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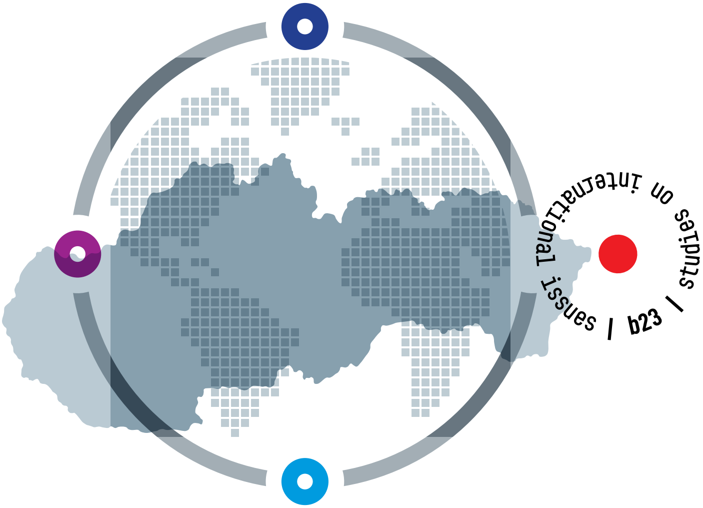

Mainstreaming geothermal in the H & C sector of Hungary and Slovakia

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Research Center of the Slovak Foreign Policy Association
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Content

Glossary

CEECGEO	Central European Geothermal
DH	district heating
DHC	district heating and cooling
H & C	heating and cooling
EU	European Union
SK	Slovakia
HU	Hungary
DE	Germany

About the CEEGEO initiative

The CEEGEO initiative aims to promote knowledge sharing and best practices to advance geothermal project development in the CEE region. This requires an active, coordinated, industry-led regional grouping with representation from all Central and Southeast Europe (CSEE) countries (EU and non-EU) to engage in:

- Comparative country-level sectoral research and data analysis
- Active consultation in national and local geothermal and heat planning
- Development of financial instruments with national and international financial institutions.

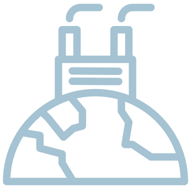
Special focus is given to the industry stakeholders, the actors with firsthand knowledge, keen on proposing actions to improve the investment climate for geothermal and support participating countries in achieving their EU and national energy objectives.

CEEGEO started informally at the annual Central European Energy Conference (CEEC) in Bratislava, Slovakia in November 2023, when a small group of leading Hungarian and Slovak industry representatives agreed on the need for a regional coalition to share ideas, build collective momentum for key government recommendations, and unlock the abundant investment opportunities—a race to the top, mainstreaming geothermal energy. The growing momentum was reinforced during the next CEEC in Bratislava in December 2024, which brought together key private and public stakeholders from both Hungary and Slovakia for an exchange of ideas and best practices.

In fact, Hungary and Slovakia are a logical strategic entry point for regional geothermal development. They are natural partners with a shared border area of similarly favourable geological conditions on the northern boundary of the Pannonian basin. While Hungary has positioned itself as a regional leader with a mix of industry experience and political ambition—from its revised geothermal strategy to its role advocating for EU-level conclusions during its EU Council Presidency in 2023—Slovakia remains at an earlier stage of development, still lacking a national strategy, but moving in that direction. For example, it was the first country to apply the Just Transition Fund to a geothermal DH project, in the Kosice region. Also, Slovakia is more optimistic and ambitious when it comes to DH infrastructure, which it views as a key enabler for H & C transition. Hungary also realizes the importance of upgrading this critical infrastructure, but the sector has been struggling under the current regulatory regime for more than a decade.

As one can see, there is tremendous potential for spillover effects between the two countries, which was on display in Bratislava in 2024 during the CEEC event. This can be deepened and expanded—deepened between both countries, engaging financial institutions and local authorities in addition to the initial national policy focus, and expanded to other countries from the region. These countries share many of the same energy and economic characteristics while at various stages of geothermal development, meaning they can learn from each other to grow the industry.

CEEGEO seeks to pick up where the Danube Region Leading Geothermal Energy (DARLINGe) project left off in 2019: completing full regional representation from Sarajevo to Warsaw; creating a permanent steering committee to coordinate activities and messaging; and providing a repository of open access country-level data and analysis.



Foreword

This is a comparative report which attempts to close remaining knowledge gaps between Hungary and Slovakia while further justifying and encouraging national policies aligned with the EU's Energy Efficiency and Renewable Energy Directives and REPowerEU to promote the utilization of geothermal in the H & C sector. Our methodology includes a literature review, structured stakeholder surveys and consultations, expert analysis of national regulatory frameworks and project pipelines, and DH mapping.

