WHY IS GEOTHERMAL ENERGY UNDERDEVELOPED IN THE E.U?

By

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AUTHOR'S DECLARATION

I, the undersigned, **Isabelle Clark**, candidate for the BA degree in Philosophy, Politics and Economics declare herewith that the present thesis titled "Why is Geothermal Energy Underdeveloped in the E.U?" is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

Vienna, 26 May 2025,

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Abstract

This thesis investigates the underlying causes of the underdevelopment of geothermal energy in the E.U. The three identified obstacles to the development of geothermal energy in the E.U. are: 1) complex technology with a short supply of specialized workforce in the sector; 2) inadequate energy policy for the geothermal industry in the E.U. and 3) high upfront costs. The results show that geothermal energy, a highly clean and sustainable energy, is on the rise thanks to climate goals set by the E.U; however, to become an established industry, amendments around geothermal energy policy must be addressed. The chosen methodology for this thesis is desktop research.

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Introduction

Renewable energy is central to the climate crisis as it is the main solution for moving towards a growing and sustainable economy and society. Yet, in the European Union (E.U.), it seems like only certain renewable energy sources are promoted. The wind and solar lobbies in the E.U. operate on several millions euros worth of costs, while the geothermal lobby runs on two hundred thousand euros in costs (Lobbyfacts E.U. n.d.). My initial interest in geothermal energy was sparked when I learned that my hometown, Vienna, was building a geothermal heating system that will be able to supply heat to up to 200 000 households (OMV n.d.). This news brought to my attention the geothermal energy sector and it led me to my research thesis question: why is geothermal energy underdeveloped in the E.U? In short, geothermal energy is a sustainable source of energy that consists of heat extracted from the subsurface of the Earth. The energy can be directly used for heating systems or converted into electricity. Additionally, geothermal energy has the advantage of producing locally sourced energy for countries that have accessible heat reservoirs, and once geothermal infrastructures are operational, they produce energy year-round. What is more, the European Union's main climate goal is to become a carbon-neutral continent by 2050, meaning that the economy of the Union will not produce any greenhouse gas emissions (European Commission n.d.). So, if geothermal energy has all these benefits and can contribute to the E.U. becoming a carbon-neutral continent, why does it only account for 0.5% of total electricity generated by renewable sources in the E.U. in 2024 (European Commission n.d.)? This topic is highly relevant as it touches upon technology, economics, geopolitics, policy and ultimately, the future of our planet. After doing my research on this question, I have identified three main reasons as to why the geothermal energy sector is underdeveloped. The identified reasons are obstacles which inhibit in their own way the expansion of the sector. The first chapter highlights the complex technology behind geothermal energy sources. The precise knowledge and expertise needed to build and operate a geothermal energy project is currently lacking in the workforce. The second chapter investigates renewable energy policies across the E.U, and how they apply to the geothermal energy sector. Lastly, the third chapter shows that the financing needed for geothermal energy acts as a barrier to its development. The high upfront costs of a geothermal project significantly disincentives private sectors from investing in geothermal energy. Due to the time constraint and scope of this thesis, I have proceeded with desktop research to answer my research question. As one issue regarding geothermal energy is the fragmented nature of information and statistics in the sector (Dulian 2023, 1), this research will contribute to the literature, by gathering in one document informative insights regarding various aspects of geothermal energy.

Literature Review

As I mentioned in the introduction, the literature regarding geothermal energy is largely fragmented and so information on the subject has to be gathered from multiple sources. One of the biggest sources on the topic is the European Geothermal Energy Council (EGEC) which advocates for stronger policies for the energy sector at the E.U. level, and is intended to support the expansion of the geothermal industry.

Chapter 1: What is geothermal energy and how is it being used in the E.U?

1.1 To what end are geothermal reservoirs exploited? As a source of electricity and heat.

Before analyzing the central question of this thesis, geothermal energy must be precisely defined. According to Monika Dulian, a member of the European Parliament Research Service, “geothermal energy is heat generated within the Earth's crust [...]. Thermal energy is stored in rocks and fluids in the centre of the Earth. Drilled wells connect the geothermal resource with the surface in order to use the energy contained in the fluid”(Dulian 2023, 2). The source of energy can then either directly be used for heating in heating systems, which is its most common use, or alternatively, turned into electricity. To produce electric power, “geothermal power plants draw fluids from underground reservoirs to the surface to produce heated material. This steam or hot liquid then drives turbines that generate electricity before it is reinjected back into the reservoir” (Electricity Generation n.d.). Considering this is a social science thesis, the highly technical explanations of various geothermal power plant mechanisms are beyond its scope and therefore will not be included. But a basic understanding of the technology is required to understand the challenges of producing geothermal energy. Various power plant designs have been developed depending on the rock’s temperature and presence of fluid. Three types of power plants exist: dry steam, flash steam, and binary cycle (Dulian 2023, 1). Additionally, an enhanced mechanism called “Enhanced Geothermal System” (EGS) can be applied to flash and binary cycle power plants. The first kind of power plant, dry steam, is the rarest, as it relies on the geothermal source naturally producing steam, which is directly extracted to the surface and the heat triggers the electric generator (Electricity Generation n.d.). The first operating plant of this kind was established in Tuscany, Italy, in 1904

