Discussion Paper

Geothermal Market Growth in Türkiye

Policy and Legislative Insights for New Market Entrants

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Summary

In 2023, Türkiye endured a devastating earthquake that tested the resilience of its infrastructure and underscored the nation's seismic vulnerability, as the Anatolian Peninsula is among the most tectonically active regions in the world. This geographic reality presents both significant challenges and distinct opportunities for Türkiye's energy sector, particularly geothermal energy. While proximity to tectonic plate boundaries can trigger catastrophic natural events, it also positions Türkiye advantageously in terms of geothermal potential. The geothermal reservoirs beneath the country's surface are a byproduct of the same tectonic activity that makes the region earthquake-prone, providing an abundant baseload energy source that could play a key role in diversifying the national energy mix and sustainably meeting energy demand. This duality of risk and opportunity has catalyzed efforts to harness Türkiye's substantial geothermal potential. The sector's advancement has been marked by continuous reforms in legislative frameworks, market liberalization, technological efficiency, and financing schemes. Türkiye is the leading geothermal electricity generator in the Middle East and a global front-runner in the sector. With 1.7 gigawatts electrical (GWe) of installed geothermal capacity, Türkiye ranked fourth globally in geothermal electricity generation as of 2024. The country also ranks second globally in direct geothermal use,[1] with a thermal capacity of 5.1 GWth (TEİAŞ 2025).

Keywords: Geothermal, Türkiye, Policy, Regulations, Energy, Market, Technology, Project, Financing, Governance, Licensing, Renewables, Decarbonization, Electricity, Incentives

1 Direct use involves utilizing geothermal heat, typically below 90°C, without converting it to electricity, for applications such as heating, cooling, and industrial processes (Alsuwailem et al. 2024).

Key Points

- Following the 2001 economic crisis, Türkiye adopted a series of structural reforms under the guidance of the International Monetary Fund, including the liberalization of its energy markets. These reforms coincided with rapid economic growth, industrialization, and urbanization, which increased national energy demand and spurred substantial investment in energy infrastructure, particularly renewable energy such as geothermal power.

- To rationalize energy demand growth, reduce energy prices, and mitigate the pace of energy import expansion, Türkiye has undertaken a comprehensive restructuring of its energy system. These reforms have targeted modernization, liberalization, and increased domestic production capacity, resulting in considerable diversification of the energy mix over the past decade (IEA 2025).

- Multilateral development finance institutions, notably the World Bank and the European Bank for Reconstruction and Development, international export credit agencies via Ex-Im banks, and local commercial banks have played a pivotal role in financing Türkiye's energy transition. These institutions have mobilized capital through geothermal-specific frameworks, equipment and technology imports, and tailored domestic credit channels.

- For more than half a century, Türkiye's General Directorate of Mineral Research and Exploration has played a central role in identifying and mapping the country's geothermal reservoirs. These efforts led to the discovery of numerous sites suitable for power generation. The enactment of the Geothermal Law in 2007 enabled these publicly discovered fields to be auctioned to private entities, significantly lowering entry barriers for private developers.

- The 2011 feed-in tariff[2] incentives guaranteed fixed purchase prices for selected renewables and provided a stable financial framework for long-term investments. Leveraging these conditions, Türkiye's private sector rapidly developed geothermal fields, resulting in a swift increase in installed capacity. As of today, 66 geothermal power plants are operating in the Republic.

- Turkish geothermal developers have demonstrated agility in adopting technologies, expertise, and methodologies from the oil and gas industry to enhance project efficiency. By leveraging the country's established workforce, technical infrastructure, and operational know-how, developers have pursued deeper targets and more complex well designs, contributing to higher construction efficiency and increased energy production.

- Nevertheless, the number of new geothermal wells has declined since 2018 due to a combination of factors, including field maturity, front-loading of drilling to secure feed-in tariff incentives before their 2021 expiration, macroeconomic pressures, and competition with the domestic oil and gas industry for drilling rigs and services. Turkish economic growth slowed from 5.1% in 2023 to 3.2% in 2024.

- The country has yet to fully develop its geothermal resources. Exploration activity and all geothermal power plants are concentrated in the western regions, while the eastern and central regions remain largely untapped despite strong potential. Hot dry rock resources remain unused, and repurposing abandoned oil wells in the southeast represents a promising opportunity for both direct use and power generation.

- To further advance geothermal development in Türkiye, particularly in new greenfield projects, more agile governance frameworks, innovative financial instruments, and increased adoption of advanced technologies are needed. These measures would reduce uncertainty, enhance bankability, and improve efficiency across the project lifecycle.

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2 Feed-in tariffs are a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term government contracts to renewable energy producers, guaranteeing the purchase of all generated power at a fixed or premium price based on generation cost.

Introduction

01

Türkiye has emerged as a leading contender in geothermal power generation, ranking among the top five countries globally in installed geothermal capacity. As of 2024, Türkiye's geothermal power capacity exceeds 1.7 GWe, making it the leading geothermal market in Europe, surpassing Iceland, and one of the fastest-growing markets worldwide (IEA 2024).

The country's most extensively exploited geothermal resources are concentrated in western Anatolia, a region rich in high-enthalpy reservoirs suitable for electricity production and favorably located near key demand centers.

Türkiye's success in scaling geothermal power reflects a combination of resource abundance, state-supported mature exploration, strategic policy support, and adequate financial support mechanisms. Several key enablers have driven the country's rapid geothermal expansion. Chief among them is the Renewable Energy Resources Support Mechanism, which introduced feed-in tariffs and other incentives, as well as guaranteed grid access, significantly reducing project finance risks. In addition, Türkiye's electricity market liberalization enabled greater private sector participation, allowing the development of readily discovered geothermal fields.

The General Directorate of Mineral Research and Exploration, a scientific institution dedicated to mineral research, has played a vital role by identifying and mapping potential resources, thereby de-risking resource assessments. Discovered geothermal fields were subsequently auctioned to independent power producers. This hybrid model, balancing public leadership with private initiative, has been instrumental in sustaining investor interest and accelerating project timelines.

This paper focuses on geothermal power in Türkiye, a field of growing significance within the national energy mix. It examines the evolution of geothermal power generation and aims to provide policymakers, new market entrants, and the public with a comprehensive understanding of the country's geothermal landscape. The analysis highlights key progress, persistent challenges, and emerging opportunities, with particular attention to regulatory frameworks, risk mitigation schemes, access to capital, and fit-for-purpose technology.

Structured into three main sections, the paper first examines Türkiye's national energy and climate policies, electricity market evolution, and supporting risk mitigation schemes. The second section focuses on the rise of geothermal energy, driven by private sector actors and service providers, and highlights the role of technology, financiers, regulatory bodies, scientific communities, and advocacy groups. The paper concludes by outlining policy options and future pathways to accelerate geothermal development in Türkiye.

Although Türkiye ranks second globally in direct geothermal use, with a thermal capacity of 5.1 gigawatts thermal, this publication does not cover this field, as it merits a separate discussion given the scale and diversity of direct-use applications.

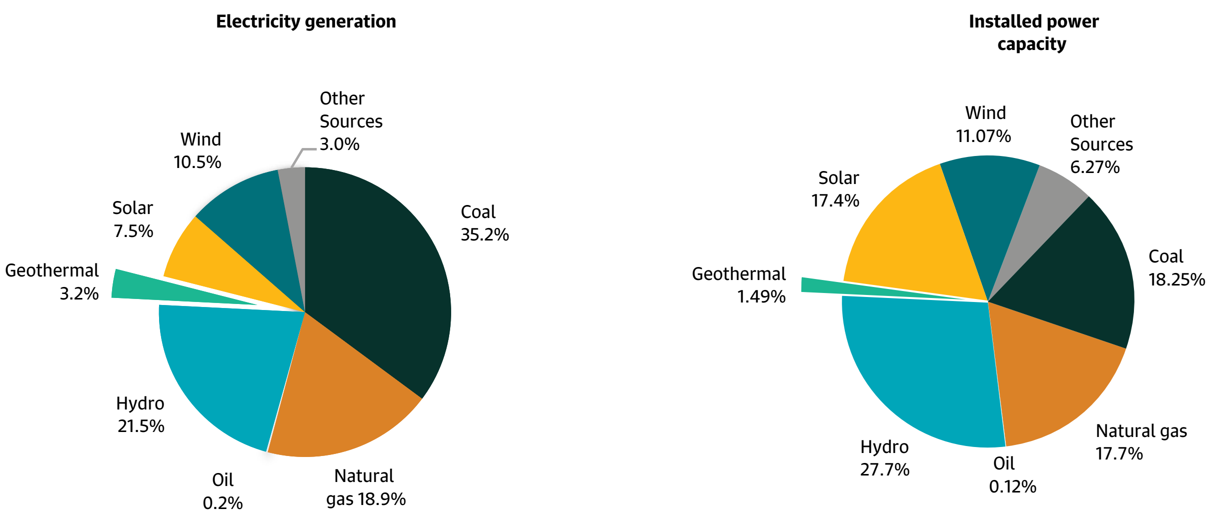
Overview of Türkiye's Power Sector

02

Türkiye's power sector has undergone a significant transformation over the past few decades, driven by a confluence of critical factors, including the pursuit of energy security, the demands of rapid economic and population growth, and the global push toward environmental sustainability.

In 2024, Türkiye's electricity consumption increased by 5.5% compared with the previous year, reaching 353.6 terawatt-hours (TWh), while electricity production rose by 7.1% year over year to 354.6 TWh, as depicted in Figure 1. This growth highlights significant progress in diversifying Türkiye's energy mix and expanding its electricity generation capacity.

Figure 1. Türkiye's electricity generation and installed power capacity by source in 2024.



Source: MENR (2025).

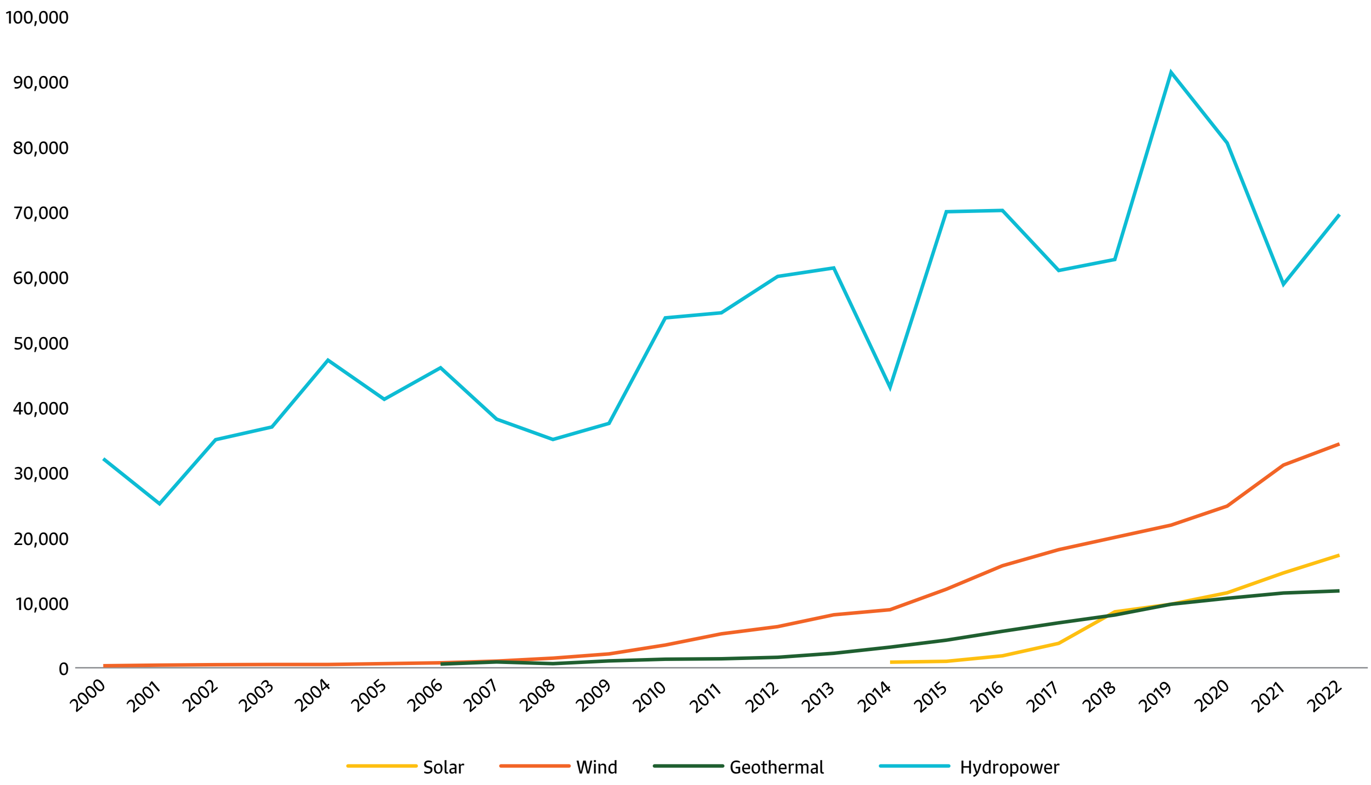
As of the end of 2024, 54% of Türkiye's power generation was derived from coal and natural gas. The remaining 46% was generated from alternative energy sources, predominantly renewables such as hydropower, wind, solar, and geothermal energy, as illustrated in Figure 1. Türkiye's total installed power capacity reached 115.9 GWe in 2024. During the year, 4,280.9 megawatts (MWe) of solar capacity, 1.1 gigawatts (GWe) of wind capacity, and 0.2 GWe of hydropower capacity were commissioned. Newly added capacity in 2024 consisted of 99% renewable energy sources. By the end of 2024, the share of renewables in total installed capacity had increased to 59.3% MENR (2025).

Türkiye's mountainous terrain provides ample opportunities for hydropower, which remains the Republic's primary renewable energy source. Before the 2000s, hydroelectric power plants were prioritized as the dominant renewable option, given their ability to deliver large and stable output. During this period, geothermal energy was considered immature, with limited exploration activity and low awareness of its potential. The first geothermal power plant, Kızıldere Single Flash, was commissioned in 1984 with a gross capacity of 20.4 MWe (Serpen and Türkmen 2007), a relatively small output compared with large hydroelectric plants. Consequently, investment was heavily concentrated in large-scale hydropower projects.

By 1990, approximately 40% of Türkiye's electricity was generated by hydropower. Over time, hydropower has emerged as the country's most cost-effective source of electricity. However, increasing sedimentation in reservoirs and the impacts of climate change, particularly more frequent and severe droughts, have significantly reduced water availability for hydropower generation. Declining water flows have introduced greater variability in electricity output, affecting the reliability of hydropower. As illustrated in Figure 2, a severe drought in 2020 led to a 10% decline in electricity generation from hydropower.

Compounding this challenge, most of Türkiye's prime hydropower sites have already been developed, leaving limited scope for further large-scale expansion. These factors significantly constrain Türkiye's potential to expand hydropower capacity and limit its role in the country's future energy strategy.

Figure 2. Annual electricity generation from renewables in Türkiye in gigawatt hours (GWh).



Source: Bulut (2024).

Solar and wind energy have steadily penetrated the power mix since the mid-2000s, quickly outpacing geothermal in installed capacity. This rapid growth can be attributed to a convergence of factors, including the modular nature of solar and wind projects, shorter development timelines, and declining technology costs, which have significantly lowered barriers to entry.

Although geothermal energy has long been part of Türkiye's natural landscape due to its abundant high-enthalpy resources, it was not incorporated into the country's energy mix until the early 2010s. This delay was primarily due to the absence of robust incentive mechanisms, limited policy focus on renewables, and the lack of viable financial models to attract private sector investment in geothermal development. The turning point came with the convergence of several key factors, including the maturation of regulatory frameworks, the introduction of targeted incentives for renewable energy, particularly geothermal, and the broader liberalization of the energy market. These developments, which are examined in detail in this paper, collectively created a more favorable environment for private investment and accelerated the growth of Türkiye's geothermal sector.

National Energy Policies and the Role of Geothermal Energy

Türkiye relies heavily on fossil fuel imports, primarily coal and natural gas, to meet its energy needs. In 2024, a total of 40% of imported coal and natural gas was used for electricity generation, heating, and other industrial applications (EMBER 2025). This reliance reflects a dynamic of energy interdependence rather than unilateral dependency. Türkiye plays a critical role in the global energy landscape due to its strategic geographic position, serving as an energy corridor between energy-abundant regions such as the Caspian, the Middle East, and the Commonwealth of Independent States, and energy-dependent markets in Europe. Major oil and gas pipelines, including the Trans-Anatolian Natural Gas Pipeline and the Baku-Tbilisi-Ceyhan pipeline, along with key maritime routes through the Bosporus and Dardanelles, reinforce the country's role as an energy corridor (Ministry of Foreign Affairs of the Republic of Turkey 2022).

