allis, Bromley, and Currie 2009; Grant 2011).

From a regulatory perspective, longevity planning should be embedded within existing permits. Legislators should set clear sustainability objectives such as maintaining reinjection ratios and monitoring subsidence while granting developers flexibility in technical implementation. World Bank/ESMAP analysis highlights the need for geothermal resource management frameworks that simultaneously protect the sustainability of the resource and provide sufficient regulatory certainty to facilitate private investment (World Bank 2016a; ESMAP 2021; Gehringer and Loksha 2012).

2.2.4 Monitoring and Surveillance

Monitoring and surveillance are crucial during construction and development. Regulatory frameworks require developers to monitor environmental impacts, subsurface conditions, and technical performance. These obligations, embedded in licensing conditions, ensure that construction proceeds safely and in accordance with legal requirements.

Table 6. Best practices in monitoring and surveillance from Iceland and New Zealand.

Aspect	Iceland (Type I)	New Zealand (Type II)
Legal and regulatory framework	Resource Act No. 57/1998; Electricity Act No. 65/2003; Act No. 48/2011; Environmental Impact Assessment Act No. 106/2000.	Resource Management Act 1991 (RMA); unified environmental legislation; no specific geothermal licensing regime.
Licensing and oversight	National Energy and Environment Agency (NEEA); municipal authorities are also involved.	Regional Consent Authorities issue and oversee resource consents.
Monitoring obligations	Legally mandated and customized in license conditions and appendices; includes annual reporting and detailed documentation.	Monitoring is required via consent conditions, varies by activity, and includes real-time or periodic environmental and compliance reports.
Types of data required	Technical, environmental, and operational data; temperature, chemical composition, drilling logs, mineral discoveries.	Environmental health, discharge impacts, and compliance data; adaptive monitoring triggers possible.
Reporting frequency	Annual and monthly, with specific requirements per license.	Monthly to annually, depending on activity and sensitivity.
Transparency and data access	Reports archived by NEEA; public release post-confidentiality period; includes national borehole register.	Consent documents and monitoring results are public by default; regular publications by regional councils.
Purpose of monitoring	Ensure environmental protection, optimize resource use, and inform future licensing.	Safeguard subsurface and surface environments, enforce adaptive management, and ensure legal compliance.
Key tools/registers	National Borehole Register (geological and technical well data).	State of the Environment reports, online databases of consent, and monitoring data.

Sources: Elements by BBA//Fjeldco 2025).

Iceland and New Zealand represent best practice examples using different approaches. Iceland codifies monitoring obligations in statute, while New Zealand derives them from consent conditions under environmental law. Table 6 categorizes these into two regulatory models:

- **Type I – Statutory monitoring regime:** Monitoring obligations are legally mandated and customized in license conditions, with annual reporting and detailed documentation requirements overseen by the National Energy and Environment Agency (Iceland).

- **Type II – Consent-based monitoring regime:** Monitoring is required via consent conditions issued by Regional Consent Authorities under the Resource Management Act 1991, varying by activity and including real-time or periodic environmental and compliance reports (New Zealand).

2.3 Operational Phase

The operational phase is the longest stage in the geothermal lifecycle, during which the asset transitions from construction to full commercial operation. This phase requires a regulatory framework addressing operational permits, offtake and pricing mechanisms, taxation and royalty structures, and ongoing regulatory oversight.

2.3.1 Operational Permits

The permitting framework formalizes operating rights, tariff approvals, environmental obligations, and monitoring duties. It ensures continued compliance with safety, environmental, and consumer-protection standards. World Bank/ESMAP analyses emphasize that geothermal development depends on (i) clear, predictable licensing and permitting arrangements, (ii) risk–reducing regulatory clarity that supports mobilization of private capital, and (iii) effective oversight and safeguards across the project lifecycle (World Bank 2016a; ESMAP 2021; Gehringer and Loksha 2012). Permitting frameworks under this phase can be divided into two sub-stages (see Table 7).

- **Sub-stage 1 – Market entry and commencement of operations:** This sub-stage begins once commissioning tests confirm that the facility meets technical and safety standards. The operating or energy-utilization license grants the right to produce, use, and sell geothermal energy, conditional on successful commissioning, well integrity confirmation, and design compliance. The license should include a validity period aligned with the field's economic life and provisions for renewal.

  An offtake and pricing approval validates the revenue mechanism, which may take the form of a PPA, a feed-in tariff (FiT) scheme, or a contract for difference (CFD), depending on market structure.

  Environmental and water permits from earlier phases are converted into long-term operational consents covering emissions, noise, groundwater abstraction, reinjection quality, and waste management. Operational permits should define procedures for periodic inspections, emergency response, and public disclosure of monitoring data. The integration of network and access compliance within the operating license ensures that all safety and reliability obligations are met before commencing continuous operation.

- **Sub-stage 2: Ongoing operations, expansion, and modification:** Once the geothermal system is fully operational, permitting focuses on performance monitoring, reporting, and adaptive management. Developers submit periodic production and reinjection data, well integrity test results, and environmental monitoring reports. These reports should include temperature and pressure data, induced seismicity monitoring, and chemical analysis of reinjected fluids.

  Environmental and safety obligations remain binding throughout the operational term. Regulatory authorities should conduct routine audits and impose corrective measures for deviations from permit conditions. Permits must provide clear triggers for adaptive management, including temporary shutdown when thresholds for emissions, noise, or seismicity are exceeded. The framework should also facilitate minor modifications or incremental expansions within pre-approved parameters, with full permit review required for expansions exceeding those parameters.

  A critical component is recognition of direct-use and cascaded applications. Many mature jurisdictions explicitly include secondary heat uses within operating licenses, maximizing social and economic returns. Ongoing tariff and consumer-protection oversight is also essential, with regulators periodically reviewing tariff adjustments and compliance. Robust post-licensing oversight and monitoring arrangements are important to sustain geothermal project performance through operations (World Bank 2016a; Gehringer and Loksha 2012). They also support transparency, accountability, and compliance with permitting and safeguard requirements over the project cycle (ESMAP / The World Bank 2021; ESMAP 2024).

Table 7 categorizes permitting frameworks into two sub-stages:

- **Sub-stage 1 – Market entry and commencement:** Requires operating licenses, offtake and pricing approvals, and conversion of environmental permits into long-term operational consents.

- **Sub-stage 2 – Ongoing operations and modifications:** Focuses on performance monitoring, periodic reporting, and adaptive management, with streamlined procedures for minor modifications and full permit review for major expansions.

2.3.2 Regulatory Oversight and Tariff Approval

Regulatory oversight is crucial in geothermal pricing, given the long-term nature of conciliary risk measures. In some jurisdictions, even where tariffs are negotiated between an independent power producer (IPP) and a utility, regulatory approval is required for consistency with national energy policy and consumer protection standards (Commercial Law Development Program, U.S. Department of Commerce, and African Legal Support Facility 2020).

In early-stage markets, national regulators play a central role. For example, Tanzania's EWURA must review all power purchase agreements (PPAs) by TANESCO, and Uganda's ERA approves tariff structures for renewable energy projects (Energy and Water Utilities Regulatory Authority n.d.; IEA 2023).

Strong regulatory frameworks enhance bankability by ensuring that approved tariffs are enforceable and shielded from arbitrary revision, balancing investor protection with public oversight across both emerging and liberalized markets.

Table 7. Benchmark schedule of permitting requirements – operation phase.

Sub-stage	Permit or authorization	Core requirements	Competent authority / oversight	Indicative duration
Market entry and commencement of operations	Operating (energy utilization) license	Commissioning verification, well integrity, safety certification, interconnection confirmation	Energy or mining authority (e.g., Türkiye, Indonesia, Kenya)	20-45 days
	Offtake / pricing approval (tariff order, power purchase agreements, or contract for difference allocation)	Contract registration, tariff validation, metering and settlement scheme	Energy regulator or market operator (e.g., France, Kenya, Indonesia)	30-60 days
	Operational environmental and water permits	Long-term emission and reinjection limits, monitoring plan, and reporting obligations	Environmental or water authority (e.g., France, Indonesia, Türkiye)	30-60 days
Ongoing operations, expansion, and modification	Periodic compliance and performance reporting	Production, reinjection, seismicity, and environmental data submission	Relevant licensing authorities (e.g., France, Germany, Kenya)	Ongoing (quarterly or annual)
	Minor modification or expansion consent	Like-for-like replacement, expansion within approved envelope	Lead licensing office (e.g., France, Netherlands)	10-30 days

Sources: Authors' analysis, based on Türkiye Geothermal Law No. 5686; Indonesia MEMR Reg. No. 7/2017; Kenya Energy Act (2019); French Energy Regulation Code (2023); German Federal Mining Act (2023); Dutch Mijnbouwwet (2022).

2.3.3 Taxation and Royalties

Royalty[6] obligations depend on the legal status of geothermal resources, which varies by jurisdiction. Agreements typically include lease payments and royalties based on electricity revenues or heat output. In some U.S. jurisdictions, royalties of 10% of gross revenues are common. In Kenya, the Energy Act 2019 introduced royalty rates of 1%-2.5% for the first 10 years, increasing to 2%–5% thereafter.

Royalty structures include fixed royalties (set amount per MWh), ad valorem royalties (percentage of revenue), and variable royalties that adjust with resource depletion or project stage. Studies show that variable ad valorem royalties linked to reservoir temperature can incentivize sustainable reservoir depletion by encouraging developers to prioritize long-term productivity rather than short-term gain (Malafeh and Sharp 2015).