(Electricity Generation n.d.), a region that is still highly rich in geothermal sources today. The flash steam and binary cycle power plants are similar to each other in that steam is not naturally produced, and instead, it is produced by triggering differences in water pressure at the surface. Binary cycle plants differ from flash power plants in that the natural temperature of the rock is lower in binary cycle plants, so another fluid that boils at a lower temperature is used to create the water pressure change (Electricity Generation n.d.). For both flash steam and binary cycle plants, however, the change in pressure creating steam at the surface is what drives the electric generator. Binary cycle plants can repeat this pressure conversion process up to three times leading to higher electricity generation, but also to loss of energy in the conversion processes (Zarrouk and Moon 2014). As previously mentioned, a technology that can be applied to the above-mentioned types of power plants for extracting geothermal heat when the reservoir is not easily accessible, is Enhanced Geothermal Systems (EGS), which functions on hydraulic fracturing. This technology is applied to geothermal sources that do not naturally have water reservoirs or not in a sufficient amount; therefore, water has to be forcefully, but carefully, incrusted with pressure into crevasses of the rock to create a network of fractures (U.S department of Energy n.d., 2). The operation proceeds until a large network of fractures exists to create a steady flow for the water to circulate (U.S department of Energy n.d., 2). The heated water is pumped to the surface and converted into steam. So, EGS is not a type of power plant but a technology that is applied to flash and binary cycle power plants when there is insufficient water in the reservoir.

In summary, dry steam plants are most efficient in terms of energy conversion and costs, as there are no pressure conversion steps; however, such sources are very geographically scarce and thus not widespread. While flash and binary cycle power plants are more common, the cost of the technology required to build and maintain them is higher, and the energy loss during the conversion process larger, particularly for binary cycle power plants (Zarrouk and Moon 2014).

As a result, flash power plants are the most widespread choice for geothermal electricity plants in the world and the E.U (United Nations Climate Change n.d.). No matter what system is used, however, a high level of technological knowledge and expertise is needed to implement it.

Although geothermal sources are exploited for their electricity capacities, they are still mainly used for heating and, alternatively, cooling systems. These functions serve mainly residential buildings, industries and public spaces (EGEC n.d.). Heating through heat pumps is a consistent source of energy as it does not rely on weather conditions and is efficient, as the heat is directly distributed through pipes to local areas. Additionally, heating systems require less technology than electric production and the drilling can be less deep. According to The European Geothermal Energy Council (EGEC), "drilling at a depth of 1 to 3 km is potentially enough to install geothermal heating networks everywhere in Europe. Today many European cities - such as Paris, Munich, Milan, Southampton - are powered by this system"(EGEC n.d.).

It should be noted that a side benefit from geothermal exploration and drilling is potentially mineral extraction. Minerals such as lithium, silica, zinc, manganese, as well as several rare-earth elements can be found near geothermal sources (Dulian 2023, 3). Lithium, in particular, is highly in demand for all smart technologies, including electric cars, as it is used to produce their batteries. "Furthermore, sourcing lithium from geothermal brines is more environmentally friendly than traditional lithium production from dry salt lakes or hard-rock mining" (Dulian 2023, 3). I will explore this matter in further depth in the second chapter on E.U. policy, because this aspect plays a major role in the E.U.'s quest for energy and resource sovereignty.

In summary, geothermal sources can be used for a variety of purposes; including electricity, heating and acquisition of minerals, which should make the exploitation of geothermal energy an attractive choice for investors in the industries.

