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Overview of the different geothermal systems: role of geophysics in exploration and production

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1.1 What is geothermal energy?

Geothermal energy is all about tapping into and utilizing the Earth's internal heat, which comes from two primary sources: the decay of radioactive elements and the residual heat left over from the planet's formation billions of years ago. Heat is a form of energy associated with the movement of particles within matter. Heat can be transferred in three ways: conduction, convection, and radiation. Heat

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naturally flows from areas of higher temperature to areas of lower temperature. These processes create a transfer of heat from the Earth's hot interior to its cooler surface where we live, resulting in what's known as a geothermal gradient, which is a measure of how temperature increases with depth (Figure 1.1). In general, the deeper we go into the Earth's crust, the hotter it gets. On average, temperatures rise by roughly 25–30 °C for every kilometer below the surface, but this geothermal gradient varies significantly depending on location due to the underlying geology.

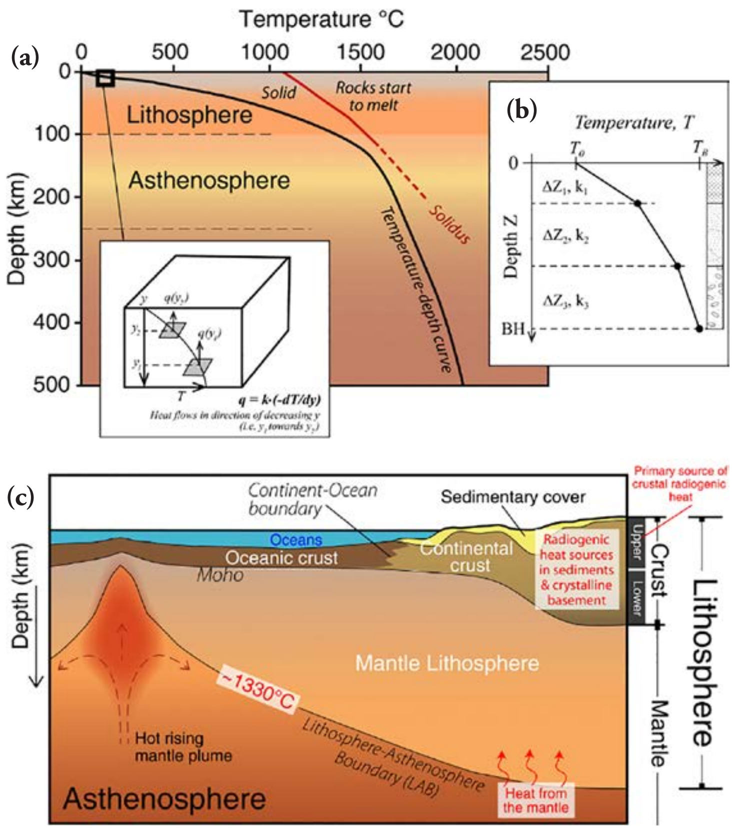


Figure 1.1 *From Kolawole and Evenick (2021). (a) Typical averaged (and simplified) temperature profile of the Earth, showing the variation of temperature with depth (modified after Mckenzie and Bickle, 1988; Boehler, 1996). Inset in panel (a) shows a zoom-in of the non-zero curvature of slope of temperature(T)-depth(y) profile, in which the local slope is defined by Fourier's law, and for a constant thermal conductivity (k), heat flow (q) is a function of depth, y, q = q(y) (modified after Turcotte and Schubert, 2002). (b) Schematic representation of variation in geothermal gradient with depth (Z) as a function of k in sedimentary sequences (after Chapman et al., 1984). (c) Cartoon showing the crustal and lithospheric structures of the Earth with the primary sources of geogenic heat (after Evenick, 2019).*

Variation in measured heat flow at the surface of the Earth (Figure 1.2) highlights significant lateral differences across regions, suggesting a strong influence of subsurface characteristics. Indeed, the subsurface is far from being homogenous. This heat is stored in rocks and reservoirs of water deep underground. Different rock types, fractures, water presence, and other geological features, particularly related to tectonic plate activity, play a role in how heat is stored and transferred underground.

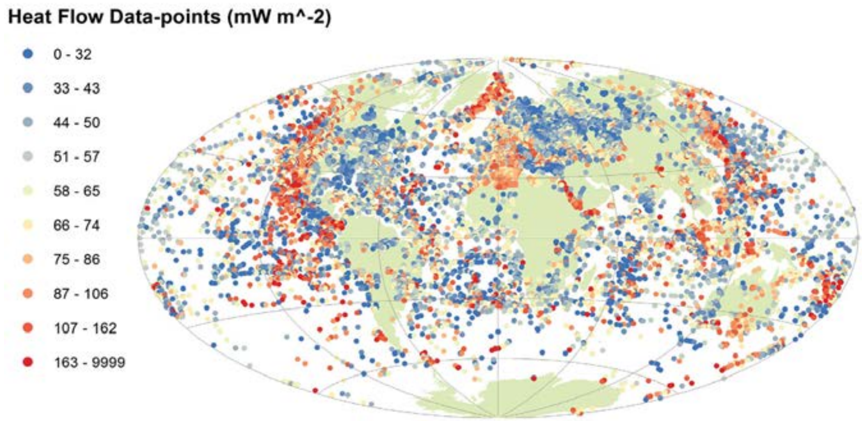


Figure 1.2 *From Davies (2013). Map of heat flow measurement points.*

Geothermal energy is all about harnessing the natural heat generated beneath the Earth's surface. However, harvesting geothermal heat directly from the Earth's surface is challenging because on average, the natural geothermal heat flux reaching the Earth's surface is only about 0.06 watts per square meter, which is a tiny amount compared to solar power, which delivers around 200 watts per square meter on a sunny day.

While the Earth's surface temperature is highly influenced by atmospheric conditions, fluctuating with daily and seasonal changes, this effect diminishes rapidly just a few meters below the ground. After descending around 10 to 20 meters, the Earth's temperature becomes nearly constant throughout the year, insulated from surface weather variations. This stable temperature zone is primarily influenced by the geothermal gradient. This stable subsurface temperature zone is crucial for surface geothermal applications, as it provides a reliable, year-round source of heat for geothermal heat pumps.

