Policy Paper

Benefits of the Closed Loop Geothermal Technology

Structure

FPE

Executive Summary

Geothermal energy is a form of energy derived from heat emanating from within the Earth through underground rocks and fluids. This type of clean, sustainable energy, permanently available is used to produce electricity and heat, which is then distributed to consumers through grids.

However, the use of this type of energy is still limited in Romania also because of the significant limitations that the conventional (open loop) heat capture systems present, requiring to be situated nearby hot water sources as well as very high temperature gradients. The requirement for high temperature gradients and the existence of permeable aquifers significantly limit the large-scale development of conventional geothermal energy projects, making it a niche technology suitable only in hot regions (Rybach, 2010). A further restriction is that geological hot water resources need to be close to heat demand, represented by cities with heating networks.

Closed loop geothermal systems (CLGSs) offer a solution for universalising the use of this type of energy, including in Romania, a country with longstanding tradition in the exploration, drilling and exploitation of mineral resources, as well as with deep know-how and expertise in this field.

The closed loop technology, currently already in use in Canada, Germany, and the US, presents significant key advantages with respect to the conventional (open loop) system. These include the absence of fracking, the possibility to exploit geothermal energy regardless of the availability of hot water aquifers nearby the cogeneration plant, the lack of risks relating to induced seismicity, no use of water involved, the absence of any elements subject to corrosion/erosion/deposition and the direct connection between demand cities and hot water resources.

Moreover, the closed loop technology can guarantee a permanent (24/7) baseload in electricity production and competitive costs compared to renewables, the latter being considered relatively limiting in terms of considerable land footprint and asset longevity, but also in terms of generation source availability. Furthermore, given the extremely small land footprint of the technology as well as the quiet operations, the social impact of the operations is minimal. Applied on a large scale, and in parallel by upgrading heat distribution systems in cities, the technology can replace current heat sources with a sustainable source more efficient costs and permanent availability.

The closed-loop system involves drilling pipes made of a special thermally conductive material into the ground at significant depths, near the magmatic rock layer, where temperatures of around 300°C are recorded. Similar to a radiator through which water is recirculated, the pipe system captures the underground heat of the magmatic rocks and brings it to the surface as a hot liquid, which is then converted within the cogeneration plant into both electricity and heat power.

In this context, a unique legislative approach is recommended to regulate geothermal power, associated with the Mining Act 85/2003 as the only key legislative framework suitable to govern this distinct type of mineral resource, and not to other existing pieces of legislation.

From a legislative perspective, the wider use and exploitation of geothermal energy could be facilitated in Romania by reviewing the current Mining Act 85/2003, to provide: (1) a clear definition of geothermal energy, including an extended terminology to explicitly define geothermal heat, geothermal power, and geothermal water exploitation among the resources which can be exploited; (2) a simplified /single authorisation process, with transparent criteria for investors' requests; (3) easy access to authorisation procedures, and reasonable granting periods; and (4) longer periods for drilling permits granted for geothermal applications.

An important aspect to be considered is that the initial investment in this case is much higher than in the case of conventional heat capture systems, with payback over time. However, operational costs in the long run are significantly more efficient than in the case of traditional applications.

Furthermore, this sector has the potential to generate new workplaces, as well as improve the country's overall environment performance as Romania recently joined European and wider efforts aiming to reduce carbon emissions and increase the amount of energy obtained from renewable sources.

The government and the private sector should collaborate to ensure that Romania benefits from the latest applications available on the market, and the clear advantages presented by the closed loop technology, to turn the benefits of geothermal power into reality for a wider population.

1. Introduction: Traditional geothermal energy and its limitations

1.1. Definition

Geothermal energy is a form of energy derived from heat emanating from within the Earth through underground rocks and fluids. This type of energy is used to produce electricity and heat, which is then distributed to consumers through grids. Installed power is used in thermal applications, but **the use of this type of energy is still limited in Romania.**

Geothermal energy is **a renewable and inexhaustible source of energy** that can be used continuously in locations which meet the technical conditions. In terms of the usefulness of conventional geothermal energy in buildings, geothermal sources up to a few tens of metres away can be used to heat small systems using heat pumps.

For electricity generation, exploitation operations are carried out at depths ranging between 2,000 and up to 7,000 metres, at temperatures above 150°C (super-hot rock geothermal).

1.2. Technology used in the open circuit heat capture system *(open loop)*

In an *open loop* heat capture system, groundwater is directed from a nearby aquifer to an indoor geothermal heat pump. After the water leaves the house, it is discharged back through a well, which is located at an adequate distance. Water may also be directed to a nearby pond or an approved drainage ditch, depending on local regulations.

Within this system, the earth loop consists of a system of pipes buried underground. These underground pipes are filled with fluids that facilitate heat exchange.

At a later stage, the heat pump exchanges heat between the air and the ground loop system, capturing heat from the air or from the loop, depending on the level of heating or cooling desired. The heat is sent to the pump via a heat exchanger. The distribution system is then the element that supplies heated or cooled air throughout the entire household. The longer the ground loop is, the greater the amount of heat that can be collected. The length of the ductwork should be designed depending on the size of the property and the amount of heat required, so that a comfortable temperature can be maintained throughout the year, regardless the season.

It is important to note that the earth absorbs almost half of the solar energy it receives every day. The ground remains at a constant temperature even in winter, which means that **a geothermal system can be used all year round.**

In the case of the open loop system, geothermal water can also be exploited through a doublet system, consisting of injection and production wells. The characteristics of this system also depend on the specific geological conditions. These conditions include:

- Tanks
- Heat flow
- Fluids

It should be noted that sedimentary aquifers are defined by their lithology as well as their thermal properties. These characteristics can influence fluid and heat transport respectively and a correct understanding of the influence of these characteristics is essential for understanding the performance of doublet systems and correct project planning.

A significant limitation of traditional geothermal applications is that the water resource, the hot water reservoir, needs to be located close to a district heating or industrial offtaker. Another important limitation is that **conventional geothermal systems work only where geothermal gradients are high.** The variation of temperature with depth is referred to as **geothermal gradient.**

While temperature, pressure, volume, enthalpy and entropy are thermodynamic properties of a certain system, **heat** refers to "energy in transit", meaning the energy flowing due to temperature differences. **Enthalpy** is the measure of heat (energy) content of a system. Geothermal resources are classified in terms of the enthalpy of the heat carrier, into low, medium and high-grade enthalpy.