1.2 What is the status quo of geothermal energy in the E.U?

Although geothermal energy carries many benefits, as we have seen, it is still largely underexploited in the E.U. Within the E.U, the amount of total electricity produced by geothermal power plants in 2021 "amounted to 6 717 GWh, with Italy responsible for most of it (6 026.1 GWh). Other countries have considerably smaller productions: Germany 231.0 GWh, Portugal 217.2 GWh, France 133.2 GWh, Croatia 93.7 GWh, Hungary 16.0 GWh, and Austria 0.1 GWh" (Dulian 2023, 3). Even if these numbers may sound like a considerable amount, geothermal sources still only accounted for 0.5% of total electricity production in the E.U. in 2024 (Eurostat 2025). According to Eurostat, the E.U. reached 47% of renewables in the electricity mix in 2024. "Wind and hydro power accounted for more than two-thirds of the total electricity generated from renewable sources (39.1% and 29.9% respectively). The remaining one-third of electricity came from solar (22.4%), combustible fuels (8.1%) and only around 0.5% from geothermal energy" (Eurostat 2025). In sum, wind and hydro electricity generation are largely favored and exploited over geothermal plants. Although the E.U. is promoting the development of geothermal energy, the sector nevertheless has minor barriers to its development, such as negative drilling side effects and a lack of expertise in the field, which the upcoming section 1.3 will uncover.

1.3 What are some minor constraints of geothermal energy?

To access geothermal energy sources, drilling is required, however, drilling can cause seismic activity in surrounding locations. Typically, drilling depths range from 1 to 5 km in depth. In 2006, in Basel and later in St. Gallen, Switzerland, earthquakes have been recorded and linked to the drilling of geothermal energy (Swiss Seismological Service n.d.). Earthquakes of 3.4 and 3.5 magnitude hit the surrounding cities and caused the termination of the related projects.

Seismic activity is linked to the depth of the drilling; if the depth is greater than 3km the induced odds for causing earthquakes are higher, but the likelihood of seismic activity is also linked to the type of geothermal plant (Swiss Seismological Service n.d.). Enhanced Geothermal Systems, which we have brought up in section 1.1, are more problematic. “During EGS reservoir creation and stimulation, rocks may slip along pre-existing fractures and produce microseismic events”(U.S department of Energy n.d.); however, the induced seismicity usually occurs at very deep levels and are of low magnitude, so it is rarely felt at the surface. Furthermore, lack of monitoring in the hydraulic fracking process can lead to higher magnitude earthquakes. Consequently, the development of geothermal plants can result in public disapproval, although rare, and lead to the abandonment of projects.

Another minor constraint results from the geothermal energy sector being underdeveloped. There is a lack of the needed specialized labor force, such as engineers, geologists, project managers, and project coordinators (European Commission n.d.), although this challenge could be overcome by the conversion of the oil and gas workforce to that of geothermal energy, as the two sectors are closely related. Instead of drilling for oil, companies would be drilling for geothermal reservoirs. “Some of the largest overlaps between the skills and expertise of the oil and gas industry and geothermal projects apply to project evaluation, planning and management; drilling and completion; surface facility construction and maintenance; and operations and production monitoring” (IEA n.d.). The transfer of the workforce from the oil sector to the geothermal sector is a process that will not happen immediately, because fossil fuel extraction is still ongoing. Nevertheless, large oil companies are looking to expand to the renewable energy sector to stay relevant in the environmental transition.

In conclusion, apart from EGS potentially causing minor seismic activity during the drilling process and the low supply of geothermal industry workers, geothermal energy is highly sustainable and available to many countries. And yet, as mentioned above, it only represents

0.5% of the electricity produced in the E.U. In this following chapter, Chapter 2, I will look at how the current E.U. policy lacks adequate endorsement of geothermal capacity and how this is one of the main obstacles to its development.

Chapter 2: What are current and future E.U. policies and deals regarding geothermal energy?