To access deep geothermal energy for more energy-intensive applications like direct heating or power generation, we must drill deeper into the Earth's crust, where temperatures are significantly higher. For direct heating applications, temperatures typically need to reach between 50 °C and above. At these depths, geothermal fluids can be used directly for district heating, greenhouse heating, aquaculture, and industrial processes. For electricity generation, however, much higher temperatures, generally above 150 °C, are required to produce steam or vaporize a working fluid that drives turbines.

The diagram displayed in Figure 1.3 highlights how different temperature levels of geothermal fluids are suited for various direct-use applications. It showcases the versatility of geothermal energy, illustrating how it can be utilized for both power generation and numerous direct heat applications, depending on the resource temperature. At the high end of the temperature spectrum, above 150 °C, geothermal fluids are typically used for electricity generation through dry steam, flash steam, or binary cycle power plants. Moving down in temperature, between 100 °C and 150 °C, geothermal fluids can be used in processes like drying, industrial heating, and chemical extraction. At lower temperatures, around 50 to 100 °C, geothermal fluids are ideal for district heating, aquaculture, greenhouse heating, and various agricultural applications. Finally, even low-temperature geothermal fluids, between 20 and 50 °C, have applications in bathing, balneology, and heat pump systems for residential heating and cooling.

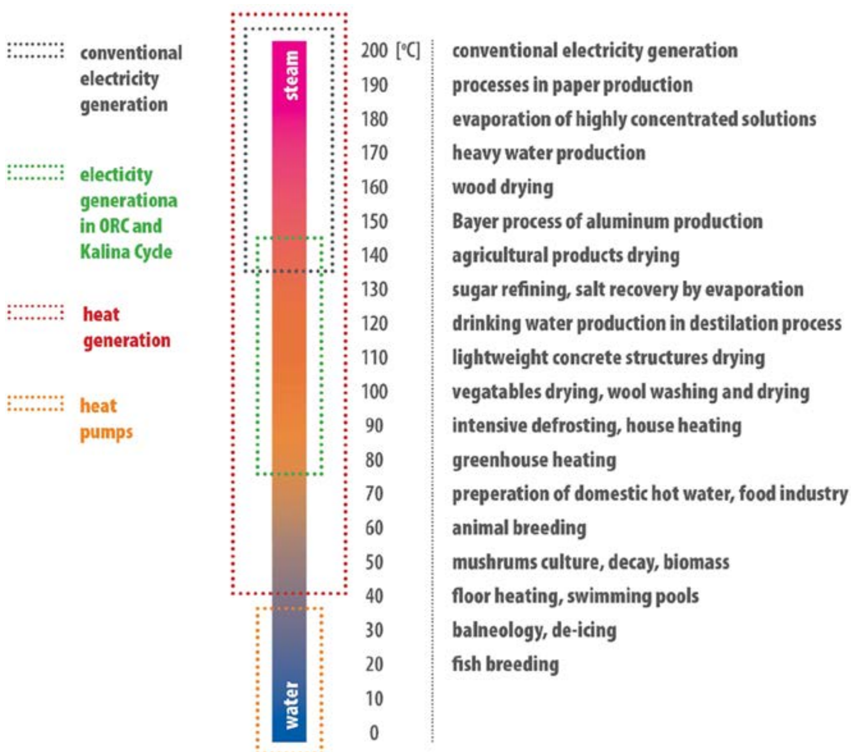


Figure 1.3 *Modified Lindal diagram about possible usage of geothermal fluids (from Kaczmarczyk et al., 2020; based on Gudmundsson et al., 1985; Operacz and Chowaniec, 2018).*

Heating has always been essential to human societies, forming the backbone of daily life and industrial activities. Today, heating and cooling account for a substantial portion of global energy consumption worldwide. According to the International Energy Agency (IEA), heating alone, used for residential, commercial, and industrial purposes, accounts for about 50% of final energy consumption globally (Figure 1.4). In colder climates, space heating for homes and buildings is a major energy expense, especially during winter, and accounts for nearly 40% of energy demand in the building sector. Meanwhile, the need for cooling is rapidly increasing, especially in warmer regions, where air conditioning and refrigeration demand has soared over the last few decades. Given the immense need for heating and cooling, geothermal energy presents a powerful, sustainable alternative, as it can provide constant, low-emission heat for both buildings and industry, helping to meet this demand while reducing greenhouse gas emissions.

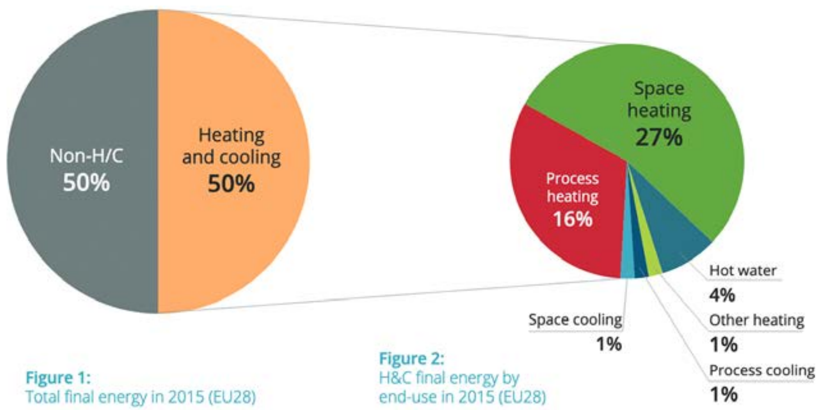
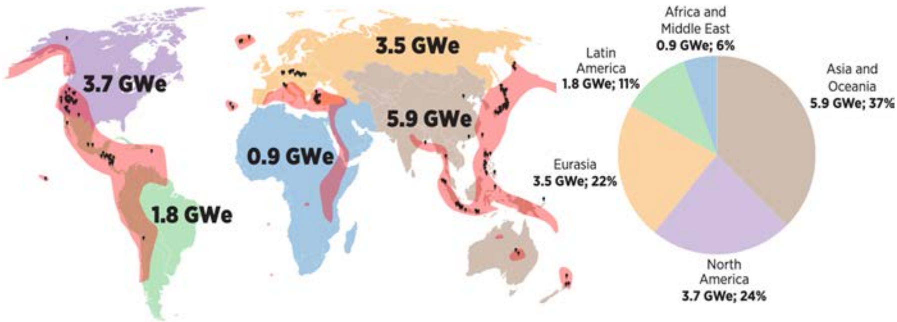