Governments must determine how royalty regimes serve broader public policy goals. This includes deciding whether to maximize state revenue or to keep electricity prices low for consumers. In some cases, royalty revenues can be reinvested into environmental or community development programs.

Various jurisdictions have introduced or are in the process of introducing royalties for their geothermal resources. Table 8 below categorizes royalty structures into two principal models and summarizes the geothermal royalties in selected jurisdictions:

- **Type I – Progressive royalty regimes:** Royalty rates increase over time to reflect resource maturity and project profitability, typically ranging from 1%-2.5% during the first 10 years of production and increasing to 2%-5% thereafter (Kenya, U.S. Federal).
- **Type II – Fixed government share mechanisms:** A fixed percentage of gross income from generated power or incidental income is paid as a government share throughout the project lifecycle (Philippines, Hawaii).

6 Royalties are an economic instrument that can reduce depletion and contribute to sustaining the productivity of geothermal resources. They result in payments made by geothermal developers to the legal owners of geothermal resources, whether the state or private landholders, as compensation for the right to extract and utilize these resources. Royalties can take the form of fixed payments, production-based fees, or value-based (ad valorem) percentages.

Table 8. Taxation and royalties in selected countries.

Type	Jurisdiction	Energy related act	Royalty description
Type I	Kenya	Energy Act, 2019 (section 85)	1%-2.5% of the value of geothermal energy for the first 10 years; 2%-5% for each year after.
	U.S. (Federal)	Energy Policy Act of 2005; John Rishel Geothermal Steam Act Amendments (30 U.S.C. §1004)	1%-2.5% of gross proceeds from electricity sales for the first 10 years; 2%-5% for each year after.
Type II	Philippines	Renewable Energy Act of 2008 (section 13)	Called "government share"; 1.5% of gross income from generated power or incidental income.
	Hawaii	Hawaii Revised Statutes (2024): Title 12, Chapter 182: Reservation and Disposition of Government Mineral Rights, State of Hawaii	Royalties are fixed by the board to encourage production. 50% of royalties go to the state, 25% to the county.

Sources: Energy Act (2019); Renewable Energy Act of 2008; Energy Policy Act of 2005; John Rishel Geothermal Steam Act Amendments (30 U.S.C. §1004); Hawaii Revised Statutes (2024): Title 12, Chapter 182: Reservation and Disposition of Government Mineral Rights. State of Hawaii.

2.4 Decommissioning and Post-Operational Management Phase

2.4.1 Termination and Revision of Licenses

License termination may occur through natural expiry or regulatory action due to non-compliance. On termination, rights typically revert to the state or landowner.

Geothermal utilization licenses are typically granted for long durations: up to 37 years with 20-year extensions in Indonesia, up to 65 years in Iceland for state-owned land, and without statutory limit in New Zealand (Elements by BBA//Fjeldco 2025).

Licenses may be terminated early for non-compliance, including failure to commence operations, non-payment of fees, or environmental violations. For example, Italy's Legislative Decree No. 22/2010 permits revocation for various breaches (Elements by BBA//Fjeldco 2025). As best practice, authorities should issue written warnings before termination, allowing license holders to seek remedies.

A notable example of the enforcement of non-compliance termination can be found in Kenya, where the government has actively exercised its authority to terminate rights for non-performance. A prominent case involved the Suswa geothermal license held by WalAm Energy. The license, granted in 2007 for a 30-year term, was revoked in 2012 after the investor failed to carry out the required exploration work and demonstrated insufficient capacity (Richter 2020).

License revision is important given the long lifespan of geothermal projects. Changes in technology, geological data, or environmental standards may require adjusting license conditions without halting the project.

In many jurisdictions, license holders can request revisions (e.g., Türkiye and Indonesia). In others, like New Zealand, the consenting authority may initiate reviews, potentially leading to amendments or revocation based on updated assessments (Elements by BBA//Fjeldco 2025).

In BOT (build-operate-transfer) and BOOT (build-own-operate-transfer) models, end-of-license planning requires specific contractual mechanisms, as operations often continue under a new operator. Modern public-private partnership (PPP) practice emphasizes detailed handover provisions, including facility maintenance, knowledge transfer, and technical data delivery. Governments should conduct joint condition assessments in the final contract years, and agreements may include reserve accounts or performance guarantees to ensure continuity of resource management (World Bank 2019).

2.4.2 Asset Decommissioning

Best practice requires the licensing authority to mandate decommissioning obligations, typically outlined in a plan submitted before authorization and updated regularly. The decommissioning plan may include a proposal for continued production or shutdown, options for further use, partial or complete removal, disposal, or abandonment. Some jurisdictions require financial guarantees (e.g., bonds or escrow) to ensure proper decommissioning. While full decommissioning is not always required at handover in BOT or BOOT projects, certain measures such as plugging non-productive wells may be necessary. The focus is on ensuring structured transfer of operational responsibility and maintaining resource integrity.

Stranded Assets and Liability Transfers

Like other energy infrastructure, geothermal projects face stranded asset risk when assets are retired before their expected economic life. The issue involves determining who bears the cost of unused assets, presenting significant considerations for policymakers and investors (Bos and Gupta 2019).

Government responses to stranded assets can be broadly categorized into roughly three main policy approaches:

1. Full compensation, where governments provide financial relief or buyouts, potentially assuming ownership of assets after the concession period.
2. Partial compensation, by exempting pre-existing investment from new legislation.
3. No relief, where the license holder pays the full cost of decommissioning, dismantling facilities, plugging wells, and restoring the site (Bos and Gupta 2019).

Regulations often stipulate that all project infrastructure must be removed and land rehabilitated. For example, Kenya's Energy Act, Section 176(2), requires surface restoration by the licensee, with costs recoverable if the owner must carry out restoration in case of the licensee's default.

To prevent public exposure to post-closure liabilities, some jurisdictions require decommissioning bonds held in escrow or trust accounts, covering facility removal and land restoration (e.g., decommissioning bonds for exploration on federal lands in the U.S.).

International environmental standards supplement geothermal-specific rules. In the EU, geothermal plant decommissioning falls under Directive 2008/98/EC on waste, imposing obligations to recycle or safely dispose of equipment.

Developers must factor in end-of-life handling of infrastructure, meeting recycling targets, and minimizing landfill. ESIA regulations often require decommissioning plans at project approval, and the World Bank's environmental safeguards similarly call for plans to mitigate impacts during construction, operation, and "in certain cases decommissioning", with funds set aside if necessary (World Bank 2016b).

2.4.3 Environmental Restoration

Decommissioning is followed by site restoration, which may include surface restoration (removal of facilities, waste, and revegetation) and subsurface restoration (well plugging and reservoir management) (Berman et al. 2018). Well plugging is especially important, since unused geothermal wells are potentially hazardous to public health, groundwater, and the environment. Government enforcement of well owners' responsibility for proper plugging has proven prudent (Berman et al. 2018). Best practices require both surface and subsurface restoration, commonly embedded in licenses and enforced through regulatory oversight, financial bonds, or statutory mandates.

Table 9 categorizes restoration frameworks into two principal approaches and compares environmental restoration and decommissioning frameworks for geothermal projects across selected jurisdictions:

- **Type I – Statutory restoration mandates:** Restoration obligations are embedded directly in utilization licenses or statutory provisions, requiring well plugging, facility dismantling, and land rehabilitation, with financial bonds securing compliance (U.S., Iceland, Kenya).

- **Type II – Consent-based restoration regimes:** Restoration duties are defined through resource consent conditions under environmental legislation, including structure removal, land recontouring, and vegetation replanting, with financial assurance required where appropriate (New Zealand).

2.4.4 Decommissioning Permits

The decommissioning phase is the final regulatory step, ensuring wells, facilities, and reservoirs are safely closed, restored, and documented. A well-defined permitting framework provides clarity on closure obligations, liability, and financial assurance (World Bank 2014).

Decommissioning activities are authorized through a Closure and Rehabilitation Permit, confirming approval of a Decommissioning and Site Restoration Plan detailing plugging procedures, facility removal, waste management, and post-closure monitoring.

Developers must notify the permitting authority at least 90 days in advance, allowing site inspection. Approval is contingent on demonstrated safe plugging and sealing, verified by certified reports. On successful inspection, financial assurance may be released. Some jurisdictions maintain post-closure monitoring for three to five years to verify thermal and hydraulic stability.

A simplified decommissioning framework, with clear technical standards and release conditions, reduces regulatory burden while ensuring environmental protection. As noted by IFC, "Managing closure of well heads including sealing well with cement, removing the well head, and backfilling depression around the well head, as necessary" (IFC 2007).

Table 9. Surface and subsurface restorations in selected countries.

	Country	Obligations	Legal source	Notes
Type I	U.S	On federal lands, operators must plug and abandon geothermal wells that are no longer in use. They must remove surface facilities and restore disturbed land to a safe and stable condition.	Geothermal Steam Act; BLM regulations	Release of the operator's bond is contingent on full compliance, which creates a strong financial incentive.
	Iceland	A decommissioning plan is often required as part of the power plant license. The Environmental Impact Assessment addresses environmental restoration measures.	Act No. 57/1998 (Utilization of Ground Resources), Article 18	Restoration obligations are embedded directly in the utilization license.
	Kenya	Mandatory dismantlement of all infrastructure, land rehabilitation, and prescribed closure actions.	Energy Act 2019, Sec. 186	License holders must follow good practices when decommissioning geothermal projects.
Type II	New Zealand	Restoration duties are set through consent conditions, including removal of structures, recontouring of land, and replanting of vegetation. Financial assurance may be required where appropriate.	Resource Management Act (RMA) consent conditions	Example: Contact Energy is required to maintain an NZ$5 million bond for potential subsidence-related damage (Mizuno 2013).