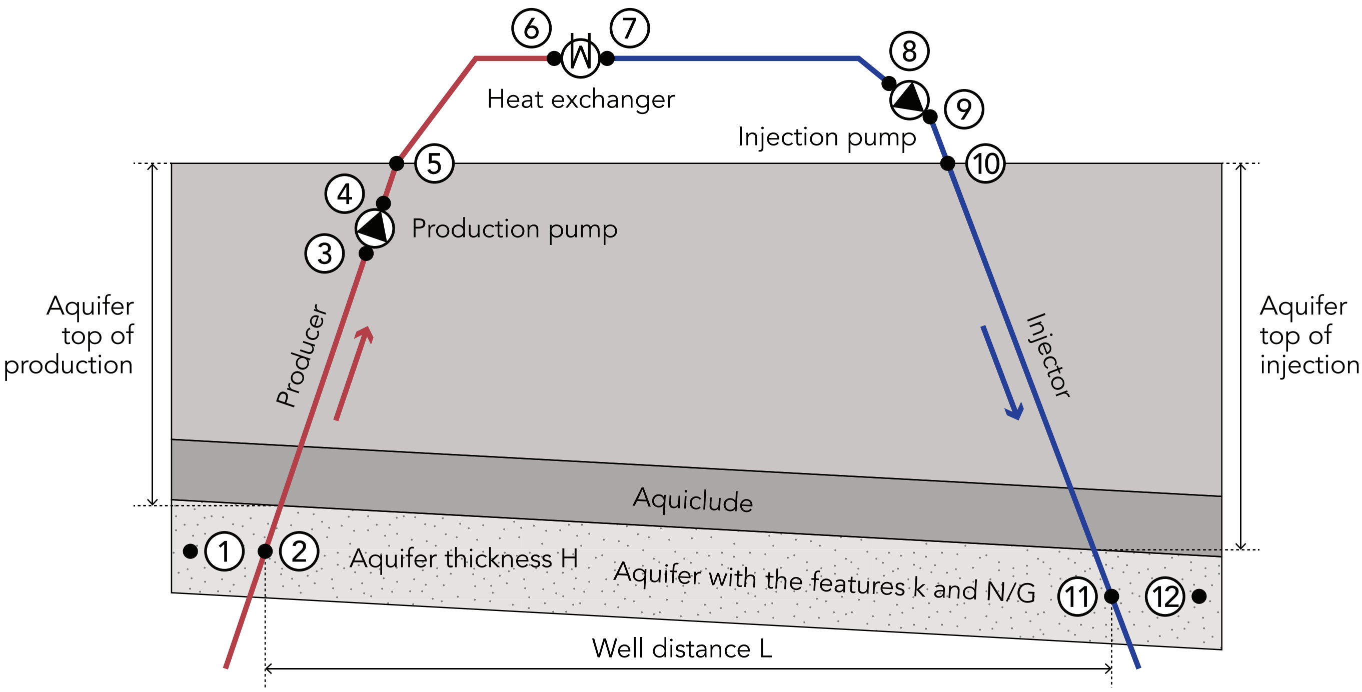
Data from over 45,000 oil and gas reservoirs indicate the benefits of hotter and shallow rocks, as temperature is strongly correlated with debts (Wood Mackenzie study). According to the same study, highly permeable reservoirs are not common at greater depths, which means that above-average geothermal gradients are usually very important to hot and permeable reservoirs.

Thus, the requirement for high temperature gradients and the existence of permeable aquifers significantly limit the large-scale development of geothermal energy, making the conventional (open loop) technology a suitable choice only in hot regions (Rybach, 2010).

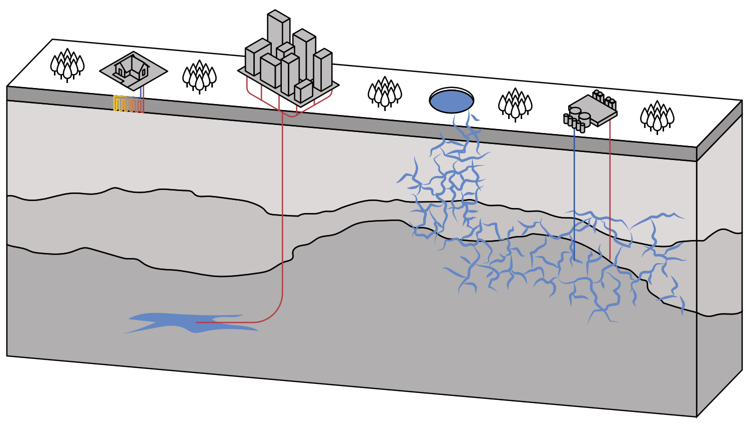
Furthermore, **reservoir features need to meet economic limits in terms of porosity, permeability** and ensuring high flow rates. Furthermore, it is worth noting that water should not contain gas or any other disturbing elements (Ca, Mg, etc).

The pictures below illustrate the technical characteristics and components of conventional *(open circuit)* heat trapping systems.

Heat exchanger for drilling/heat pumps
Classical geothermal - Dual systems: 1. Aquifer, 2. Fractured reservoir



Classic/conventional geothermal systems
Source: eavor.com



2. Launching the closed *loop system* technology

2.1. Closed loop system technology for underground heat capture (technical characteristics)

Closed-loop heat capture is a new technology that has been developed and tested in countries such as Canada, the US and Germany for several years now, which can contribute to diversifying the sources of heat production at national level. **The system has been tested and improved,** involving the construction of a cogeneration heat and power plant. At the same time, geothermal systems are classified according to production temperatures.

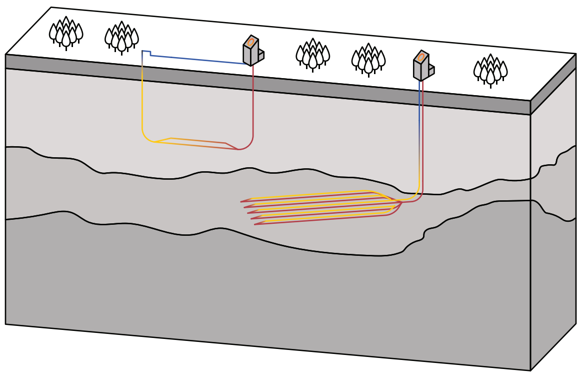
In Canada, the test loop has been running since 2019, while in Germany (Geretsried) drilling operations are still ongoing.