2.1 What are the current policies regarding geothermal energy, and the barriers to its expansion?

A key issue regarding the expansion of the geothermal energy sector in the E.U. is the red tape barrier. This barrier consists of "official rules and processes that seem unnecessary and delay results"(dictionary Cambridge 2025). In management, this barrier occurs very often, especially around large-scale projects. Geothermal energy sources, whether they are exploited for electric power or heating capacity, operate on a large scale involving a multitude of stakeholders. The red tape barrier concerns mainly the development stage of a project and implementation of it. To build a geothermal energy project, project developers must be granted permission by local or national level authorities to explore the geological subsurface. The exploration process in itself can take long periods of time, as geological data and maps can either be inadequate, not granted access to project developers, or do not even exist (General Secretariat of the Council 2024, 9). Consequently, project developers need to hire geologists to collect accurate subsurface data and create a reliable map to correctly plan out the location and type of infrastructure needed to conduct the project. Additionally, and more importantly, the barrier in the development stage of building a geothermal energy project is the administrative license-granting procedure. Before even starting to collect subsurface data, project developers need to have permission to dig holes and investigate geological terrain. It is important to highlight that geothermal energy projects are often Public-Private Partnerships (PPPs) so private companies work together with state-owned energy companies or national agencies to conduct such projects. These partnerships facilitate the licensing procedure but are not enough to overcome the administrative barrier. The European Commission, the main executive body of the European Union, is aware of this licensing barrier and consequently adopted in June of 2024, the Net-Zero Industry Act (NZIA). The NZIA "aims to enhance European manufacturing capacity for net-zero technologies and their key components, addressing barriers to scaling up production in Europe"(European Commission n.d.). The Act bolsters the development of European industrial technology and infrastructure that conform to the climate goal of carbon neutrality for the continent by 2050. Geothermal heat pumps and geothermal power plants are included as technologies benefiting from this Act as well as other technologies linked to geothermal reservoirs. Concretely, the Act forces Member states to set a time limit on licensing permit procedures and to create a "one stop-shop" single point of contact for project developers (European Commission n.d.). This promotes efficiency and transparency. Although this is extremely positive for the future of renewable energies and particularly for geothermal energy which greatly suffers from red tape barrier, the Act is not sufficient to address the specificities of geothermal energy projects. The document comprising notes concluding a meeting on "The promotion of Geothermal Energy" from the Council of the European Union in December 2024, states that Members are encouraged to diminish local permit-granting barriers (General Secretariat of the Council 2024, 5). Additionally, the Council calls on the Commission to draw up a comprehensive strategy for geothermal energy and a "European Geothermal Action Plan" which includes measures to develop the industry (General Secretariat of the Council 2024, 6). If this "European Geothermal Action Plan" comes to life, it would bolster investments and lead to greater projects in geothermal energy. As I mentioned earlier in this section, streamlining permit-granting procedures and creating a single touch point for communication and access to information would enable investors in the geothermal sector to compete on the same level as established energy sectors, like gas and oil, which already have the proper mechanisms to tackle this barrier. In conclusion, even if the E.U. could have started its endorsement of geothermal energy sooner as well as addressing the red tape barrier, the European Union's policy regarding geothermal energy is making progress towards its expansion.

2.2 Where does Geothermal energy stand in the Green Deal and the Critical Raw Materials Act?

I could not proceed with this thesis without mentioning the European Green Deal. Launched in 2019, the European Green Deal lays the climate objectives the E.U. wants to meet within a set timeline. The sectors concerned are: energy, agriculture, transportation, Research and Development, climate, environment and oceans, industry, finance and regional development, and urban landscaping and management (European Commission 2021). This deal between E.U. Members encompasses the whole European framework. It sets out to be a climate neutral continent by 2050 and to diminish net greenhouse gas emissions by 55% by 2030 compared to 1990 levels (European Commission 2021). The European Green Deal is the blueprint for E.U. projects, so it encompasses many directives, acts, and funding programs including the Net-Zero Industry Act (start date 2024), the Critical Raw Materials Act (CRMA) (2024), REPowerEU (2022), and Horizon Europe (2021) which are the most relevant for the development of geothermal energy. Acts within the E.U. are legally binding on every Member state and must be implemented within the agreed timeline, therefore they carry weight on a supranational level. "The European Green Deal focuses on 3 key principles for the clean energy transition" (European Commission 2022): firstly, insuring a stable and affordable supply of clean energy, secondly, creating an interconnected and digitalized EU energy market, and thirdly, insuring energy efficiency and optimization of energy performance of buildings (European Commission 2022). Geothermal energy is most relevant in the third key principle by having the capacity to supply efficient and affordable heating through district heating systems. Additionally, as mentioned in the first chapter, geothermal energy has the advantage of supplying heat directly to the consumers, so it satisfies local energy demands and works as a step towards national energy sovereignty.

Following on the thought of energy sovereignty, the Critical Raw Materials Act, adopted in 2024 by the European Commission, is a plan to establish secure supply chains of critical raw materials for the E.U. The aim is to move away from geopolitically unstable suppliers by seeking out other reliable suppliers and extracting strategic materials within the E.U. directly. This Act touches upon the geothermal energy sector in two ways. Firstly, as mentioned in the first chapter in subsection 1.1, drilling for geothermal sources enables the potential extraction of lithium in its drilling sites. Lithium is classified as a strategic material in the E.U. and its "demand is expected to increase twelve-fold by 2030 and twenty-one-fold by 2050" (European Commission n.d.). Lithium is used to create lithium-ion batteries which serve a multitude of purposes like the supply of power in electric cars but more importantly in wind and solar power plants to store energy when there is excess production, to then compensate the decrease of electric production on still days or overcast days in the case of solar energy (Harvest 2025). Secondly, the Act benefits the geothermal industry by streamlining permit-granting procedures (European Commission n.d.). The official website of the European Commission for the CRMA, explicitly states: "EU countries will also have to develop national programmes for exploring geological resources"(European Commission n.d.). This will directly support the exploration of subsurface water reservoirs used for geothermal energy, thus catalyzing the expansion of geothermal projects.