Figure 1.4 *Heat Roadmap Europe (2019), Heating and Cooling facts and figures.*

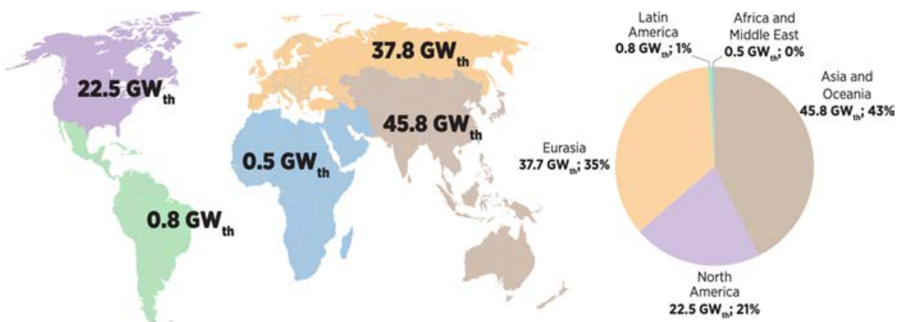
By tapping into this steady, abundant heat source, geothermal systems can produce electricity, provide direct heating, and power industrial processes with minimal environmental impact. Geothermal energy offers a unique advantage in the push to decarbonize societies because it provides a constant, reliable power supply independent of weather conditions.

The installed capacity for geothermal heat and power generation has seen a steady increase, with global geothermal power capacity exceeding 16 gigawatts in recent years (Figure 1.5) and direct-use heating capacity growing even faster (Figure 1.6), especially for district heating, greenhouses, and aquaculture. As of the latest trends, geothermal heating is expanding quickly in regions with abundant low-to-medium temperature resources, while geothermal power plants continue to rise in areas with high-temperature resources. In recent years, advancements in geophysics, hydrogeology, and drilling technology, and have expanded the potential of geothermal energy.



Source: IRENA, 2022a; ThinkGeoEnergy, 2022 (b); Huttrer, 2021.

Figure 1.5 *From IRENA and IGA (2023). Estimated installed geothermal electricity capacity, by region, 2021.*

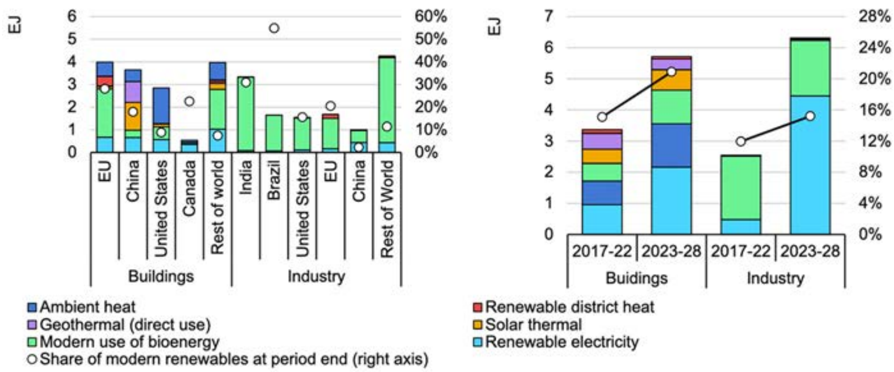


Adapted from: Lund and Toth (2021).

Figure 1.6 *IRENA and IGA (2023). Estimated geothermal heating and cooling installed capacity, by region, 2020.*

In the renewable energy sector, there is competition between technologies like solar, wind, biomass, and geothermal for investment, policy support, and market share. Solar and wind energy have surged in deployment due to their rapid advancements, decreasing costs, and modular nature, making them accessible and scalable across a wide range of locations (Figure 1.7). In contrast, geothermal energy faces distinct challenges that can slow its expansion despite its potential for stable, baseload power or direct heat usage. One of the significant hurdles is the regulatory landscape: accessing deep geothermal resources requires extensive permits and regulatory compliance due to their subsurface nature.

Another challenge for geothermal energy deployment is the inherent risk and complexity of drilling deep into the Earth to access high-temperature resources. Deep drilling is costly and carries geological risks, including the lack of targeted geothermal fluids or the possibility of triggering seismic activity. Current drilling technologies also have limitations, as they can only reach certain depths before technical constraints and costs become prohibitive. This restriction means that vast geothermal potential, notably for power generation remains untapped. Addressing these challenges requires continued advancements in drilling technologies, risk mitigation strategies, investment, and regulatory support, all of which would help make geothermal a more prominent player in the global renewable energy mix.



IEA. CC BY 4.0.

Notes: EU=European Union. Ambient heat from heat pumps used in the industry sector is not accounted for due to limited data availability

Sources: IEA (2023), World Energy Outlook 2023; IEA (2023), Global Energy and Climate Model.

Figure 1.7 *Renewable energy consumption and shares of heat demand in selected regions, 2022 (left), and global increases in renewable energy consumption, 2017-2028 (right). Source: World Energy Outlook 2023 (IEA Report, 2023).*

1.2 What are the main geothermal systems?

In nature, geothermal activity is well known through phenomena like geysers, hot springs, and fumaroles, where the Earth's internal heat escapes to the surface. These features form in geologically active areas, such as near tectonic plate boundaries or volcanic zones, where heat is channeled through fractures in the Earth's crust, bringing hot water or steam to the surface. Historically, these natural hot water sources have been harnessed by people for bathing, cooking, and warming homes, using the naturally occurring thermal energy produced deep within the Earth.