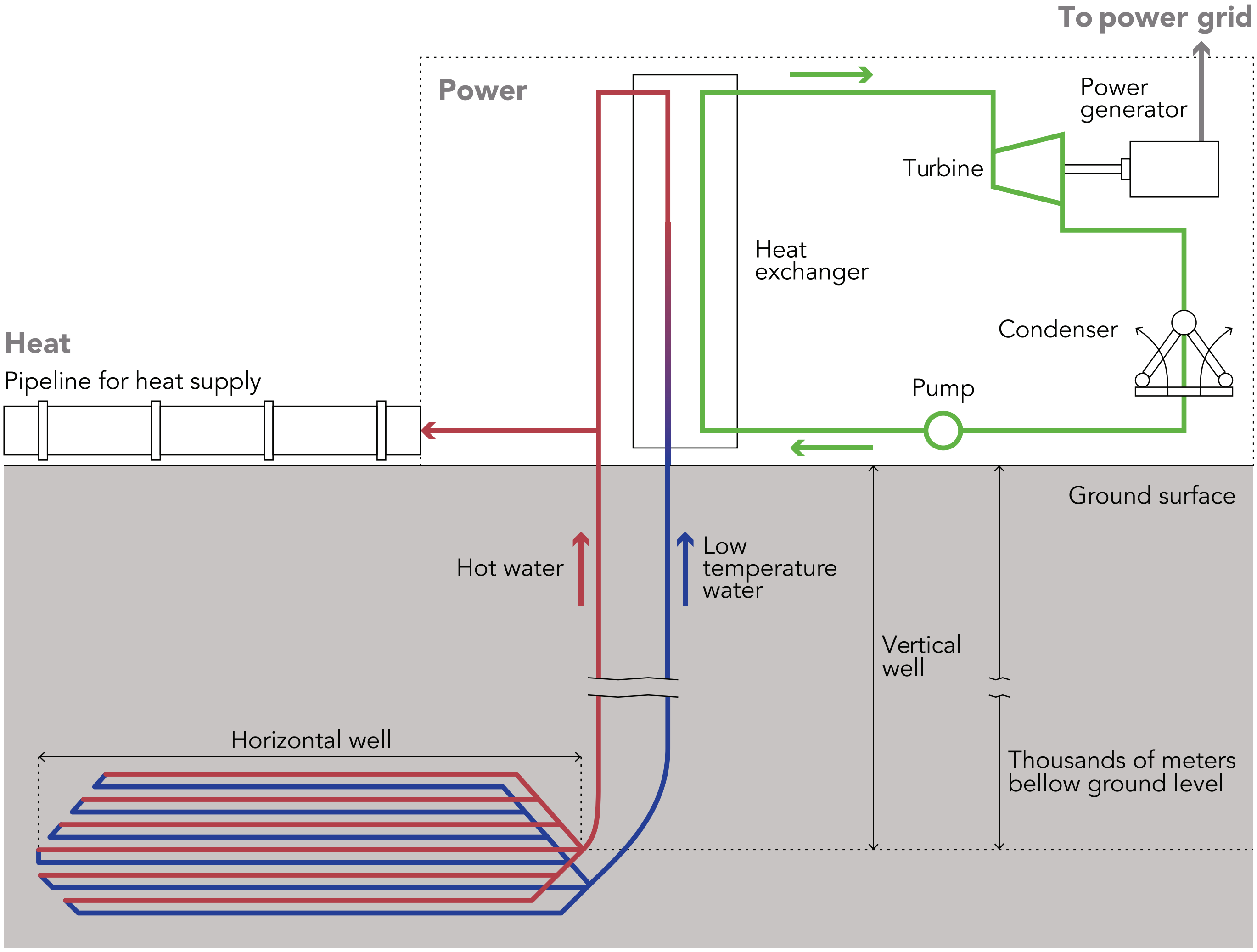
The closed-loop underground heat-trapping system involves drilling pipes made of a special thermally conductive material into the ground at **significant depths** (up to 7,000 metres) near the magmatic rock layer, where temperatures of around 300°C are recorded. Similar to a radiator through which water is recirculated, the pipe system captures the underground heat of the magmatic rocks and brings it to the surface as a hot liquid. This liquid is then converted within the cogeneration plant into both electricity and heat power.

It should be noted that with this closed-loop technology, water-seeking boreholes are replaced by the existence of a single well or several wells connected together in a closed loop. These installations collect heat from deep underground in a structure that can be compared to a radiator. This eliminates uncertainty about fluid exchange and reservoir.

The picture below illustrates the technical characteristics of the new closed loop heat trapping systems.

New geothermal systems





To power grid
Power
Power
generator
Turbine
Heat
exchanger
Condenser
Pump
Heat
Pipeline for heat supply
Ground surface
Hot water
Low
temperature
water
Vertical
well
Horizontal well
Thousands of meters
bellow ground level

2.2. Key benefits and differences from traditional geothermal energy

The closed-loop system differs from traditional geothermal energy in several ways. **Closed-loop capture does not use natural resources, as it does not extract hot (geothermal) water from underground.** The closed-loop technology also does not require pumping devices, as the hot liquid is returned to the surface through natural thermosiphon.

It should be noted that this **new technology does not use hydraulic fracturing,** so there is no risk of induced seismicity. It also releases no carbon dioxide or greenhouse gases and **has more efficient operating costs** than traditional geothermal systems. On the other hand, **the initial investment in this case is much higher than in the case of conventional** (open loop) heat capture systems, with payback over time.

At the same time, **traditional geothermal energy has never been globally scalable, unlike closed-loop underground heat capture systems.**

The table below illustrates the differences and key features of conventional heat capture systems and new technology.

Description	Classical geothermal		Improved geothermal system	Advanced geothermal system
	Doublet watertight system	Doublet fracture system		
Type of system	Open		Open	Closed
Water flow	Water flows through a reservoir, with fluid exchange between system and reservoir			Water circulates separately from the reservoir, with minimal or no fluid exchange
Heating mode	Thermal convection		Thermal convection	Thermal conduction
Geology	Permeable tank	Fractured permeable tank	Waterproof tank	Waterproof tank
Depth	Depends on geology and geothermal gradient (2.5 km - 5 km)			
Induced seismicity	Redus	Environment	Picked up	Negligible
Operational difficulties	Detraction, flow drop, pump damage		Regular hydraulic fracturing is necessary	Loss of working fluid and well collapse
Need for pump	From	From	From	No, due to the thermosiphon effect
Decline in heat output over time	Constant			Small decrease over time
Scalability	Reduced		Reduced	Medium
Costs involved	Low capital expenditure, high operational expenditure		Medium capital expenditure, high operating expenditure	High capital expenditure, efficient operational expenditure

2.3. Benefits of using closed loop ground heat capture system

Closed-loop heat-trapping technology can be implemented in any areas with high temperatures underground. For a country like Romania, characterised by a long tradition of drilling operations in the oil and gas industry, the implementation of new closed-loop technology represents a real opportunity to use local expertise and knowledge already applied by the oil sector.

The use of this technology represents an opportunity to sustainably supply heat to industry, but also to cities in Romania, especially those located in areas with high underground temperatures. **Geothermal heat** can be an optimal solution for **supplying heat in Romania at more competitive prices,** particularly in areas with very high und erground temperatures. **The closed-loop system can thus generate industrial-scale electricity** or enough heat to heat the equivalent of 16,000 homes with a single installation.
Production temperature between 45°-150° C are capable of generating heat use applications or even low enthalpy electricity (75°C), while production temperatures of less than 45° can be used for heating purposes, with a ground source heat pump.
The electricity that can be produced through the new closed-system technology from underground heat could bring up to 25 TWh per year to the market, thus replacing consumption needs from imports. Over time, this resource can replace electricity produced from fossil fuels (coal, oil products or natural gas), given the European and international trend as well as Romania's recent commitments in the framework of the Long-Term Strategy for the Reduction of Greenhouse Gas Emissions.

At the same time, the technology can guarantee a permanent (24/7) baseload in electricity production and competitive costs compared to renewable sources, the latter being considered relatively limiting in terms of considerable land footprint and asset longevity, but also in terms of generation source availability. In addition, given the **extremely small land footprint of the technology,** as well as quiet operations, the social impact of operations is minimal, according to experts.

The technology can thus replace current heat sources a sustainable source with a sustainable source, an innovative solution with permanent availability.

2.4. Contribution to combating climate change

Closed-loop geothermal projects significantly contribute to mitigating climate change by providing a sustainable and low-emission energy source. Unlike traditional fossil fuels, these systems generate heat and electricity with **minimal carbon emissions.** They use a closed underground loop to extract thermal energy, reducing land use and environmental impact. Unlike some other renewables that depend on weather conditions (for example the intermittency of solar, wind and hydropower), this renewable energy source is also **consistent and reliable,** which makes it the ideal for the energy transition.