These Acts agreed upon in the E.U. are a set of directives which orient the direction of the Union's current and future energy mix. "However, it is up to the individual countries to devise their own laws on how to reach these goals" (European Union n.d.). The energy mix plans of Member states are collected and revised by the E.U. to make sure they will meet the goals stated in the Green Deal. So, it is up to Member states to include geothermal energy in their energy mix or not. Therefore, the upcoming subsection will examine the plans of the four countries which include geothermal energy as part of their solution to the green transition.

2.3 Is geothermal energy adequately promoted in the energy mix plans of E.U. Members?

Since 2018, Member states of the E.U. have had to hand in their National Energy and Climate Plans (NECP) to the European Commission (European Commission n.d.). These plans are a detailed plan that the country is aiming to implement in the upcoming years to tackle climate change and reliance on foreign countries for energy imports. The initial drafts of the plans are sent to the European Commission to be assessed and receive recommendations from the Commission. Since the launch of this procedure in 2018, Member states have had to resubmit a newer draft in 2023, which outlined their energy mix goals until 2030. The European Commission then handed in their final comments and recommendations in 2024.

Regarding the general assessment of each Member's plan, the Commission's report states that many countries lack detailed policies regarding how they are expecting to meet the targets, and many countries do not conform to all the regulations put in place (EUR-Lex 2023). Additionally, some countries have more ambitious plans which go beyond the targets set by the E.U, while others fall short of the set objectives. However, the benefits produced by these ambitious countries is not enough to cancel out the weak plans of other countries, leading to severe gaps within E.U. Members (EUR-Lex 2023). Unfortunately, the general assessment is not more precise in stating which specific countries this previous statement applies to. "Geothermal energy sources are mentioned in several draft plans in various sections, in particular for heating and cooling (e.g., France, Germany, Hungary, Slovakia), but with no significant detail on measures to deploy them" (EUR-Lex 2023). In conclusion, from this general assessment by the European Commission, there seems to be a substantial gap between what the European Commission aims to implement and what countries actually produce in terms of policies towards achieving these goals. This shows that policies surrounding the expansion of geothermal energy need to be legislatively stronger to concretely be carried out on national level.

Having analyzed the main recommendations of the European Commission, let us take a closer look at the four NECPs which mention geothermal energy. Out of all plans submitted, only France, Germany, Slovakia and Hungary included geothermal projects as a solution to climate change (EUR-Lex 2023). France focuses on the heating capacity of geothermal sources rather than its electrical capacities. Geothermal heating combined with other renewable heating sources such as biomass (burning of biomass elements such as wood), and solar energy, are projected to increase from 182,7TWh heat produced in 2021 to 297TWh in 2030, and a bracket of 330 to 419 TWh, in the best case scenario for 2035 (NECP France n.d., 75). This production increase in renewable heat is aimed mainly at residential consumption and less so for industrial or agricultural purposes. Shallow level geothermal energy capacity, used for producing heat, represents a larger share of the market than deep geothermal heat capacity. The former produced 3,9TWh in 2021, and is expected to increase to 10TWh by 2030 (NECP France n.d., 75). While deep geothermal energy produced 2,3TWh in 2021 and is projected to increase to 6TWh in 2030 (NECP France n.d., 75). A possible explanation for this difference between shallow and deep geothermal heat development could be that shallow geothermal projects are less costly and more accessible (no deep drilling) and mainly used for residential consumption compared to deep geothermal projects, and France, as mentioned earlier, focuses on geothermal heat capacity for residential uses. Additionally, the plan states that legislative steps will be simplified for the installation of geothermal district systems (NECP France n.d., 123). In conclusion, France's NECP is superficial regarding geothermal energy policies and future plans. The sector is very briefly mentioned compared to other renewable energies. No detail is provided regarding the country's ambitions to develop the sector; it is simply stated as part of the solution for renewable heating networks.

Germany's plan reflects the country's ambition to implement measures outlined in the Net-Zero Industry Act of the E.U. These measures include: cutting red tape barriers, creating a Net-Zero Industry Data platform to exchange valuable data to project developers, facilitating market access to renewable energy technologies, and lastly fostering "net-zero acceleration valleys" which aim to create clusters of technological development and simplified permitting procedure zones (Federal Ministry for Economic Affairs and Climate Action 2024). In addition, Germany is participating in the Strategic Energy Plan (SET), a cooperation between E.U. Members in research development in the area of renewable energies, including geothermal technologies (Federal Ministry for Economic Affairs and Climate Action 2024, 265). The plan is even shallower than France's in regard to geothermal energy policies. There is no mention of a concrete plan to expand the geothermal energy sector, simply vague ambitions.