The study contains the latest H & C, DH and geothermal data in each country, but does not discuss the cost and financial environment for geothermal projects. This is reserved for the next phase of the research, as part of a comparative economic analysis of competing heat inputs and network costs using DH market modelling to assess the impact of policy instruments. This will open the process by addressing technical and regulatory conditions for geothermal development in Hungary and Slovakia.

Executive Summary

Hungary and Slovakia have become overly dependent on highly emitting and insecure heat sources—natural gas and biomass—despite abundant geothermal potential for direct heat purposes that is vastly underutilized. This is a signal that energy policies in these countries are failing and/or ineffective.

Tailored policies are needed to level the playing field for geothermal—even among renewables—to fit its unique investment profile. Its technical characteristics unfortunately is not flexible and amenable to existing infrastructure systems, like biomass or natural gas which enjoy drop-in and incumbency advantages. In fact, it is quite the opposite: heat networks and buildings need to be adapted to geothermal (and other low temperature renewables), which equates to the modernisation of old and inefficient infrastructure.

Although geothermal targets and dedicated financing are advised to be part of any serious national geothermal strategy, it is important to consider the wider regulatory framework affecting DH infrastructure and building renovation—which need to become enablers, but so far have been obstacles. These are the most regulated and politically sensitive segments of the energy sector, which is why so little has changed over the years, even after the vulnerability (natural gas dependency) was fully exposed by the 2022–23 energy crisis.

Hungary's DH sector has been in decline for many years, so it is obvious changes are needed. Likewise, for Slovakia to realize its ambitious plans for centralized renewable heat, it will need to alter course from the status-quo. This process should start at the core, ensuring that regulatory philosophies and practices are 'fit-for-purpose,' to catalyze investment into geothermal and low temperature heat systems.

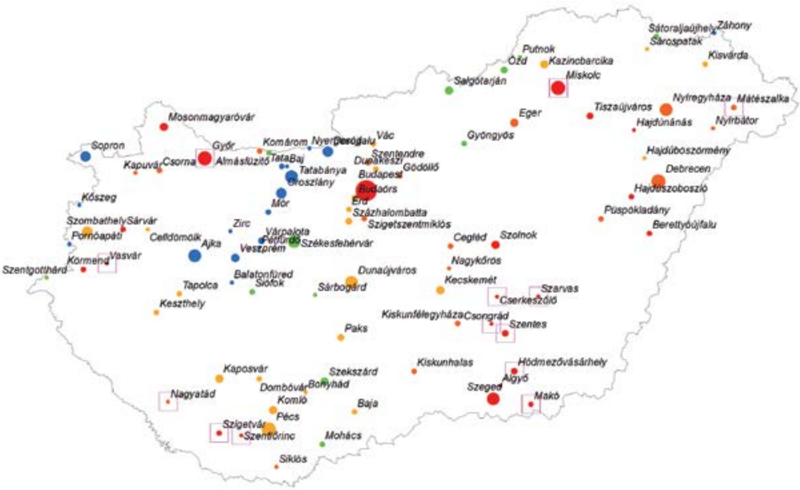
The structure of the paper is as follows: First, introducing geothermal potential and the current heat landscape in Hungary and Slovakia, which is connected to the data and literature review. Next is an overview of the geothermal regulatory treatment and support policies in each country, extending to the wider H & C sector and DH in particular. This is followed by a German case study and the presentation of Hungary and Slovakia DH Mapping. The final section attempts to tie everything together and recommends a course of action.

Proven geothermal potential

The geothermal potential in Hungary, located in the heart of the Pannonian basin, is well-documented across several projects and studies over the years. The estimated (economically available) geothermal DH potential for Hungary is 9–15 million GJ/year, which is 30–50% of the existing DH sector, translating to 300–500 million m3 of natural gas savings (Arctic Green Engineering, 2024).

The robustness and availability of Hungary's subsurface data is world class. The Hungarian Geothermal System (OGRe), launched in 2021, was the first of its kind English language geothermal online mapping platform in Europe, providing up to date and reliable information on geological, hydrogeological and geophysical data. Figure 1 shows the potential for overlapping DH and subsurface data mapping.

Figure 1: **Hungary geothermal and DH map,** source: Arctic Green Engineering.