By replacing carbon-intensive energy sources and unreliable renewables, closed-loop geothermal systems help **reduce greenhouse gas emissions,** which is a critical factor in combating climate change, **while not consuming any limited resources of the planet.** These systems avoid the water usage and potential groundwater contamination issues associated with traditional geothermal methods. By providing a stable and clean energy source, they help in the transition to a more sustainable and low-carbon energy future, crucial in the fight against climate change. Its continuous energy supply and the technology, which minimizes surface impact and reduces greenhouse gas emissions, makes it the ideal candidate to tackle pragmatic responses to climate change, especially when compare d to other energy sources that are a fundamental part of the energy mix.

Geothermal energy is highlighted in the latest version of the **National Integrated Plan in the field of Energy and Climate Change** (PNIESC), as a modern technology based on renewable energy sources, generating low or zero emissions. According to the plan, Romania benefits from several sources of geothermal resources, which can be used to produce electricity as well as heat residential areas.

Geothermal energy is also mentioned in Romania's **Long Term Strategy for emissions reduction** as an instrument which may support the implementation of several types of interventions responding to national objectives. These objectives include further development and investments in the agri-food sector aiming to produce energy from renewable sources, while contributing to reducing greenhouse gas emissions (GHG).

2.5. Examples of successful pilot projects implemented at European and international level (Vancouver - Canada, Geretsried - Germany, Fervo Energy/Google, Nevada - USA)

Vancouver case study

The closed-loop geothermal project in Vancouver, Canada, was characterised as one the most innovative contemporary approaches to sustainable energy. It is efficient and environmentally friendly, significantly reducing the carbon footprint compared to the alternative traditional energy sources available in Canada.

Creative Energy, a leader in district energy solutions, is collaborating with Eavor Technologies, a global geothermal company based in Canada, to integrate Eavor-Loop™, a closed-loop geothermal technology, into Vancouver's downtown energy system. This project, part of Creative Energy's long-term plan to transform into a zero-carbon utility, aims to revitalise and decarbonise their natural gas-fired downtown steam plant. The integration could reduce Vancouver's greenhouse gas emissions by approximately 30,000 tonnes annually, contributing significantly to Canada's net-zero emission goals. Eavor recently received a substantial grant from the Canada Growth Fund, highlighting the project's potential as a model for urban decarbonisation.

One of the key current projects includes the decarbonisation of their downtown Vancouver steam plant which currently depends on natural gas-fired boilers in a central plant, producing heat which is distributed to end customers as steam through a network of underground piping.

Once this project is completed, this will be one of North America's largest thermal fuel-switch initiatives, providing downtown Vancouver with renewable energy infrastructure. As part of its plans to further decarbonise the system, Creative Energy is currently developing its long-term resource plan. This plan proposes a strategy to transform the system into a zero-carbon utility, including converting the distribution system from steam to hot water to accommodate clean technologies.

Geretsried case study

Eavor's project in Geretsried, Germany, the company's first commercial-scale power plant, has been possible thanks to a €91.6 milion grant from the EU's Innovation Fund[1]. The project is currently under construction in Geretsried, southern Germany. The plant is being built on the same site which had been previously selected for a traditional geothermal project, then abandoned as an adequate reservoir had not been identified.

Given that the Eavor-Loop system does not require a source of hot water, the team working on the new project was able to even use installations from the prior initiative. The new plant site will include two vertical wells connected horizontally. Once this closed circuit is in place, a special fluid will be circulated through it to collect heat from underground. Through a radiator-like effect, the difference in density between the warm and cold fluids across the system brings heat up to the surface, and the heat obtained in this way can then be transported into the local heating network or turned into electricity.

At Geretsried, Eavor Deutschland has so far completed the first two vertical boreholes and reached a depth of 4,500 m. The company has also managed the deflection, that is the curve to the horizontal plane, and is currently continuing to drill horizontally. At the same time, the power plant which will produce electricity is also being currently built. Initially, electricity will be produced, and later on, heat will also be produced.

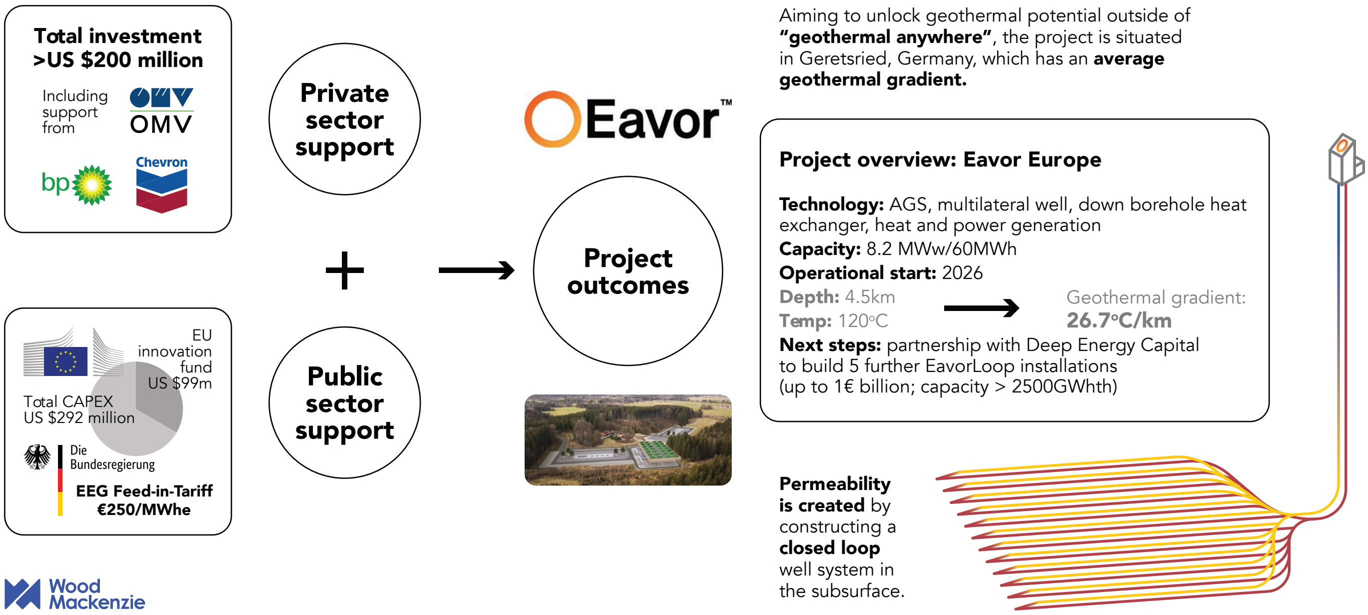
The Geretsried plant is expected to be fully operational as of late 2026. During its initial 30-year life cycle, **the plant is expected to produce nearly 65 MW of thermal energy and more than 8 MW over electricity.** Since only 1 MW can power between 400 and 900 households per year, this plant is expected to contribute significantly to the greening of local heating and electricity grids, **by preventing around 45,000 tonnes of CO_2 annually from being released** into the atmosphere. This figure is equivalent of the emissions produced by heating over 10,000 homes with a gas boiler for one year.