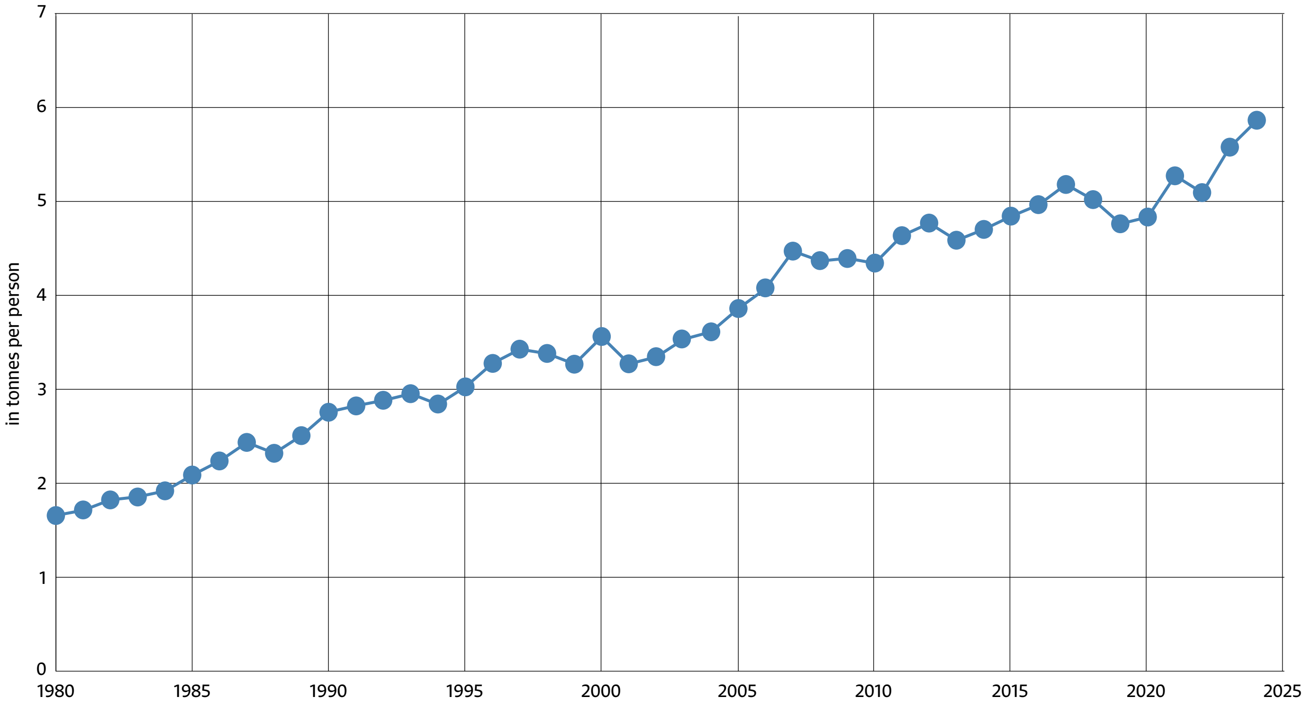
Nevertheless, this interdependence is not without challenges. While Türkiye benefits from transit revenues and enhanced geopolitical leverage, its significant reliance on imported fossil fuels, particularly natural gas and coal for electricity generation, exposes the country to energy market volatility and foreign exchange pressures. The rapid depreciation of the Turkish lira (₺) against the U.S. dollar ($) in recent years has further exacerbated the cost of energy imports, increasing the overall unit cost of electricity and placing additional strain on the national economy (Ağbulut et al. 2023).

National Commitments and Climate-Driven Imperatives

Türkiye's renewable energy transition has been shaped by international climate commitments, domestic legislation, and pro-market reforms, yet its effectiveness remains limited. The country ratified the UNFCCC in 2004 (UN 1992), the Kyoto Protocol in 2009 (UN 1998), and the Paris Agreement in 2021 (UN 2015), pledging to achieve net-zero emissions by 2053. Complementary legislation includes the UNFCCC accession law (2003), the Energy Efficiency Law (2007), the Kyoto Protocol ratification law (2009), and the Climate Law (2025), which introduces mechanisms such as emissions trading and institutional governance frameworks.

Beginning in the early 2000s, Türkiye adopted EU-aligned policies, including the National Renewable Energy Action Plan, which targeted a 30% share of renewables in electricity generation by 2023 and 61 GWe of installed capacity (EBRD 2014). The Renewable Energy Law (2005), later amended in 2011, established feed-in tariffs to incentivize renewable investment, supported by steady economic growth between 2002 and 2018. These measures increased the role of renewables in Türkiye's energy mix; however, greenhouse gas emissions have continued to rise. As shown in Figure 3, CO_2 emissions per capita have increased over time.

Figure 3. Historical carbon emissions per capita in Türkiye.



Note: Carbon dioxide (CO_2) emissions are from the combustion of fossil fuels and industrial processes, including transport, electricity generation, and heating, and excluding land-use change.
Source: Our World in Data (Ritchie et al. 2025), based on Global Carbon Budget and population data from multiple sources.

Compared with the EU Climate Law, which mandates climate neutrality by 2050, enforces interim emissions reduction targets, and incorporates robust governance and social equity mechanisms, Türkiye's framework remains largely aspirational. As shown in Figure 1, the country's installed power generation capacity remains heavily reliant on fossil fuels, with approximately 54% derived from coal and natural gas. Nevertheless, current legislation does not specify binding interim targets, a clear timeline for phasing out fossil fuels, or mechanisms to ensure a just transition. This absence underscores the need for clear implementation strategies and closer alignment between energy security and climate objectives to achieve long-term goals.

Diversification and Domestic Resource Development

Turkish policymakers have adopted a multifaceted energy strategy aimed at enhancing self-sufficiency and energy resilience. Domestically, efforts have focused on expanding indigenous energy production. Notable examples include the exploration and development of natural gas reserves in the Black Sea, exemplified by the Sakarya field development, and investment in a civilian nuclear energy program, represented by the Akkuyu Nuclear Power Plant. However, while these initiatives represent important steps forward, the pace of domestic energy production remains insufficient to fully meet the country's growing energy demand (Siccardi 2024).

Internationally, Türkiye has sought to diversify its portfolio of energy suppliers by forging strategic partnerships with a wide range of countries across different regions. This outward-facing approach complements domestic measures by ensuring diversified resource flows, thereby reducing vulnerability to supply disruptions and enhancing long-term energy security (Siccardi 2024).

The Role of Renewable Energy

For Türkiye, the transition to renewable energy is primarily driven by energy security considerations. Renewable energy development offers an opportunity to reduce import dependence and stimulate green economic growth. It is estimated that by 2035, Türkiye will add 9 GWe of renewable energy capacity (Kazancı 2024). Furthermore, the sector's expansion is projected to create approximately 110,000 new green jobs (Colle 2022), emphasizing its potential as a driver of employment generation, technological innovation, and industrial development.

Geothermal Energy: A Renewable Lever to the Republic's Energy Security?

Constrained by limited fossil fuel resources yet endowed with abundant geothermal potential, Türkiye has increasingly leveraged geothermal energy for electricity generation and a range of applications, including geotourism, greenhouse heating, and district heating systems. These efforts reflect the country's commitment to maximizing the multifaceted benefits of geothermal energy and fostering a more sustainable and diversified energy landscape.

Türkiye's geothermal capacity targets have evolved over time in response to shifting policy priorities and market dynamics. According to the National Energy Plan, the combined capacity of both geothermal and biomass power plants is projected to reach 5.1 GWe by 2035 (Aslan and İyikul 2023). The International Energy Agency projects that Türkiye will achieve the second-highest net geothermal capacity additions globally by 2030, following Indonesia (IEA 2024).

National energy and climate policies must be effectively cascaded into concrete actions to achieve meaningful outcomes. High-level strategies and commitments provide direction, but their impact depends on their translation into clear regulations, targeted incentives, and actionable frameworks that engage both public and private stakeholders. Without such alignment, even ambitious national energy goals remain more aspirational than transformative.

Geothermal Proliferation in Türkiye's Energy Mix

03

Geothermal energy has played a longstanding role in Türkiye's history, with its use dating back to ancient civilizations. The Romans, followed by the Seljuks and Ottomans, used hot springs for bathing, therapeutic, and medicinal purposes. This historical reliance on geothermal resources underscores the country's deep-rooted tradition of harnessing natural heat to meet societal needs.

Türkiye, situated on the geologically active Alpine-Himalayan orogenic belt, possesses significant geothermal energy potential due to its distinctive tectonic, volcanic, and geological characteristics. This region is among the world's most seismically and geothermally active zones. Across the country, more than 2,000 wells[3] and 415 geothermal fields have been identified, exhibiting a wide range of temperatures and confirming both the scale and diversity of Türkiye's geothermal resources (Dağıstan 2022).

The country's geothermal potential is particularly high, with most resources classified as low- to mid-enthalpy.[4] These resources are especially well suited for direct-use applications such as district heating, greenhouse cultivation, and thermal tourism. In terms of geographic distribution, approximately 78% of Türkiye's identified geothermal potential is concentrated in western Anatolia, a region characterized by elevated heat flow and intense tectonic activity. Central Anatolia accounts for 9% of the potential, followed by the Marmara Region with 7%, eastern Anatolia with 5%, and the remaining 1% distributed across other regions (see Figure 4) (Ağbulut et al. 2023). However, most geothermal exploration activity in Türkiye has historically been concentrated in the west, driven by higher population density, clustered industrial activity, and corresponding growth in electricity demand.

Geothermal fields in Türkiye are commonly categorized by reservoir temperature into three main classes: low-enthalpy fields below 100°C, medium-enthalpy fields ranging from 100°C to 200°C, and high-enthalpy fields above 200°C (Benderitter and Cormy 1990). This classification is important for determining optimal resource use, as temperature directly affects the feasibility of electricity generation and other end uses. High-enthalpy fields are typically used for electricity generation, while low- to medium-temperature resources are better suited for direct-use and heating applications. It is important to

3. More than 8,000 geothermal wells have been drilled globally. Wells in Türkiye account for approximately 10% of the total geothermal well count (Adjei 2025).

4. Geothermal enthalpy refers to the amount of heat energy contained in geothermal fluids, such as hot water or steam, that can be extracted from the Earth's crust.

Figure 4. Distribution of geothermal resources in Türkiye.

Source: Modified from MTA (2025c).

note that advances in power plant technology have enabled the development of geothermal power plants operating with resource temperatures as low as approximately 100°C (GMK Enerji 2018). The spatial distribution of these geothermal resources across the country is illustrated in Figure 4.

In terms of utilization, Türkiye's geothermal resources are employed in two primary domains: direct-use applications and electricity generation. Direct use represents the country's most extensive form of geothermal utilization, particularly for space heating and cooling, greenhouse agriculture, industrial processes, and balneological services. District heating, in particular, dominates direct-use applications in Türkiye (Dağıstan et al. 2015). Electricity generation, while accounting for a smaller share of total geothermal use, has experienced rapid growth in recent years, positioning Türkiye among the leading geothermal power producers globally, as discussed earlier.

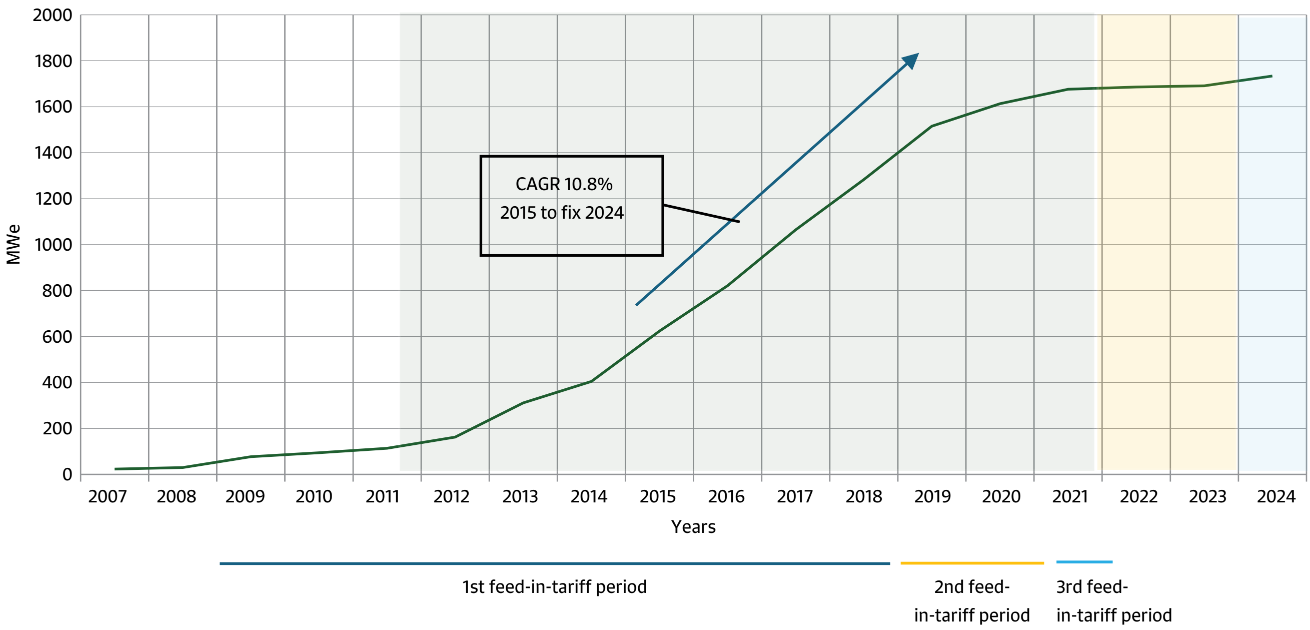
Current Status and Performance

By the end of 2024, Türkiye's total installed geothermal capacity had reached 1.7 GWe, accounting for approximately 3.2% of national electricity production (see Figures 1 and 2). At that time, 66 geothermal power plants were in operation, most of them located in the western regions of the country. The average working capacity, defined as the ratio of electricity generated to gross installed capacity, of active geothermal power plants in Türkiye was 64.5% as of the end of 2019 (Aydın and Şentürk 2020). This performance notably exceeds the capacity factors[5] reported for other renewable energy sources in the Republic, including wind, solar, and biomass (Aslan and İyikul 2023).

The Renewable Energy Resources Support Mechanism schemes, which are discussed in detail later in this paper, have played

5 The capacity factor of a geothermal power plant measures how effectively the plant is utilized relative to its maximum possible output. Geothermal power plants typically exhibit high capacity factors, often ranging from 70% to 95%, because they provide baseload power and operate continuously, unlike intermittent sources such as solar and wind energy (EIA 2025).

Figure 5. Installed geothermal power capacity in Türkiye (MW_e).



Source: Authors' analysis based on EPDK (2025b).

a crucial role in the proliferation of geothermal energy in Türkiye. The scheme introduced in 2023 has resulted in a slight increase in geothermal project development, as shown in Figure 5. However, ongoing concerns regarding long-term financial viability continue to limit further developments.

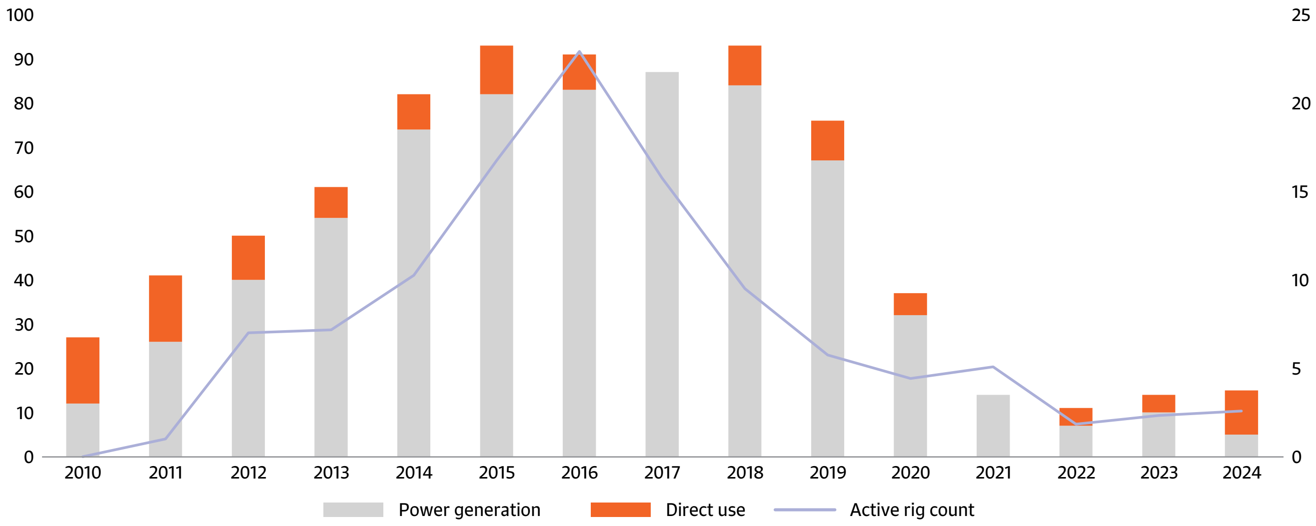
Notwithstanding, despite this trajectory of growth and technological progress, geothermal energy continues to constitute a relatively modest share of Türkiye's overall energy mix (EPDK 2025b). By the end of 2024, geothermal accounted for approximately 3.2% of domestic electricity production and only 1.49 of total installed power capacity (see Figures 1 and 2) MENR (2025).

Several factors contribute to this low penetration rate. Structural and sector-specific challenges help explain the divergence between rapid sectoral growth and a limited national share, including the geographically constrained nature of high-potential geothermal resources, the capital-intensive requirements of exploration and development, and the risk of delayed returns on investment due to subsurface uncertainty. The depreciation of the Turkish lira, particularly since the COVID-19 pandemic, has further increased the cost of geothermal exploration and production. Geothermal wells, whether production or injection wells, typically account for more than 60% of total project capital costs (Alsuwailem et al. 2024).

Figure 6 depicts the number of new geothermal wells drilled annually. Drilling activity peaked in 2018, with 92 new wells completed for power generation and direct-use applications, but has declined since then. Several factors have contributed to this slowdown:

- **Mature field development**: Many previously identified geothermal fields have reached advanced stages of development, reducing the need for new drilling. Most of the new wells shown in Figure 6 are associated with capacity expansions at existing power plants, primarily intended to offset declining production rates. These declines are attributed to two main factors: first, a reduction in non-condensable gases within reservoirs, which lowers production efficiency (Serpen and DiPippo 2022); and second, the close proximity of licensed areas among competing producers, which has resulted in significant interference between geothermal wells (Aydın and Şentürk 2020).

Figure 6. Annual number of geothermal wells drilled per type and active rig counts in Türkiye.



Note: The active rig count refers to the number of rigs in operation during a given week. The rig counts shown in this chart include rigs used for both geothermal and gas storage projects.

Source: Analysis based on Baker Hughes Rig Count (2025) and Rystad Energy (2025).

- **Feed-in tariff deadlines**: Developers accelerated drilling activity to take advantage of feed-in tariffs valid through 2021, completing much of their planned development ahead of schedule.
- **Economic challenges**: Türkiye's economic downturn reduced investment capacity. Rising interest rates constrained project financing, while depreciation of the lira further increased costs in this capital-intensive, largely dollar-denominated service industry.
- **Competition for other natural resources**: Increased hydrocarbon exploration activity diverted technical expertise and drilling equipment away from geothermal development, contributing to a slowdown in sector growth.