Sources: Elements by BBA//Fjeldco (2025); NREL (2023); Energy Act (2019).

Financial and Risk Mitigation Considerations for Geothermal Development

03

Risk Profile of Geothermal Development

Geothermal energy development requires long planning horizons, high upfront capital investment, and staged financing. Unlike other renewables, geothermal projects have a front-loaded risk structure, where exploration and drilling account for a large share of costs before revenue is realized. The financial architecture therefore evolves through a continuum of public, hybrid, and private structures as information certainty improves.

The early stages are dominated by public intervention absorbing geological uncertainty, while later stages rely on private capital structured around long-term offtake agreements. The optimal financing mix is adaptive to both the development phase and national market maturity (Gehringer and Loksha 2012; World Bank 2016; IRENA 2020b; Dumas, Garabetian, and Le Guénan 2019).

Evolution of Business Models

In early exploration phases, risk concentration is high and commercial viability uncertain. Governments or public agencies typically take the lead, financing geological surveys and exploratory wells with multilateral support. Once the resource is confirmed, private developers enter through joint ventures, PPPs, or IPP models (see Table 10). At full operation, financing transitions toward conventional project finance backed by stable offtake contracts such as PPAs, feed-in tariffs (FiTs), or contract for differences (CfDs) (see Appendix 1 for more information).

Table 10 presents a synthesis of global business-model archetypes and their allocation of ownership, risk, and financing responsibilities. The models are not mutually exclusive, but collectively illustrate how geothermal financing matures alongside regulatory certainty.

Business Model Progression and Policy Design

The financial progression reflects shifting risk allocation. During early exploration, governments absorb geological uncertainty through public-led drilling and cost-sharing funds. As projects move toward construction and operation, the focus shifts to revenue stabilization through pricing mechanisms – regulated tariffs, PPAs, and CfDs – that provide predictable revenue aligned with long investment cycles.

Table 10. Global business-model archetypes and benchmarks.

Archetype	Ownership and role split	Revenue instrument (typical)	Risk allocation (headline)	Financing stack (typical)	Illustrative markets / Examples
Public developer (single buyer)	State entity explores, drills, builds, and operates; may contract operations and management services.	Regulated tariff or utility offtake.	Early subsurface and construction risk borne by state; offtake and price risk socialized.	Sovereign budget plus concessional loans; later refinancing via development banks.	Iceland, Costa Rica, Nicaragua, El Salvador (World Bank 2016).
Public-led confirmation ⟶ IPP plant (steam-supply PPP)	State confirms resource and provides steam; IPP finances, builds, and operates plant; utility is offtaker.	Long-term PPA.	Exploration risk is public; EPC and operational risk is private; offtake risk is mitigated by PPA.	Combination of multilateral, concessional and private project finance.	Kenya (Menengai model); Indonesia (Gehringer and Loksha 2012; Nyokabi et al. 2022).
Public sector-led exploratory drilling, then transfer	Government drills exploratory wells to confirm resource, and then auctions or negotiates development rights.	PPA or regulated tariff after transfer.	Geological risk reduced for private investors; competitive allocation ensures efficiency.	Public and concessional finance transitioning to private project finance.	Mexico, New Zealand, France (World Bank 2016).
Cost-shared private exploration	Private developers lead exploration; government reimburses a share of unsuccessful wells or provides guarantees.	PPA or FiT after confirmation.	Dry-hole and geological risk is shared; operational and financing risk is private.	Private equity combined with cost-sharing fund.	Türkiye (Risk Sharing Mechanism); Guatemala, Kenya, Indonesia (World Bank 2016).
Fully private IPP (mature zones)	Private company explores, builds, owns, and operates.	PPA, FiT, or CfD; corporate PPAs emerging.	Most risks borne by private entity; price risk hedged by contract.	Commercial debt and equity; political or credit guarantees possible.	U.S., Japan, Chile (Micale, Trabacchi, and Boni 2015b).
Direct-use heat utility / concession	Municipal or private utility aggregates heat demand; developer supplies geothermal heat.	Regulated heat tariff or feed-in premium.	Resource risk mitigated by national guarantee schemes; demand risk shared with utility.	Municipal or utility debt; public grants and heat premiums.	Netherlands (Dumas, Garabetian, and Le Guénan 2019).

In mature markets, private developers assume greater exploration risk due to regulatory predictability and accessible guarantee mechanisms. In emerging markets, public or blended models remain indispensable. The legal environment should provide flexibility for hybridization, allowing states to intervene early but exit progressively as private confidence builds.

Evolution of Financial Instruments and Market Maturity

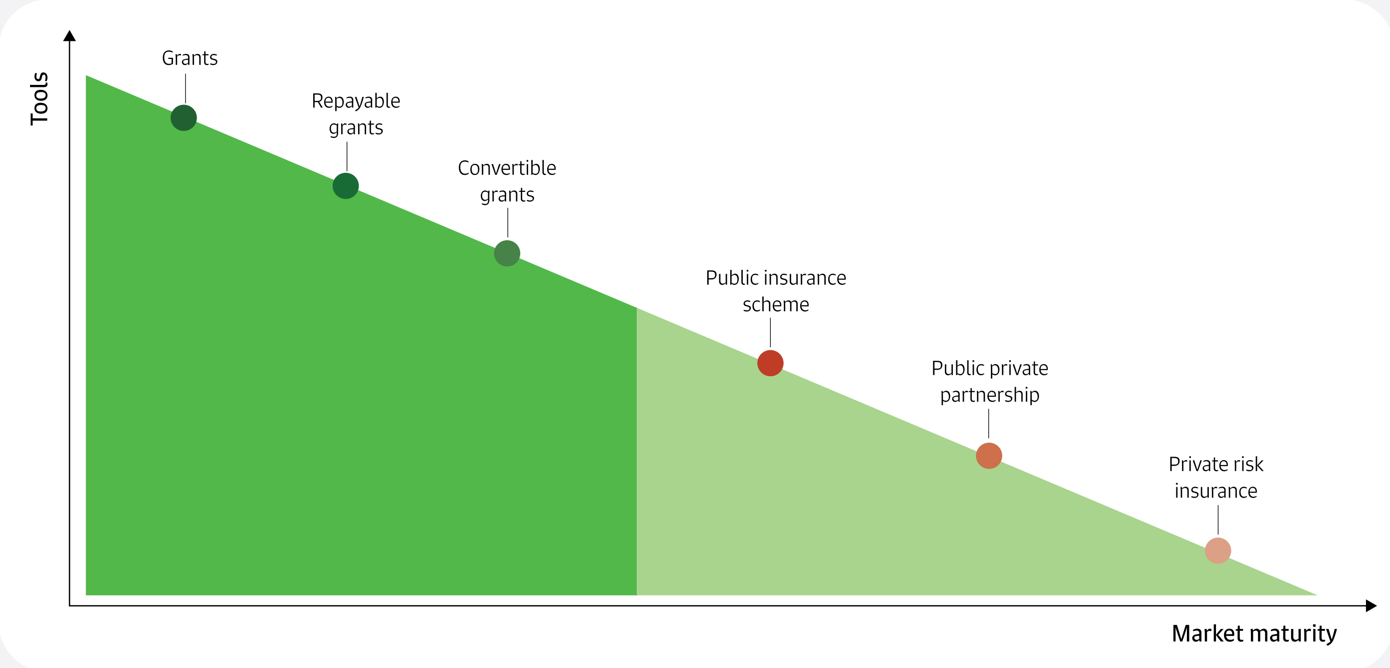
Market maturity strongly influences available financial tools (see Figure 4). In immature markets, non-repayable grants and concessional funds stimulate exploration. As knowledge accumulates, financing transitions toward repayable grants, public guarantee schemes, and PPPs. In mature markets, project-financed IPPs predominate.

Risk Mitigation and Financial De-Risking Instruments

Geothermal development faces multiple layers of uncertainty – geological, operational, and market-related. Effective de-risking requires coordinated financial instruments that evolve across these dimensions – from early-stage geological risk to mid- and late-stage construction and market risks.

Countries with advanced geothermal sectors have institutionalized risk mitigation schemes covering

Figure 4. Evolution of financial tools along geothermal market maturity.



Source: Dumas, Garabetian, and Le Guénan (2019).

exploration-stage drilling or operational performance risks. These typically operate as public guarantee funds or insurance mechanisms. Two prominent examples are Türkiye's Risk Sharing Mechanism and France's Geothermal Fund.

Table 11 compares the risk mitigation schemes across the selected jurisdictions. Based on the stage covered and the mechanism type, three distinct models can be categorized:

- **Type I – Exploration and early drilling only:** Post-drill cost sharing for failed wells, with success fees on productive wells, covering 40%-60% of eligible drilling and exploration costs, capped per project (Türkiye's Risk Sharing Mechanism).
- **Type II – Exploration and productivity:** State-backed guarantee schemes covering both exploration and operational productivity risks, including subsurface performance guarantees tied to heat tariff and feed-in support schemes (Netherlands), and partial coverage of drilling and reservoir risk for licensed developers deployed for clustered district-heating fields (Germany).
- **Type III – Exploration and operational phases for deep heat:** Short-term and long-term guarantees covering low flow/temperature, corrosion, and fouling, with coverage up to 90% of eligible drilling costs and extended scope for de-risking studies (France).