Furthermore, since the closed-loop system does not involve energy to operate, the plant's own greenhouse gas emissions during its operation stage will be close to zero. On a local scale, it is worth noting that **the project is expected to generate 4,000 jobs in Geretsried and nearby areas.**

1 https://climate.ec.europa.eu/news-your-voice/news/eavorloop-story-harnessing-earths-energy-greener-transition-2023-11-06_en.

Once the Geretsried project is proven to be operational, Eavor will invite other energy developers to consider deploying this technology in their own initiatives.

Pilot projects proving emerging technologies
Case study: Eavor



Nevada case study

In the United States, Fervo Energy has partnered with Google to develop a similar closed-loop geothermal project in Nevada. This project aims to supply clean, renewable energy to Google's data centers, showcasing a significant investment in sustainable energy technologies by a major tech company. Both projects are examples of how closed-loop geothermal systems are being used to advance renewable energy solutions in North America.

Google has successfully integrated carbon-free electricity from an advanced geothermal project by Fervo Energy in Nevada to power its data centres. This milestone demonstrates the potential of geothermal energy to contribute significantly to climate change solutions. The project utilizes innovative drilling techniques and closed-loop systems, marking a significant step in geothermal technology development. Fervo's success allows room for larger projects, emphasising geothermal energy's role as a reliable, clean energy source to achieve 24/7 carbon-free energy targets.

As of last November, Google announced that the 3.5 geothermal power project co-developed with Fervo Energy in order Nevada his officially started delivering power to the local grid, which also supplies the data centres of Google in Nevada. The geothermal power facility in Nevada is a full scale enhanced geothermal system initiative. In late 2023, Fervo announced[2] successful results after drilling and stimulation, with the doublet able to support 3.5 MW of electricity production with a flow rate of 63 L/s at high temperature.

Google considers geothermal energy an important part of reaching their goal of achieving **carbon-free electricity supply in their operations** and data centres by 2030. The company has also announced a new partnership with Project InnerSpace, aiming to address critical challenges facing geothermal development, including the development of a global geothermal resource mapping and assessment instrument.

2 https://www.thinkgeoenergy.com/fervo-and-google-geothermal-power-facility-starts-grid-supply/, November 2023.

3. Opportunities for exploiting closed loop heat capture systems in Romania

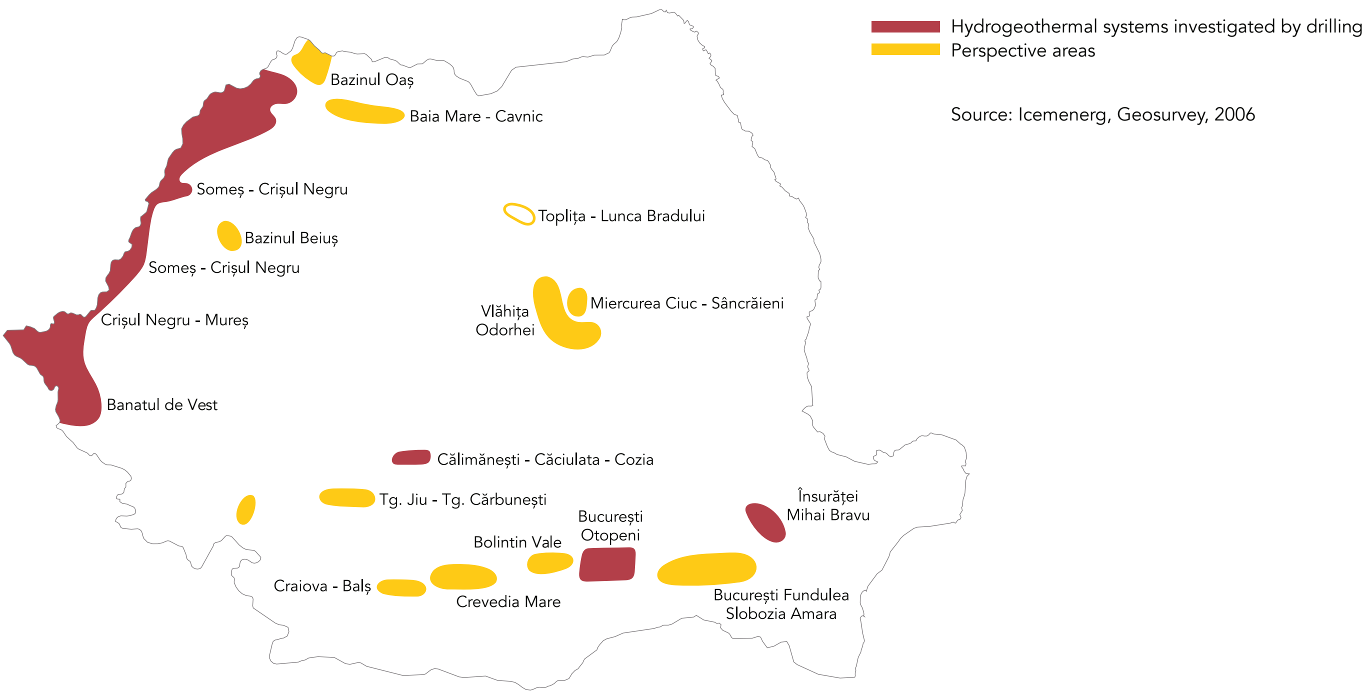
3.1. Romania's geological potential

The exploration of geothermal resources started in Romania in the 1960s. More than 250 boreholes drilled at depths ranging between 800 and 3,500 meters have indicated the presence of low enthalpy (40-120°C) geothermal resources. The equipping and experimental exploitation of more than 100 boreholes in the last 25 years has allowed the evaluation of the exploitable heat from these geothermal resources.

Romania is among the top five European countries with geothermal energy potential, with exploration currently being conducted at 24 sites. Nevertheless, Romania has a far more substantial number of underground geothermal waters sources.

Over 250 wells dug at depths ranging between 800 and 3,500 meters have indicated the existence of geothermal resources with low enthalpy (40 – 120° C). However, for higher depths, at around 4,500 meters, the high temperature gradient has been confirmed by wells made while searching for hydrocarbons.

Geothermal systems in Romania



Source: Icemenerg, Geosurvey, 2006

3.2. Technological potential. Transfer of know-how from the domestic oil and gas sector to new heat capture technology

Romania has a long tradition in oil and gas exploration, as well as a deep expertise in this field. These elements present an opportunity for the transfer of know-how from the domestic oil and gas sector to develop sustainable methods to use geothermal power for domestic heating, and potentially, in the long run, for industrial use purposes.

Oil and gas companies operating on the Romanian market have the necessary capacity to ensure the transfer of drilling technology for the implementation and use of the closed loop technology.

Since 2018, synthetic reverse emulsion drilling fluids have been increasingly used, especially in wells deeper than 2,000 m, leading to reduced drilling time and reduced differential sticking and wellbore instability problems.