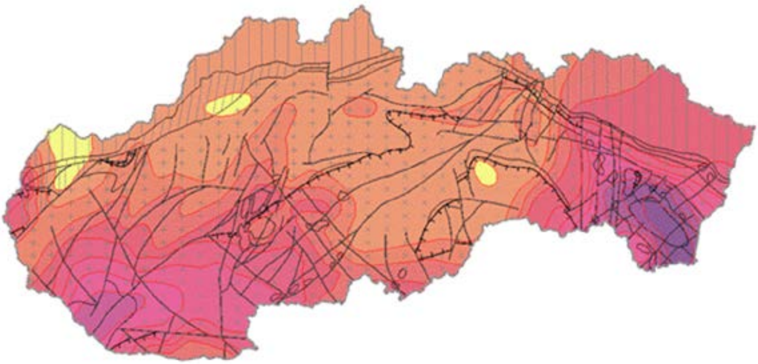
Legend:

- Cities with existing DH system are shown
- Colours represent the (known or assumed) geothermal potential. (red is the highest > orange > yellow > green > blue is the lowest)
- Size of the circle represents the size of the DH system (heat market)
- Purple squares mark the already existing geothermal DH systems.

While electricity production is limited due to lower temperature gradients, Slovakia has high geothermal potential for are the use—estimated to be in the range of 5,000 MW of thermal energy for direct applications (Euractiv, 2022). The most promising regions are the Košice Basin, Levice, Galanta, and south-central Slovakia, where aquifers allow for sustainable use.

In Slovakia, subsurface data is accumulating. Mapping efforts are underway by the State Geological Institute of Dionýz Štúr (ŠGÚDŠ), also within EU-funded projects, to further improve this resource data. So far in Slovakia it has mapped 27 prospective areas with geothermal energy and more than 150 boreholes have been drilled.

Figure 2: **Detailed geothermal mapping, Slovakia,** source: State Geological Institute of Dionýz Štúr (ŠGÚDŠ).



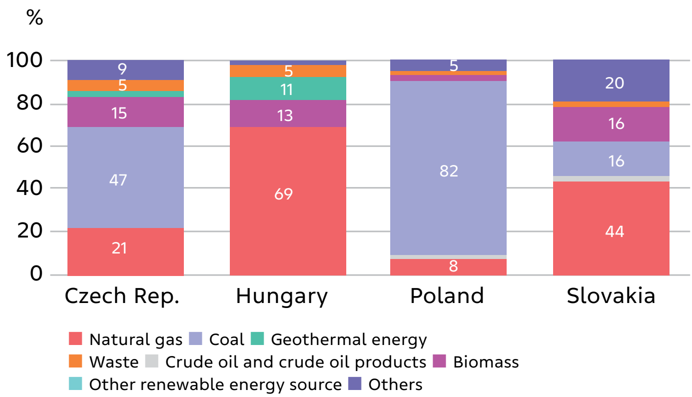
The heat equation: Over dependence on natural gas and biomass

The vast majority of heat production in Hungary and Slovakia is produced from the combustion of natural gas and biomass. Each was perceived to be abundant, cheap and desirable from a climate and environmental perspective relative to coal—despite significant methane emissions and air pollution, respectively. However, these perceptions are changing. In the case of natural gas, rather suddenly, following Russia's full-scale invasion of Ukraine. For biomass the trend is more gradual, but stricter regulations likely to follow.

Hungary (73%) and Slovakia (75%) stand out well above the EU average (64%)—and indeed are the highest among the V4 countries—in the share of household heating in total energy consumption. Hungary (60%) and Slovakia (44%) are also above the EU average (39%)—and highest among V4 countries—in the use of natural gas for household heating, followed by biomass (Tóth, 2023).

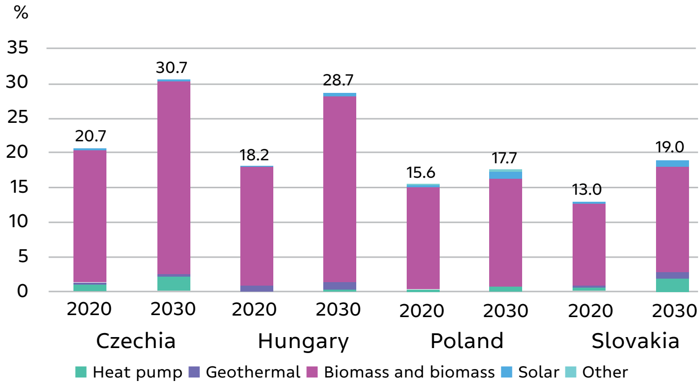
The share of DH is quite high in Slovakia (around 16%) while Hungary (8%) is near the EU average (10%), translating to 35% and 16% of households connected, respectively. In both Hungary (69%) and Slovakia (44%), natural gas is the largest DH fuel source, followed by similar shares of biomass—13% and 16% respectively. Geothermal is the third highest source in Hungary (11%), while for Slovakia it is coal (16%) (Tóth, 2023).

Figure 3: **Fuel mix of V4 DH, 2021,** source: V4ETTP, REKK.