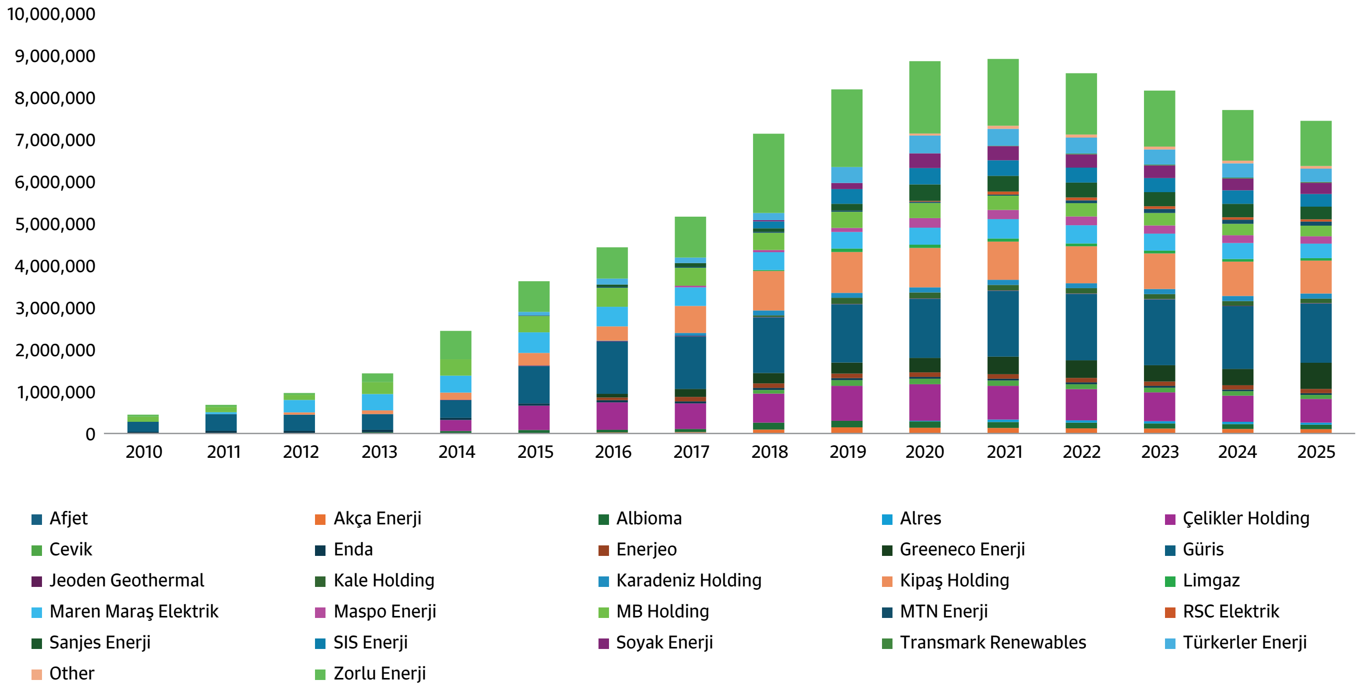
There is growing interest in direct geothermal use for agricultural purposes. This trend is reflected in the allocation of most credit loans under the World Bank's risk-sharing mechanism to geothermal greenhouse projects. Incentives provided by the Ministry of Agriculture have also played a key role in accelerating this development. Figure 6 further illustrates a notable increase in the number of new wells drilled for direct use, with the most significant growth occurring in greenhouse heating applications.

Geothermal Market Developers and Service Providers in Türkiye

According to Rystad, more than 25 geothermal operators are currently active in Türkiye, many of which are vertically integrated and participate across the energy value chain, from power generation to distribution. As of the end of 2024, the largest geothermal energy portfolios are held by Zorlu Enerji with 305 MWe, Gürmat with 260 MWe, Kipaş Holding with 230 MWe, and Çelikler Holding with 215 MWe. Notably, the Gürmat portfolio stands out for having the largest total installed capacity concentrated in a single province, Aydın in western Türkiye, and for achieving the highest electricity generation among geothermal operators in the country (see Figure 7) (Aslan and İyikul 2023).

In recent years, international developers have shown increasing interest in Türkiye's geothermal energy sector, attracted by its substantial untapped potential and strategic geographic position. A notable example is Ignis Energy, a U.S.-based geothermal exploration and development company, which has initiated operations in eastern Anatolia. This move aligns with the company's strategy of maintaining a risk-balanced

Figure 7. Power generation in megawatt hours by operator.



Source: Analysis based on Rystad Energy (2025).

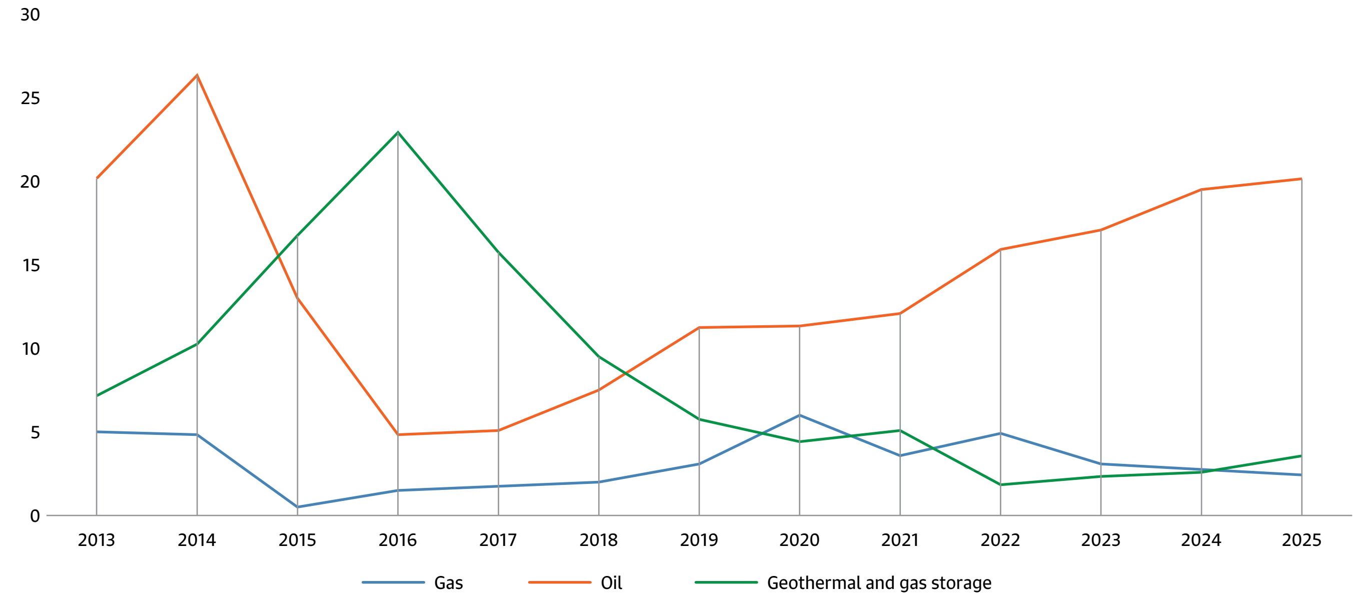
portfolio of power generation opportunities in high-enthalpy environments worldwide. Ignis is currently working toward the development of its first commercial geothermal project in Türkiye, which is envisioned as a scalable model for future development in underexplored geothermal basins (Ignis Energy 2025).

Another international player is Albioma, which entered the Turkish geothermal market by acquiring a majority stake in the Gümüşköy and Kuyucak Geothermal Power Plants in western Anatolia (Albioma 2025). This strategic acquisition marked Albioma's first global investment in geothermal energy and reflects the company's broader ambition to diversify its renewable energy portfolio beyond biomass and solar. As stated by Albioma's CEO, "This initial project in partnership with a recognized local player allows us to rapidly develop our expertise in this business while keeping capital investment to a reasonable level. We will be able to capitalize on this know-how in the coming years" (ThinkGeoEnergy 2021b).

The expansion of Turkish geothermal operators into emerging neighboring markets has the potential to accelerate geothermal development in these regions by leveraging technical expertise and operational experience to capitalize on new opportunities. Recently, the Soyak Group announced the acquisition of a license to develop a 98 MWe geothermal project in Croatia, marking a step forward in its international growth strategy (Richter 2025).

The geothermal energy sector in Türkiye has benefited substantially from the technological maturity and workforce expertise developed within the oil and gas industry. Following the discovery of oil in southeastern Türkiye in 1945, Türkiye Petrolleri Anonim Ortaklığı (TPAO) was established in 1954 under Law No. 6327, which aimed to promote private investment and foster the development of the petroleum industry. TPAO was tasked with conducting hydrocarbon exploration, drilling, production, refining, and marketing on behalf of the Turkish Republic. The enactment of this law also facilitated the entry of numerous international exploration and production (E&P) companies, such as Mobil, BP, Shell, and later Perenco, as well as oilfield service providers. These companies introduced advanced well-construction technologies and operational expertise. Over subsequent decades, they contributed to building local capacity by employing and training engineers, technicians, and skilled workers, enabling knowledge

Figure 8. Number of drilling rigs actively operating in Türkiye, sorted by types.



Source: Baker Hughes Rig Count (2025).

transfer and establishing a strong technical foundation that later supported geothermal exploration and development.

Middle East Technical University and Istanbul Technical University rank among the leading engineering institutions in Asia. Researchers from these universities have played key roles in advancing geothermal energy in Türkiye through high-impact work in reservoir engineering, geological research, policy development, and EU-funded projects. Their contributions have supported both academic and industrial progress.

During the 2014-16 downturn in global oil prices, exploration activities by both national and private oil companies in Türkiye declined significantly. This reduction in operations of E&P companies resulted in a corresponding decrease in demand for oilfield services, particularly those related to oil and gas drilling, as illustrated in Figure 8. This enabled the geothermal industry to capitalize on the availability of an experienced workforce and idle oilfield service capacity.

There are 11 primary contractors and service providers operating in the country, in addition to more than a dozen drilling rig companies and subcontractors. These entities are categorized by ownership, and their areas of specialization are presented in Appendix A. Their role in de-risking geothermal projects is discussed in the following section.

Turkish Electricity Market Structure

Türkiye's electricity market has undergone significant structural changes, particularly in its legal and regulatory framework, to increase private investment in the energy sector and meet growing demand. Historically, electricity utility services were provided directly by state-owned enterprises and similar government bodies to ensure fair prices and quality in a market of critical sensitivity. Over time, however, this approach resulted in inefficiencies that placed an excessive burden on the government. In addition, the lack of competition, a fundamental feature of network economies, meant that the electricity supply chain was never as effective as it could have been. To address these challenges, the state opted to privatize and liberalize electricity utilities (Karamustafaoğlu 2021).

The electricity market in Türkiye currently operates under a quasi-liberalized structure, characterized by substantial private sector participation alongside strategic state oversight. Notably, large-scale hydropower plants remain excluded from the privatization program, allowing the government to retain a dominant share of generation capacity. This retained capacity enables the state to influence market dynamics, particularly by maintaining electricity prices within targeted thresholds aligned with macroeconomic and political objectives. By leveraging its control over hydropower assets, the government can moderate wholesale electricity prices even amid rising natural gas costs. As a result, market prices may remain relatively stable despite fluctuations in global energy markets (Acar, Selçuk, and Dastan 2019).

Despite liberalization, the state continues to maintain a presence in the sector through entities such as the Turkish Electricity Generation Company (EÜAŞ), the principal state-owned enterprise responsible for a substantial share of thermal and hydropower generation. EÜAŞ functions as a stabilizing force in the market, helping to ensure supply security, particularly during periods of volatility or market imbalance.

The state also guides the sector through regulatory frameworks and incentive programs to ensure system stability and advance broader energy policy objectives. Institutions such as the Energy Market Regulatory Authority (EMRA) oversee licensing, tariffs, and market behavior, seeking to maintain a competitive yet orderly market environment (see Figure 9).

Türkiye's electricity demand has seen consistent growth, fueled by demographic expansion, rapid urbanization, and increased industrial and infrastructure development. This rising demand has required continuous investment in electricity infrastructure, particularly in transmission and distribution networks. Modernizing the national grid, expanding access to underserved

Figure 9. Electricity market structure after the electricity market law (No. 6446) in 2001.

MENR	EMRA	TEİAŞ	EÜAŞ	EXIST	YEGM
• Strategy and policy maker • The Ministry of Energy and Natural Resources is the main governmental body responsible for carrying out energy-related policies	• Independent regulator • The Energy Market Regulatory Authority is responsible for regulating and supervising the electricity, natural gas, and oil markets • It oversees the Renewable Energy Resources Support Mechanism (YEKDEM), which supports the integration of domestic and renewable energy through feed-in tariffs and other incentives	• Transmission operator • The Turkish Electricity Transmission Company is the state-owned monopoly that owns and operates electricity transmission market in the Republic	• Public generation • The Electricity Generation Company owns and operates the state-owned power plants and following July 2018 also took over the wholesale trading responsibilities of TETAŞ (former state -owned whole sale electricity company)	• Market operator • The Istanbul Energy Exchange is the market operator responsible for operating the day-ahead, intra-day and balancing markets in the country, and has managed the eligible consumers in the spot markets since March 18, 2015.	• Renewable energy promotion • The Renewable Energy Directorate (YEGM) focuses on promoting and developing renewable energy projects and technologies

Source: Modified from Invest.gov.tr (2023).

regions, and integrating new generation sources, especially renewables, have become key priorities. In this evolving landscape, municipalities and private sector actors have assumed a greater role in generation and distribution activities, contributing to a more decentralized and diversified electricity sector that is better positioned to respond to local and national energy needs (Aslan and İyikul 2023).

Rewiring the Grid: Türkiye's Energy Sector Transformation

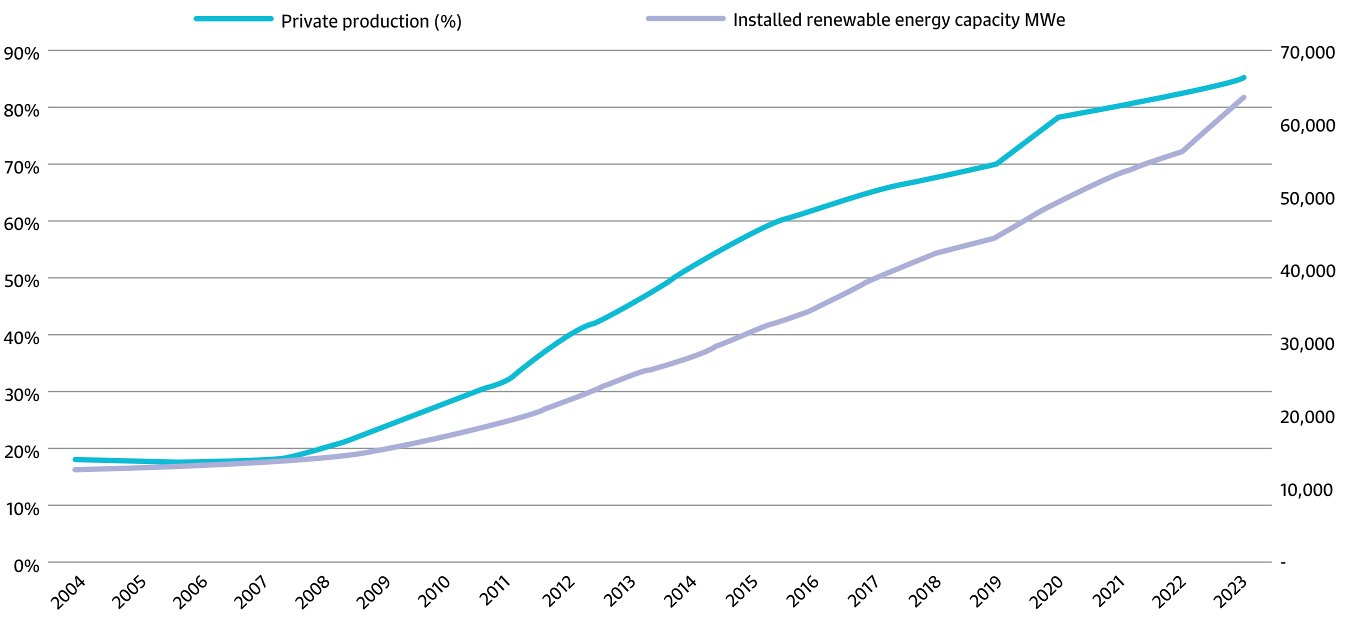
Following the 2001 economic crisis, Türkiye implemented a comprehensive set of structural reforms under the auspices of the International Monetary Fund (IMF) and the World Bank. These reforms were primarily aimed at stabilizing the macroeconomic environment, curbing inflation, strengthening the financial sector, and fostering a more liberalized and competitive market economy to attract foreign investment. As a candidate for EU membership, Türkiye was required to align its legal and regulatory frameworks with the acquis communautaire. This process involved adopting EU directives related to competition policy, energy market liberalization, and public procurement. As a result, previously state-dominated sectors, including electricity, natural gas, and telecommunications, were progressively opened to market competition.

A central component of this agenda was the liberalization of the energy market, which entailed the privatization of state-owned energy enterprises and the establishment of independent regulatory institutions. These measures aimed to reduce state intervention, promote transparency, and encourage private sector participation, thereby aligning the sector with international best practices and improving overall efficiency.

The success of this approach is reflected in the steady rise in private sector participation in electricity generation over the past two decades. An upward trend in power generation has been sustained during this period, as illustrated in Figure 10. Notably, between 2013 and 2023, Türkiye recorded the highest net geothermal power capacity additions globally (IEA 2024), underscoring the effectiveness of its energy strategies and market liberalization reforms.

It is important to note that a progressive and evolving regulatory and policy framework has driven Türkiye's increased integration of geothermal energy into its power mix. The liberalization of the energy market facilitated the entry of private actors into a sector previously dominated by state-owned enterprises. Encouraged by improved market access and supportive regulations, private firms have made significant contributions to renewable energy development, promoting a more diversified and sustainable energy mix (outlined below).

Figure 10. Private production share in the electricity market in % and renewable energy capacity in GWh.



Source: Analysis based on EPDK (2023) and Bulut (2024).