In 2018 and 2019, three HPTP exploration wells were drilled, reaching depths of up to 5,600 m measured, these wells requiring specific equipment and experienced personnel to perform the operations safely. The use of casing equipment has allowed a reduction in turnaround and circulation time.

The intensive use of depth-rate motors has had an impact in increasing drilling speed and reducing the risk of missing the target. Reducing the time interval between the drilling intention and the actual start date of drilling led to the solution of "cluster" drilling of a group of 2-3 wells drilled simultaneously. Horizontal and steeply inclined drilling were also considered. Thus, in 2018 and 2019, 25 inclined wells were drilled in the Vața field with depths between 881 and 1,308 m. Another initiative to reduce the time between the drilling plan and the actual drilling start date was the adoption of an integrated software solution in support of digitalization process and which drastically reduces the time and burden related to design and project management.

All this has made possible notable results such as: +3,000 m drilled with a 6-inch PDC well (I9A- Swan West well) respectively with the highest number of stages installed for a high-pressure stimulation (HP), 12 stages.

With respect to drilling related to the geothermal sector, the closed-circuit underground heat trapping system has been in use since 2019. Currently, the technology has been tested and improved, involving the construction of a combined heat and power plant. Technically, the closed-loop underground heat-trapping system requires two parallel, vertical boreholes to be drilled underground, with depths varying from zone to zone, depending on the location of the magmatic rock layer in the earth's crust. The boreholes are designed to house two pipes made of a special material that is thermally conductive but resistant to both pressure and high temperatures.

At the point where the boreholes and pipes reach the magmatic rock layer, they will deflect at an angle of 160 degree s,
at which point the pipes will branch off. The branches will merge into the magmatic rock layer up to a maximum depth of 7,000 metres. One of the two pipelines will transfer low-temperature water from the cogeneration plant to the underground. The liquid used will be circulated through a special pipeline system located in the magmatic rock layer, an area where ground temperatures are very high (approx. 300°C). Due to the material from which the pipelines are made, the liquid will pick up the heat emitted by the magmatic rock and heat up, being lifted to the surface through the second pipeline, which will bring the heated liquid to the surface. The liquid reaches the surface through the natural thermosiphon, because the hot fluid has a specific gravity that allows it to rise through the outlet pipe.

The hot liquid is then converted in the CHP plant into both electricity and heat. The hot liquid used to produce electricity and heat, once cooled, can be returned to the ground to recirculate and reheat. The closed loop geothermal system (CLGS) relies on conductive heat transfer without the need for a permeable aquifer. **CLGS does not use water, nor hydraulic fracturing,** nor it has any elements subject to corrosion/erosion/deposition, requires no fluid disposal, requires no rare metals, and occupies a relatively small surface area (Toews, Riddell, Vany, & Schwartz, 2020).

The main disadvantage of CLGS limits the rate of heat transfer through hot rock which is a slow physical process. The required borehole area in contact with the hot rock must be very large to avoid this drawback and make the project economical. Drilling of Multilateral Closed Loop Geothermal Systems (MCLGS) in which one probe is connected with several side probes for heat accumulation is one method to create a sufficiently large contact area.

At the same time, in this system, special attention is being paid during such operations to environmental protection. Drilling fluid services are combined with the management of drilling waste. Neutralisation additives, processing equipment and transport conditions to approved landfills are just some of the ways to reduce environmental impact, in line with existing legislation.

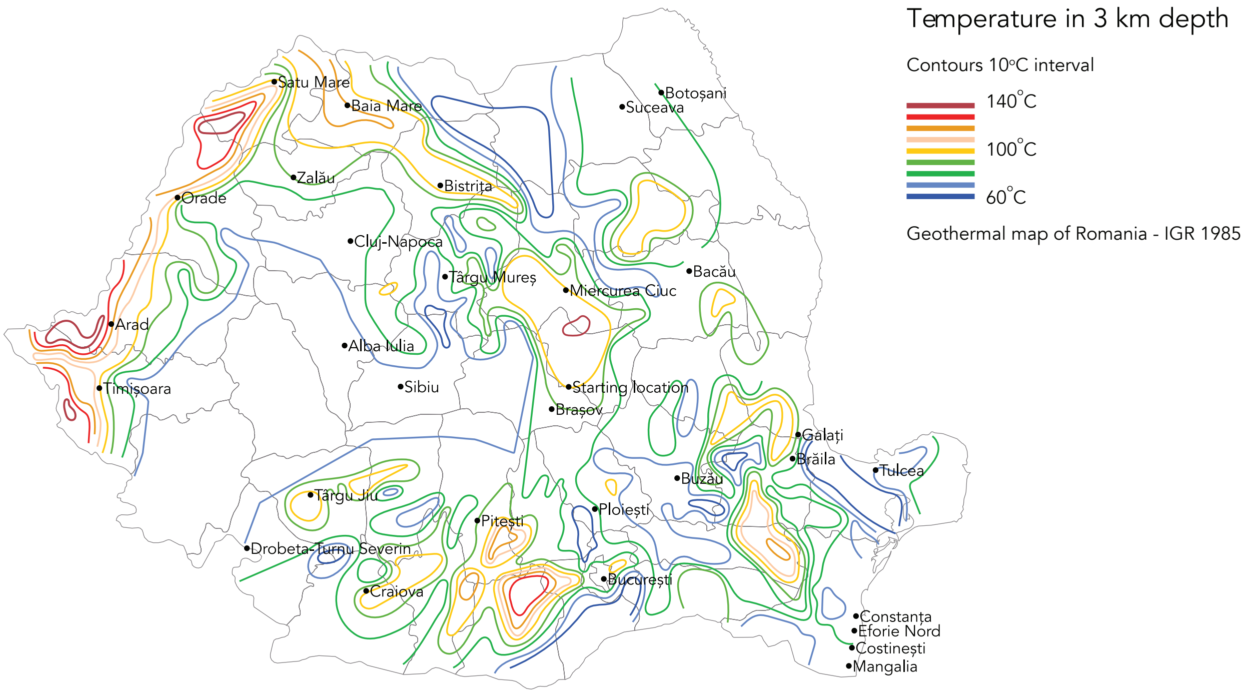
3.3. Relevant areas for the implementation of the new technology (mapping of relevant geographical areas across the country)

Several locations in Western Romania, close to the border with Hungary, present suitable geological conditions for the development of innovative geothermal projects, and the application of the closed loop systems to capture heat.

Western Romania has an unexplored potential in terms of geothermal energy. This feature can contribute to gradually reducing the use of fossil fuels and achieving energy independence in a regional context marked by protracted conflicts, which also impact the energy market.

Proven geothermal reserves in Romania are currently about 200,000 TJ in 20 years for standard geothermal systems. However, **by using the innovative closed loop heat capture system, Romania has the potential to develop a thousand times more geothermal energy in the long run.**

Geothermal gradients in Romania



As part of its geothermal hot dry rock project, one of the major oil and gas companies in Romania is currently acquiring subsurface data in Western Romania, being expected to launch the execution of the first pilot loop drilling in late 2025 and the first quarter of 2026.

Under this initiative, in the first quarter of 2024, drilling operations are expected to take place from 1,500 to 3,000+ meters in the basement structures, to check tightness and constant temperature gradient, as well as verify bit performance.