The first deliberate attempt to generate power from geothermal energy was made in 1904 in Larderello, Italy, where the French engineer François Jacques de Larderel used steam from a geothermal well to generate electricity. Since then, geothermal technology has evolved significantly, with modern techniques now allowing us to drill deep into the Earth and access high-temperature geothermal reservoirs. Today, geothermal power plants can produce electricity by tapping into hot water, two-phase or steam reservoirs, while enhanced geothermal systems (EGS) create artificial reservoirs by injecting water into low permeability rocks to generate hot geothermal fluids. Additionally, ground-source heat pumps make it possible to use stable temperatures just below the Earth's surface for efficient heating and cooling in residential and commercial buildings.

These advancements allow us to make use of geothermal energy far beyond natural manifestations, making it a sustainable and reliable source of heat and power. However, it's essential to recognize that geothermal energy is not a one-size-fits-all resource. We can classify geothermal systems based on the intended usage, the fluid or geological context involved, and even the energy production design.

Classifying by Usage

- Direct Use of Hot Water: This is one of the oldest and most straightforward uses of geothermal energy, in which naturally heated water (30–80 °C) from geothermal springs or wells is used for heating buildings, agricultural greenhouses, aquaculture ponds, and industrial processes.
- Electricity Generation: Higher temperatures, typically above 150 °C, are required to produce electricity. In these systems, steam from geothermal reservoirs drives turbines connected to generators. These are commonly used in areas with high geothermal activity, like volcanic regions.
- Geothermal Heat Pumps (GHPs): GHPs leverage stable ground temperatures (10–16 °C) found a few meters below the surface to provide efficient heating and cooling for buildings. This technology is widely applicable and doesn't require high temperatures.

Classifying by Geological Settings

- Shallow Geothermal Systems: This involves tapping into the moderate temperatures found at shallow depths, typically up to a few hundred meters, to power geothermal heat pumps.
- Sedimentary Basin Systems: In regions with porous/fractured/karstified sedimentary layers, geothermal reservoirs of hot water can be found at moderate depths, often used for direct heating or low-temperature electricity production.
- Volcanic Systems: High-temperature geothermal reservoirs in volcanic regions are ideal for electricity generation. Countries like Indonesia and New Zealand are renowned for tapping volcanic geothermal resources for power.
- Rift and Fault Zones: In areas where tectonic plates pull apart or fracture, crust is thinner and heat flow is higher than usual promoting geothermal reservoir development in conjunction with volcanic activity.
- Fractured Granite and Crystalline Rock: Some geothermal resources are found in fractured hard rock, where engineered geothermal systems (EGS) create or enhance pathways for water to circulate and absorb heat.

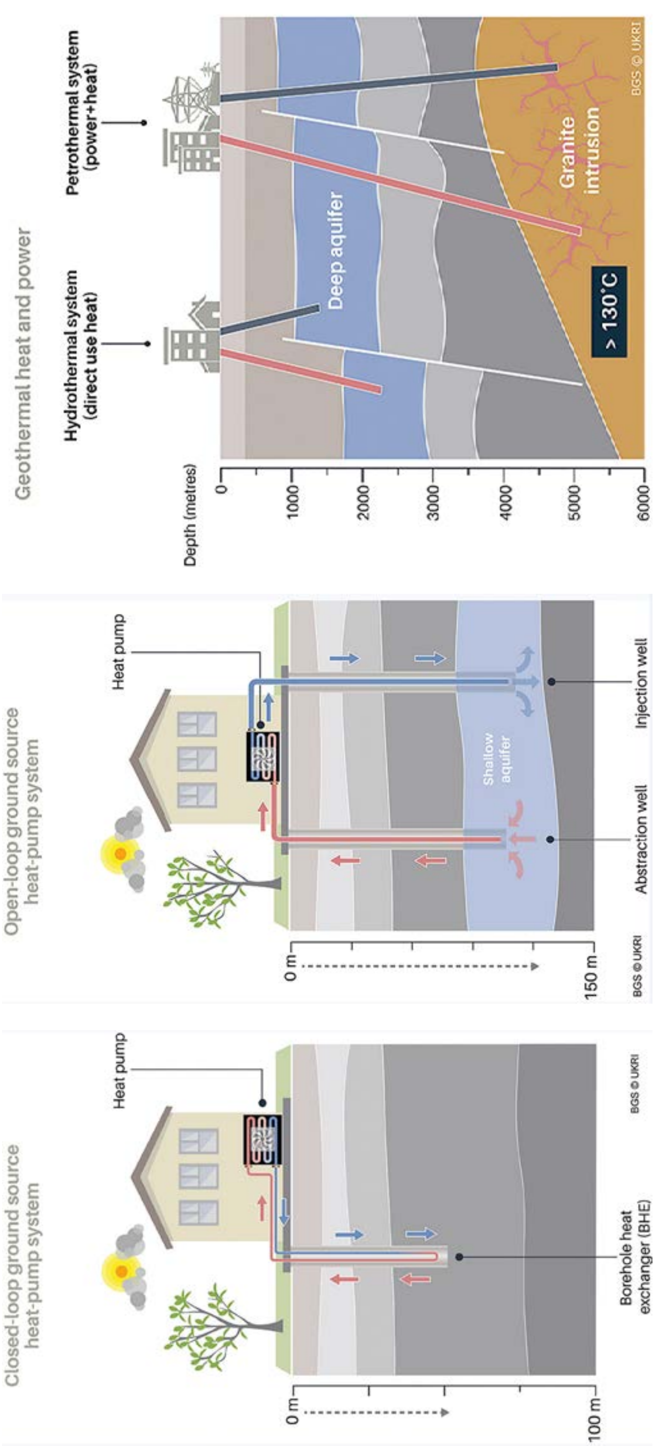


Figure 1.8 *Diagrams showing the processes for shallow and deep geothermal systems source*[1].