Opening the Grid: Foundations of Electricity Market Reform

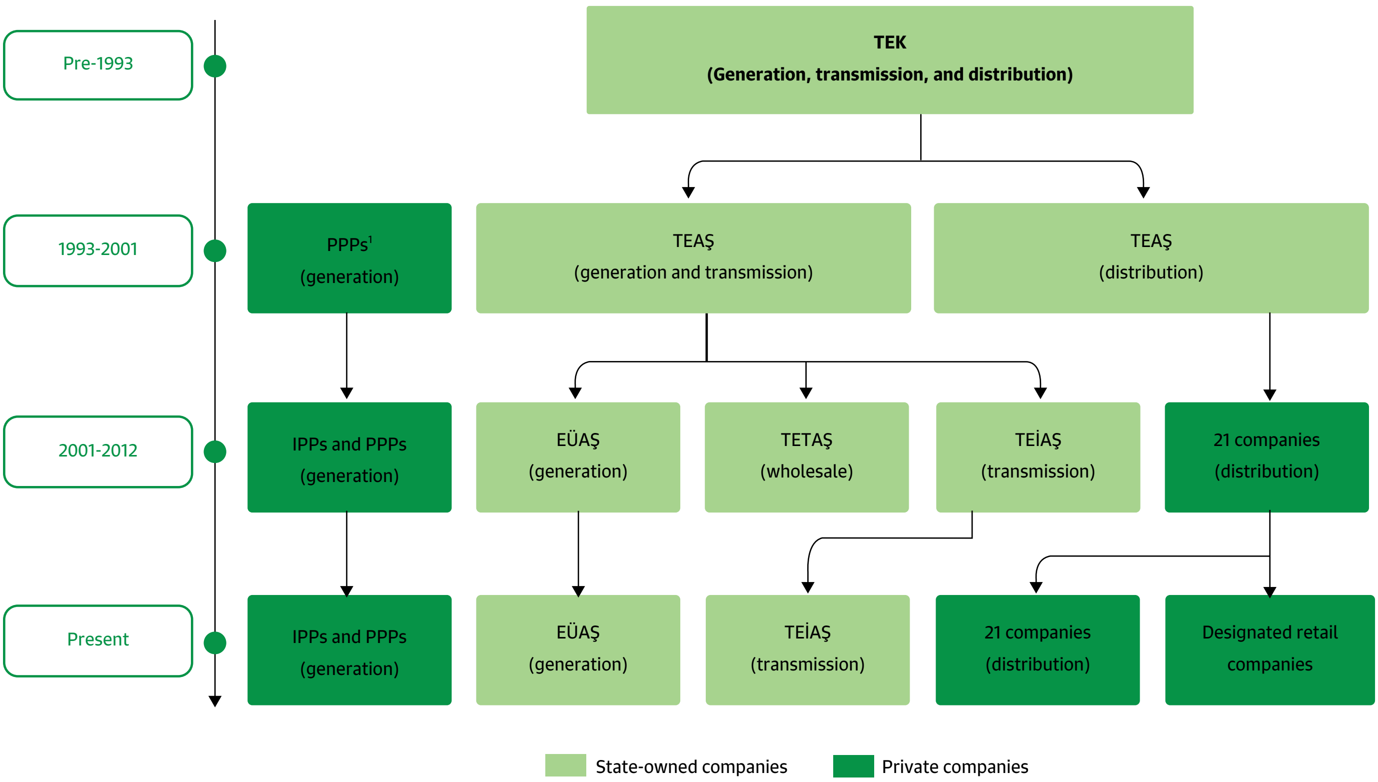
Prior to the 1980s, the Turkish Electricity Authority (TEK) held a monopoly over electricity generation, transmission, and distribution. In the early 1980s, Türkiye began liberalizing its electricity market in line with global trends toward privatization and deregulation to improve sectoral efficiency and competitiveness. Between 1984 and 1997, key legislation was enacted to attract private investment, introducing financing models such as build-operate-transfer (BOT) and transfer of operating rights.

In 1993, TEK was unbundled into the Turkish Electricity Generation and Transmission Company (TEAŞ) and the Turkish Electricity Distribution Company (TEDAŞ), marking an effort to separate operational functions and expand private sector participation. Despite these reforms, early privatization efforts faced implementation challenges and did not immediately attract the anticipated level of investment. Nevertheless, between 1996 and 2006, approximately 9,200 GWe of new capacity, primarily from natural gas, coal, and hydropower sources, was commissioned under these models (see Figures 2 and 11) (Şener and Uluca 2009).

From Monopoly to Market: Law No. 4628 and the Birth of the Energy Market Regulatory Authority

As part of the shift toward a quasi-liberalized electricity market, as outlined earlier, and in response to the need to align domestic regulations with EU legislation during accession negotiations, Law No. 4628 was enacted and entered into force on March 3, 2001. The law's primary objective was to liberalize the electricity market by removing legal barriers and enabling competition in

Figure 11. The evolution of the electricity market governance in Türkiye.



Source: Aslan and İyikul (2023).

electricity generation and retail sales. It regulated electricity generation, transmission, distribution, wholesale, import, and export activities, as well as the rights and obligations of entities operating in these segments, thereby establishing the foundations for a stable and competitive electricity market (Karamustafaoğlu 2021).

Henceforth, the electricity market was restructured by unbundling generation, transmission, and wholesale trading activities into distinct entities (see Figure 11):

- Electricity Generation Company (EÜAŞ)
- Turkish Electricity Transmission Company (TEİAŞ)
- Turkish Electricity Trade and Contracting Company (TETAŞ) (dissolved in 2018)

The law also established EMRA to regulate, supervise, and license market participants. It laid the foundation for a competitive market by introducing a balancing mechanism and enabling bilateral agreements (Aslan and İyikul 2023).

Toward Market Maturity: Law No. 6446 and Energy Exchange Istanbul

The new Electricity Market Law No. 6446 entered into force in early 2013. This law repealed all provisions of the previous Law No. 4628, except for the provisions of EMRA's organization, powers, and duties, and introduced new regulations.

With this law, Energy Exchange Istanbul (EXIST), officially known as Enerji Piyasaları İşletme A.Ş. (EPİAŞ), was established under Electricity Market Law No. 6446 in accordance with the Turkish Commercial Code and private law provisions (see Figure 9). Its creation marked a significant step in the liberalization and modernization of Türkiye's energy sector.

EPİAŞ was entrusted with managing and operating organized wholesale electricity markets, including the Day-Ahead Market, the Intraday Market, and the Power Futures Market. In addition to market operations, EPİAŞ is responsible for conducting financial settlement transactions within these markets and managing related financial activities. Collectively, these responsibilities are defined under the law as "market operating activities" (EPİAŞ 2025).

Today, EMRA continues to regulate market operations and promote competition, while TEİAŞ manages the national transmission grid and regional distribution companies are responsible for electricity distribution. In addition, EMRA oversees the Renewable Energy Resources Support Mechanism (YEKDEM), which supports the integration of domestic and renewable energy through feed-in tariffs and other incentives, thereby advancing the country's energy transition objectives (see Figures 5 and 10).

Countries seeking to exploit geothermal energy for power generation can benefit from decentralizing their electricity markets, as demonstrated by Türkiye's gradual liberalization, which enhanced competition, attracted private investment, and facilitated renewable energy integration. However, decentralization is not a one-size-fits-all solution. Governments must carefully design regulatory frameworks to govern the sector and establish transparent pricing mechanisms and policy levers that encourage investment in geothermal projects.

Enabling Bankability: Feed-in Tariffs and Financial Incentives

Türkiye introduced a suite of financial mechanisms to attract private investment in renewable energy. These instruments were designed not only to diversify the energy mix and reduce reliance on imported fossil fuels but also to enhance the bankability of renewable projects. Central to these efforts is YEKDEM, an incentive-based system that has played a pivotal role in reducing remuneration risk, strengthening investor confidence, and accelerating deployment across multiple renewable energy technologies, including geothermal energy (see Table 1) (Korkmaz and Önöz 2022).

YEKDEM was introduced as part of Türkiye's broader strategy to diversify its energy mix and enhance energy security. The enactment of Renewable Energy Law No. 5346 in 2005 laid the foundation for renewable energy support mechanisms. However, the initial feed-in tariffs, denominated in Turkish lira, were relatively low and did not attract significant investor interest. The incentive scheme has since evolved in response to economic and market dynamics, as follows:

- **Phase I:** Recognizing these limitations, policymakers revised the framework in 2011 by introducing an updated YEKDEM scheme that offered U.S. dollar-denominated tariffs differentiated by technology type, along with a 10-year purchase guarantee. This shift was intended to provide investors with predictable returns. In addition, a five-year local content premium was introduced to encourage the use of domestically manufactured equipment and stimulate the development of a national renewable energy supply chain. As a result of the favorable feed-in tariff, geothermal drilling activity increased from 2,000 meters per year in 2004 to 28,000 meters per year in 2018 (Aydın and Şentürk 2020). Over time, the YEKDEM system has undergone several amendments to align with evolving market conditions. A summary of major YEKDEM updates is presented in Table 1.

- **Phase II:** Following the conclusion of the 10-year support period under the previous scheme, a new support mechanism was introduced in 2021 with comparatively less attractive incentives. This mechanism applies to renewable energy power plants commissioned between July 1, 2021, and December 31, 2025. Under the revised framework, feed-in tariffs and the local content premium are denominated in Turkish lira (₺) and adjusted quarterly in January, April, July, and October based on a predetermined formula. The transition aimed to reduce the fiscal burden on the state and improve cost efficiency in the renewable energy sector. However, sustaining further geothermal development will require new exploration initiatives in under-investigated regions that have received limited public exploration support. These areas entail higher geological risks and uncertainty, necessitating more extensive geoscientific research. Furthermore, comparatively less attractive feed-in tariffs, combined with the obligation for private investors to assume exploration costs and associated risks, have constrained investment and slowed sectoral expansion (Munyar and Kındap 2024).

- **Phase III:** As of year-end 2023, in response to stagnation in geothermal development, the support period was extended to 15 years and the tariff structure was adjusted on a monthly basis to better reflect inflation and currency depreciation. The tariff for geothermal energy was revised to $0.0945 per kWh, with a cap of $0.1155 per kWh. These revisions were intended to reinvigorate geothermal investment. However, as noted by the IEA (2021), access to affordable financing remains a persistent challenge due to currency depreciation and high interest rates (see Table 1 and Figure 12).

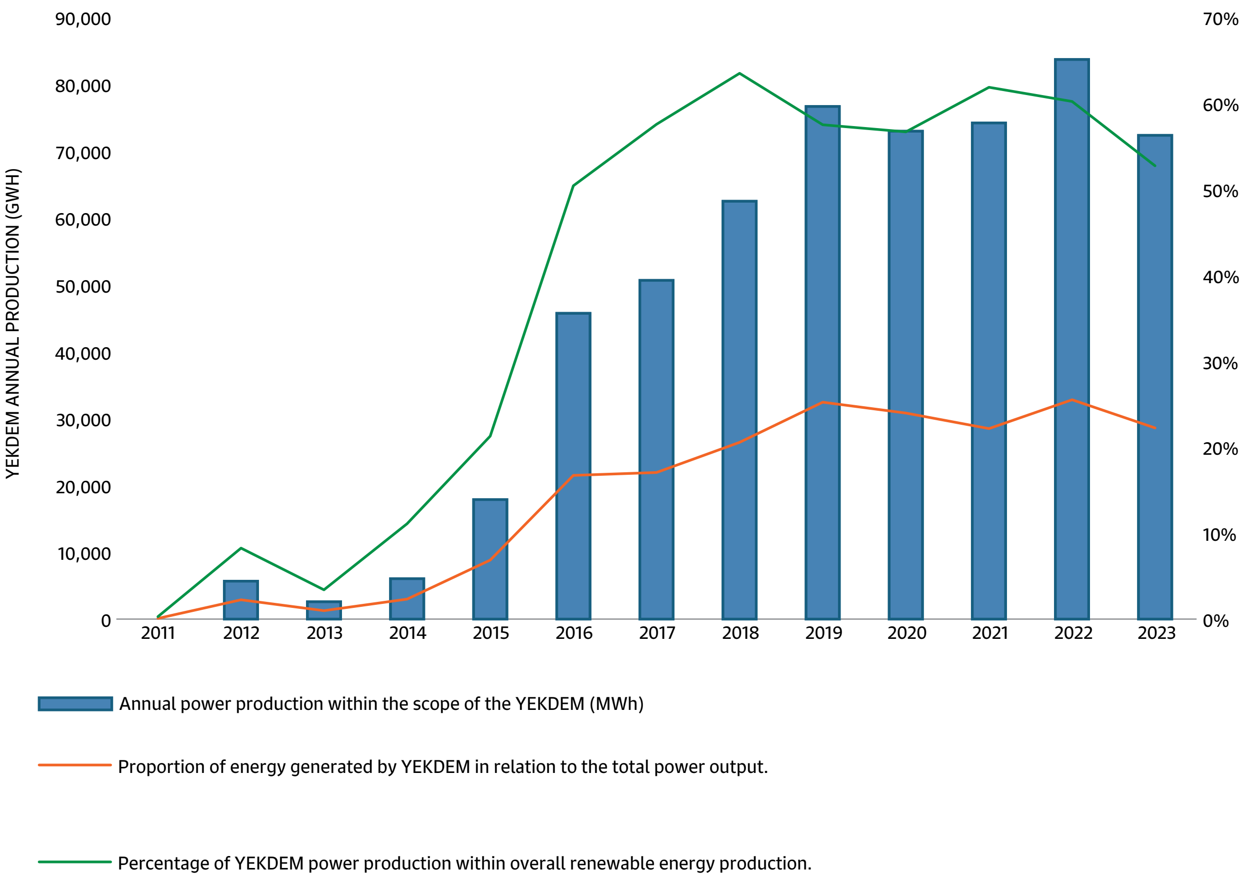
Additionally, the introduction of incentives for locally manufactured equipment catalyzed the development of a robust domestic manufacturing base to support the renewable energy industry. YEKDEM has contributed to the establishment of 126 primary suppliers and approximately 500 sub-suppliers, resulting in the creation of 50,000 jobs and the development of in-house technical expertise. By 2024, an estimated 65% of geothermal power plant components are locally produced (Albayrak 2024).

Table 1. Evolution of the feed-in-tariffs and other incentives for geothermal power generation.

Year	Currency	Purchase period	Feed-in tariff base price	Cap price	Domestically manufactured equipment use bonus	Bonus period	Validity
2011	U.S. dollars ($)	10 years	$0.105 /kWh	–	$0.027/kWh	5 years	Plants commissioned before June 2021
2021	Quarterly adjusted to ₺	10 years	–	0.086$/kWh	₺0.08/kWh	5 years	Plants commissioned until December 2025
2023	Monthly adjusted to ₺	15 years	$0.0945/kWh	0.1155$/kWh	₺0.4308/kWh	5 years	Plants commissioned between 2021 and 2030

Source: Analysis based on EPDK (2025a).

Figure 12. Impact of YEKDEM on Türkiye's power production over the years.



Source: Albayrak (2024).

For countries seeking to exploit geothermal resources, it is essential to establish independent regulatory authorities or strengthen existing ones to ensure fair market competition. Such authorities can oversee the unbundling of generation, transmission, and distribution, thereby reducing conflicts of interest, improving efficiency, and facilitating the entry of new market participants.

The choice among feed-in tariffs, power purchase agreements, and contracts for differences depends on national market structures. Regardless of the mechanism adopted, support schemes should be periodically revised to reflect macroeconomic conditions. When a robust and adaptable financial model is in place, market proliferation is more likely to occur.

Under the current scheme in Türkiye, credit loan structures are based on projected capacity factors multiplied by fixed tariffs over a guaranteed period, providing a predictable revenue stream for investors. This structure enables lenders to assess repayment schedules and credit servicing requirements with greater accuracy.

The current incentive plan applies only to power plants commissioned between 2021 and 2030. However, considering the time required to establish a geothermal power plant, which includes proper evaluation of the reservoir, exploration activities, bureaucratic processes, land acquisition, and construction, the project timeline can be estimated at a minimum of five years.

According to the Geothermal Energy Association (Jeotermal Enerji Derneği, JED), the 2030 deadline appears insufficient to stimulate sustained interest in geothermal energy. Additionally, given the relatively long return on investment associated with geothermal projects, producers have indicated that a 20-year purchase period would provide stronger support for industry development (Munyar and Kındap 2024).

Additional Incentives for Renewable Energy Investments

In addition to feed-in tariffs and purchase guarantees, incentives for renewable energy use in power generation include grid connection priority, reduced licensing fees, license exemptions in exceptional circumstances, and various procedural facilitations related to project preparation and land acquisition (Aydın and Şentürk 2020).

Türkiye also offers general investment incentives applicable to a wide range of energy and industrial projects, including renewables. Although there are no tax exemptions specific to renewable energy, investors can benefit from a comprehensive package of fiscal support that reduces both capital and operational expenditures (KPMG 2016; Ulusoy and Dastan 2018). These incentives include:

- **Value-added tax exemption**: Exemption from VAT on the procurement of domestic and imported investment equipment. VAT on such equipment typically ranges from 10% to 20%.
- **Customs duty exemption**: Exemption from customs duties on imported investment equipment used in renewable energy projects. Applicable duty rates normally vary by equipment type and country of origin.
- **Exemption from additional funds and fees**: Power plants that became operational before December 31, 2020, are eligible for an 85% discount on land lease and usage rights related to energy infrastructure for a period of 10 years.
- **Stamp duty and transaction fee exemption**: Exemptions apply to documents and transactions executed during the investment phase of power plant development.
- **Transmission fee discount**: A 50% discount on transmission system usage fees is granted for five years from the start of commercial operations.

Broad-based fiscal and investment incentives can strongly support the bankability of geothermal projects and support the expansion of geothermal energy. Investment-friendly policies that target financial bottlenecks across multiple stages, including procurement, construction, and operation, can accelerate project deployment and encourage greater private sector participation.

Investment and Access to Capital

Türkiye's economy grew at an average annual rate of 5.6% between 2002 and 2018. During this period, the total financing volume increased tenfold to $563 billion. Bank loans accounted for 40% of all fixed capital investment, including those in the energy sector. Between 2002 and 2018, total energy demand increased by more than 90%, driving substantial investment in energy infrastructure and higher energy imports. Over the same period, the private sector's share of electricity generation rose from 32% in 2002 to 75% by the end of 2018 (Shura 2019).

Significant experience has been accumulated at both national and international levels in financing energy sector investments through a range of sources and models. However, the rapid depreciation of the Turkish lira since mid-2018, as discussed earlier, has increased economic uncertainty and disrupted long-term planning. To advance the energy transition and address inherited challenges, it is essential to diversify financing options, leverage new technologies, and develop innovative financial models (Shura 2019).

Level and Scope of Investments

Geothermal energy development in Türkiye has attracted substantial investment over the past two decades, evolving from publicly led exploration to a predominantly private sector-driven model. Initially, the Turkish government played a direct role by fully funding exploration, drilling, and well testing activities, after which successful fields were leased to private developers (Serpen and DiPippo 2022). As the sector matured, all geothermal projects, including exploration phases, have been financed by private entities, with developers typically contributing around 20% in equity. The remaining financing has been sourced from a diverse mix of international funds, financial institutions, implementation agencies, and local commercial banks.