4. Needs for implementing the new technology

The use of geothermal power is about to become one of the cornerstones for facilitating a safe transition to the use of clean energy, through the development of local projects, which can ensure Romania's energy security in the long run.

Romania has a total installed capacity of geothermal power of 150 MW, with the energy produced being used for heating purposes. Furthermore, as highlighted by the closed loop project implemented in Geretsried, Germany, this technology has the potential to generate **new workplaces,** as well as **improve the country's overall environment performance.**

Geothermal energy represents an optimal alternative for delivering heating services at **more competitive prices,** while the electricity which could be produced through the new closed loop technology may bring to the market up to 25 TWh per year.

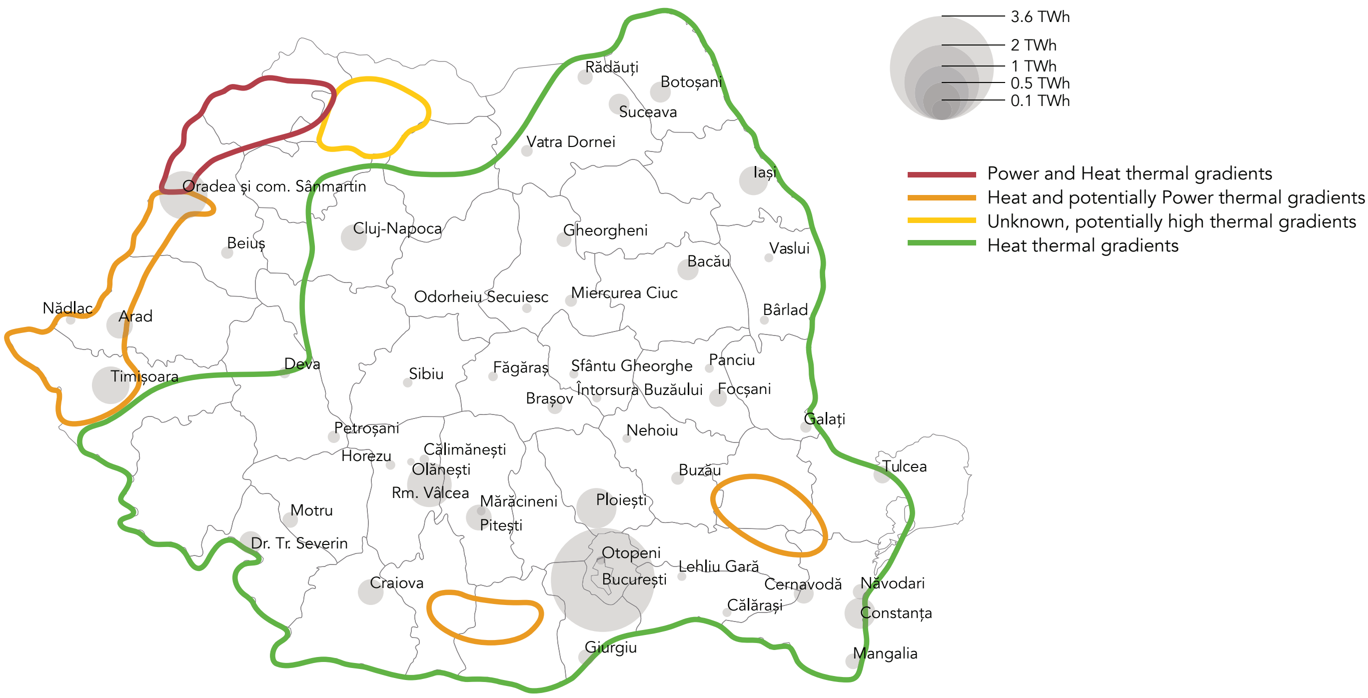
Most importantly, drilling and development of geothermal heating projects based on the conventional heat capture system are expensive and involve several operational risks. Such systems can be used for heating households and greenhouses, with operational sites being located in counties such as Arad, Bihor, Harghita, Ilfov, Satu Mare, Timiş and Vâlcea. The operators of these sites are entitled to **49-year concession contracts** for exploitation.

Several cities in Western Romania are already interested in exploring and using geothermal energy to heat residential areas. These cities include Timişoara, Oradea and others.

Companies have already launched a dialogue with municipal authorities in Timişoara, to explore ways in which the closed look technology can be implemented, to provide end users with heating services, based on geothermal energy. These cities are particularly interested in switching entirely their heating systems from fossil fuels to renewable energy sources, with local communities being increasingly vocal in this regard.

The map below highlights the thermal energy sold in 2021, as well as the areas explored so far, with related power and heat thermal gradients.

Thermal energy sold in 2021 and areas explored



5. Opportunities to update the current legislative framework

5.1. Missing elements in the current legislation

Currently, the exploration and exploitation of mineral resources, including geothermal energy, is currently regulated by the Mining Act no. 85/ 2003. The mineral resources regulated by this Law include, among others, **geothermal waters and related gases,** as well as mineral therapeutic waters, and the residual mineral debris.

The definition of geothermal heat is a key issue for the sector's adequate regulation. In this context, there is a necessity for lawmakers to decide whether geothermal heat is subscribed to the definition of "mineral resources" or whether it should be regarded as a specific characteristic of the earth. **This distinction is fundamental both for establishing the property regime as well as for establishing an adequate regulation, authorization and monitoring of operations relating to geothermal heat capture.**

Based on the analysis of the current legislation, a conclusion is that any new attempt to regulate the definition of geothermal heat will require the elaboration of norms which are subscribed to the definition used by the Mining Act no. 85/2003. Furthermore, the National Agency for Mineral Resources (NAMR) is the authority with in-depth experience in regulating the exploitation of geothermal power and particularly with respect to the regulation of underground drilling operations involved.

Thus, ANRE has no competencies with respect to the extraction of mineral resources located underground, but ANRM does. These elements are specified in the Mining Act 85/2003 and in the Oil Act 238/2004.

Concurrently, **the earth's energy cannot be included in the definition of oil or oil reservoirs.** Furthermore, while in the case of crude oil the regulated resource can be measured in quantitative terms, this is not applicable to geothermal heat. The latter cannot be determined in quantitative terms, as this resource is not extracted from the underground, but only used as a recirculation system.

Along the same line of argumentation, it is worth noting that oil extraction is regulated through a system based on oil concession contracts, based on a specific model, with assumed financial risks. This model is designed to facilitate extensive extractive operations. However, this model is not currently applicable also to geothermal energy. One of the **significant barriers** limiting the wide use of geothermal energy is related to the **significant upfront capital costs** which need to be covered in an initial development stage, characterised by high uncertainty with respect to the success of the project.

In this context, it is worth noting that over the past years, the Romanian legislative framework has witnessed an excessive number of legislative norms, resulting in a **significant lack of predictability.** Concurrently, the high number of decisions pronounced by the High Court of Cassation and Justice indicates that this legislative phenomenon may lead to contrasting interpretations of a norm, with parallel provisions becoming a normality.