Integrated De-Risking and Capital Sequencing

Geothermal financing follows a sequenced de-risking logic. Exploration relies on public intervention where grants and concessional loans act as first-loss capital. As projects progress into construction, concessional finance pairs with project finance structures backed by long-term revenue contracts.

Once in operation, private capital dominates, with regulatory certainty and bankable offtake agreements being the most effective de-risking tools. At the end of the lifecycle, financial assurance instruments secure the decommissioning phase, ensuring that closure obligations are fully funded and that post-closure environmental monitoring continues as required by law.

This sequential blending allows governments to withdraw gradually as private markets mature, beginning with high public-risk absorption during exploration and ending with fully private operation. Each transition depends on transparent regulation, standardized permitting, and reliable data access.

Table 11. Risk mitigation schemes in selected countries.

Country / Scheme	Stage covered	Mechanism	Coverage / Key terms	Notes
Türkiye – Risk Sharing Mechanism	Exploration and early drilling.	Post-drill cost sharing for failed wells; success fee on productive wells.	Covers 40%-60% of eligible drilling and exploration costs, capped at US$4 million per project; supports up to three wells with success fees on successful wells.	Administered by the Development and Investment Bank of Türkiye; active since 2018
France – Geothermal Fund (Fonds Chaleur)	Exploration and operational phases for deep heat.	Short-term and long-term guarantees covering low flow/temperature, corrosion, and fouling.	Covers up to 90% of eligible drilling costs; extended in 2023 to include de-risking studies.	Financed by Agence de la transition écologique with project owner contributions; updated scope in 2023-2025 .
Netherlands – National Guarantee Approach (Deep Heat)	Exploration and productivity.	State-backed guarantee fund for subsurface performance.	Public guarantees for deep heat projects; tied to heat tariff and FiT support schemes.	Commonly paired with district-heating premiums.
Germany – Public Guarantee Scheme	Exploration and productivity.	Risk-cover mechanism through public programs and insurers.	Partial coverage of drilling and reservoir risk for licensed developers.	Deployed for clustered district-heating fields

Sources: ADEME (n.d.); Development and Investment Bank of Türkiye (2021); Dumas, Garabetian, and Le Guénan (2019).

Pricing Mechanisms

During operations, revenue is secured through offtake agreements defining how electricity, heat, or by-products are sold. Given high upfront costs, pricing arrangements must ensure stable, long-term income to attract financing and mitigate price and offtake risk.

Geothermal pricing mechanisms aim to secure revenue certainty, remove barriers to entry, promote cost efficiency, and accelerate renewable deployment. In the power sector, these are implemented through regulated tariffs, feed-in tariffs, feed-in premiums, PPAs, and CfDs (see Appendix 1). Selecting the appropriate mechanism depends on market maturity, policy implementation, and market dynamics (Setiawan et al. 2022).

Pricing structures for direct use of geothermal energy, such as district heating or industrial heat supply, differ from those used for electricity offtake. Direct-use projects commonly utilize heat purchase agreements or regulated heat tariffs.

Strategic Lessons for Policy and Market Design

Global experience underscores that geothermal investment frameworks succeed when public and private roles are clearly defined and complementary. The state must focus on de-risking the unknown through early exploration support, technical data publication, and guarantee mechanisms. The private sector, conversely, should drive efficiency, innovation, and operational performance once the geological resource is confirmed. Hybrid models – such as cost-shared drilling, repayable grants, and risk-mitigation facilities – represent the pragmatic bridge between these two domains.

A coherent national geothermal finance policy should thus establish the following:

1. Dedicated risk-mitigation facilities at the exploration stage.
2. Access to concessional credit and PPP mechanisms for field development.
3. Stable, transparent pricing and offtake frameworks during operation.
4. Financial assurance provisions for responsible closure and decommissioning.

By linking financial instruments to the technical and regulatory maturity of each phase, governments can transform geothermal development from a high-risk, capital-intensive venture into a predictable, scalable component of national energy and heat systems. As demonstrated across diverse markets – from Iceland's state-led buildout to Kenya's PPP model and the Netherlands' district-heating programs – the alignment of financing, risk management, and legal certainty remains the foundation of sustained geothermal expansion (Gehringer and Loksha 2012; World Bank 2016b; Dumas, Garabetian, and Le Guénan 2019; Nyokabi et al. 2022).

Practical Drafting Notes for Statutes, Regulations, and Permits

Streamlining procedures and institutional frameworks is critical for geothermal projects. International best practices demonstrate the importance of establishing either a dedicated national geothermal organization or a "one-stop shop" model centralizing coordination among relevant authorities.

Effective governance requires inter-agency coordination among energy, environmental, and land-use authorities to reduce overlapping mandates and clarify institutional responsibilities in legislation. Enhancing institutional capacity through training, funding, and access to technical expertise is essential for effective sector governance.

To establish a one-stop shop, an existing public agency or department should be designated as the central coordinating body for geothermal projects, with responsibilities including:

1. Issuing licenses and permits.
2. Monitoring geothermal activities.
3. Overseeing the sector.

This entity serves as the primary contact point for applicants and operators, leading communication with other relevant permitting authorities to enhance clarity, predictability, and institutional coordination.

Iceland exemplifies this approach through its recent licensing reform initiative. The Ministry for Environment, Energy, and Climate launched a licensing reform initiative to simplify and streamline the administrative process. A key step in this process was the merger of the former National Energy Authority with part of the Environment Agency to create the NEEA. Additionally, the Ministry has presented a bill granting NEEA the authority to consolidate various permits into a single licensing procedure, including permits from other agencies, effectively implementing a one-stop-shop model.

The role of municipalities and regional governments should also be clearly defined. These authorities may be involved in spatial planning, land-use approval, public consultations, and local environmental oversight. Effective coordination with local authorities enhances public trust and supports social acceptance of geothermal projects. Local authorities should be encouraged to adopt local action plans with clear targets and policies for integrating geothermal energy into district heating systems in regions with geothermal potential. Where appropriate, they may also encourage or recommend that end-users connect to existing geothermal district heating networks, thereby supporting economies of scale and uptake of clean heat. To ensure sustainable and efficient use of geothermal resources, technical design standards for heating systems in these areas should be established and enforced. Furthermore, local authorities should be involved early in the permitting process, especially for projects with significant land or community impacts, to foster transparency and increase social acceptance.

A durable framework should read like an engineering specification written into law: precise terms, explicit institutional roles, standard forms, and enforceable decision clocks. It should begin by defining key terms – geothermal resource, reservoir, well, reinjection, drilling plan, utilization license, production license, resource area, and decommissioning – in primary legislation, using a shared glossary across statutes, regulations, and permit templates. The definitions should be limited to measurable parameters only where they serve a clear policy purpose, avoiding thresholds that would make the law obsolete as technology evolves (Gehringer and Loksha 2012). Ownership should be clarified, as should access to heat and fluids, as well as the relationship between minerals and groundwater. Where the state owns subsurface resources, exclusive rights should be granted within a mapped polygon, with work obligations on a set schedule (World Bank 2014).

Institutional design should establish a single front door with statutory power to coordinate and issue consolidated decisions. The law should name the lead authority, list each co-regulator, and require an interagency operating manual incorporated by reference. The statute should mandate a permit matrix mapping activity to permit, decision-maker, standard, and clock. Service standards should be explicit: a completeness check within five business days, exploration title within 45 days, drilling plan approval within 30 days, reinjection authorization within 30 days, a utilization title within 60 days, and a generation license within 90 days. Stop-the-clock rules limited to defined reasons should be included, and should require monthly performance dashboards and use deemed-complete provisions to prevent silent delay, but deemed approval for safety-critical permits should be avoided (NREL 2023; World Bank 2016).

Technical safeguards belong in regulations and permit conditions rather than in statutes. A national geothermal code covering casing, cementing, well control, mechanical-integrity testing, corrosion management, monitoring, induced-seismicity thresholds, and subsidence management should be codified, with the regulator empowered to revise the code on a fixed cycle (e.g., every 24 months) after public consultation (Duffield and Sass 2003; NREL 2023). A reservoir management plan is required for production phases demonstrating pressure maintenance through reinjection, with adaptive triggers for operator action.

Data policy should make early-stage information investable while building a national evidence base. Standardizing reporting, specifying formats, and defining confidentiality windows that expire automatically (e.g., two to five years) is necessary, as is requiring non-confidential data in a national repository and empowering the lead authority to publish basin-scale syntheses. Where public finance is provided, confidentiality windows should be shortened in exchange for support (World Bank 2014; NREL 2023).

Commercial provisions should be authorized in statute and operationalized in secondary instruments. The lead authority should be allowed to run competitive tenders, approve standard-form PPAs, or award feed-in premiums or CfDs as appropriate (Setiawan et al. 2022). PPAs should include geothermal-specific clauses on reservoir performance risk, makeup wells, curtailment, and step-in rights (Gehringer and Loksha 2012). Risk-mitigation instruments in law should be enabled, with transparent eligibility and success metrics (World Bank 2016a).