1. https://www.bgs.ac.uk/geology-projects/geothermal-energy/geothermal-technologies/

Region / Play type	The Americas Eastern Pacific	Asia Pacific	Europe Atlantic Africa
Convection-dominated plays			
Magmatic play type *Geologic controls*: Intrusion of different age, hydrothermal *Geologic setting*: active to extinct volcanic fields (convergent, divergent, transform faults, hot spots, plumes)	46	57	36
Extensional domain type *Geologic controls*: active faults, amagmatic, high porosity, high permeability strata *Geologic settings*: active rifts, metamorphic core complexes, back-arc basins, segmented strike-slip faults	21	4	11
Conduction-dominated plays			
Geologic controls: Faults, fractures, lithofacies, diagenesis *Geologic settings*: sedimentary basins, basement provinces, orogenic belts	0	2	10

Figure 1.9 *Geothermal systems (187) developed worldwide, grouped by play types and regions. Sources: IGA and IFC (2014); systems drawn from www. thinkgeo-energy.com; www.geotis.de; Zheng and Dong (2008).*

Conventional and Non-Conventional Geothermal Resources

- Conventional Hydrothermal Systems. These systems involve naturally occurring hot water or steam reservoirs. They are typically used in volcanic or high-geothermal-gradient areas and are well-suited for electricity generation.
- Non-Conventional Systems (Enhanced Geothermal Systems and Closed Loop). In regions lacking natural hydrothermal reservoirs, EGS can artificially create or enhance pathways in hot dry rock/low permeability rocks for water to circulate, picking up heat for use at the surface. Closed-loop systems involve circulating a working fluid through pipes underground without any interaction with natural groundwater, making them potentially viable and after a complete economic assessment in a broad range of geological environments.

Here's a summary of the geothermal energy landscape in France from the 2023 report from the AFPG (2023), including upcoming projects, current operations, and both deep and shallow geothermal energy contributions:

- Upcoming Projects:
  - 22 geothermal research permits granted for mainland France,
  - 7 research permits were issued for geothermal exploration in French overseas territories.
- Heat Production:
  - 79 deep geothermal operations are currently active in France,
  - 1 million people benefit from geothermal heating in the country,
  - Deep geothermal operations generate 2.05 TWh of heat energy annually.

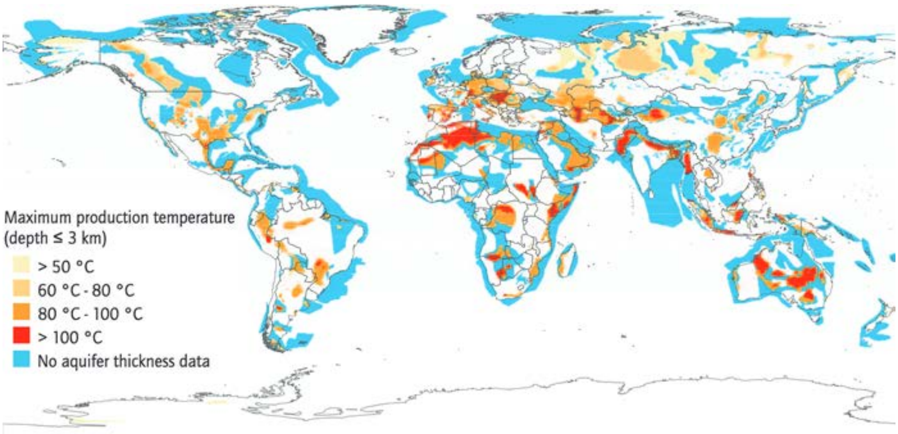


Figure 1.10 *World map of estimated deep aquifer systems from IEA Report (2011). Source: TNO.*

- Geothermal lithium extraction: several projects in Upper Rhine Graben are underway.
- Power Generation, two geothermal power plants are operational:
  - Bouillante, Guadeloupe: 15.5 MW capacity,
  - Soultz-sous-Forêts, Alsace: 1.7 MW capacity.
- Shallow Geothermal Energy:
  - Over 205, 300 shallow geothermal installations provide heating and cooling,
  - Shallow geothermal systems contribute 4.58 TWh of heating and cooling energy annually from near-surface resources.

This range of geothermal initiatives highlights France's commitment to leveraging both deep and shallow geothermal energy for sustainable heating, cooling, and power generation.

Geothermal district heating in the Paris Basin, France, is one of Europe's most successful examples of sustainable heating from geothermal resources (Negrel and Lasne, 2021). The Paris area sits atop an extensive low-temperature geothermal reservoir within the Dogger aquifer, a sedimentary horizon rich in warm groundwater. Found at depths between 1500 and 2000 meters, this aquifer has temperatures ranging from 55 to 85 °C, making it ideal for direct heating applications. Since the 1970s, Paris and its surrounding suburbs have developed a network of geothermal district heating systems that utilize this geothermal resource to provide heat for residential buildings, schools, hospitals, and other public facilities. In geothermal district heating systems, a well doublet is typically drilled to optimize the extraction and reinjection of geothermal fluids from a deep aquifer reservoir.

This doublet consists of one production well and one reinjection well, Figures 1.11 and 1.12. The production well taps into the geothermal reservoir to bring hot water to the surface, which is then circulated through a primary network. This hot geothermal fluid is directed to a heat exchanger, where its heat is transferred to a secondary network used to distribute warmth to buildings across the district. After the heat has been extracted, the now-cooled geothermal fluid is directed into the reinjection well, where it is returned to the underground reservoir. This reinjection process is critical for maintaining the pressure balance within the geothermal reservoir, ensuring that the resource remains stable and sustainable over the long term.

A list of the good practice guidelines on deep geothermal drilling and exploitation from experience in the Paris Basin (Dogger and Albian aquifers) is regularly published (Hamm et al., 2022).