Slovakia handed in its final plan on the 15th of April 2025, almost a year later after its deadline. Slovakia's plan mentions geothermal energy in several instances. First, it is part of its strategy of development, research, and competitiveness of energy. In launching an exploration strategy of raw materials and geothermal sources, Slovakia seeks to efficiently exploit their untapped resources and gain competitiveness on the European market (Ministry of Economies Slovakia 2025). The Slovak government is aware of the country's high geothermal energy capacity, and is seeking to exploit it to move towards the decarbonatization of heating systems (Ministry of Economies Slovakia 2025, 16). The main initiative to enable the transition is through financial support policies (Ministry of Economies Slovakia 2025, 16). In Slovakia's NECP, a table categorizes the "estimate of the total expected contribution (final energy consumption) of each renewable technology in Slovakia in heating and cooling over the period 2025-2030 (ktoe)[1]"(Ministry of Economies Slovakia 2025, 43). Deep geothermal heat consumption is expected to grow from 7ktoe in 2025 to 40ktoe in 2040 (Ministry of Economies Slovakia 2025, 43). This increase is substantial, but Slovakia has an advantage over other E.U. Members, thanks to its geologically accessible geothermal sources (Obernauer 2009). The plan also includes the electricity capacity of geothermal power plants. Starting from 2029, Slovakia is expected to produce 29GWh from geothermal sources and grow to 30GWh in 2030 (Ministry of Economies Slovakia 2025, 42). Until 2029 no electricity is planned to be generated by geothermal sources. Slovakia emphasizes the financial aspect of R&D for geothermal technologies and extraction of raw materials (Ministry of Economies Slovakia 2025, 92). In an effort to promote "support for the prospection and exploration of geothermal energy sources with a view to making them available for energy purposes", Slovakia will mobilize around 13 million euros of E.U. funding resources (Ministry of Economies Slovakia 2025, 116). Similar to other countries exploiting geothermal energy, Slovakia aims to reduce the time and steps for permit-granting procedures for drilling and exploration (Ministry of Economies Slovakia 2025, 125). Slovakia is deeply committed to the expansion of geothermal energy capacity. "The most important geothermal energy project in Slovakia is the national project 'Use of geothermal energy in the Košice Basin', funded by the Just Transition Fund" (Ministry of Economies Slovakia 2025, 249). The Just Transition Fund, is an E.U. fund allocated to finance renewable energy projects in E.U. countries with smaller economic capacities. Slovakia received 215 million euros in total for the expansion of geothermal energy (Ministry of Economies Slovakia 2025, 314). With the implementation of this project in Košice, which is planned to start in 2027, the renewable heating energy mix is planned to increase to 42% in the region of Košice (Ministry of Economies Slovakia 2025, 249).

[1] Ktoe:kilotonne of oil equivalent.

In conclusion, although Slovakia submitted their NECP with some delay, the plan is rigorous and proposes concrete policies, ambitions, and funding technicalities for geothermal energy. The country shows its dedication to the sustainable energy transition by exploiting its local resource: geothermal sources, which are planned to be used both for heating and electricity generation.

Lastly, Hungary plans to include geothermal heating and electricity in their projected energy mix of 2030. In 2025 geothermal heating produced 0,20Mtoe[2] and it is planned to reach 0,29Mtoe by 2030 (Hungary, NECP n.d., 54). Hungary currently heavily relies on natural gas imports and seeks to move away from this dependency and supply its own heating power with geothermal district heating. Hungary sets out to explore shallow and deep geothermal projects. The country is benefiting from support by the Swiss Fund, a financial cooperation between Hungary and Switzerland to fund geothermal projects (Hungary, NECP n.d., 96). Hungary is also looking to optimize its current geothermal infrastructure to maximize energy efficiency (Hungary, NECP n.d., 99). In addition, to current infrastructure, Hungary will seek to explore deep geothermal sources which are partly on the border with Croatia (Hungary, NECP n.d., 261); making the cooperation between the two countries essential.

As we have seen, policies play a major role in the development of energy mixes. Certain countries favor other energy sources over geothermal energy, because the former are more accessible from a geological and technological point of view. The E.U. has ambitions to become a climate neutral continent by 2050, however this ambition is not necessarily a clear path for Member states. Fulfilling the climate goals requires thorough policies to promote green energy technologies. What is more, the financial aspect is also highly important, and it plays a role in who is able to invest in geothermal technology. Therefore, this third chapter will uncover

[2] Mtoe: Million Tonnes of Oil Equivalent.

the financial costs of geothermal energy and how states and private companies can create partnerships to expand the industry.

Chapter 3: How do high upfront costs of geothermal energy projects act as a barrier, and how to tackle them?