Compliance, enforcement, transfer, and closure should be specified with engineering precision. Statutory inspection powers should be required, as well as clear non-compliance tiers, proportionate penalties, and financial assurance sized to decommissioning liabilities, released only after verified plugging and rehabilitation. Decommissioning plans at first major approval should be mandated, with updates at defined milestones. The transfer of titles with prior consent and fitness tests should be allowed. Finally, the lead authority should be required to issue an annual state-of-the-resource report, convene a technical advisory committee, and conduct whole-framework reviews at least every 24 months (Duffield and Sass 2013; NREL 2023).

Remarks on Shallow Geothermal Systems

While this paper has been focused on deep geothermal systems, it can also be an inspiration for shallow geothermal systems, typically at depths of 500 meters or less. Such systems represent a near-term opportunity to accelerate the decarbonization of buildings and campuses through direct-use applications, such as ground-source heat pumps and small district loops.

Given their lower subsurface risk and shorter development timelines, a dedicated and proportionate legal pathway should be established to govern their deployment. This can be achieved through a unified “shallow geothermal pathway” administered by a single lead authority – preferably housed within the water regulator – to coordinate environmental and land-use inputs, issue standardized permits, and maintain a public cadastre of installations.

The framework should comprise two simplified, time-bound authorizations: a “Site Screening and Pilot Authorization” for low-impact exploratory works and a “Build-and-Operate License” for construction, operation, and decommissioning within defined technical and environmental limits. Statutory decision targets of 14 days and 30 days, respectively, supported by standardized design files, technical codes, and continuous monitoring, can ensure predictability while maintaining groundwater and environmental safeguards. International examples, such as France’s notification-based shallow geothermal regime paired with AQUAPAC risk insurance, demonstrate that streamlined permitting coupled with clear technical standards can significantly accelerate uptake without compromising safety or resource protection (World Bank 2014; NREL 2023; Dumas et al. 2019b; Elements by BBA//Fjeldco 2025).

Conclusion

04

The development of geothermal energy represents a critical opportunity for new market entrants seeking to diversify their energy portfolios and achieve decarbonization goals. However, the unique characteristics of geothermal projects, including high upfront capital requirements, long development timelines, and significant geological uncertainties, demand carefully crafted regulatory frameworks that evolve with project maturity.

For emerging markets, the key lesson is that regulatory certainty is not merely beneficial but essential for unlocking geothermal investment. The policy paradox identified in this analysis reveals that while regulatory certainty is needed to attract investment, investment is often necessary to justify regulatory reforms. Breaking this cycle requires forward-looking, risk-tolerant governance that proactively supports geothermal development with fit-for-purpose frameworks, even before markets mature.

The most effective approach involves establishing phased, transparent, and adaptable regulatory frameworks that align with the sequential stages of geothermal project development. Critical legal areas include clear resource ownership and access rights, streamlined permitting procedures, comprehensive environmental regulations, and reliable offtake mechanisms for both electricity and direct-use applications. Countries must also address decommissioning provisions and long-term reservoir management to ensure sustainable resource utilization.

Financial de-risking emerges as equally important, requiring an evolution from public-led exploration support to private-sector-dominated operational phases. Successful markets demonstrate that governments should focus on absorbing geological uncertainty through early-stage risk mitigation facilities while establishing stable pricing frameworks that provide long-term revenue certainty.

The framework presented here is not a one-size-fits-all solution but rather practical guidance for policymakers designing legal and institutional systems for geothermal development. Success requires multidisciplinary engagement across geology, engineering, economics, environmental science, and legal expertise, coupled with strong institutional coordination and stakeholder engagement. For new market entrants, the evidence clearly demonstrates that comprehensive regulatory preparation is the foundation for sustainable geothermal expansion and energy security.

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References

Agence de la transition écologique (ADEME). n.d. "Geothermal Fund: Guarantees for Deep Geothermal Heat." https://agirpourlatransition.ademe.fr/entreprises/aides-financieres/20240122/fonds-chaleur-garanties-geothermie-profonde.

Aldubayan, Mohammad, and Majed Al-Suwailem. 2025. "Ground-Source Air Conditioning: A Potential Solution for Saudi Arabia's Building Sector." Commentary. Riyadh: King Abdullah Petroleum Studies and Research Center (KAPSARC). https://www.kapsarc.org/our-offerings/publications/ground-source-air-conditioning-a-potential-solution-for-saudi-arabia-s-building-sector.

Allis, Rick, Chris Bromley, and Steve Currie. 2009. "Update on Subsidence at the Wairakei-Tauhara Geothermal System, New Zealand." *Geothermics* 38, no. 1 (March): 169–180. https://doi.org/10.1016/j.geothermics.2008.12.006.

Baker McKenzie. 2018. "MEMR Regulation on Geothermal Data Protection Is Finally Issued." Client alert. https://www.bakermckenzie.com/-/media/files/insight/publications/2018/09/finance--projects--memr-regulation-on-geothermal-data-protection.pdf.

Barich, Amel, and Alicja W. Stokłosa. 2021. *Social License to Operate for Geothermal Energy.* Reykjavík: CROWDTHERMAL. https://www.crowdthermalproject.eu/wp-content/uploads/2022/01/CROWDTHERMAL-D1.5-SLO.pdf.

Berman, L. W., Tómas Fridriksson, Ximena Rocío Herbas Ramírez, Menaka Jayawardena, Joshua S. Armstrong, Scott Peabody, John A. Turner, and Sergio A. Rivera Zeballos. 2018. *Opportunities and Challenges for Scaling-Up Geothermal Development in Latin America and Caribbean Region*. Washington, DC: World Bank Group; Energy Sector Management Assistance Program (ESMAP). https://doi.org/10.1596/30895.

Bos, Kyra, and Joyeeta Gupta. 2019. "Stranded Assets and Stranded Resources: Implications for Climate Change Mitigation and Global Sustainable Development." *Energy Research & Social Science* 56: 101215. https://doi.org/10.1016/j.erss.2019.05.025.

Cariaga, Carlo. 2023. "UK Increases Maximum Auction Price for Geothermal, Other Renewables." *ThinkGeoEnergy*, November 16. https://www.thinkgeoenergy.com/uk-increases-maximum-auction-price-for-geothermal-other-renewables/.

Cariaga, Carlo. 2024a. "Ten Geothermal Projects in the Netherlands to Receive SDE Subsidy." *ThinkGeoEnergy*, June 19. https://www.thinkgeoenergy.com/ten-geothermal-projects-in-the-netherlands-to-receive-sde-subsidy/.

Commercial Law Development Program, U.S. Department of Commerce, and African Legal Support Facility. 2020. *Understanding Power Purchase Agreements: Second Edition Update*. Washington, DC: Commercial Law Development Program, U.S. Department of Commerce, in Partnership with USAID, Power Africa, and African Legal Support Facility. https://cldp.doc.gov/programs/cldp-in-action/understanding-power-purchase-agreements-second-edition.

Contact Energy Ltd. 2023. "Contact Signs 10-Year Renewable Energy Agreement with Microsoft on New Geothermal Power Station at Te Huka." May 25. https://contact.co.nz/investor-centre/news/2023/contact-signs-ten-year-renewable-energy-agreement-with-microsoft/.

de Wit, Joeri, and Elin Hallgrimsdottir. 2023. "Geothermal Data Management: Good Practices and the Role of Regulators and Developers." *LiveWire*. Washington, DC: World Bank. https://doi.org/10.1596/39800.

Department of Energy (DOE) Philippines. 2024. *Revised Omnibus Guidelines Governing the Award and Administration of Renewable Energy Contracts and the Registration of Renewable Energy Developers: Department Circular No. DC2024-06-0018.* Department Circular. Taguig City: Department of Energy (DOE) Philippines. https://www.doe.gov.ph/sites/default/files/pdf/issuances/dc2024-06-0018.pdf.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2024. *Diagnóstico del Marco Regulatorio para el Uso Directo de la Energía Geotérmica en los Países Miembros del SICA*. San Salvador: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://gizcentroamerica.org/wp-content/uploads/2024/11/Informe-de-diagnostico-marco-regulatorio-usos-directos-region-SICA.pdf.

Development and Investment Bank of Türkiye. 2021. *RSM Beneficiary Manual. Risk Sharing Mechanism for Geothermal Resource Validation*. https://rpmjeoturkiye.com.

Duffield, Wendell A., and John H. Sass. 2003. *Geothermal Energy: Clean Power from the Earth's Heat*. U.S. Geological Survey Circular 1249. Menlo Park, CA: U.S. Geological Survey. https://doi.org/10.3133/cir1249.

Dumas, Philippe, Thomas Garabetian, and Thomas Le Guénan. 2019. *Geothermal District Heating: Policies, Financing, and Risk Mitigation*. Paris: European Geothermal Energy Council. https://www.egec.org.

Dumas, Philippe, Thomas Garabetian, Thomas Le Guénan, Beata Kępińska, Aleksandra Kasztelewicz, Spyridon Karytsas, Gunter Siddiqi, et al. 2019a. "Risk Mitigation and Insurance Schemes Adapted to Geothermal Market Maturity: The Right Scheme for My Market." In Proceedings of the European Geothermal Congress 2019. The Hague. https://www.publications.mygeoenergynow.org/grc/1034067.pdf.