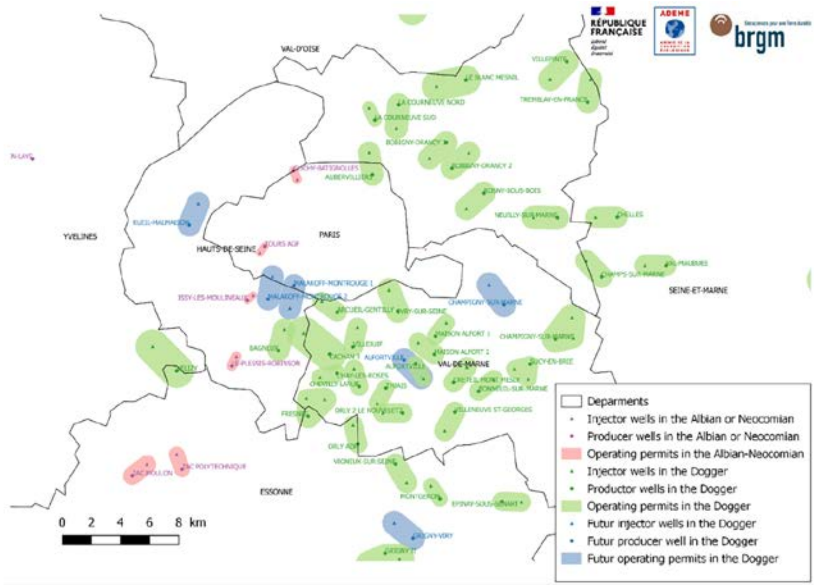


Figure 1.11 *Localization of the geothermal doublets taping the Albian or Neocomian sands (pink) or the Dogger Limestones (green and blue) in Paris area (Hamm et al., 2022).*

In the Alsace region, geothermal energy in fractured granite and crystalline rock represents a promising frontier for accessing geothermal resources. The dense granite or crystalline rock basement of the Upper Rhine Graben sometime lacks adequate permeability. To overcome this, water is injected into the rock to create or expand existing fractures (Enhanced geothermal systems or EGS). The high thermal conductivity of granite and crystalline rock makes them efficient at transferring heat, allowing them to reach elevated temperatures that are suitable for both direct heating and electricity generation. France's Soultz-sous-Forêts project, for example, has demonstrated the feasibility of EGS in fractured granite, highlighting the potential of these formations to supply substantial geothermal energy.

Figure 1.12 *Drilling pad for a geothermal doublet near Paris (source: CFG).*

The Bouillante geothermal plant in Guadeloupe is one of the Caribbean's most significant geothermal power projects, providing renewable energy to the island. Located on the western coast of Basse-Terre, this power plant taps into a high-temperature hydrothermal system associated with volcanic activity. Geothermal fluid is extracted from production wells at depths of 500 to 1000 meters, where temperatures can reach 250 °C. The steam and brine are then used to generate electricity through turbines, producing approximately 15.5 MW of gross power.

1.3 The role of geophysics

Geophysics is becoming increasingly important not only in the exploration of geothermal resources but also in their exploitation and monitoring (Paixach, 2024). By measuring variations in the subsurface's physical properties, geophysical surveys can provide valuable insights into geological features, helping to identify critical characteristics of geothermal systems before the costly process of drilling. Ultimately, geophysical surveys aim to optimize the success of exploration and minimize risks. Generally, no single geophysical method can characterize all the elements of a geothermal play. Each technique has unique strengths and limitations, responding to specific subsurface properties and functioning at different scales, depths, and spatial resolutions. Therefore, selecting the most cost-effective geophysical methods for a given geothermal prospect requires a customized approach, Figure 1.13. Often, this includes conducting onsite feasibility studies to verify that the selected methods are effective in the particular geological conditions.

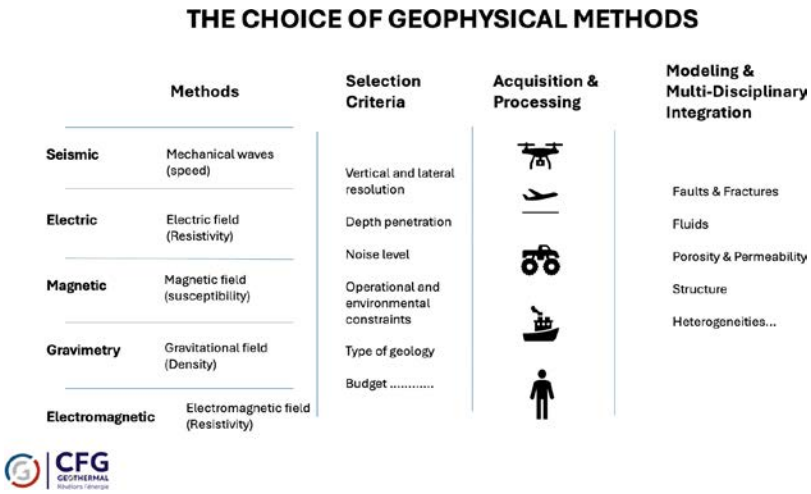


Figure 1.13 *Geophysical methods.*

The concept of hydrothermal play is central to understand and explore geothermal resources. A geothermal play refers to a naturally occurring geological system with conditions favorable for the accumulation, heating and circulation of fluids. Heat is stored in the reservoir host rocks. Water is the vector to transfer energy to the surface. Successful geothermal exploration relies on a detailed understanding of these plays, as they dictate where, how, and to what extent geothermal energy can be effectively extracted. Hydrothermal plays, like other geological plays (such as petroleum systems), are complex systems that depend on a specific set of geological conditions. Four main elements define a hydrothermal play:

- Heat Source: The heat source in a hydrothermal play can be due to natural geothermal gradients (the Earth's internal heat flow), magmatic intrusions, or tectonic activity. In volcanic regions, for example, magma intrusion degassing and cooling represent the prime heat source for geothermal developments.
- Reservoir: The reservoir is the underground porous and/or fractured formation where the hot geothermal fluid is stored. The host rock can be of sedimentary, magmatic, volcanic or metamorphic origin. The quality of a geothermal reservoir depends on the rock's porosity, permeability and productive thickness, which determine how much fluid it can store and how easily fluids can flow.
- Fluid (Hydrothermal System): Geothermal energy depends on the presence of fluids that absorb heat from the reservoir rock and can be brought to the surface. In hydrothermal plays, the water is meteoric water or seawater that has infiltrated into the Earth's crust, circulated, chemically reacted with host rock and been heated. Fluid is essential to transport heat from the reservoir to the surface, either naturally or through engineered systems.
- Caprock or Seal: A caprock is an impermeable layer that helps trap geothermal fluids within the reservoir, preventing them from migrating to the surface or into

other rock layers. Without an effective caprock, the hydrothermal fluids could escape, reducing the potential of the play.