The scope of investments spans a wide range of project scales and applications, from large-scale electricity generation plants exceeding 100 MWe to small-scale direct-use applications such as greenhouse heating, district heating, and thermal tourism. Financial models are typically structured around projected capacity factors and loan repayment periods, supporting bankability and investor confidence. The sector has also benefited from blended finance structures that combine concessional loans, commercial credit lines, and technical assistance, enabling both large infrastructure projects and smaller, distributed energy systems.

Türkiye maintains strong relationships with multilateral and bilateral financing institutions, notably the IMF, World Bank, and the European Bank for Reconstruction and Development (EBRD), to support its economic and energy transitions. These partnerships have been driven by the need to stabilize the economy following periods of inflation, currency volatility, and fiscal deficits. Türkiye has received multiple IMF loans, especially during economic crises, most notably in 2001, which led to significant structural reforms, including reforms in the energy sector.

The economic crisis of the early 2000s marked a turning point for Türkiye. The country adopted pro-market and pro-EU policies, and its commitment to renewable energy, alignment with EU agreements, and steady economic growth between 2002 and 2018 created a more stable environment for financing renewable energy projects.

Bilateral and Multilateral Funding Sources

Multilateral development finance institutions and international export credit agencies have played a pivotal role in financing Türkiye's energy transition in recent years, mobilizing investment capital through a diverse range of channels (see Appendix B), including:

- World Bank and EBRD, which offered geothermal-specific financing frameworks.
- Foreign export-import (Ex-Im) banks, which primarily supported equipment and technology imports.
- Local commercial banks, which provided tailored credit lines under programs such as the Sustainable Energy Financing Facilities (SEEF).

Multilateral development finance institutions have contributed significantly to the policy framework at the outset of the transition process and guided domestic financial institutions in developing project appraisal capacity. They have also directly financed investments by energy companies and public enterprises and provided funding through Türkiye's local banks (Shura 2019). In addition, they have partnered with national intermediaries such as the Industrial Development Bank of Türkiye (TSKB) and the Development and Investment Bank of Türkiye (TKYB), which act as implementing agencies by disbursing funds, conducting due diligence, and providing assistance to project developers throughout the investment cycle.

The second-largest source of financing consisted of country loans from international export finance institutions, working in conjunction with technology suppliers from their respective countries. The volume of financing from these institutions, provided under guarantees by local banks or through joint financing arrangements, increased following the introduction of renewable energy incentives and the strengthening of local banks' institutional capacity (Shura 2019).

In addition to deploying their own untied funds, local financial institutions, including development banks and public and private commercial banks, have raised capital from international financial markets through syndicated loans and bond issuances, as well as through funding from international development finance institutions and export credit agencies. Leasing institutions have also begun to serve as alternatives to banks for unlicensed solar energy projects, while participation banks, which rely on alternative funding sources, have assumed a more prominent role (Shura 2019).

Key Institutions' Role in Geothermal Financing

World Bank – Geothermal Development Program

Launched in 2016 and expanded with additional funding in 2021, the Türkiye Geothermal Development Project aims to increase private sector investment in geothermal energy development. The project comprises two main components.

1. **Risk-sharing mechanism**: Designed to mitigate the high resource risk associated with early-stage geothermal exploration by providing partial cost recovery for unsuccessful wells. Historically, many geothermal fields in Türkiye were initially explored by the General Directorate of Mineral Research and Exploration, whose efforts significantly reduced resource uncertainty. However, following the enactment of Geothermal Law No. 5686 in 2007, exploration responsibilities shifted to the private sector, resulting in a noticeable slowdown in new geothermal exploration activities. This decline is primarily attributable to the high financial risk associated with exploration drilling, which private developers must bear. The challenge is further compounded by the limited availability of commercial financing for early-stage projects, as most lenders require resource confirmation before extending credit. To address this gap, the World Bank's geothermal loan program has been implemented in Türkiye through TKYB, providing targeted financial support to de-risk exploration and stimulate private sector participation. The program includes a $39.8 million grant from the Clean Technology Fund. Two rounds have been completed to date, benefiting six exploration wells, and the third and fourth rounds are expected to conclude by 2027.
2. **Loan facility for resource development**: This component of the Türkiye Geothermal Development Project provides debt financing to private developers for key stages of geothermal project development, including capacity drilling, reservoir development, and power plant construction. The financing totals $316 million, comprising $250 million from the World Bank and $66 million in co-financing from TSKB and TKYB. Funds are delivered through intermediary banks, namely TSKB and TKYB, with the guarantee of the Republic

of Türkiye. These banks offer loans at market rates but with longer repayment periods than typically available, helping to close the financing gap faced by license holders during the most capital-intensive phases of geothermal development (World Bank Group 2025).

3. **ESMAP grant program for geothermal direct-use projects**: Within the scope of the Geothermal Development Project Additional Financing (GDP-AF), the Energy Sector Management Assistance Program (ESMAP) has provided a grant to finance a new technical assistance subcomponent supporting feasibility assessments for geothermal direct-use projects. The total amount of the grant is $350,000, and eligible geothermal developers may receive up to 50% of the estimated cost of the proposed studies, with a limit of $50,000 per project. The grant is implemented by TKYB. The main objective of the ESMAP grant program is to provide potential geothermal developers with technical assistance through on-demand support for the preparation of pre-feasibility studies and market analyses and the development of business plans or feasibility studies for geothermal direct-use investments, such as greenhouse heating, district heating, and balneological or thermal tourism facilities. The program also aims to increase women's representation in both technical and nontechnical roles within geothermal companies, which is one of the eligibility requirements (ESMAP 2025).

European Bank for Reconstruction and Development

EBRD has played a pivotal role in financing geothermal energy development in Türkiye. The bank has supported the sector in three main areas:

1. **Policy dialogue**: The National Renewable Energy Action Plan for 2013-2023, supported by EBRD, this plan outlines sectoral targets, feed-in tariffs, and licensing reforms aimed at encouraging renewable energy investment.

2. **Technical assistance**: The EBRD has supported Türkiye's geothermal sector through targeted technical assistance focused on industry best practices, market analysis, and environmental safeguards. This support includes reviewing the country's geothermal potential, assisting developers with early-stage project planning, and ensuring compliance with international environmental standards. Initiatives such as the Private Sector Early-Stage Geothermal Development Framework (PLUTO) have provided risk-sharing tools and advisory services to encourage sustainable and bankable geothermal investments. PLUTO is a financing initiative launched in collaboration with the Clean Technology Fund (CTF) in 2016, with the objective of mitigating the high financial risks associated with early-stage geothermal exploration in Türkiye. The framework has a total funding envelope of $125 million, comprising $100 million from the EBRD and $25 million in concessional finance from the CTF. PLUTO is structured in two phases. The first phase provides concessional loans to support exploratory drilling and resource confirmation, while the second phase offers commercial financing for geothermal power plant construction once the resource has been proven (Herrera-Martinez 2017).

3. **Financial instruments**: The European Bank for Reconstruction and Development (EBRD) has invested more than €22 billion in Türkiye since 2009 across 484 projects, with the majority of funding directed toward the private sector and green initiatives (EBRD 2025). The bank offers a range of financial instruments tailored to project scale, including direct financing for large-scale developments, syndicated loans and co-financing arrangements, concessional funding from climate-related sources, and support for small-scale geothermal initiatives through SEFF. By 2018, EBRD had directly invested in eight geothermal projects, contributing to a total installed capacity of approximately 479 MWe (Herrera-Martinez 2017).

Development and Investment Bank of Türkiye

Established nearly half a century ago, TKYB has played a pivotal role in financing projects that support Türkiye's industrial development, energy transition, infrastructure expansion, and sustainability objectives. As a state-owned development bank, TKYB has been instrumental in channeling international climate finance into the Turkish economy, with a strong focus on the renewable energy sector. The bank maintains a long-standing partnership with the World Bank and serves as an implementing agency for major initiatives such as the Türkiye Geothermal Development Project and the Türkiye Emission Reduction Project. Through these collaborations, TKYB facilitates access to concessional and long-term financing for private-sector developers, helping to bridge the investment gap in early-stage and capital-intensive clean energy projects.

In addition to its collaboration with the World Bank, TKYB has partnered with a range of international financial institutions to mobilize funding for renewable energy and energy efficiency initiatives, including geothermal development. TKYB has established agreements with development agencies such as the European Investment Bank, Islamic Development Bank, Industrial and Commercial Bank of China, Japan Bank for International Cooperation, Council of Europe Development Bank, German Development Bank, Agence Française de Développement, and China Development Bank. On December 10, 2019, TKYB secured its first loan from the Asian Infrastructure Investment Bank, amounting to $200 million, to support investments in renewable energy and energy efficiency. TKYB also serves as the implementing agency for climate finance facilities, including a loan facility funded by the German Development Bank and a grant facility supported by the International Climate Initiative, further reinforcing its role in advancing Türkiye's clean energy transition (Development Bank of Türkiye 2025).

Through these mechanisms, TKYB effectively connects international funding sources with local private sector actors, offering financing solutions that are otherwise limited in the Turkish market (Development Bank of Türkiye 2025).

Industrial Development Bank of Türkiye (TSKB)

Founded in 1950 with the support of the World Bank, TSKB has maintained a close partnership with the International Bank for Reconstruction and Development. Since its establishment, TSKB has continued to collaborate with the World Bank in financing projects across various sectors, contributing added value to the Turkish economy. TSKB has partnered with the World Bank, EBRD, European Investment Bank, European Investment Fund, German Development Bank, and other multilateral institutions to channel funding into geothermal projects. It co-manages the Türkiye Geothermal Development Project alongside TKYB. Under this program, TSKB provides long-term loans to private developers for drilling, reservoir development, and power plant construction, helping to bridge the financing gap in early- and mid-stage geothermal development.

TSKB has also integrated environmental and social risk evaluation tools into its lending practices, ensuring that geothermal projects meet sustainability and compliance standards. In recent years, more than 70% of TSKB's loan portfolio has been aligned with sustainability goals, including significant contributions to Türkiye's installed renewable energy capacity, such as hydropower and geothermal (TSKB 2025).

Impact of These Investments

- Risk mitigation and financial leverage:
  - Funding from multilateral and bilateral sources has significantly mitigated the financial risks associated with geothermal exploration and development. By providing concessional loans, grants, and equity investments, these sources have enhanced the financial viability of geothermal projects.
  - Leveraging funds from these institutions has also attracted private sector investment, creating a multiplier effect that increases the overall capital available for geothermal development.

- Capacity building and technical assistance:
  - Beyond financial support, these funding sources provide technical assistance and capacity-building programs that are essential for developing local expertise and advancing geothermal technologies.
  - Training programs, workshops, and knowledge exchange initiatives have strengthened the technical skills of local stakeholders, supporting the sustainable and efficient operation of geothermal projects.

- Policy and regulatory support:
  - Multilateral and bilateral donors have been crucial in supporting policy reforms and regulatory improvements in Türkiye's geothermal sector. Their involvement has helped create a conducive environment for investment and development.
  - Technical assistance in policy formulation and implementation has strengthened the regulatory framework, ensuring transparency, efficiency, and sustainability in geothermal development.

Despite having one of the lowest levelized costs of electricity, geothermal projects are capital-intensive and typically have long payback periods (Alsuwailem et al. 2024). Concessional finance, grants, and equity from multilateral and bilateral institutions reduce risks and enhance bankability throughout the project lifecycle, while also attracting private sector capital through leverage and multiplier effects.

Beyond funding, international partners provide technical assistance, capacity building, and policy support, thereby strengthening local expertise, enhancing regulatory frameworks for greenfield projects, and fostering a more transparent and sustainable investment environment.

In the case of Türkiye, it is important to note that foreign direct investment functioned not merely as energy financing but also as a macroeconomic stabilizer. These financial institutions formed a collaborative ecosystem that blended concessional finance, risk-sharing instruments, and policy advisory services.

Geothermal Legal Framework and Institutional Foundations

The legal framework governing geothermal energy in Türkiye was formally established in 2007 with the enactment of Law No. 5686 on Geothermal Resources and Natural Mineral Waters. Prior to this legislation, geothermal exploration activities were primarily conducted by the General Directorate of Mineral Research and Exploration (MTA). These activities were carried out under the authority of the Ministry of Energy and Natural Resources and the State Planning Organization, in accordance with approved investment plans and annual work programs. The introduction of the law aimed to establish a clear legal and administrative framework to facilitate private sector participation by reducing bureaucratic barriers and clarifying licensing procedures. A key objective was to streamline institutional responsibilities and governance across the geothermal project lifecycle.

Three principal government entities, provincial authorities, MTA, and the General Directorate of Mining and Petroleum Affairs, play critical roles in the exploration, development, and utilization of geothermal resources. The following sections provide a detailed examination of these institutions and their respective mandates within Türkiye's geothermal energy sector under the Geothermal Resources and Natural Mineral Waters Law (Law No. 5686).

Enacted in 2007, Law No. 5686 on Geothermal Resources and Natural Mineral Waters, together with its implementing regulation No. 26727, outlines the procedures and principles governing the exploration, development, production, and protection of geothermal and natural mineral water resources. The law defines the legal framework for resource rights, environmental compatibility, abandonment, licensing, ownership, governance, sanctions, and the roles and responsibilities of administrative and governmental bodies. It aimed to promote the use of renewable energy sources for electricity production and represents a major milestone in Türkiye's renewable energy policy framework. The law incorporated multiple incentives, including feed-in and purchase guarantees, as well as priority grid connections for renewable energy plants.

General Directorate of Mineral Research and Exploration

MTA is a publicly funded scientific organization affiliated with the Ministry of Energy and Natural Resources. The directorate has contributed to Türkiye's geothermal capacity and continues to promote research and development related to economic minerals and geothermal energy.

The modern development of Türkiye's geothermal sector was driven by state-led industrialization strategies in the Republic's early years. In the context of limited private capital, the state assumed responsibility for resource development. In 1935, the state established MTA to lead the systematic exploration of mineral and energy resources, including geothermal energy (Mertoğlu et al. 2024).

Starting in the 1960s, MTA initiated comprehensive geological, geophysical, and geochemical surveys that led to the identification of numerous geothermal fields. This work culminated in the construction of the first pilot geothermal power plant in 1974 at Kızıldere, in collaboration with the United Nations Development Programme. The plant had a modest capacity of 0.5 MWe. In 1986, Türkiye commissioned its first commercial geothermal power plant at Kızıldere, with an installed capacity of 20.4 MWe. Between 1970 and 2007, MTA discovered several low- to mid-enthalpy fields, enabling direct-use applications. Notable examples include the Balçova and Narlıdere fields near İzmir, which have been used for district heating and greenhouse cultivation (Mertoğlu et al. 2024). MTA also conducted geothermal surveys and exploration drilling in the western regions of the country, identifying several high- to mid-enthalpy fields suitable for power generation.

Until the enactment of Geothermal Law No. 5686 in 2007, MTA was the primary institution responsible for investigating and mapping geothermal resources across Türkiye, playing a central role in advancing geothermal exploration. The law also granted MTA the authority to tender explored and discovered fields to the private sector, generating additional budgetary resources for the directorate. Under this framework, geothermal fields identified by MTA were transferred to investors through a competitive tendering process. Between 2008 and 2015, MTA leased geothermal fields to the private sector for approximately $545 million (Dağıstan et al. 2015). Unlike many global counterparts, private geothermal investors in Türkiye were able to capitalize on MTA's extensive exploration efforts, benefiting from reduced subsurface uncertainty and enabling more efficient and cost-effective geothermal development.

MTA continues its exploration activities and, to facilitate this work, holds a special status for exploration licenses, as it is not required to pay license fees or down payments. Following discovery, licenses are auctioned to private investors. Auction revenues are used to cover exploration costs, with the remaining amount shared between the provincial administrative office and MTA (Dağıstan et al. 2015; MTA 2025b). MTA maintains its own drilling services department, encompassing logging, drilling, and rig operations. This institutional self-sufficiency enables the directorate to operate independently of external service providers and to generate additional revenue through the rental and provision of its services.

The directorate has a scientific advisory role to the Ministry of Energy and Natural Resources, as well as to other government bodies. It provides technical input for geothermal licensing, feasibility studies, and environmental assessments. Additionally, it oversees activities throughout the entire resource lifecycle, from exploration to operation and abandonment, ensuring compliance with international standards and environmental protection requirements. License holders are required to submit annual scientific research and operating reports to MTA. The directorate also provides scientific and technical support to geothermal applicants to safeguard the sustainability of geothermal production while maintaining reservoir productivity (Resmi Gazete 2007).

MTA is one of the main contributors to Türkiye's geothermal innovation ecosystem, supporting policy and investment decision-making. It contributes to scientific knowledge through the publication of geothermal maps and technical reports, collaboration with universities and research institutions, and the organization of national and international geothermal conferences. MTA also advises on geothermal projects and supports Türkiye's scientific community by employing young geoscientists and engineers and offering internships, training programs, and research opportunities. In addition, it collaborates with academic institutions on graduate research and provides scholarship opportunities.

In 2024, aligned with the country's energy strategy, the directorate's exploration budget reached a record high of $41 million, with a focus on coal, radioactive raw materials, and geothermal resources (Yanık 2024).

For new entrants, a designated government body responsible for conducting geological, geophysical, and geochemical studies of natural resources such as geothermal, minerals, and hydrocarbons is essential to advance geothermal development. Its core functions include mapping geological structures, assessing mineral and energy resources, monitoring seismic activity, drilling discovery wells, and providing data critical for land-use planning and environmental protection.

By integrating geological and geophysical data, this scientific and technical body can help mitigate risks associated with the exploration phase. Moreover, its collaboration with universities, international research institutions, and energy companies can accelerate the creation of a national geothermal database, support pilot projects, and inform regulatory and policy frameworks that enable the commercial use of geothermal resources.

General Directorate of Mining and Petroleum Affairs

Following the enactment of Law No. 5686 on Geothermal Resources and Natural Mineral Waters in 2007, provincial administrative authorities (İl Özel İdareleri) or Provincial Directorates of Investment Monitoring and Coordination (Valilik Yatırım İzleme ve Koordinasyon Başkanlığı) oversee the governance of geothermal resources. They are responsible for organizing public tenders (auctions) for geothermal resource licenses within their jurisdictions. These authorities work in coordination with the General Directorate of Mining and Petroleum Affairs to ensure that licensing processes are transparent, competitive, and aligned with national energy and environmental strategies (Resmi Gazete 2007).