3.1 What are the costs and financial risks of geothermal projects?

Geothermal energy, unlike wind and solar energy, represents high upfront investment costs with high risk factors. Building a geothermal plant or heat pump necessitates extensive preparation before drilling. The seven phases to completing a geothermal project can be divided into three stages: 1: identifying and exploring the source, 2: building the powerplant/heat pump, and 3: maintenance. The first stage involves: the preliminary survey (obtaining permits and resource mapping), exploration (testing the viability of the subsurface by testing for seismic activity and drilling temperature-gradient wells for heat data), and test drilling (this step is crucial as it determines the viability of the project, the test involves drilling 1-5 wells which determine the characteristics of the intended geothermal heat/water reservoir) (Carbon Counts n.d.). Next, the building stage counts three steps: project review and planning (creating a project timeline and coordinating management), field development (reservoir stimulation, cooling water wells) and finally, building the power plant or heating system (Carbon Counts n.d.). The last stage for completing a geothermal project is maintaining the power plant.

The riskiest and costliest step in the development of a geothermal project is stepping from the exploration phase to the test drilling. The success rate of building a viable geothermal drill in a previously unexploited area, is between 33% and 50% (Carbon Counts n.d.). Also, the "identifying and exploration" phase costs between US$12-40 million for a 50 MW power plant (Carbon Counts n.d.). Note that this number dates back to approximately 10 years ago, but it is still relevant. These upfront costs are extremely high for project developers to invest in a sector that is so risky. For the oil industry, paying high upfront costs for a risky drilling project is not a critical issue because the return on investment, if successful, will largely offset the costs (Carbon Counts n.d.), whereas geothermal power plants are not as lucrative as the oil sector and the geothermal energy industry does not have as many resources. Therefore, geothermal projects need financial policies to support investments in the construction of power plants or heat pumps. These measures can be implemented through various fiscal policies. It can be through tax breaks and reliefs for companies, or incentives such as capital subsidies and risk mitigation funds, a.k.a. drilling insurance (Carbon Counts n.d.). These measures are typically implemented at the national level, nevertheless the E.U. also has measures to boost investment in renewable energy. The E.U. introduced eight funding programs to reach their climate ambitions. They are as follows: Innovation Fund, Important Projects of Common European Interest (IPCEI), Connecting Europe Facility, Horizon Europe, InvestEU, Modernisation Fund, Just Transition Fund, and Enhanced European Innovation Council (EIC) pilot (European Commission n.d.). The European Investment Bank (EIB) also participates in granting loans to projects; it oversees, for example the financial dealings of the Innovation Fund. Note that the Just Transition Fund, which is listed above, is the fund that Slovakia benefits from for the development of their geothermal sector in their NECP for 2030.

A recent example of substantial funding to a geothermal project is the Eavor-Loop project in Bavaria, Germany. The large-scale geothermal project will provide both heat and electricity to the region by the end of 2026. The project launched by Eavor-Loop, a Canadian energy company, received a loan of close to 45 million euros from the EIB (Germany 2024). Additionally, the project benefits from a 91.6 million euro grant by the E.U. Innovation Fund (Germany 2024). This project in Germany is extremely costly as we can see; however, the proper funding provided by E.U. entities enables the project to proceed and, in turn, works towards reducing carbon emissions and reliance on natural gas imports. While funds and grants awarded to geothermal projects are extremely helpful, project developers often do not want to incur the risk, both technical and financial, of building a geothermal energy project.