Geothermal exploration begins with identifying regions that meet the basic geological conditions for a hydrothermal play. Then, specific techniques, including geological, geochemical and geophysical surveys (the 3G), Figure 1.14, are employed to gather data about subsurface structures, fluid presence, and temperature.

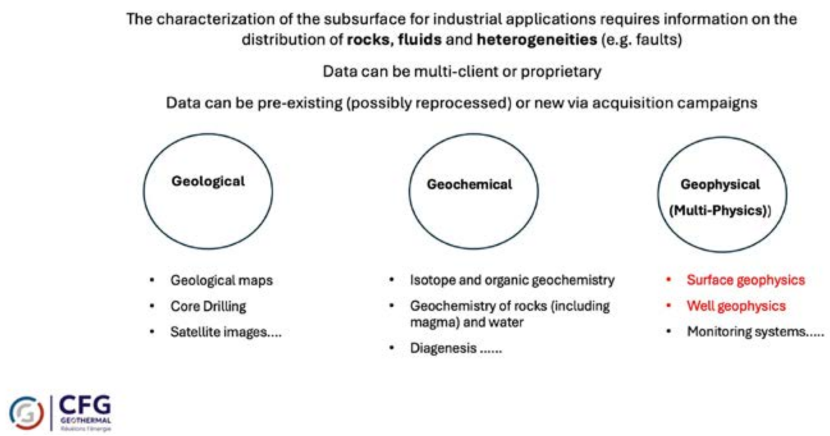


Figure 1.14 *Type of data required in geothermal exploration.*

Geophysical methods provide essential insights that can significantly assist engineers in optimizing and managing geothermal projects. During exploration, scientists and engineers focus on understanding how the different elements of the hydrothermal play interact. For instance, determining the temperature distribution in the reservoir, mapping potential fault lines and fractures that could act as fluid pathways, and locating caprock layers are all crucial to evaluating a play's feasibility. In practice, hydrothermal plays require a combination of geological, geophysical, hydrological, and thermal studies to build a model of the system that can guide drilling campaigns and optimize resource extraction.

One of the main challenges in geothermal exploration is that no single geophysical, geochemical or geological method can directly identify and assess a hydrothermal play. Instead, a combination of techniques, often termed a "multi-physics" approach, is used to obtain a comprehensive view of the subsurface conditions.

This is precisely where one of the greatest challenges facing geophysicists lies: in the transformation of geophysical models (resistivity, velocity, density, susceptibility, permittivity, etc.) into reservoir models (faults, rock types, cavities, aquifers, hydrocarbons, minerals, etc.). This transformation lacks uniqueness and requires contextualizing the geophysical model with an initial subsurface model and integrating boundaries and constraints derived from other data types.

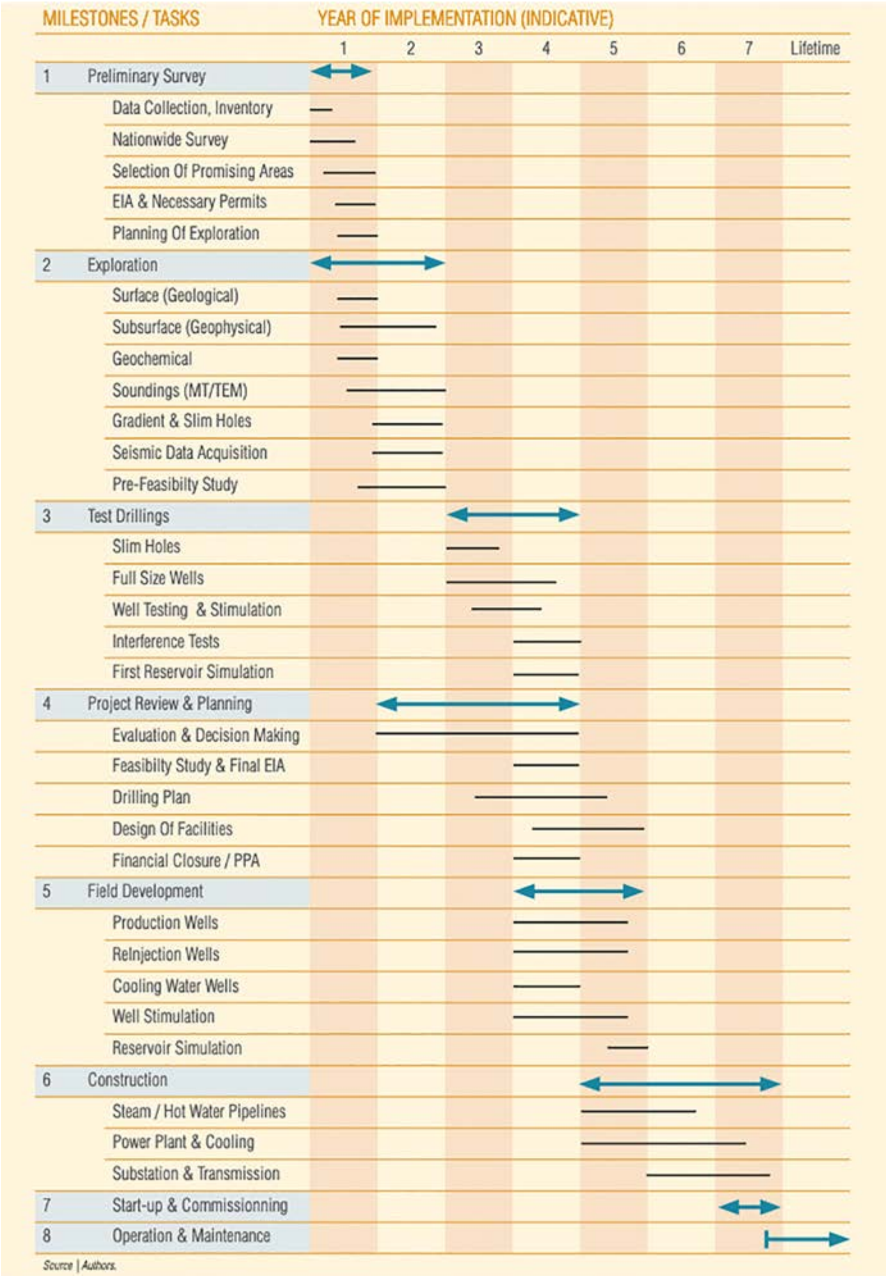


Figure 1.15 *Example of geothermal project development phases for a Power Plant. Source: ESMAP (2012).*