Provincial Authorities

In metropolitan municipalities, geothermal licenses are issued by the Provincial Directorates of Investment Monitoring and Coordination (30 centers), while in non-metropolitan provinces they are issued by special provincial administration offices (51 centers). Provincial authorities oversee and regulate activities within licensed geothermal areas to ensure compliance with national legislation and operational standards. Their responsibilities include verifying that exploration and production activities align with approved project plans and comply with environmental regulations, occupational health and safety standards, and technical guidelines. They are also responsible for supervising site rehabilitation following extraction and ensuring that Environmental and Social Impact Assessments are conducted and implemented as required. Furthermore, provincial authorities maintain records and inventories of geothermal resources, including data on exploration, production, and resource potential.

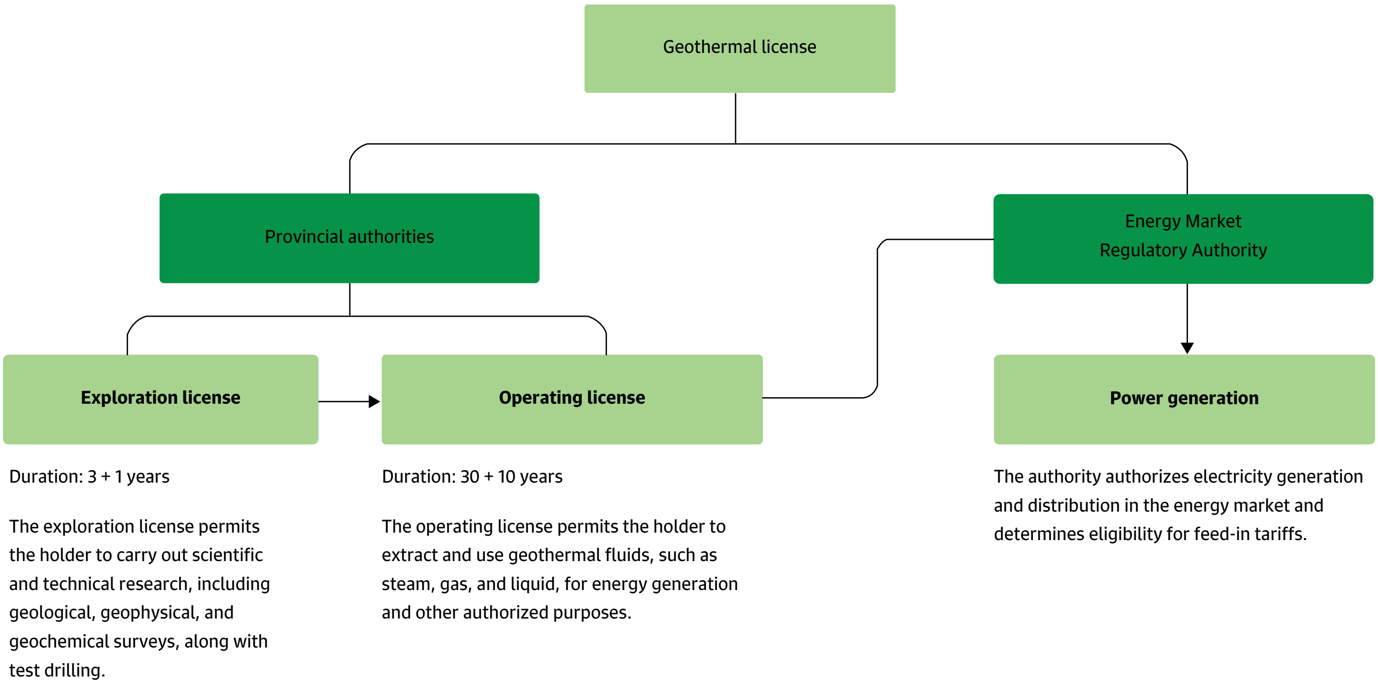
However, many local administrations lack the technical infrastructure and qualified personnel needed to carry out these duties effectively. This capacity gap often results in poor reservoir management, as discussed in subsequent sections. Combined with ineffective governance and insufficient measures for reservoir protection and suitability assessment, these shortcomings pose significant risks to the sustainable utilization of geothermal resources.

The lack of technical expertise to enforce environmental standards can significantly impact the livelihoods of local communities, leading to environmental degradation that fosters perceptions of injustice (Öztürk and Aydın 2025). These deficiencies often erode the “social license to operate” – the informal social approval of local stakeholders – which is increasingly recognized as critical to project success.

Geothermal License Types in Türkiye

There are three types of licenses in Türkiye for geothermal exploration, production, and power generation (see Figure 13).

Figure 13. Geothermal license types and their issuing authorities in Türkiye.



Source: Analysis based on Resmi Gazete (2007).

Exploration License

An exploration license is granted for an initial period of three years, with the possibility of a one-year extension upon justified request. This license authorizes the holder to conduct scientific and technical investigations, including geological, geophysical, and geochemical surveys, as well as test drilling. Limited-scale production is permitted solely for testing and evaluation purposes.

Throughout the exploration period, license holders are required to submit annual progress reports detailing their findings and activities. MTA and the relevant provincial administrative authority review these reports to assess the validity and credibility of the studies conducted.

At the conclusion of the exploration phase, the license must either be returned or converted into an operating license, subject to the submission and approval of a comprehensive development plan.

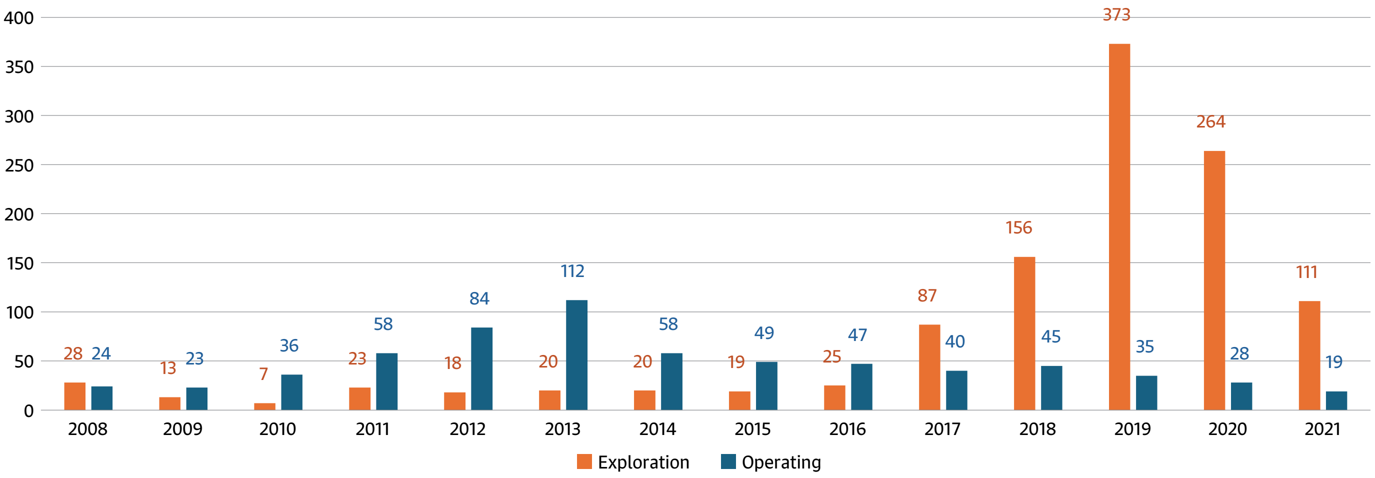
Operating License

An operating license is issued for a period of 30 years, with the possibility of a 10-year extension. The license grants the holder the right to extract and use geothermal fluids, including steam, gas, and liquid, for energy production and other approved uses.

License holders are required to submit a detailed operational plan, which must include:

- A strategy for sustainable resource management.
- An Environmental Impact Assessment (EIA). A simplified environmental assessment is sufficient for geothermal power plants with a capacity below 25%. Projects exceeding this threshold must submit full EIA reports to the Ministry of Environment, Urbanization, and Climate Change.
- Health and safety protocols.
- Measures for site rehabilitation and environmental protection.

Figure 14. Operating and exploration licenses issued over time, by type.



Source: Analysis based on MAPEG (2022).

These documents are submitted to the relevant provincial authority and to the Ministry of Environment, Urbanization, and Climate Change for review and compliance monitoring. Failure to comply with regulatory requirements, including reporting obligations and environmental safeguards, may result in license revocation by provincial authorities.

Over the years, several trends have emerged in the granting of geothermal licenses. Since 2008, the number of licenses issued for both exploration and operation has steadily increased, with a dominant focus on operating licenses until 2017. In subsequent years, however, exploration licenses rose sharply, surpassing operating licenses. This shift aligns with private industry efforts to leverage pre-explored fields and develop them for production.

After peaking in 2019, the number of exploration licenses began to decline, reflecting the macroeconomic challenges the country faced after 2019. Notably, of the exploration licenses granted between 2017 and 2021, only 20% were eventually converted into production licenses (see Figure 14).

Power Generation License

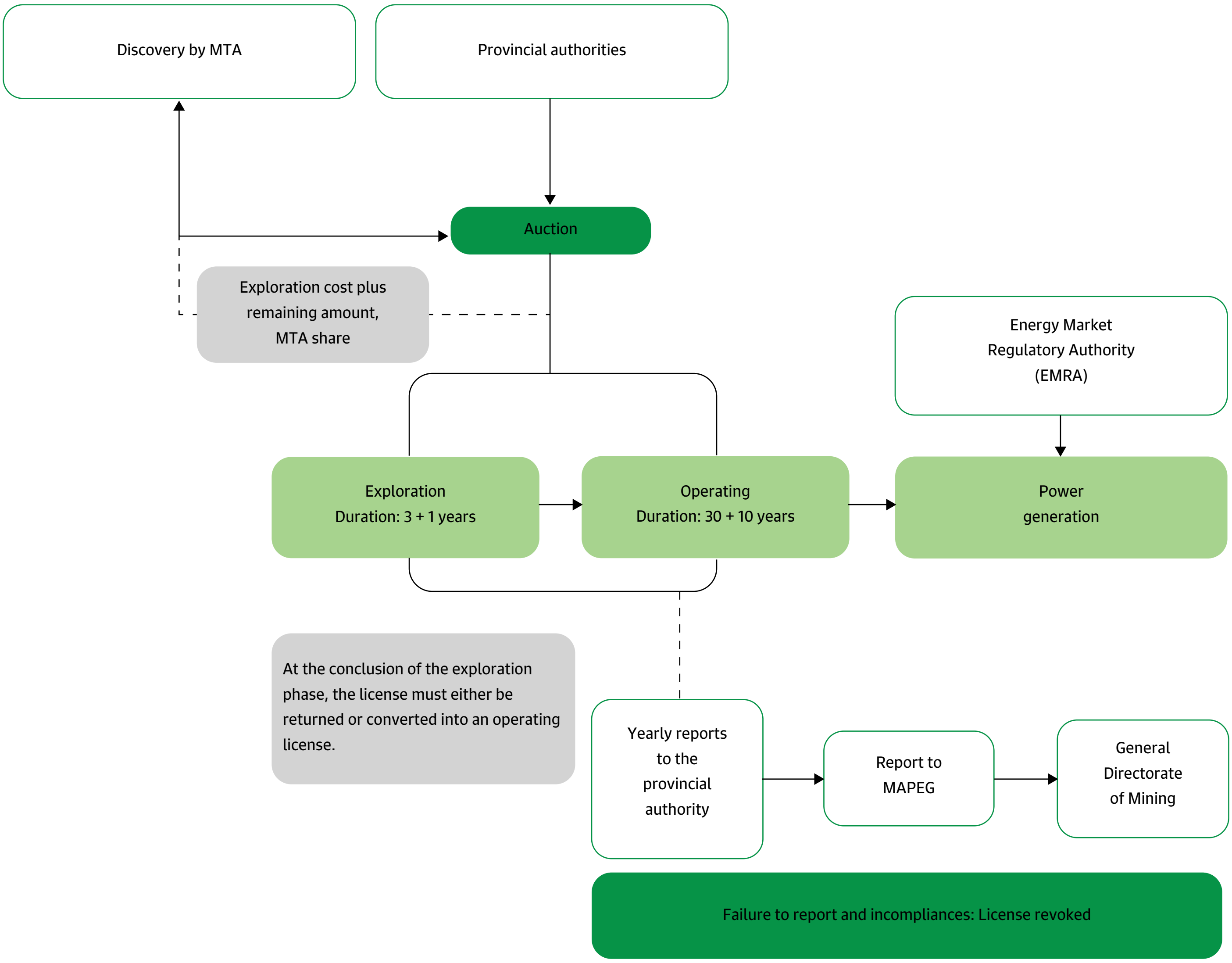
The process of obtaining an electricity generation license from the Energy Market Regulatory Authority (EMRA) begins after an operating license is obtained. Project developers are required to submit a comprehensive application to EMRA. The application is subject to administrative, technical, and financial reviews to verify compliance with national energy regulations and to confirm eligibility for feed-in tariffs. Once approved, a generation license is issued, permitting electricity production and sales within the energy market.

Geothermal Development Process in Türkiye

In Türkiye, the development of geothermal energy projects follows a structured, multistage licensing process governed by distinct regulatory authorities. The process begins with an auction conducted by provincial authorities or MTA for an exploration license. Upon successful completion of exploration activities and submission of the required technical reports, developers may apply for an operating license, which enables the commercial use of the geothermal resource.

Disputes between different types of energy licenses are resolved by the General Directorate of Mining and Petroleum Affairs (MAPEG) for petroleum licenses and by the Ministry of Energy and Natural Resources for other energy-related licenses. For electricity generation, a subsequent application must be submitted to EMRA to obtain a generation license. EMRA's role is to ensure that the project complies with national energy market regulations, including technical and legal standards for electricity production. This stage involves the evaluation of grid connection approvals, verification of tariff eligibility under the feed-in tariff mechanism, and alignment with broader energy policy objectives. The generation license formalizes the project's right to produce and sell electricity within Türkiye's liberalized energy market. A summary of the procedural flow is presented in Figure 15.

Figure 15. Geothermal licensing system and regulatory oversight in Türkiye.



Source: Analysis based on Resmi Gazete (2007).

The Role of the Scientific Research Community and Advocacy Groups

Scientific Research Community

The scientific community, including academics, has played a pivotal role in advancing geothermal energy development in Türkiye by contributing to the body of scientific knowledge and raising awareness of the sector's potential. Through academic research, peer-reviewed publications, and participation in international conferences, scientists have highlighted the environmental and economic benefits of geothermal energy. The establishment of professional geothermal associations and the promotion of international knowledge sharing have further supported this effort.

Notably, the World Geothermal Congress held in Türkiye in 2005 was pivotal in changing perceptions of geothermal energy, as its importance was communicated to ministers, parliamentarians, scientists, and bureaucrats. The congress was instrumental in the enactment of Law No. 5686 on Geothermal Resources and Natural Mineral Waters, which facilitated the establishment of the sector (Mertoğlu et al. 2024).

Geothermal Advocacy Groups

As the geothermal industry has expanded, multiple associations have emerged to share best practices and collaborate in advocating for geothermal development. In an interview conducted by the author with Ufuk Şentürk, chair of the board of the Geothermal Power Plant Investors Association, it was emphasized that civil society organizations are key stakeholders in regulatory processes. These associations represent investor perspectives by influencing governance and policymaking. Their involvement helps ensure that sectoral growth supports a more predictable and stable investment environment.

This collaborative approach, particularly through public-private partnerships, enhances the efficient and environmentally responsible use of Türkiye's geothermal potential. Renewable energy associations, in particular, provide technical input to public institutions on critical issues such as licensing for exploration and operation, EIA, reinjection practices, land use permissions in pasture areas, and the structure of technical committees. Notably, these associations have played a significant role in recent efforts to revise Law No. 5686, demonstrating their influence and contribution to shaping the legal and institutional landscape of geothermal energy in Türkiye.

There are five main associations, namely the Türkiye Geothermal Association (JTD), the Geothermal Power Plant Investors Association (JESDER), the Geothermal Energy Association (JED), and the Geothermal and Natural Mineral Water Investors Association (JEMYAD) (see Appendix C for a detailed explanation of each association).

Türkiye's geothermal success has been shaped not only by government policy and financing mechanisms but also by the proactive role of advocacy groups, scientific communities, and professional associations. These actors have been critical in building awareness, legitimizing the sector, and influencing key legislation.

New market entrants should encourage the establishment of not-for-profit technical associations, where none exist, or engage with international organizations such as Geothermal Rising and the International Geothermal Association. This engagement can help policymakers navigate licensing, environmental compliance, and policy processes more effectively while aligning investments with sustainability goals.

The Role of Technologies in Unlocking Geothermal Exploration and Production

In Türkiye, state and private companies established a robust drilling industry through oil and gas exploration. This industry developed significant expertise and infrastructure over time. However, between 2010 and 2020, the global oil and gas market experienced a sharp decline in prices, resulting in a substantial reduction in drilling activities. Consequently, many drilling rigs and associated equipment became idle and were available for use in the geothermal sector.

During this period, rig contractors and service companies redirected their technologies and services toward geothermal applications. This transition facilitated the adoption of best-in-class practices from the oil and gas industry, including advanced methods and tools originally developed for drilling in hostile environments. These innovations enabled geothermal operators to access deeper targets with more complex well trajectories. This strategic shift allowed the sector to optimize well construction performance through the gradual development of specialized know-how. The integration of advanced technologies and equipment from oilfield service companies further improved drilling efficiency and operational outcomes. Combined with an evolving learning curve for managing complex drilling conditions, these advancements enabled companies to enhance productivity and strengthen the economic viability of geothermal projects.

Subsurface Technologies

The adoption of fit-for-purpose technologies has focused on enhancing drilling performance in complex geological environments, primarily through drilling optimization aimed at reducing overall project costs. This has included the use of specially designed drill bits that provide greater speed and durability, enabling longer drilling intervals under challenging conditions. Additionally, steering systems have been implemented to improve directional control, drilling precision, and overall performance. The geothermal sector has also incorporated established oil and gas techniques, such as directional drilling, which facilitates the placement of multiple wells from a single surface location. This approach reduces the operational footprint and project costs and enables drilling in challenging areas, such as mountainous terrain (see Figure 16) and remote regions (Pedrosa et al. 2023). Collaboration between well service providers and geothermal operators has further facilitated access to hydrothermal reservoirs, allowing the development of deeper and higher-temperature geothermal wells for electricity production. For new entrants, strong foundations in operational know-how remain critical to advancing geothermal projects, while tailored solutions, including advanced technologies and techniques, serve as key enablers of efficiency and sustainability.