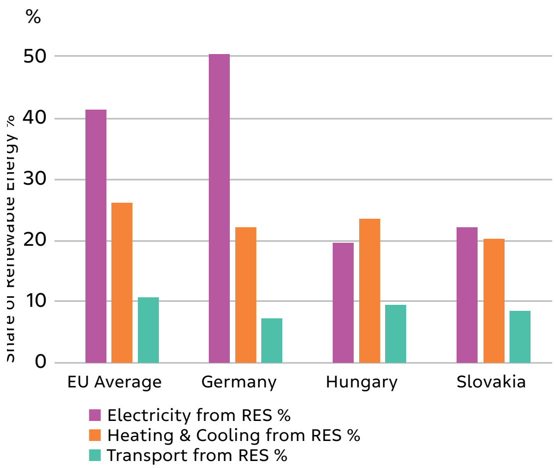
Hungary's 2030 NECP target (28.7%) is much higher than Slovakia's (19%), but both are premised on significant biomass expansion.

Figure 4: **Share of renewables in heating and cooling sector in 2020 and 2030, updated NECPs (2023),** source: V4ETTP, REKK.



Despite the high shares of biomass, Hungary (23.5%) and Slovakia (20.2%) are still lagging behind the EU average (26.2%) renewable share in H & C. In fact, renewable penetration is quite low overall, particularly in the electricity sector relative to the EU. As of 2023, Hungary's renewable energy share was 14.6% compared to Slovakia's 17.3% (Eurostat, 2024). This underscores a systemic challenge for renewables uptake and the need for accelerated efforts (Figure 5).

Figure 5: **Renewable energy shares by sector in 2023 in Hungary, Slovakia and Germany,** source: Eurostat, 2024



Uncertain future for natural gas and biomass

Natural gas is particularly problematic for Europe because it creates dependency and can cause serious economic damage, like it did in the 2022–23 energy crisis. The economic case against natural gas cannot be overstated; not only is it volatile and capable of driving up electricity prices for end-consumers, but it diverts money that could be invested locally into capital outflow. The total cost of imported fossil fuels more than tripled in 2022 (€604 billion) compared to 2020 (€164 billion) (European Commission, 2025).

Russia's full-scale invasion of Ukraine marked the end of the era of 'cheap' pipeline gas, but this will be even more acutely felt in landlocked CEE countries like Hungary and Slovakia. The reorientation of gas flows from Russian piped East-West to LNG from the West, North or South, accruing border tariffs along the way, means it will come with a premium and competitive disadvantage relative to countries with direct access to LNG facilities.

Biomass heating, meanwhile is a mature technology with reliable operating characteristics, moderate up-front costs and low investment risks. The technical characteristics of biomass combustion integrate easily with almost any type of DH network (flow temperature) and building stock. Furthermore, there are a wide range of inexpensive local biomass sources for biomass plants, including roundwood, forestry and agricultural residues.

Hungary and Slovakia have traditionally relied on individual biomass for household heating in rural areas, but more recently biomass co-fired combined heat and power (CHP) plants have become central to 2020 and 2030 renewable heating targets in National Energy and Climate Plans (NECPs). However, there are growing concerns over its climate neutrality (emissions vs. carbon sequestration) on top of longstanding environmental issues centering on forest management and air quality. Indeed, both countries have struggled with air quality challenges for several years. Hungary exceeds WHO PM2.5 thresholds by 2.5 times, especially in geothermal-rich Northern Hungary, while Slovakia surpasses them by nearly six times (WHO, 2021). Low-efficiency wood-burning stoves, typical in the region, emit pollutants from incomplete combustion—including volatile organic compounds and gaseous pollutants NOx and SOx. One scientific report shows health costs associated with outdoor air pollution are higher from the residential building sector than the transport sector, with over 30% of the costs attributable to traditional wood burning stoves (EPHA, 2023). All of this risks further tightening of regulations, potentially making it more difficult for Hungary and Slovakia to continue relying on biomass so overwhelmingly for meeting renewable targets.

Achieving energy security and local development through decarbonisation

A multi-phased, multi-faceted approach is needed to decarbonise and secure resilient H & C sectors in Hungary and Slovakia, turning it from a weakness into a strength, from energy dependency to local economic development. This starts with serious efforts to maximize energy savings and energy efficiency and utilise waste heat, which are the most cost-effective and sustainable solutions. The remaining heat from fossil fuels and un-sustainable biomass should be replaced with a mix of low temperature renewables, prioritizing geothermal where it is technically available.