Furthermore, the geophysicist must communicate not only the results but also how various geophysical methods operate, the limitations of their usage, and the inherent measurement uncertainties and resolution limits. Clear and comprehensive communication of geophysical work results is paramount, especially for organizations seeking assurance in the design and planning of their projects. The value of geophysicists lies not only in obtaining the optimal geophysical model but also in their ability to integrate it effectively into the geological or geotechnical context. This process requires deep expertise to overcome challenges related to the interpretation of geophysical models and the communication of results and related uncertainties to engineers and project stakeholders. For industries, such as geothermal energy, where geophysical studies play an important role, the ability to articulate how the methods work, their applicability limits, and the uncertainties surrounding the results become critical.

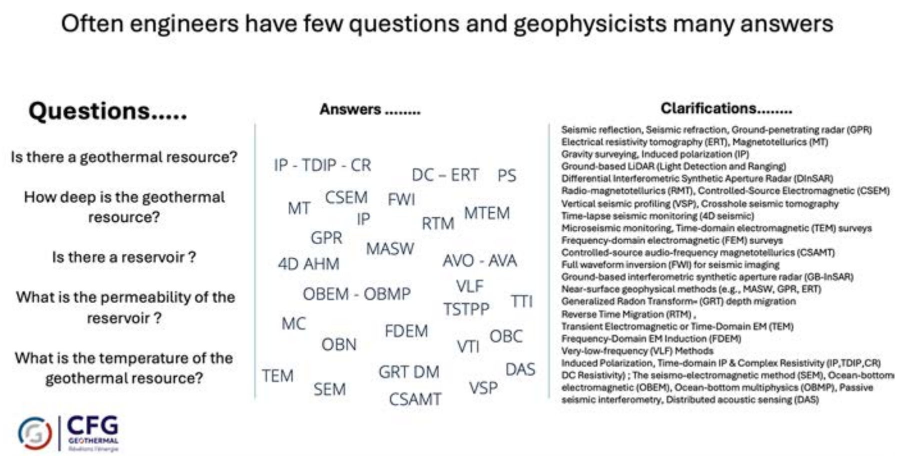


Figure 1.16 *Selected list of geophysical techniques available to contribute to geothermal exploration and exploitation.*

By providing insights into the subsurface's physical properties, geophysical methods help better understand, assess, and monitor geothermal resources. The goal is to enable engineers to optimize production, mitigate risks, and ensure the sustainability of the reservoir. Here is a selected list of the key information that geophysicists can contribute.

- Identifying Subsurface Structures:

  It is important to assess the subsurface structure for geothermal energy production. For instance, faults, fractures, and geological boundaries between different geological formations are important to characterize. By understanding the geometry and distribution of these structures, engineers can identify areas where geothermal reservoirs are likely located.

- Temperature Distribution:

  One of the primary goals of geothermal exploration is identifying areas with high heat flow. Mapping the temperature distribution underground and monitoring its variation over time allows engineers to target regions with sufficient heat for effective geothermal energy production.

- Characterizing Rock Types and Reservoir Properties:

  It is important to have insights into rock types and properties away from the wellbore to estimate the size, depth, porosity, permeability and productive thickness of the geothermal reservoir.

- Geothermal fluids:
  - Identifying Fluid Pathways: Locate pathways within the reservoir that allow geothermal fluids (hot water or steam) to circulate,
  - Assessing Fluid Properties: Estimate fluid properties such as salinity, temperature, and pressure, which are critical for predicting how fluids will behave during extraction and reinjection,
  - Tracking thermal and cold fronts in the reservoir. This monitoring allows engineers to observe changes in temperature and fluid pathways over time, providing critical feedback on how injected fluids interact with the reservoir. With this information, engineers can adapt injection strategies to optimize heat extraction while preserving the resource.

- Others Monitoring:

  Fault activity Assessment: By identifying active fault zones, geophysics helps engineers assess potential hazards, which is crucial for designing safe drilling paths. Avoiding active faults minimizes the risk of induced seismicity and other drilling complications, enhancing operational safety.

  Real-Time Well Steering During Drilling: Geophysical data provides guidance for steering wells during drilling. This information enables engineers to keep the well trajectory in contact with the hottest, most permeable zones while avoiding undesirable features like low-permeability zones or faults, maximizing heat extraction efficiency.

In geothermal exploration, geophysics provides a non-invasive and cost-effective way to gather critical information about the subsurface, reducing the risk associated with drilling. It helps in identifying potential geothermal sites, mapping underground structures, estimating heat flow, characterizing reservoirs, and monitoring the long-term sustainability of geothermal systems. By combining different geophysical methods, scientists can develop a more comprehensive understanding of the geothermal potential of an area.

In geothermal exploration, a single method rarely provides all the information needed to understand the resource. Instead, multi-physics approaches combine several geophysical techniques, allowing experts to construct a more reliable picture of the subsurface. By integrating data from seismic, magnetotelluric, gravity, and geochemical surveys, geophysicists can develop models of geothermal systems that help guide drilling decisions and reduce financial risk.

Geothermal energy offers a unique and promising solution to meet society's heating, cooling, and power needs. By understanding different geothermal systems and employing advanced geophysical techniques, we can harness this sustainable energy more effectively. Geophysics provides the tools to explore and define these hidden geothermal resources, giving us the insight to tap into the Earth's heat with precision and efficiency, ensuring that geothermal energy continues to play an essential role in a sustainable energy future.

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