Successful geothermal well construction requires both advanced technologies and proven techniques. Technologies encompass high-end drilling and logging-while-drilling tools, while techniques refer to accumulated experience, methodologies, and operational know-how developed through drilling similar wells. Such expertise is readily available in resource-rich countries with well-established oil and gas industries.

However, the implementation of cutting-edge technologies is not always economically feasible, as geothermal projects operate under tighter margins than oil and gas projects. Consequently, operational efficiency has a greater impact on overall project economics, and time to production is a critical determinant of project viability. Achieving fit-for-purpose solutions requires a comprehensive understanding of drilling challenges and the development of a holistic approach.

Figure 16. Geothermal drilling in mountainous and remote regions, Alaşehir Türkiye, taken in 2021.

Source: Courtesy of Baker Hughes.

Surface Technologies

Binary Power Plants

Since the first commercial binary power plant was built in 1967 in the then Soviet Union with an output of 670 kWh, binary units have gradually grown in size and power capacity. This progression toward larger units has been driven by economies of scale, whereby smaller units are replaced with larger ones, increasing overall capacity.

For Türkiye, binary cycle power plants are more suitable for generating electricity from medium-enthalpy geothermal resources. These plants are typically applied to reservoir temperatures in the 150-240°C range. Other systems, such as flash, dual flash, or triple flash plants, require higher resource temperatures and are less efficient under these conditions. Binary plants operating in the 150-240°C range achieve relative efficiencies of approximately 10%-12%, outperforming flash-type plants at medium enthalpy levels (Ateş and Serpen 2016).

Türkiye ranks second globally in terms of the number of geothermal power plants and has notable achievements in both installed capacity and the size of binary units, with an average of approximately 17.5 MWe per unit. This figure reflects economies of scale and is higher than the average unit size of other binary plants worldwide, which is typically around 10 MWe (Serpen and DiPippo 2022).

Non-Condensable Gas Handling and Downhole Pump

Non-condensable gases (NCGs) occur naturally in geothermal fluids as a result of fluid-rock interactions within geothermal reservoirs. These gases are termed "non-condensable" because, unlike water, they cannot be converted into liquid form through the cooling processes that occur at geothermal power plants at the surface.

In Türkiye, the non-condensable gases present in geothermal resources consist primarily of carbon dioxide (CO_2), with smaller amounts of hydrogen sulfide (H2S). CO_2 emissions from new geothermal power plants in Türkiye are among the highest globally. High concentrations of non-condensable gases in Turkish geothermal resources enhance well productivity but also create challenges for condensers in flash plants and raise environmental concerns.

A significant portion of CO_2 dissolved in geothermal fluids is released into the atmosphere during production. High CO_2 emissions associated with geothermal operations have contributed to declining public support for such projects. One of the most effective solutions for managing NCGs, particularly CO_2, is reinjection into the reservoir together with the produced brine. CO_2 dissolves easily and rapidly in water. Under this method, CO_2 released during production is compressed, dissolved in reinjection water, and injected into the reservoir at pressures above its solubility threshold.

However, increased pressure in reinjection wells raises operational costs because of higher pumping and compressor energy requirements. To minimize these costs, the most economical approach is to ensure that the full volume of CO_2 is dissolved in the reinjected water, thereby reducing the pressure required for reinjection. In addition to maintaining production efficiency, CO_2 reinjection can generate revenue through voluntary carbon markets, providing financial support during both investment and operational phases. This practice also aligns with national greenhouse gas reduction targets and enables participation in carbon credit trading mechanisms (Aksoy et al. 2017).

In the absence of NCG injection, observations indicate that as production begins, NCG levels decline over time, resulting in decreased productivity. To mitigate this decline, operators may deploy downhole pumps or drill infill wells. However, due to high fracture interconnectivity, these infill wells often interfere with one another, which can limit productivity improvements.

Two types of downhole pumps are currently in use: mechanical line shaft pumps (LSPs) and electrical submersible pumps (ESPs). LSPs can be installed only in vertical wells up to 550m deep, whereas ESPs can be installed at greater depths in directionally drilled wells, provided the well design accommodates the equipment (Serpen and DiPippo 2022).

Technology spillovers from the oil and gas industry can accelerate geothermal project development by reducing geological uncertainty and lowering E&P costs. Expertise and technologies originally developed for hydrocarbon extraction, including advanced seismic imaging, directional drilling, well completion techniques, and reservoir characterization, can be directly applied to geothermal resource exploration and production.

Moreover, existing supply chains, service companies, and the skilled workforce of the oil and gas sector can be leveraged to support geothermal project development, thereby shortening project timelines and facilitating the integration of geothermal energy into the energy mix.

Cost of Geothermal Projects

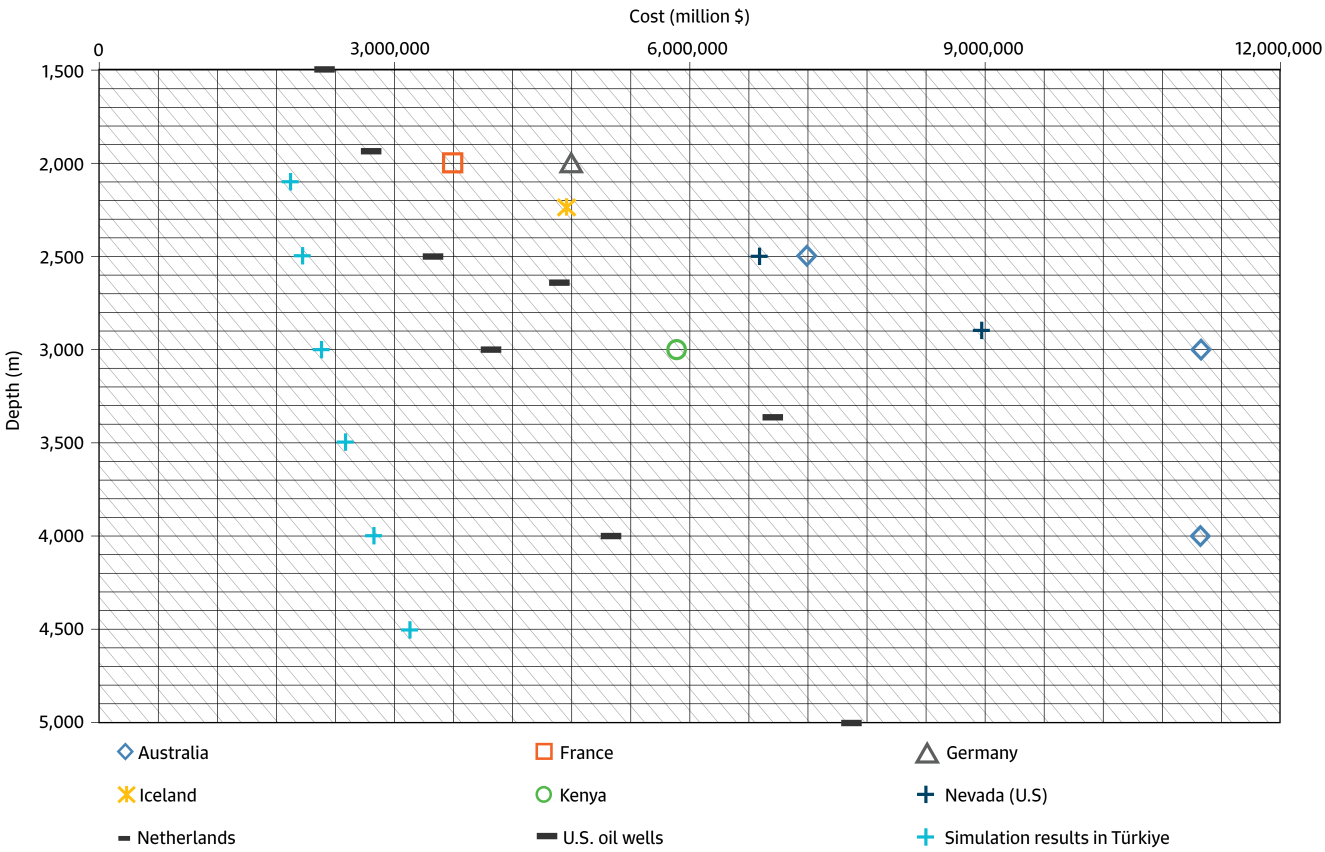
Globally, the levelized cost of energy (LCOE) for geothermal projects varies widely. In Türkiye, a combined learning curve from earlier projects and the adaptation of oil and gas subsurface technologies for more efficient drilling have contributed to lower input costs and improved project economics. These factors, together with strong financial support mechanisms, make Türkiye's geothermal projects more economically attractive than those in many traditional geothermal markets. Low drilling and operating costs position Türkiye among the most cost-effective geothermal frontier markets.

While drilling costs are competitive, global geothermal LCOEs typically range from 5-10 ¢/kWh, depending on location (IRENA 2025). By contrast, a financial evaluation of a Turkish geothermal power plant (Konyalı 2010) concluded that unit energy costs range from approximately 3.4-4.3 ¢/kWh – well below the global average.

Between 2010 and 2020, estimated drilling costs for geothermal wells in Türkiye ranged from $600 to $800 per meter (Serpen and DiPippo 2022). Although costs have increased in recent years because of post-pandemic economic pressures, they remain significantly lower than global averages. A comparative study by Gul and Aslanoğlu (2018) shows that geothermal well construction costs in Türkiye are consistently lower than those in other countries (see Figure 17). This cost advantage is attributed to three main factors: (i) lower labor costs, (ii) the use of cost-effective casing materials, as wells are not overbalanced and do not require high-grade casings, and (iii) accumulated drilling experience, which has fostered a competitive market and optimized well designs with minimal drilling times (Gul and Aslanoğlu 2018).

Türkiye's ability to maintain lower LCOEs is closely linked to its efficient well-construction capabilities, which significantly enhance the economic viability and competitiveness of geothermal projects within the renewable energy market.

Figure 17. Comparison of published well costs across different countries vs. model results at different depths in Türkiye.



Source: Gul and Aslanoğlu (2018).

Geothermal Reservoir Sustainability

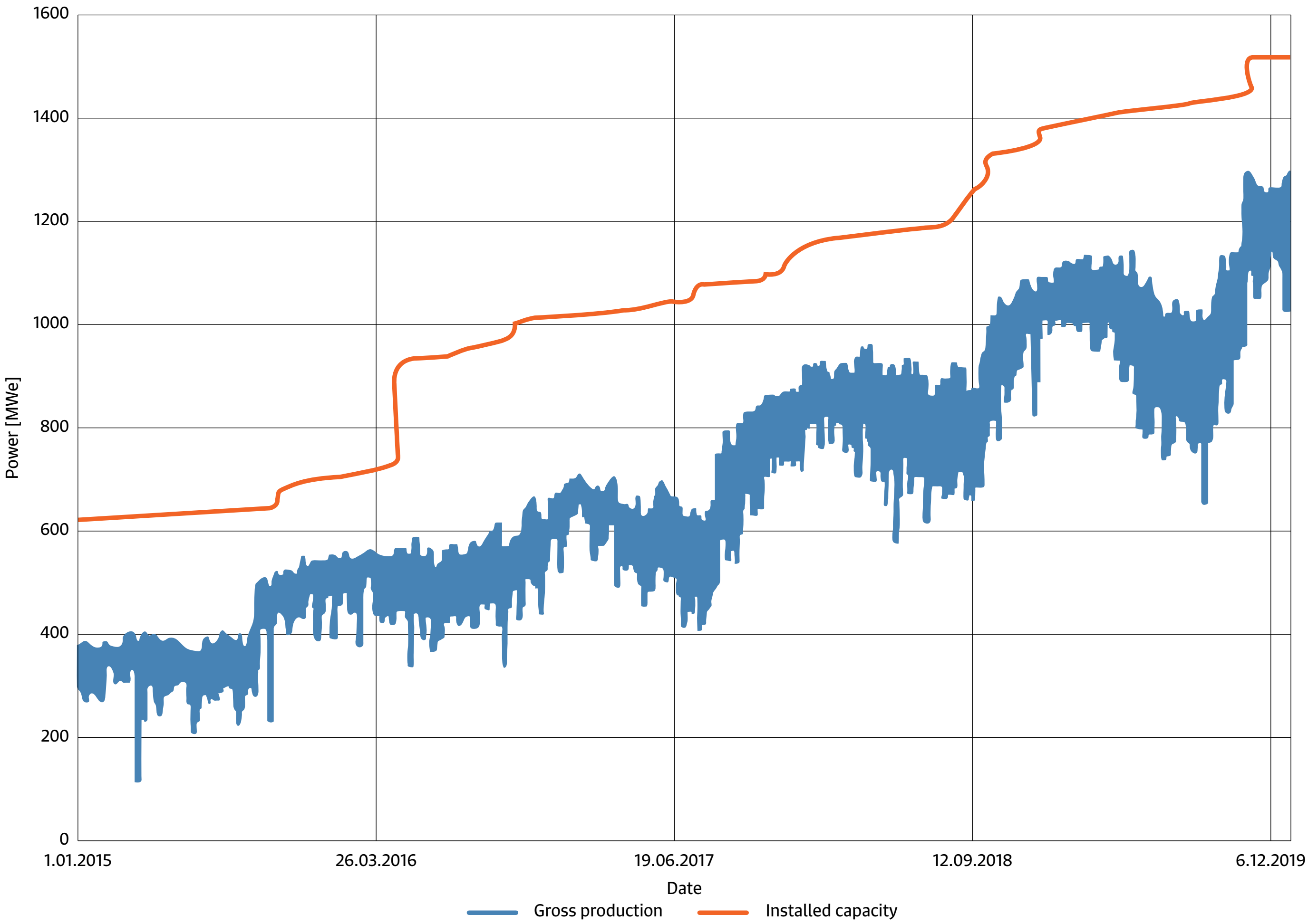
As stated by Serpen and DiPippo (2022), "Geothermal resources are not unlimited. However, they can be long-lasting and even sustainable if developed properly." Stakeholders must have a clear and realistic understanding of geothermal resources to make effective decisions. Accordingly, efficient reservoir management is critical to operating geothermal plants at maximum capacity over a given production period.

As per a study by Aydın and Şentürk (2020), the capacity factor of geothermal power plants in Türkiye has declined over time (see Figure 18). This trend can be attributed to two main factors:

1. Each geothermal developer typically evaluates only the resource within its licensed area rather than considering the broader reservoir system. This approach can lead to the construction of oversized power plants that cannot be sustained by actual resource performance.

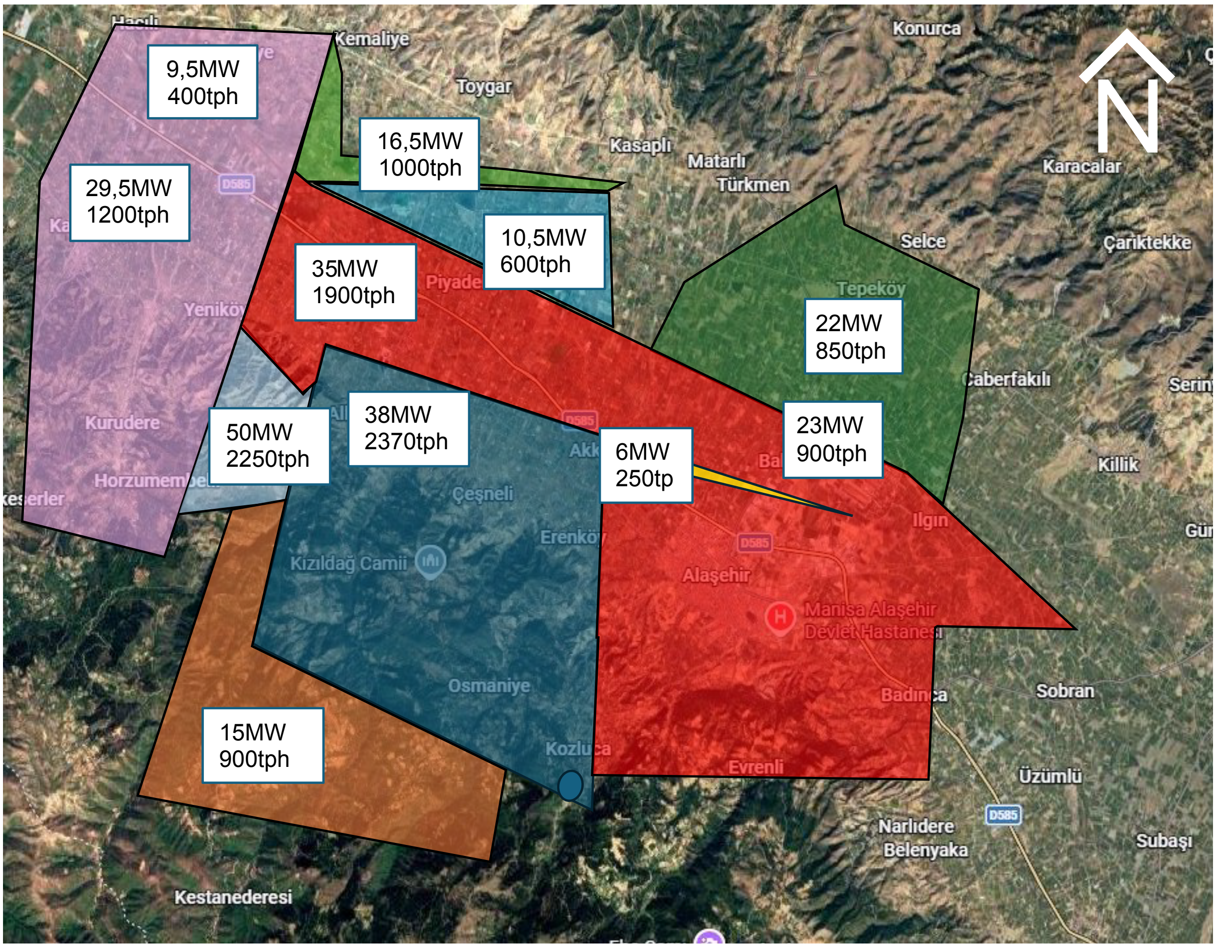
2. Although initial resource assessments often align with reservoir performance, output declines substantially over time due to poor reservoir management. This decline is frequently caused by inadequate production strategies, particularly where multiple developers operate within the same geothermal resource area.

Figure 18. Gross production capacity vs. installed power capacity of geothermal power plants in Türkiye.



Source: Aydın and Şentürk (2020).