Geothermal energy presents a critical opportunity for Hungary and Slovakia, not only for decarbonizing, but improving environmental protection, energy independence and local economic development. Midway through the 2020s, geothermal can still be a key piece of national and local government strategies to meet their 2030 climate and energy security objectives. Each country is in the process of implementing the Energy Efficiency Directive (EED) and Renewable Energy Directive III (RED), which especially focus on greening and modernizing DH systems, and oblige municipalities over 45,000 inhabitants to draft H & C plans by 2026 and while increasing the share of renewables in district systems. This is a critical juncture for geothermal to lock-in more favourable treatment and gain a foothold in the unfolding strategic architecture.

Data and literature review

National H & C data and analysis

Throughout the 21st century, European energy policy has placed significant emphasis on decarbonizing the electricity sector, while the H & C sector has received comparatively less policy and investment attention, even though it is responsible for roughly half of final energy use in the EU and is one of the most emissions-intensive and fossil-fuel-dependent segments of the European energy system (European Commission, 2020). Heating has traditionally been viewed as a Member State competence by the EU due to its focus on serving local markets. It has not benefited from decades of regulatory initiatives for market liberalisation outlined in the Internal Market for Electricity and the Internal Market for Gas. Heating overall, and DH in particular, remains under-standardized.

The lack of policy focus on the H & C sector by most of the EU Member States, together with the diffuse, local nature of H & C markets, has resulted in a significant data gaps on their characteristics, preventing the design of effective and efficient H & C policies where renewable penetration presents more challenges. This includes a lack of aggregated granular DH and building stock data, which are beyond the scope of this study. Similarly, there is limited understanding and few examples of shallow geothermal projects in either country to draw from.

This ‘above the ground’ data is the missing link from both countries with respect to local heat markets, DH heat networks and buildings. Some of this was made available for Hungary as a case study in the DARLINGe project (2019) and Heat Roadmap Europe study (2013). The other landmark study of the time, the STRATGEO report (2015), provided groundbreaking high-resolution heat demand mapping and scenario modelling for the EU. All of them are now outaded.

Danube Region Leading Geothermal Energy (DARLINGe, 2017–2019) was an ambitious project ahead of its time. It was already zeroing in on the energy security and efficiency case for geothermal energy to replace natural gas in overly dependent Central and Southeast European countries (CSEE). The purpose was to process and deliver data and information services about rich yet largely untapped deep geothermal energy resources of the south Pannonian, with six countries in focus: Hungary, Slovenia, Croatia, Serbia, Bosnia and Herzegovina and Romania. It accomplished this by making available extensive geothermal mapping resources through an online tool (DGRIP) and providing detailed overviews of national regulatory frameworks pertaining to geothermal energy and heat markets.

The Hungarian District Heating Market Model (HDMM), meanwhile, was developed in 2015, the first of its kind in the region to assess policy instruments supporting renewables in the DH system. The first modelling run in 2017 found that DH investment and operational support are effective for achieving optimal market outcomes, while support for end-user prices and renewable co-generation associated with electricity are suboptimal. It also showed that market uncertainty lowers DH renewable integration by elevating WACC which raises system costs. Therefore, the main recommendation is for the regulator to create a predictable and sustainable market environment with a long-term outlook (Mezősi, et al, 2017).

Key findings from Heat Roadmap Europe 2050 (Connolly et al, 2013) revealed that achieving 80–95% decarbonization by 2050 requires not only reductions in demand via deep building renovations, but also the strategic redesign of heat supply systems. This includes a projected increase in DH market share from around 12% to 50% of building heat demand by 2050, based on the cost-effective integration of local, renewable, and waste heat sources. The study also emphasized the unique opportunity district energy systems provide for urban areas, where heat demand density is sufficient to justify investment in network infrastructure.

The STRATEGEO (2015) report likewise underscored the significance of space heating and domestic hot water in EU energy consumption. The report estimated that fossil fuels still account for roughly 68% of heating in the EU28, with DH covering just 12%, figures even more extreme in some CEE countries. It also noted the limited penetration of geothermal and heat pumps in these markets. It noted that and Slovakia, while having widespread access to geothermal resources (due to their location in the Pannonian Basin), were underdeveloped in this regard. At the time, it estimated that Hungary supplied 6–7% of total heating demand with the potential to expand more than tenfold under a supportive policy framework.