For instance, the Law 123/2012 regulates operations relating to electricity and thermal energy producing cogeneration, by regulating the production, transport, distribution and supply of electricity. At the same time, title II of this law regulates the activities regarding the production, transport, distribution, supply and storage of natural gases and liquefied natural gas (LNG), as well as the access on the market, and criteria and procedures applicable for the granting of authorizations and licences in the natural gas sector. Under this law, the authority regulating electricity and natural gas is the National Authority for Regulation in the Energy Sector (ANRE), which also regulates the functioning of the electricity, thermal power and natural gas sector.

5.2. Recommendations to update the Mining Act 85/2003 to reflect the requirements of the closed loop system technology

Looking at other European states with interest and experience in developing geothermal power systems, it is worth noting that Hungary[3], Germany[4] and the Netherlands[5] have already regulated the exploitation of geothermal power within the framework of their respective Mining Acts. These examples could serve as reference for future attempts to regulate the use of geothermal energy.

Moreover, considering the specificity of the investments required in this sector and operations involved which may be subject to a legislative proposal seeking to regulate geothermal energy, **the Mining Act 85/ 2003 could allow such investments.** The provisions of the Mines Act are broad enough to allow the implementation of related activities. Therefore, there is **no need for an additional new legal framework to be developed** in order to regulate geothermal energy.

However, **the current Mining Act 85/2003 needs several additions** to encourage long-term significant investments in the exploration and exploitations of geothermal power in Romania.

In this context, a **unique legislative approach** is recommended **to regulate geothermal power, linked to the Mining Act 85/2003** as the key legislative framework, and not to other existing pieces of legislation.

Furthermore, to support the development of long-term geothermal power projects in Romania, **proposals to revise the Mining Act should provide the following:**

- A clear definition of geothermal power
- A simplified /single authorisation process, with transparent criteria for investors' requests
- Easy access to authorisation procedures, and reasonable periods
- Extending the terminology used in the act to explicitly include geothermal heat, geothermal energy and water exploitation among the resources which can be exploited under this legislative act
- Extended periods, up to 30 years, for **drilling permits** granted for geothermal power projects
- Removal of the fiscal burden associated with the regulation documentation.

The extension of the periods foreseen by law for drilling permits to thirty years is necessary, considering that closed loop projects require at least three years since the initial development stage until becoming fully operational. Also, the component of significant upfront costs assumed by companies developing the project is an important factor to be considered.

Also, the revision of provisions of the Law 123/2012 in relation to the extraction and exploitation of geothermal power is not opportune for several reasons:

- This piece of legislation mainly regulates the activities of production, transport, distribution and supply of electricity and natural gas, and does not include any reference to the exploitation of underground resources
- Secondly, ANRE's competencies do not cover the exploitation of underground resources
- The authorization procedures for underground resources and the related terminology are foreseen in the text of the Mining Act 85/2003 and in the Law 238/2004
- The Law 220/2008 establishing the system to promote the production of energy from renewable energy sources does not regulate the exploitation of sources from which energy is obtained, and it does not include any provisions with respect two authorisation procedures for the exploitation of energy resources.

Furthermore, the European Parliament's plenary on 18 January 2024 voted with 531 out of 553 votes in favour of the resolution 2023/2111 (INI) calling for a European geothermal strategy. The resolution calls: (1) on the European Commission to prepare an EU geothermal strategy providing concrete guidance to member states and local administrations to accelerate the deployment of geothermal energy with the aim of decarbonising heating; (2) on the Commission to design this strategy based on a "comprehensive assessment of the potential

3 Act XLVIII of 1993 on mining (the Mining Act).

4 Federal Mining Act of 13 August 1980 (Federal Law Gazette I p. 1310), last amended by Article 1 of the Act of 14 June 2021 (Federal Law Gazette I, p. 1760).

5 The Mining Act (Mijnbouwwet), https://www.nlog.nl/sites/default/files/2018-11/2018-11-04%20%20Translation%20MBW%20English%20%20MINING%20ACT%20OF%20THE%20NETHERLANDS%20PDF.pdf.

of geothermal energy in the shallow, medium, deep, and ultra-deep subsurface across all 27 member states”; (3) for the establishment of a Geothermal Industrial Alliance, composed of member states, geothermal adoption enablers, industry representatives, academia, and civil society, to promote best practices and implement “the future geothermal strategy”.

The resolution also calls on member states to explore financial de-risking solutions adequate for the majority of their local markets, such as grants, loans that are convertible to grants, state-backed guarantees, exploration insurance and hedging mechanisms. In addition, the resolution notes that an EU financial risk mitigation scheme “would be particularly useful for the least mature markets in the geothermal sector, while encouraging member states to analyse potential financial incentives to bridge this gap.

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Conclusions

For Romania, a country with extensive experience, human capital and know-how specialised in oil and gas exploration and exploitation, the existence of significant geothermal sites near the Western border as well as near Bucharest present ample opportunities to use this clean resource.

At the local level, more are more communities are interested in using geothermal energy to heat their homes.

Geothermal energy is highlighted in the latest version of the **National Integrated Plan in the field of Energy and Climate Change** (PNIESC), as an innovative technology based on renewable energy sources. The growing role of this type of energy is also mentioned in **Romania's Long-Term Strategy for Emission Reduction**.

In this context, the innovative closed loop technology brings with it several key advantages, compared to the traditional open-loop systems. Most importantly, the closed loop technology can be scaled up at the global level, and its extensive use also in Romania could allow more municipalities in Ilfov county and in western part of the country to heat up extensive residential areas with geothermal energy.

The closed loop technology has significantly more advantages compared to the traditional (open loop technology), as it involves no resources being extracted, no fluid disposal, no rare metals being used, efficient operational costs in the long run and no emissions being released during operations.

From an investor perspective, one of **the important barriers** limiting the wide use of geothermal energy is related to **the very high upfront capital costs** which need to be covered in an initial development stage, characterised by high uncertainty with respect to the success of the project.

Looking at other European states with interest and experience in developing geothermal power systems, it is worth noting that **Hungary[6], Germany[7] and the Netherlands[8] have already regulated the exploitation of geothermal power within the framework of their respective Mining Acts.** These examples could serve as reference for future attempts to regulate the use of geothermal power.

The abundance of legislative norms over the past years has generated situations leaving room for contrasting interpretations of the same norm, in some cases also with overlapping competencies of the different authorities in the energy sector.

To further stimulate significant investments in the geothermal energy sector, **Romania should focus in its future attempts to regulate the use of geothermal power on referencing the Mining Act as the only fundamental legislative framework,** to avoid creating any further legislative parallelisms.

To support the development of long-term geothermal power projects in Romania, **proposals to revise the Mining Act should provide the following:**

- A clear definition of geothermal power
- A simplified /single authorisation process, with transparent criteria for investors' requests
- Easy access to authorisation procedures, and reasonable periods
- Extending the terminology used in the act to explicitly include geothermal heat, geothermal power and water exploitation among the resources which can be exploited under this legislative act
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8 The Mining Act (Mijnbouwwet), https://www.nlog.nl/sites/default/files/2018-11/2018-11-04%20%20Translation%20MBW%20English%20%20MINING%20ACT%20OF%20THE%20NETHERLANDS%20PDF.pdf.