Dumas, Philippe, Thomas Garabetian, Thomas Le Guénan, Beata Kępińska, Aleksandra Kasztelewicz, Spyridon Karytsas, Gunter Siddiqi, Nicole Lupi, Ferid Seyidov, Annamaria Nador, Jolanda Kaufhold, Christian Boissavy, Cagri Yildirim, Cannur Bozkurt, Attila Kujbus, Evaggelos Spyridonos, Ruken Oztekin, and Katharina Link. 2019b. "Risk Mitigation and Insurance Schemes Adapted to Geothermal Market." European Geothermal Congress 2019. Den Haag: European Geothermal Energy Council (EGEC), 1–7. https://www.egec.org/wp-content/uploads/2019/06/EGC2019-Dumas-Risk-Mitigation-and-Insurance-Schemes-Adapted-to-Geothermal-Market.pdf.

Dumas, Philippe, Miroslav Serdjuk, Robert Kutschick, Stephen Fraser, Stephan Reith, and Tobias Koelbel. 2020. *Report Presenting Proposals for Improving the Regulatory Framework for Geothermal Electricity*. Brussels: GEOELEC. https://www.geoelec.eu/wp-content/uploads/2020/11/D2.2-Report-presenting-proposals-for-improving-the-regulatory-framework-for-geothermal-electricity.pdf.

Eckstein, Gabriel. 2025. "Who Owns Heat? Property Rights in Geothermal Energy." *University of Illinois Law Review 2025*: 491–553. https://doi.org/10.2139/ssrn.5066007.

Elements by BBA//Fjeldco. 2025. *The Elements Guide: Gateway to the World's Geothermal Regulations*. Reykjavík: BBA//Fjeldco. https://www.bbafjeldco.is/elementsguide.

EMR Settlement Limited. 2025. "Contracts for Difference." https://www.emrsettlement.co.uk/schemes/contracts-for-difference/.

Energy and Water Utilities Regulatory Authority. n.d. "Electricity Power Purchase Agreements." https://www.ewura.go.tz/pages/power-purchase-agreements.

Energy Sector Management Assistance Program (ESMAP). 2023. *Energy Sector Management Assistance Program Annual Report 2023*. Washington, DC: World Bank. https://www.esmap.org.

Energy Sector Management Assistance Program (ESMAP). 2024. *Geothermal Energy: Unveiling the Socioeconomic Benefits*. Washington, DC: World Bank Group. https://documents1.worldbank.org/curated/en/099122823090547278/pdf/P1744881ab11080191a03411d191385e065.pdf.

European Commission. 2022. *Communication from the Commission – Guidelines on State Aid for Climate, Environmental Protection and Energy 2022 (CEEAG), C/2022/481*. Brussels: European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022XC0218(03).

European Parliament and Council of the European Union. 2011. *Directive 2011/92/EU on the Assessment of the Effects of Certain Public and Private Projects on the Environment, as amended by Directive 2014/52/EU*. Brussels: European Union. https://eur-lex.europa.eu/eli/dir/2011/92/oj.

European Parliament and Council of the European Union. 2024. *Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 Amending Regulations (EU) 2019/942 and (EU) 2019/943 as Regards Improving the Union's Electricity Market Design. Official Journal of the European Union.* https://eur-lex.europa.eu/eli/reg/2024/1747/oj.

Falcone, Gioia, Graeme Beardsmore, Paolo Conti, Sulamith Kastl, Harmen Mijnlieff, Annamária Nádor, Greg Ussher, Marit Brommer, Charlotte Griffiths, and Hari Tulsidas. 2025. "8 Years On: Incremental Impact of Worldwide Implementation of the United Nations Framework Classification for Geothermal Energy Resources." In Proceedings of the 50th Workshop on Geothermal Reservoir Engineering (SGP-TR-229). Stanford, CA: Stanford University. https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2025/Falcone.pdf.

Garabetian, Thomas, Andrea Bogi, and Philippe Dumas. 2019. "Policy and Regulation: Impact of the New European Framework on the Geothermal Sector." In *Proceedings of the European Geothermal Congress 2019*. The Hague: European Geothermal Energy Council (EGEC). https://www.egec.org/wp-content/uploads/2019/06/EGC2019-Garabetian-Policy-and-Regulation-Impact-of-the-New-European-Framework-on-the-Geothermal-Sector.pdf.

Gehringer, M., and Loksha, V. 2012. *Geothermal Handbook: Planning and Financing Power Generation.* ESMAP Technical Report 002/12. Washington, DC: World Bank. https://doi.org/10.1596/978-0-8213-9604-5.

Government of the Netherlands. 2018. *Mining Act (Mijnbouwwet)*. The Hague: Ministry of Economic Affairs and Climate Policy. https://wetten.overheid.nl/BWBR0003245.

Government of Indonesia. 2014. *Law No. 21 of 2014 on Geothermal* Energy. Jakarta: Government of Indonesia. https://www.peraturan.go.id/files2/uu-no-21-tahun-2014_terjemah.pdf.

Hámor-Vidó, Mária, Tamás Hámor, Rim Khedri, Katalin Bódis, and Anikó N. Tóth. 2024. "The Legal Governance of Geothermal Energy in Europe: A Historical Review and an Indicator Analysis." *Beijing Law Review* 15: 793–820. https://doi.org/10.4236/blr.2024.152043.

Hasan, M., and A. S. Wahjosudibjo. 2014. "Feed-in Tariff for Indonesia's Geothermal Energy Development: Current Status and Challenges." In *Proceedings of the Thirty-Ninth Workshop on Geothermal Reservoir Engineering*. Stanford, CA: Stanford University. https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2014/Hasan.pdf.

International Association of Drilling Contractors (IADC). 2025. *IADC Geothermal Well Classification*. Houston, TX: International Association of Drilling Contractors. https://iadc.org/wp-content/uploads/2025/02/IADC-Geothermal-Well-Classification-v1.pdf.

International Bank for Reconstruction and Development (ESMAP) / The World Bank. 2021. *Preparing Feasibility Studies for Financing of Geothermal Projects: An Overview of Best Practices*. Washington, DC: World Bank. https://documents1.worldbank.org/curated/en/733791626931398765/pdf/Preparing-Feasibility-Studies-for-the-Financing-of-Geothermal-Projects-An-Overview-of-Best-Practices.pdf.

International Energy Agency (IEA). 2021. *Turkey 2021: Energy Policy Review*. Paris: International Energy Agency. https://www.iea.org/reports/turkey-2021.

International Energy Agency (IEA). 2023. *Energy Policy Review*. Paris: OECD Publishing. https://doi.org/10.1787/1b6b9a5a-en.

International Energy Agency (IEA). 2024. *The Future of Geothermal Energy*. Paris: International Energy Agency. https://www.iea.org/reports/the-future-of-geothermal-energy.

International Finance Corporation (IFC). 2007. *Environmental, Health, and Safety Guidelines for Geothermal Power Generation*. Washington, DC: International Finance Corporation.

International Finance Corporation (IFC). 2012. *Performance Standards on Environmental and Social Sustainability*. Washington, DC: International Finance Corporation, pp. 9–12. https://www.ifc.org/content/dam/ifc/doc/mgrt/ifc-performance-standards.pdf.

International Renewable Energy Agency (IRENA). 2019. *Accelerating Geothermal Heat Adoption in the Agri-Food Sector: Key Lessons and Recommendations*. Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/publications/2019/Dec/Accelerating-Geothermal-Heat-Adoption-in-the-Agri-food-Sector.

International Renewable Energy Agency (IRENA). 2020a. *Geothermal Development in Eastern Africa: Recommendations for Power and Direct Use*. Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/publications/2020/Jan/Geothermal-Development-in-Eastern-Africa.

International Renewable Energy Agency (IRENA). 2020b. *Renewable Energy Finance: Sovereign Guarantees*. Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_RE_Finance_Sovereign_Guarantees_2020.pdf.

International Renewable Energy Agency (IRENA). 2022. *Global Geothermal and Market and Technology Assessment*. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Feb/IRENA_Global_geothermal_market_technology_assessment_2023.pdf.

International Renewable Energy Agency (IRENA), and International Geothermal Association. 2021. *United Nations Framework Classification for Geothermal Energy: Pilot Applications in the Caribbean, Ethiopia and Indonesia*. Bonn: International Geothermal Association. https://www.irena.org/publications/2021/Nov/UNFC-Geothermal-Pilot-Applications.

Karytsas, Spyridon, Ourania Polyzou, and Christos Karytsas. 2019. "Social Aspects of Geothermal Energy in Greece." In *Geothermal Energy and Society*, edited by Adele Manzella, Annarita Allansdottir, and Alessandra Pellizzone, 123–144. Cham: Springer. https://doi.org/10.1007/978-3-319-78286-7_8.

Kępińska, Beata, Barbara Tomaszewska, Aleksandra Kasztelewicz, and Leszek Pająk. 2016. "Recommendations for the Regulatory Framework Facilitating the Geothermal District Heating Development in Europe." *Polityka Energetyczna – Energy Policy Journal* 19 (2): 109–118. https://doi.org/10.1515/pe-2016-0022.

Malafeh, Sam, and Basil Sharp. 2015. "Role of Royalties in Sustainable Geothermal Energy Development." *Energy Policy* 85: 235–242. https://doi.org/10.1016/j.enpol.2015.06.023.

Manzella, Adele, Thomas Garabetian, Valentina Pinzuti, Philippe Dumas, and Ben Laenen. 2018. *Framework Conditions for RD&I: Mapping of Relevant Policy and Regulatory Issues*. European Technology and Innovation Platform on Deep Geothermal. https://www.etip-dg.eu/publications/framework-conditions-for-rdi-mapping-of-relevant-policy-and-regulatory-issues/.