The recent EGEC report (2024) assesses the Hungarian and Slovakian trajectories for geothermal DH development, each at different stages of market maturity and policy support. Hungary remains one of the most active EU member states in geothermal heating development. In 2023, it ranked among the top six countries for newly commissioned geothermal heating systems and one of the leaders in terms of newly installed capacity. This expansion reflects a well-established ecosystem driven by supportive national energy strategies, local authority engagement, and integration into urban DH networks. Municipalities across Hungary have played a crucial role, often using EU funds to pilot or expand geothermal DH systems, especially in the Great Plain region (EGEC, 2024). Slovakia, on the other hand, while still in a nascent stage compared to Hungary, is gaining visibility with new geothermal DH projects launched or announced in 2023. This shift reflects increased policy interest in sustainable energy and a response to EU-wide imperatives for heating decarbonization and greater energy sovereignty. The EGEC report recognizes Slovakia as a country beginning to realize its geothermal DH potential, though its progress remains project-specific and dependent on evolving regulatory and investment frameworks. These divergent paths highlight Hungary as a useful reference point for Slovakia's potential transition, offering opportunities for bilateral learning and regional coordination (see Taable 1).

Table 1: **Hungary vs. Slovakia DH (2023 highlights),** source: EGEC 2024

Aspect	**Hungary HU**	**Slovakia SK**
Status	Advanced, fast-growing	Emerging, exploratory
New DH Systems (2023)	Among top 6 in Europe	New projects under development
Installed Capacity Growth	Among the highest in EU	Not yet a major contributor
Policy Support	Strong national & municipal support	Improving, early-stage
Market Drivers	Energy security, municipal decarbonization	EU policy, energy diversification
Challenges	Long-term financing, project complexity	Regulatory readiness, investment attraction
Potential Role in Region	Benchmark for Central Europe	Follower with regional potential

The International Energy Agency-IEA (2024a) describes Slovakia's geothermal sector as "largely untapped," with only a handful of DH-linked geothermal installations currently in operation. However, the allocation of over €100 million in modernization funds for renewable-based heating indicates a growing policy momentum. The IEA recommends the development of a national geothermal roadmap and integration of geothermal resource mapping into municipal and regional planning processes.

Ujhazy et al. (2023) argue that non-technical barriers, including fragmented regulation, limited public awareness, and lack of strategic coordination, have slowed geothermal adoption in both countries. This shows that institutional and societal factors, not resource availability, have shaped the progress of geothermal energy in the region. In Hungary, these barriers are gradually being addressed through the introduction of a National Geothermal Strategy (2024), which aims to double geothermal utilization by 2030. This policy shift includes streamlining permitting, enhancing data transparency, and expanding the use of underground thermal storage (Renewable Energy Focus, 2024).

At the same time, broader critiques of DH reform in CEE highlight persistent vulnerabilities. A study by Bankwatch (2022) found that while Hungary and Slovakia maintain extensive DH infrastructure, their systems remain fossil-fueled, inefficient, and at risk of further gas lock-in if EU funds are not conditioned on clean energy upgrades. The report underscores the importance of tying public investment to renewable integration, cost transparency, and forward-looking infrastructure planning—principles that are central to geothermal mainstreaming.

In summary, several studies note the potential for and underutilization of geothermal energy in Hungary and Slovakia. Landmark projects such as Heat Roadmap Europe, STRATEGO, DARLINGe, and REKK's HDHMM laid critical groundwork that now requires updating and localization.

EU guidance

In 2016 the European Commission issued a Heating and Cooling Strategy which created momentum for the inclusion of a non-binding renewable H & C target in the 2018 revision of the RED. The European Green Deal, which was introduced in 2020 (European Commission, 2020) by the President of the European Commission, Ursula von der Leyen, included a harmonised EU-wide carbon price on heating for residential consumers expected to come into force in 2026, the Emissions Trading System II (ETS II).

In conjunction, the Social Climate Fund was introduced to frontload investment in renewable H & C solutions to alleviate the burden and political pressure of carbon pricing directly affecting end-users for the first time (European Parliament & Council of the European Union, 2003). Furthermore, Slovakia and seven other Member States (Belgium, Czechia, Denmark, Greece, Finland, Croatia, Lithuania, Latvia and Romania) were given additional support by a special EU Technical Assistance project to develop their Social Climate Fund investment plans (European Parliament & Council of the European Union, 2023a).

The non-binding element of the renewable H & C target from the RED was made binding for all Member States with the 2023 revision. Governments are now obliged to increase their renewable H & C by 1.1% from 2026–2030 (European Parliament & Council of the European Union, 2023 b). In addition, the package places greater emphasis at the local level by introducing compulsory comprehensive H & C assessments for cities with populations above 45,000 inhabitants.

Geothermal regulatory treatment and support policies

Hungary

Licencing

Hungary's Mining Law defines geothermal energy as the internal heat energy of the earth's crust. Mineral resources and geothermal energy found underground are property of the state. However, for a licenced company paying state royalties, the extracted mineral resources and geothermal energy used for energy purposes become the property of the mining company.