3.2 How can Public-Private Partnerships (PPPs) act as a solution to mitigate risk on private investors?

This is where Public-Private Partnerships come in. PPPs are extremely prevalent in development projects, as they are mutually beneficial to both parties. Public-Private Partnerships reappeared strongly after 2008, where states looked to boost the economy with infrastructure projects, however lacked the funds to do so. Consequently, private companies came in to fill in the budget gaps (World Bank n.d.). For the government's side, PPPs are beneficial in several ways. Firstly, the partnership assures better project efficiency thanks to incentives to deliver the project on the agreed timeline and budget (World Bank n.d.). Secondly, the projects tend to provide a better service to the beneficiaries, as external private companies introduce first-rate technologies that the state may not have at hand (World Bank n.d.). Thirdly, PPPs distribute risk across the two entities over the lifetime of a project (World Bank n.d.). Therefore, no party runs the risk of ensuring the integrity of projects. For geothermal energy projects, the exploration phase associated with the highest risks and costs are usually covered by the public sector, only later during the building and maintenance phase do private companies bring in their expertise (Rifli Mubarak 2025). To illustrate how PPPs are formed to build a geothermal project, what better than to take a local example. Vienna has a large undrinkable water reservoir under its city. Between 2016 and 2022, Geotief Wien, an exploration project led in cooperation by Wien Energie, the state-owned energy provider, and OMV, a major Austrian private company specialized in oil&gas and chemical products (OMV Group | Company n.d.) explored and concluded the feasibility of exploiting the heat source below the city (Deeep n.d.). Then, in 2023 Wien Energie and OMV created a joint venture called Deeep to cooperate on the geothermal heat project in Vienna. As an initial objective for "2028, the plant is expected to supply 20,000 Viennese households with sustainable heat'' which represents an energy "capacity of approximately 20 megawatts thermal" (OMV n.d.). Within the joint venture, Wien Energie will oversee the implementation and construction of: the above-ground plant, heat exchangers, heat pumps and the district heating system to the city, while OMV is responsible for the subsurface operations such as drilling boreholes and extracting heat from the reservoir (Deeep n.d.). This joint venture so far has been successful, as the project is evolving according to its expected timeline. If this pilot project succeeds, then the joint venture will pursue the construction of up to seven other geothermal projects potentially supplying heat to 200 000 households in the Vienna area (OMV n.d.). The budget for the project is around 90 million euros and is financed by the Austrian Ministry of Climate Protection (Deeep n.d.). OMV enables the exploitation of this resource thanks to its expertise in drilling because this project requires drilling up to 3km in depth. In conclusion, PPPs are largely spread in development projects and in the renewable energy sector. The partnerships allow for a combination of: larger budgets, upscale technology, exchange of knowledge and distribution of risk.

3.3 How can proper policies and planning of R&D in geothermal energy reduce overall costs?

Research and Development (R&D) is critical in promoting geothermal energy and lowering the costs of planning and building a project. Although there is no European-wide plan specifically designed for the development of geothermal energy yet, individual countries mobilize their resources to develop the energy sector. Recalling Slovakia which introduced policy measures to develop R&D technology for geothermal energy with hopes it will become central to their energy mix. Another country implementing a strategic plan to develop the renewable energy sector is Austria. The Austrian Ministry of Climate Protection with the participation of the Climate and Energy Fund (an Austrian fund for the development of renewable technologies) hosted a gathering with experts, businesses and relevant associations, to establish the focal points of research in the agenda of geothermal development in Austria (Nachhaltig Wirtschaften n.d.). The strategic plan published in 2022, sets out the path for research and development in geothermal technologies with the intent of making it more competitive on the Austrian energy market (Nachhaltig Wirtschaften n.d.). With the help of technological advancements, geothermal energy could become far more efficient regarding resource management. In summary, improvements and investment in technology can enable the energy sector to lower its costs of production, thus becoming more competitive on the renewable energy market, resulting in a wider spread of geothermal industries.

Conclusion

In conclusion, the main reasons for the underdevelopment of geothermal energy within the European Union are manifold. The first reason is the highly technical aspect of the industry. For certain countries geothermal energy is not accessible due to geological complexities in reaching the sources, and although there are new technologies to reach the heat source, such as Enhanced Geothermal Systems which operate with hydraulic fracking, another technical difficulty that arises from this technology is the lack of skilled workforce to operate these machines. The second reason arises from the E.U. not adequately implementing energy policies that would specifically target the expansion of the geothermal energy sector. There is a lack of awareness of the potential geothermal energy has, by the policy makers in the European Commission. A stronger lobby for geothermal energy would raise awareness of the benefits it carries. The industry is complex and requires support to enable its expansion. The analysis in chapter 2.3 highlights the discrepancy between the objectives set by the E.U. and how individual countries interpret and implement these objectives. The NECPs of countries revealed that geothermal energy is not central to the agenda of renewable energies. Lastly, the combination of high upfront costs and elevated risks of planning and building a geothermal project act as a disincentive to project investors and developers. As a result, geothermal projects rely on additional support from the state to finance and assure projects.

This research has contributed to the literature by gathering information on geothermal energy that is otherwise scattered on the web. Further research can be done in future periods on the same topic, as geothermal energy is a field of study with constant evolutions: in technology, policy measures, and the geopolitical role energy plays. The geothermal energy sector might take a turn for the better very soon, because the new Energy and Housing Commissioner for the European Commission, Dan Jørgensen, has announced the release of the first Geothermal Action Plan in the first quarter of 2026 (Bech 2025). Dan Jørgensen recognizes the potential geothermal energy has in the decarbonization process of Europe (Bech 2025).

To conclude, I think geothermal energy will expand over the century as fossil fuels will be cut out from energy mixes to adhere to climate goals. And in turn geothermal energy will become a viable solution for the growing demand of energy and decrease of carbon emissions in the countries which have easily accessible access to geothermal reservoirs. Additionally, proper investment and policies to promote R&D in the sector will contribute to the development of the geothermal sector.

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