Micale, Valerio, Chiara Trabacchi, and Leonardo Boni. 2015b. *Using Public Finance to Attract Private Investment in Geothermal: Olkaria III Case Study, Kenya*. Climate Policy Initiative. https://www.climatepolicyinitiative.org/publication/using-public-finance-to-attract-private-investment-in-geothermal-olkaria-iii-case-study-kenya/.

Mizuno, Eri. 2013. *Geothermal Power Development in New Zealand: Lessons for Japan*. Tokyo: Japan Renewable Energy Foundation. https://jref.or.jp/en/activities/publication_20131108.php.

National Energy Authority (NEEA). 2023. "Utilizing Geothermal Energy." Orkustofnun (National Energy Authority of Iceland). https://orkustofnun.is.

National Energy Authority (Orkustofnun). 2023. *Integrated Licensing Procedures for Energy and Environment Sectors*. Reykjavik: Government of Iceland. https://orkustofnun.is/gogn/Skyrslur/OS-2023/Integrated-Licensing-Procedures-for-Energy-and-Environment-Sectors.pdf.

National Geographic Society. n.d. "Plate Tectonics and the Ring of Fire." https://education.nationalgeographic.org/resource/plate-tectonics-ring-fire/.

National Renewable Energy Laboratory (NREL). 2023. *Topics and Considerations for Developing State Geothermal Regulations*. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/86985.pdf.

Netherlands Oil and Gas Portal (NLOG). 2023. "Mining Act Implementation and Geothermal Data Access Framework." The Hague: Ministry of Economic Affairs and Climate Policy. https://www.nlog.nl/en/geothermal.

Nevada Division of Environmental Protection (NDEP). 2017. *Nevada UIC Permit Requirements for Geothermal Projects* (Fact Sheet, Ver. May 2017). Bureau of Water Pollution Control, Underground Injection Control Program. Carson City. https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-docs/uic-permit-req-geotherm-proj-5-2017.pdf.

Nyokabi, J., S. Mwakugu, L. Mathu, and J. Mwawasi. 2022. "Reinvigorating Geothermal Project Finance in Kenya Through Public-Private Partnership." In *Proceedings of the 9th African Rift Geothermal Conference*. https://africangeothermal.org/wp-content/uploads/2022/11/ARGeo-C9-Nyokabi-Reinvigorating-Geothermal-Project-Finance-in-Kenya-through-Public-Private-Partnership.pdf.

Parisi, Maria Laura, Mélanie Douziech, Lorenzo Tosti, Isabelle Blanc, Leen Damen, Daniele Fiaschi, Vincent Harcouët-Menou, et al. 2020. "Definition of LCA Guidelines in the Geothermal Sector to Enhance Result Comparability." *Energies* 13 (14): 3534. https://doi.org/10.3390/en13143534.

Penrod, Emma. 2024. "NV Energy Seeks New Tariff to Supply Google with 24/7 Power from Fervo Geothermal Plant." *Utility Dive*, June 21. https://www.utilitydive.com/news/google-fervo-nv-energy-nevada-puc-clean-energy-tariff/719472/.

Richter, Alexander. 2020. "Kenya Prevails in Lengthy Legal Case against Cancellation of Geothermal License." *ThinkGeoEnergy*, July 19. https://www.thinkgeoenergy.com/kenya-prevails-in-lengthy-legal-case-against-cancellation-of-geothermal-license/.

Robins, Jody C., Amanda Kolker, Francisco Flores-Espino, Will Pettitt, Brian Schmidt, Koenraad Beckers, Hannah Pauling, and Ben Anderson. 2021. *2021 U.S. Geothermal Power Production and District Heating Market Report*. Golden, CO: National Renewable Energy Laboratory. https://doi.org/10.2172/1823507.

Rystad Energy. 2025. *Geothermal Analysis*. https://www.rystadenergy.com/.

Setiawan, Andri D., Marmelia P. Dewi, Bramka Arga Jafino, and Akhmad Hidayatno. 2022. “Evaluating Feed-in Tariff Policies on Enhancing Geothermal Development in Indonesia.” *Energy Policy* 166: 113024. https://doi.org/10.1016/j.enpol.2022.113024.

Setyowati, Heratania Aprillia, Sigit Heru Murti, M. P. Dwinugroho, Novelya Martha Napitupulu, and Evita Wisnuwardhani. 2018. “ESDM One Map Indonesia: Exploring the Energy and Mineral Resources.” In *Proceedings of the XXIV ISPRS Congress*. Kuala Lumpur. https://doi.org/10.5194/isprs-archives-XLII-4-W9-129-2018.

Seyidov, Ferid. 2019. *Report on Risk Assessment (Deliverable No. 2.2)*. GEORISK. https://www.georisk-project.eu/wp-content/uploads/2019/07/GEORISK-D2.2-Report-on-Risk-Assessment.pdf.

Society of Petroleum Engineers. 2022. “Non-Hydrocarbons.” https://www.spe.org/en/industry/reserves/non-hydrocarbons/.

SPE Geo Hackathon. 2025. https://www.spegeohackathon.com/.

Tomasini Montenegro, C., E. Santoyo Castelazo, H. Gujba, R. J. Romero, and E. Santoyo. 2017. “Life Cycle Assessment of Geothermal Power Generation Technologies: An Updated Review.” *Applied Thermal Engineering* 1119–1136. https://doi.org/10.1016/j.applthermaleng.2016.10.074.

UK Department of Energy and Climate Change. 2011. *Planning Our Electric Future: A White Paper for Secure, Affordable and Low-Carbon Electricity*. London: The Stationery Office. https://assets.publishing.service.gov.uk/media/5a78b0dce5274a2acd1890be/2176-emr-white-paper.pdf.

United Nations Economic Commission for Europe and Ad Hoc Committee of the International Geothermal Association. 2022. *Supplementary Specifications for the Application of the United Nations Framework Classification for Resources (Update 2019) to Geothermal Energy Resources*. Geneva: United Nations. https://unece.org/sites/default/files/2022-12/UNFC_Geothermal_Specs_25October2022.pdf.

U.S. Department of Energy (DOE). n.d. “Permitting for Geothermal Power Development Projects.” https://www.energy.gov/hgeo/geothermal/permitting-geothermal-power-development-projects.

U.S. Department of the Interior. 2025a. “Department of the Interior Implements Emergency Permitting Procedures to Accelerate Geothermal Energy Development for National Security and Energy Independence.” May 29. https://www.doi.gov/pressreleases/department-interior-implements-emergency-permitting-procedures-accelerate-geothermal.

U.S. Department of the Interior. 2025b. “Notice of Adoption of Categorical Exclusions under Section 109 of the National Environmental Policy Act.” *Federal Register* 90 (169) September 2. https://www.federalregister.gov/documents/2025/09/02/2025-16759/notice-of-adoption-of-categorical-exclusions-under-section-109-of-the-national-environmental-policy.

World Bank. 2014. *Best Practices Guide for Geothermal Exploration*. 2nd ed. page 60-61. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/190071480069890732.

World Bank. 2016a. *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey*. https://hdl.handle.net/10986/24277.

World Bank. 2016b. *The World Bank Environmental and Social Framework*. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/383011492423734099/environmental-and-social-framework.

World Bank. 2019. *Guidance on PPP Contractual Provisions*. https://ppp.worldbank.org/sites/default/files/2021-03/Guidance%20on%20PPP%20Contractual%20Provisions_2019%20edition.pdf.

Appendix

Offtake and Pricing Mechanism Types in Geothermal Projects

A1. Feed-in Tariffs

Under a FiT scheme, utilities are obligated to purchase electricity from renewable energy producers at a fixed, guaranteed price per kilowatt-hour, typically set by regulation or law. The payment of the FiT is guaranteed for a period of time equivalent to the expected economic lifetime of the respective project. This pricing certainty insulates developers from market fluctuations, facilitating access to finance by reducing revenue risk, and it will attract renewable resources, if the price is set right, in order to meet the objective (Hasan and Wahjosudibjo 2014).