The state is entitled to a share (royalty) of the extracted mineral resources and geothermal energy equalling 2% of the value. No mining royalty is assessed on geothermal energy extracted and utilised in excess of 50% of the energy content, on geothermal energy extracted from energy sources below 30°C, on geothermal energy (heat energy) from the recooling of thermal water used for medicinal (balneological) purposes, nor hydrocarbons extracted from associated gases (thermal water often contains dissolved or accompanying gases, mostly methane) for the licencee's own use.

The exploration, extraction and utilization of deep geothermal energy through thermal water is authorized by the mining authority (under the Supervisory Authority for Regulatory Affairs—SZTFH), with the exception of medicinal (balneological) and agricultural purposes—which fall exclusively under the water authority and require a water law permit. In other words, if the thermal water is used for energy purposes only after its primary use, or if energy recovery is used to cool the thermal water to the temperature required for medical or agricultural purposes, the mining authority is not the competent authority. The key difference in the two licensing procedures is that the mining authority focuses on ensuring the orderly exploitation of mineral or geothermal resources, while the water authority is concerned with careful management of limited underground water resources and the protection of the quality of surface (and underground) waters and soils.

The utilization of geothermal energy is subject to a research permit issued by SZTFH. With a research permit, the mining company has the exclusive right to carry out measurements, tests and drilling in the research area (two research permits cannot be issued for the same area). The conditions for the issuance of a research permit are the preparation of a research work programme and the provision of financial security determined by the authority (taking into account the cost estimate included in the research plan). The guarantee (financial security) serves to cover any damage caused during the exploration and varies between a minimum of HUF 40 million and HUF 200 million (EUR 0.1–0.5 million), depending on the depth of the exploration. At depths exceeding 1,000 metres, which is typical in Hungary, this is at least HUF 100 million (EUR 0.25 million), which may be significantly higher depending on the research budget (SZTFH, 2022). The research period may not exceed four years, but it can be extended twice for a total of eight years. The research permit may be revoked by the authority if the mining company has not carried out a proportionate part of the research tasks undertaken therein.

If several companies apply for geothermal exploration permits for the same area at the same time, the mining authority determines the allocation of exploration rights. There is no clear procedure for this, but the SZTFH shall take into account that "geothermal energy extraction can be realized to the greatest extent possible" and "research can be carried out by several mining companies at the same time." According to the law, the owner, asset manager or user of real estate is entitled to submit an application for geothermal energy exploration in order to supply the real estate's heat or electricity needs with geothermal energy, even in areas where others already have exploration permits (SZTFH, 1993).

After the expiry of the research period (within a strict deadline), the company may apply for the establishment of a so-called geothermal protection zone by submitting a final research report. The protection zone delimits the part of the earth's crust below the surface where the company may exploit the stored geothermal energy. In its decision designating the protection zone, the authority shall, on the basis of the opinion of the competent water authority, determine the annual quantity of thermal water that may be extracted and the method of disposal of the extracted water.

The company is required to reinject all extracted water "to the extent technically and geologically possible." If this is not possible or only partially possible (e.g. thermal water used for balneological purposes cannot be reinjected because this would contaminate the groundwater), the used thermal water may be discharged into a suitable surface receptor (ideally a river with a high flow rate and sufficient dilution capacity, or, in the worst case, into a backwater or artificial surface channel). In this case, (no-reinjection) the operator must pay a water use fee for the extracted thermal water. Since the heat dissolved salt content and, in certain cases, toxic microelements (lead, cadmium, mercury) or phenol content of the discharged thermal water may damage the quality of surface waters and soil, if dilution is not carried out properly and the pollution exceeds the limit values, environmental fines will be assessed.

It is important to note that in Hungary, favourable geothermal conditions are mostly found in sandstone rocks, where reinjection is a technically more complex, energy-intensive process requiring greater attention—especially if the heat content of the thermal water is only partially utilized and the reinjected water is therefore at a high temperature. In such areas, the high pressure required reinjection can damage the rock and even block the well, making reinjection difficult or even impossible. To mitigate this risk, new systems typically include two reinjection wells for each production well, but this also significantly increases the investment cost.

After the geothermal protection zone has been designated, the mining company initiates the conclusion of a contract with the authority setting out the conditions for the exploitation of geothermal energy. In the contract, the entrepreneur undertakes to extract and utilise the geothermal energy: to prove this, the entrepreneur must have a legal declaration or a letter of intent ensuring the use of the geothermal energy planned to be extracted. The contract may be concluded for a maximum period of 35 years, which may be extended twice for a total of 35 additional years. The contract authorizing extraction and utilization may be terminated if the entrepreneur seriously breaches any of its obligations under the contract (e.g., failure to utilise the extracted geothermal energy, failure to reinject the water, etc.).