Figure 19. Distribution of license areas in the Alaşehir field and the current installed capacity and production of geothermal power plants.



Source: Aydın and Şentürk (2020).

Geothermal licenses are issued without considering the reservoir as a whole, fragmenting the resource into multiple licenses. Consequently, several developers may share the same reservoir, and the proximity of production areas, combined with high reservoir hydraulic connectivity, creates unfavorable pressure interference between wells. The presence of multiple geothermal developers operating within the same resource area remains a common challenge for the Turkish geothermal industry (Aydın and Şentürk 2020).

Approximately a quarter of Türkiye's total installed geothermal power capacity remains untapped due to the operation of oversized plants and poor reservoir management. To maximize production capacity, a coordinated reservoir management approach is essential. Implementing new production and injection scenarios under a unitized reservoir management scheme – in which all geothermal developers operating within the same resource area collaborate – can significantly increase field productivity (Aydın and Şentürk 2020).

Türkiye governs geothermal energy under Law No. 5686 on Geothermal Resources and Natural Mineral Waters, which administers geothermal resources similarly to mineral resources rather than treating reservoirs as integrated fluid systems. This framework, adapted from mining law principles, results in licensing based on discrete mineable parcels and fails to account for the connectedness of geothermal reservoirs (MAPEG 2024). By contrast, a reservoir-based approach similar to oil and gas regulation acknowledges subsurface connectivity and coordinates production to maintain optimal reservoir conditions. This approach would improve sustainability and reservoir performance and help prevent low capacity factors, which currently result from oversized plants and declining reservoir pressure due to fragmented operations.

The Way Forward

04

Progress and Advancement of Geothermal Energy in Türkiye

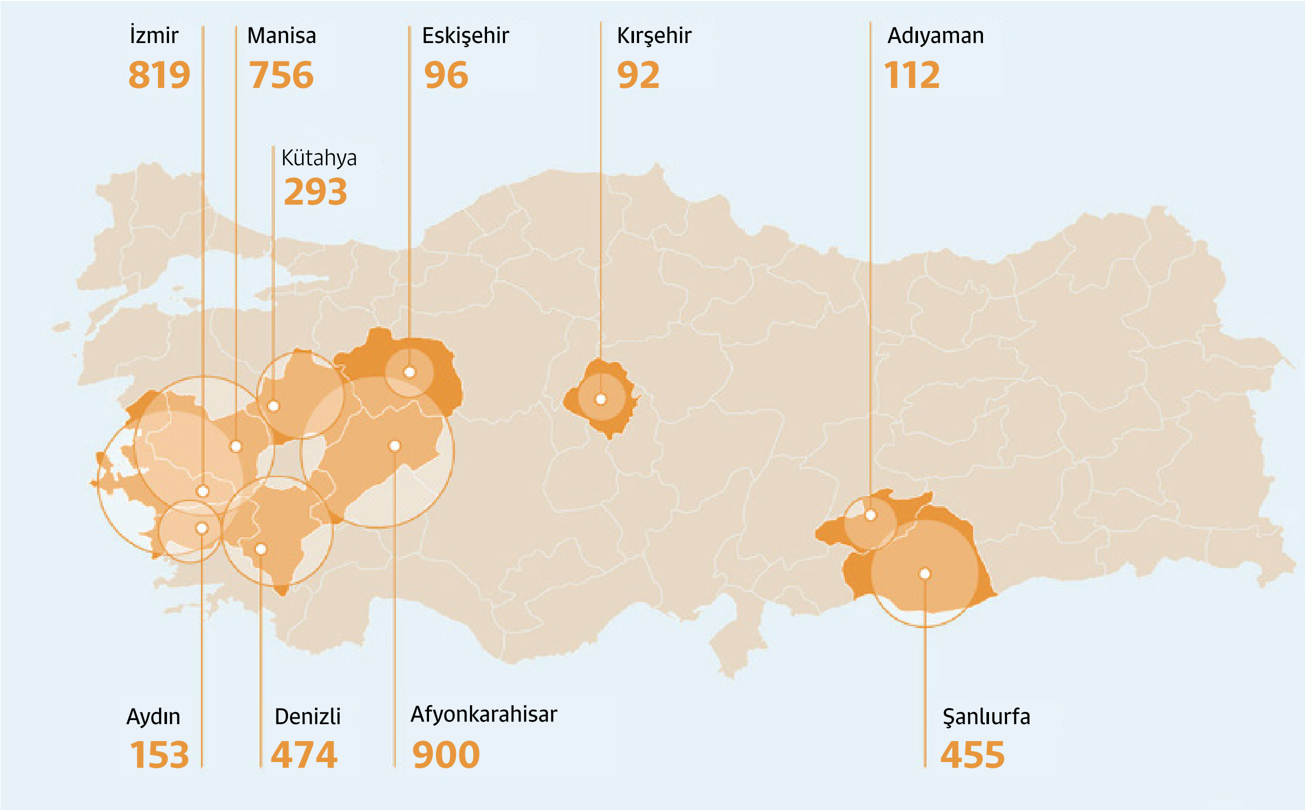
Despite significant progress in geothermal development, Türkiye still holds considerable untapped geothermal potential for both electricity generation and direct-use applications. In addition to underutilized hydrothermal fields, the country possesses considerable enhanced geothermal systems (EGS) potential, particularly in regions where hydrothermal fluids are insufficient for conventional development but geothermal gradients remain high.

In the southeastern provinces, where oil production has historically been concentrated, abandoned wells continue to yield hot water, offering a unique opportunity to repurpose these assets for district heating or agricultural applications. Realizing this potential will require targeted exploration, regulatory reform, and innovative financing mechanisms to overcome the high upfront costs and technical risks associated with early-stage geothermal development.

In recent years, the focus of geothermal investments in Türkiye has increasingly shifted toward direct-use applications, particularly in geothermal-heated greenhouses. According to a presentation by the Development and Investment Bank of Türkiye, geothermal greenhouse activity has grown by an impressive 400% since 2002 (Özbakır 2022). As of 2022, Türkiye had emerged as the global leader in geothermal greenhouse development. By August 2023, approximately 9,943 square kilometers (km^2) of greenhouse area was being heated using geothermal energy (see Figure 20) (Özbakır 2022). Reflecting this trend, recent applications to the Risk Sharing Mechanism under the Türkiye Geothermal Development Project have increasingly focused on greenhouse heating projects, highlighting a strategic shift in the sector from electricity generation toward integrated and sustainable agricultural uses.

While government interventions have enabled the rapid expansion of geothermal energy, the sector remains highly dependent on state support. New and innovative financial instruments, regulatory reforms, and the adoption of cutting-edge technologies are required to support new greenfield developments (Shura 2019).

Figure 20. Spatial distribution of geothermal greenhouses by area (hectares).



Source: Özbakır (2022).

Projects Under Development and Their Potential Impact

Current efforts in Türkiye's geothermal sector are primarily focused on field development and capacity optimization rather than new exploration. Only a limited number of companies continue to pursue greenfield exploration or initiate new projects. The slowdown in geothermal power capacity expansion is the result of several interrelated factors:

- **Project financing constraints**: The rapid depreciation of the Turkish lira, coupled with global supply chain disruptions and rising domestic interest rates, has significantly increased the cost of capital for geothermal investments.

- **Changes in financial incentives**: Modifications to the YEKDEM (Renewable Energy Support Mechanism) introduced in 2021, despite subsequent revisions in 2023, have created uncertainty and reduced the attractiveness of new investments.

- **Resource maturity and economic limits**: As noted by Serpen and DiPippo (2022), the discovery of economically viable geothermal reserves for power generation has reached a mature stage. Most easily accessible resources, initially identified by MTA, have already been developed. Further discoveries are likely to be technically more complex and financially demanding, requiring higher-risk capital and advanced exploration technologies.

- **Competing resource allocation**: In recent years, Türkiye has shifted its strategic focus toward onshore oil exploration, particularly in the southeastern regions. This shift has led to a reallocation of drilling rigs and technical personnel, many of whom are now operated by the national oil company, the Turkish Petroleum Corporation. As a result, geothermal developers face increasing difficulty in accessing well construction equipment and land drilling rigs. In many cases, even rigs owned by geothermal companies have been leased to oil exploration operations, as firms prioritize short-term revenue over continued geothermal exploration activities.

Table 2. Development pipeline for geothermal projects.

Award year	Completion year	Project	Capacity	Status
2025	2027	Kipas Hldg – Emir Geothermal Power Plant	33 MW	Contract awarded
2025 (Exp)	2027 (Exp)	Kipas Hldg – Nezihe Beren 2 Geothermal Power Plant	13 MW	Contract awarded
2026 (Exp)	2029 (Exp)	Zorlu Eng – Agri Diyadin Geothermal Power Plant	150 MW	Study
2026 (Exp)	2029 (Exp)	Turkhan Energy – Manisa Geothermal Power Plant	24 MW	Study
2026 (Exp)	2029 (Exp)	Sanko Energy – Expansion of Salihli Geothermal Plant	25 MW	Study

Source: MEED Projects September 2025.

Table 2 summarizes geothermal projects currently in the development pipeline, with a combined capacity of approximately 245 MWe. While these projects reflect continued activity in the sector, their scale remains relatively modest compared with Türkiye's existing installed geothermal capacity of 1.7 GWe.

Expected Market, Infrastructural, and Legislative Changes

The complexity of Türkiye's geothermal legislation, combined with weaknesses in administrative structuring and technical deficiencies at the provincial level, continues to hinder the effective and sustainable development of geothermal resources. Current exploration periods remain inadequate for advanced applications such as hot-dry rock systems.

A central authority such as MAPEG, which already plays a leading role in mining and petroleum licensing, could assume a more prominent position in geothermal governance by adopting a holistic approach to reservoir protection and sustainability, supported by a qualified technical unit. Establishing a centralized information system to collect data from private operators would enable strategic guidance for exploration and production, improve resource management, and align financing solutions. Creating a dedicated geothermal unit would further strengthen scientific rigor and help ensure sustainable utilization.

A new legislative effort is underway to revise Türkiye's geothermal energy law, with the aim of establishing a more centralized and coordinated governance structure. Unlike the oil and gas sector, in which MAPEG maintains comprehensive oversight, geothermal operations remain fragmented under provincial authorities that often lack technical capacity in reservoir management and geological assessment. This decentralized approach, while accelerating early-stage development, has led to inefficiencies such as the overexploitation of shared reservoirs, adversely affecting production across license holders. The proposed reforms seek to enhance institutional coordination, improve data transparency, and align geothermal governance with best practices observed in other energy sectors.

Several key reforms are needed to ensure the sustainable growth of Türkiye's geothermal sector, including adopting a reservoir-based approach to licensing, extending exploration license durations to accommodate advanced applications such as hot-dry rock systems, and establishing a technically capable central team to oversee operations and enforce technical standards. Additional measures include restructuring purchase guarantees and incentive durations specific to geothermal energy; supporting integrated use models such as greenhouse heating and district energy; increasing research and development support for domestic equipment manufacturing; and expanding access to low-interest and long-term financing. These actions are essential not only to restoring investor confidence but also to leveraging geothermal energy's strategic potential across electricity generation, agriculture, heating, and tourism, thereby contributing to Türkiye's broader goals of energy independence and sustainable development.

YEKDEM previously served as an effective investment de-risking tool until 2021. However, updates introduced in 2021 and 2023 created imbalances, as nearly half of geothermal plant costs are driven by imported equipment and foreign-currency financing. This exposure increases exchange-rate risk for developers and limits the scheme's ability to provide adequate protection. Unless the policy environment evolves, large-scale power development is likely to remain subdued over the next five years (Rystad 2025). Renewed growth depends on whether the government can deliver a framework that restores financial predictability and aligns geothermal investment with national priorities by introducing a tariff structure that fully protects developers from currency risk – either through foreign-currency indexation or government-backed guarantees (Rystad 2025).

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Appendices

Appendix A: Key Contractors and Service Providers in Türkiye's Geothermal Power Sector

Company	Type	Specializations and services
TPIC (Turkish Petroleum International Company)	State-owned	Rig contractor and oil field services supplier, including seismic research and directional drilling
BorDrill	Private (local)	Rig contractor and oilfield services provider, including completion, cementing, and acidizing services
Çelikler, Enerjeo, Kipaş	Private (local)	Self-managed drilling infrastructure, including rigs, directional equipment, and crews
GEOS	Private (local)	Drilling fluids company and waste management services
ME-ADS	Private (local)	Rig contractor
Pars	Private (local)	Rig contractor providing tubing, cementing, workover, wireline, pressure pumping, and geothermal testing services
Baker Hughes	International	Energy technology company with oilfield services capabilities
Schlumberger	International	Oilfield services company
TAQA	International	Oilfield services company
Viking International	International	Rig contractor and oilfield services provider, including directional drilling, geophysical services, cementing, drilling fluids, coiled tubing, and workover services. Oilfield services company
Weatherford	International	Oilfield services company

Source: Authors' analysis based on market research.

Appendix B: Key Funding Institutions Supporting Geothermal Development in Türkiye

Institution	Role in geothermal financing	Notes
World Bank	Geothermal development project additional financing, with two components: (1) a risk-sharing mechanism for resource validation and (2) a loan facility for resource development, including an ESMAP grant program for geothermal direct-use projects	Implementing agencies: • Türkiye Kalkınma ve Yatırım Bankası A.Ş. (TKYB) • Türkiye Sınai Kalkınma Bankası A.Ş. (TSKB)
Clean Technology Fund (CTF)	Concessional co-financing for early-stage projects	
European Bank for Reconstruction and Development (EBRD)	Private Sector Early-Stage Geothermal Development Framework (PLUTO)	Financing types: • Direct financing • Syndicated loans and co-financing • Concessional financing • Small-scale geothermal project financing through Sustainable Energy Financing Facilities (SEEF)
European Union (EU)	Technical assistance and grant support	Capacity building and SEEF
International Finance Corporation (IFC)	The IFC, a member of the World Bank Group, partners with local banks to provide credit lines and financial products supporting renewable energy investments, including geothermal	For large-scale projects, they co-finance with EBRD
Japan International Cooperation Agency (JICA)	JICA provides renewable energy and energy efficiency investments aimed at reducing greenhouse gas emissions	Implementing agency: • Türkiye Sinai Kalkinma Bankasi A.Ş. (TSKB)
German Development Bank (KfW)	KfW Climate Finance Loan offers concessional loans for projects in renewable energy, energy efficiency, energy storage, and electric vehicle technology in Türkiye	Implementing agencies: • Türkiye Kalkinma ve Yatirim Bankasi A.Ş. (TKYB) • Turkiye Sinai Kalkinma Bankasi A.Ş. (TSKB)
Industrial Development Bank of Türkiye (TSKB)	Intermediary for World Bank and EBRD funds	On-lending for private geothermal developers
Development and Investment Bank of Türkiye (TKYB)	TKYB has multiple funding sources for renewable energy projects, including geothermal, and serves as an intermediary for World Bank long-term investment loans for geothermal power plants and direct-use facilities, as well as for risk-sharing mechanisms and the ESMAP grant program, as the implementing agency	Local project financing
Ziraat Bankası	Financing for geothermal-based agriculture and heating projects	Greenhouse heating projects
Garanti BBVA, Vakifbank, İşbank, Akbank and Yapı Kredi	Lending funds provided by international financial institutions	Access to capital for small- and medium-scale geothermal developers

Source: Organized as per the authors' market research.

Appendix C: Key Geothermal Advocacy Groups in Türkiye

Türkiye Geothermal Association (JTD)	Established in 1992, JTD is the oldest geothermal-focused organization in the country. Its primary mission is to raise awareness of the benefits of geothermal energy and to foster collaboration among small- and medium-sized enterprises operating in the sector.
Geothermal Power Plant Investors Association (JESDER)	Dedicated to geothermal electricity production, the association represents power plant investors, advocates for sustainable energy generation, and works closely with public institutions to help shape energy policy. According to the author's interview, the association made significant efforts related to the 2023 amendments to YEKDEM. It exerts influence through press releases, consultations with relevant public institutions, and formal correspondence. As a civil society organization, it acknowledges that its ability to drive change is limited; however, it advances its objectives by engaging in dialogue with legislators to identify and address shortcomings. During the YEKDEM process, these negotiations proved particularly effective.
Geothermal Energy Association (JED)	Established in 2021, the association comprises corporate members representing approximately two-thirds of installed geothermal power capacity through investments in the sector. Its objective is to strengthen stakeholder relations and to promote the widespread use of geothermal energy across the value chain, from resource discovery to production (ThinkGeoEnergy 2021a).
Geothermal and Natural Mineral Water Investors Association (JEMYAD)	A sectoral organization dedicated to promoting the sustainable and environmentally responsible use of geothermal and mineral water resources in Türkiye, its focus spans a wide range of applications, including heating, agriculture, and thermal tourism. JEMYAD actively supports investors by advocating for improved regulatory frameworks and facilitating dialogue among stakeholders, with the aim of enhancing the efficiency, safety, and environmental integrity of geothermal resource utilization across multiple sectors.

Source: Authors' analysis.

About the Authors

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Selin Pedrosa is a Global Strategic Sales Manager in the Well Construction segment at Baker Hughes. She has 13 years of professional experience spanning field operations, drilling engineering, and strategic sales. She began her career in Türkiye and has actively contributed to the drilling of numerous geothermal, oil, and gas, and underground gas storage projects. Her multidisciplinary background includes work in mining, geothermal energy, and upstream oil and gas, and she is a published author in the field of high-temperature, hostile-environment geothermal drilling. Selin holds a Bachelor of Science in Geological Engineering from Middle East Technical University. She is currently based at the Drilling Services headquarters in Germany, where she leads strategic sales enablement initiatives, supports global sales operations, and contributes to the advancement of drilling services technologies.

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Osamah Al-Momen serves as strategy and marketing director for the Middle East, North Africa, Türkiye, and India region at Baker Hughes. His work focuses on studying and evaluating macroeconomic and microeconomic drivers in the region affecting the energy and industrial sectors, which informs his role in new business strategy development. Osamah has more than 20 years of experience in the oil and gas sector and has served at multiple major service companies across a range of disciplines and roles in the upstream business. He holds a Bachelor of Science degree in Electrical Engineering from King Fahd University of Petroleum and Minerals (KFUP) in Dhahran, Saudi Arabia.

About the Project

This project provides 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 in Saudi Arabia. The overarching objective is to support strategic initiatives that advance the development and integration of geothermal energy in alignment with the Kingdom's goals for a sustainable and resilient energy future.

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