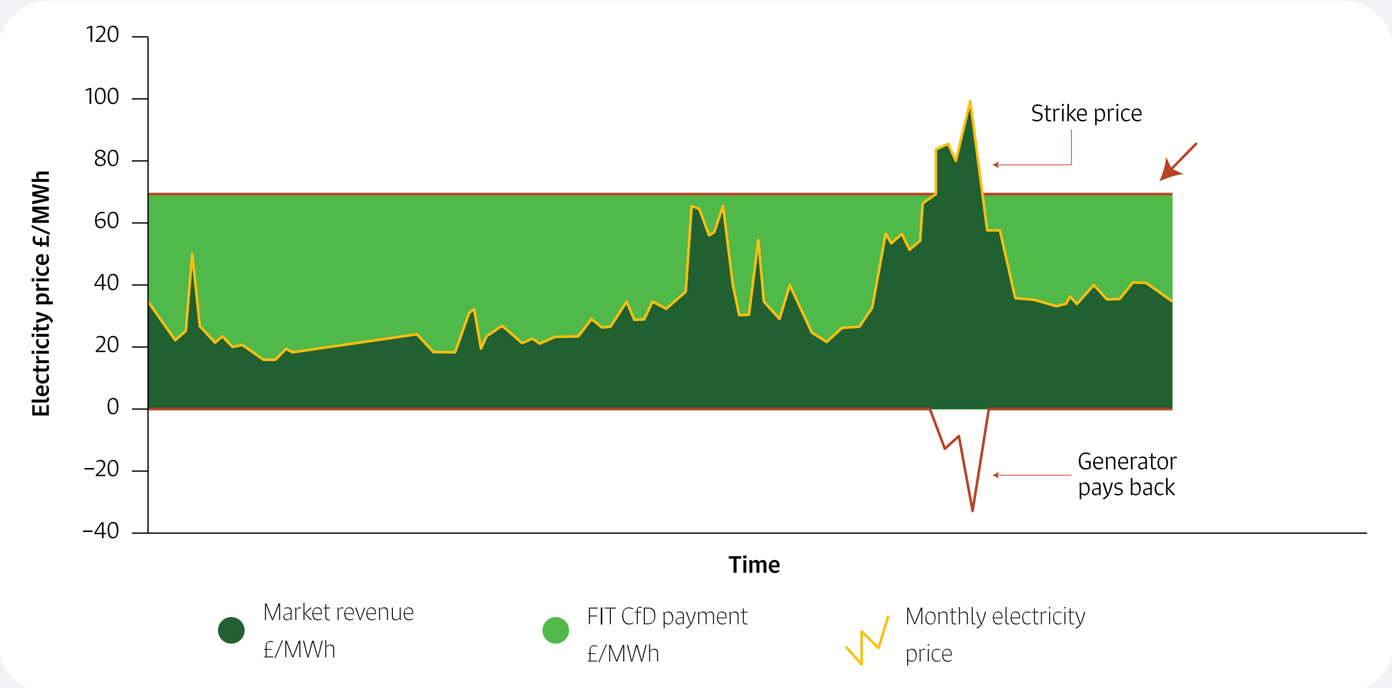
Currently, in most FiT support schemes, the price is based on the nature of the resource, market conditions, and the expected rate of return of potential investors. This allows the developer/investor to recover the different costs (capital, operation and maintenance, financing, etc.) while realizing a return on their investment depending on the assumed financing costs. In some cases, the FiT is calculated based on the avoided costs for the electricity system or society, including, for example, environmental externalities.

In Indonesia, the introduction of feed-in tariffs has played a significant role in accelerating geothermal development and has been considered effective in attracting private investment and supporting project bankability (Setiawan et al. 2022).

A2. Contracts for Difference

In liberalized and mature markets, CfDs can also support geothermal pricing. A CfD scheme guarantees a set price for electricity, known as the strike price. Depending on the state of the market, the power producer either receives an additional payment up to the strike price from the public counterparty or pays back any surplus above the strike price to the same counterparty. This mechanism

Figure A1. Structure of CfDs in the UK.



Source: EMR Settlement Limited (2025).

preserves exposure to electricity market signals while providing long-term revenue stability for investors. CfDs are particularly suitable for mid- to large-scale geothermal installations where market risk is a significant barrier to deployment, while FiTs remain relevant for small-scale geothermal projects. This is shown in Figure A1 (UK Department of Energy and Climate Change 2011).

CfDs must reflect the cost structures of different generation technologies, whereas geothermal energy differs significantly from solar PV or wind power in terms of upfront investment and project duration, which may require tailored strike prices or contract lengths to ensure viability. CfDs should not isolate producers from wholesale markets, and the design of the strike price and the contract duration must ensure that producers have incentives to dispatch energy efficiently, aligning with grid and demand conditions. A competitive bidding procedure is encouraged for CfDs to ensure transparency and competition. Public support must be cost-effective and proportionate, but certain exemptions may be warranted for small-scale or pre-commercial projects, where competition may be limited. Further, CfDs must be supported by transparent regulatory frameworks that clearly define the roles of contracting parties, and the treatment of revenue flows (e.g., Article 19d of Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943) as regards improving the Union's electricity market design (European Parliament and Council of the European Union 2024).

In the EU, the regulatory framework support schemes for renewable energy, including geothermal, has increasingly shifted toward mechanisms that promote market integration, cost efficiency, and competitive allocation of public resources (European Commission 2022). For instance, the EU's preferred support mechanism for new geothermal electricity generation projects is the two-way CfDs. Nevertheless, geothermal energy's unique characteristics, including high upfront costs, long development timelines, and baseload capacity, may warrant specialized consideration within these frameworks.

In the UK, the primary mechanism for supporting low-carbon power infrastructure is a CfD scheme. During the fifth round of allocation, for the first time in the scheme's history, CfDs were allocated to geothermal projects for a maximum bid price of (£119/MWh) or roughly US$158/MWh for a total capacity of 12 MWe over 15 years. In view of the sixth round, the UK Government increased the maximum price of geothermal by 32%, from around US$158/MWh (around £119/MWh) to £157/MWh (or roughly $208/MWh) (Cariaga 2023).

A3. Feed-in Premium

Feed-in premiums and regulated heat tariffs are commonly used for direct-use geothermal applications, particularly in the Netherlands. These mechanisms compensate for the difference between the cost of sustainable heat production and market revenues, supporting the deployment of geothermal district heating and industrial heat supply (Dumas, Garabetian, and Le Guénan 2019).

Table A1 illustrates how the Dutch Sustainable Energy Production and Climate Transition Incentive Scheme (2023 SDE++) supports geothermal development across different depth categories. The subsidy is calculated for a period of 12 to 15 years, depending on the energy resource.

Table A1. Subsidy schemes and outcomes in the Netherlands.

Category	Support mechanism	Tender results
Shallow geothermal (500-1500m)	Subsidy compensates the difference between the cost price of sustainable energy (or CO_2 reduction) and revenue.	€691 million awarded (projects with heat pumps).
Deep geothermal (minimum 1500 m)	Same mechanism.	€791 million
Ultra deep geothermal (minimum 4000m)	Same mechanism.	N/A

Source: (Cariaga 2024a).

A4. Power Purchase Agreements

Globally, PPAs have proven to be an effective mechanism for accelerating investment in renewable energy, providing several benefits. For developers, PPAs enhance revenue certainty, mitigate risk, facilitate project financing, and provide predictability. For offtake-buyers, PPAs provide several commercial benefits, including price stability, which can act as a hedge against volatility in wholesale electricity markets. From a sustainability perspective, PPAs also support corporate decarbonization goals.

PPAs for geothermal power usually address the same issues as PPAs for other power generation technologies. However, some issues unique to geothermal must be addressed, especially regarding operational risks, which would prevent the operator from reaching the agreed-upon output. Issues include, for example, reservoir degradation and costs related to increased maintenance due to geological or chemical factors, such as make-up wells and force majeure (Gehringer and Loksha 2012). Table 13 illustrates geothermal PPAs, ranging from hybrid frameworks to corporate agreements.

Table A2. Analysis of power purchase agreements in selected projects.

Case study	Country	Project/capacity	PPA features
Olkara III	Kenya	110 MWe	The Olkaria III project was initially financed through equity, but after the first 8 MWe PPA was signed in 1998, a renegotiated 20-year agreement enabled the project to secure debt for expansion. The revised PPA was specifically structured to mitigate financial, operational, and foreign exchange risks.
Indonesia PPA Framework	Indonesia	Geothermal sector	Indonesia employs a hybrid model that combines regulated ceiling tariffs with negotiated contracts. Tariffs are quoted in U.S. dollars but paid in Indonesian rupiah and indexed to the JISDOR rate. PPAs may run up to 30 years, with provisions for annual tariff reviews and escalation. Although projects are still procured through direct appointment by PLN, the framework introduces price caps based on regional generation costs to enhance transparency.
Te Huka III/ Microsoft	New Zealand	51.4 MWe	In 2023, Contact Energy signed a 10-year corporate PPA with Microsoft, under which all renewable energy attributes from the new geothermal plant are transferred to the company. This agreement enables Microsoft to claim a 24/7 renewable supply for its forthcoming New Zealand data center.
Google/ Fevro “Corsac Project”	United States	115 MW	Fervo Energy entered a 15-year PPA with NV Energy, which will deliver geothermal electricity to Google under Nevada’s new Clean Transition Tariff. The fixed-rate agreement supports Google’s 24/7 carbon-free energy goals while allowing NV Energy to invest in firm renewable capacity under least-cost procurement rules.

Sources: Contact Energy Ltd. (2023); Penrod (2024); Micale, Trabacchi, and Boni (2015b).

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Majed Alsuwailem is a Senior Fellow in the Oil and Gas department with notable expertise in geoeconomics, natural resource governance, and sustainable energy policies. With over 15 years of experience in the oil and gas industry, he has expertise in simulation and modeling, asset management, oil field development, disruptive technologies, and business planning, gained at Chevron and Saudi Aramco. His recent research interests are highly pertinent to the evolving energy landscape and include the economics of geothermal energy, China's energy strategy, and phantom oil. Majed holds an M.S. in Public Economics and Policy from Purdue University (2021), an M.S. in Reservoir Geosciences and Engineering from the Institut Français du Pétrole (IFP School), an M.S. in Petroleum Engineering from Texas A&M University, and a B.S. in Petroleum Engineering from the University of Tulsa.

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About the Project

This project offers a comprehensive analysis of fiscal policies, regulatory frameworks, technological developments, and innovative investment strategies in key emerging geothermal markets. Drawing on these insights, the study aims to deliver actionable recommendations to inform national energy policy. The overarching objective is to support strategic initiatives that advance the development and integration of geothermal energy, aligning with the Kingdom's goals for a sustainable and resilient energy future.

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