An environmental impact assessment (EIA) is only required for geothermal energy extraction and utilization if the total capacity exceeds 20 MW or if extraction takes place in special areas (within the protection zones of mineral, medicinal and drinking water resources, protected natural areas or Natura 2000 sites).

National Strategy

Hungary announced its revised National Geothermal Strategy (Government of the Republic of Hungary, April 2024), which set an ambitious target of doubling current geothermal energy (6.4 PJ) by 2030 (13–15 PJ). The government has since published a National Geothermal Energy Utilization Concept (Hungarian Ministry of Energy, September, 2024) reiterating the commitment to doubling geothermal energy utilization between 2022 and 2030, and going a step further by doubling geothermal heat production again between 2030 and 2035. This would increase the share of geothermal energy in total heat production from 6% in 2022 to 25–30% in 2035. The financial underpinning remains somewhat vague, with the creation of a "three-pillar state financing framework" and a total budget of HUF 165 billion to finance a state guarantee to reducing geological and financial risks, a geothermal investment loan scheme, municipal heating subsidies and a geothermal heat pump installation programme (see: National Geothermal Strategy, 2024).

This ambitious programme counts on funding from the European Union's Recovery and Resilience Facility that has not been made available due to rule of law concerns in Hungary, which could seriously jeopardize the implementation of the entire initiative.

Licencing

Slovakia's Geological Works Act (Slovak Republic, 2007) defines geothermal energy as the thermal energy of the earth's body, the source of which is the residual heat of the earth and the heat generated by the radioactive decay of rocks and by the action of tidal forces. The Ministry of the Environment is responsible for implementing the Geological Works Act by decree in promotion of renewable energy.

According to the legislation, geothermal resources remain the property of the state in all circumstances. An investor can become the owner of an extraction well and adjacent structures, such as a geothermal power plant or pipelines, however it never becomes the owner of the groundwater itself. Regular payments to the state (royalties) are based on annual reports of the extracted water.

Geothermal projects in Slovakia require licences for each stage—exploration, exploitation, and operation. The licensing process is governed primarily by the Geological Works Act, Water Act, and the Act on Environmental Impact Assessment. While there is no single legal definition of what constitutes "deep" vs. "shallow" geothermal energy in Slovak law—the words are not mentioned in legislation—there was always a distinction for wells 500 metre or deeper. These are regulated by the Mining Act, while the Building and Water Act (Slovak Republic, 2004 b) is applied above 500 m), and until recently automatically triggered an EIA review (Slovak Republic, 2006).

An exploration licence is granted for four years, with potential extensions based on the project's needs. In addition to a geological final report, a hydrodynamic test must be carried out in order to confirm the prerequisites for groundwater extraction and submitted to a committee in the Ministry of Environment for stock classification. Within six months, the committee should begin the approval procedure.

The exploitation licence is typically valid for 20 to 30 years and renewable upon proof of continued safe and sustainable operation. According to the legislation, any new borehole is defined as "exploratory" until the two documents mentioned above—approval of the final report and the permit for extraction and discharge or reinjection—have been obtained. Thereafter, the well may be reclassified as “pumping”. A permit to pump geothermal energy in a given area and with specific parameters is issued for up to ten years, after which it can be renewed.

At this point a mining licence must be obtained, which is where an EIA could be required. A recent legislative revision aiming to reduce administrative barriers obstructing geothermal development no longer makes an EIA mandatory for wells deeper than 500 metres (Slovak Republic, 2024). Instead, a screening process will determine whether a project needs a full EIA based on risk level, not just the depth. In general, systems involving groundwater extraction or lacking re-injection are subject to stricter scrutiny. Projects using closed systems or re-injection may be eligible for simplified or exempted procedures.

The oversight of the construction and water authorities depends on the type of project. The former assesses objects that are not in direct contact with geothermal water, such as geothermal borehole shelters or substation objects, while the latter assesses objects that are in contact with geothermal water, like pipelines or process equipment.

Heating plant licences correspond to the plant's projected lifespan and resource availability, often renewed based on technical and environmental audits. To obtain a licence, operators must submit comprehensive documentation including building permits, detailed design plans, energy supply and efficiency analyses, and connection strategies for integration into the DH network.

An updated hydrological balance sheet recording the amount of water extracted must be submitted to the Slovak Hydrometeorological Institute each year. If the holder does not spend at least 10% of the planned budget in the first two years and 70% by the end of the fourth year, the exploration area is cancelled. If the conditions are met, on the other hand, the licence can be extended and the project can be further developed. Finally, regulatory bodies may periodically re-evaluate licence terms to incorporate advances in technology or respond to updated environmental data, ensuring that Slovakia's geothermal sector evolves in a sustainable and responsible manner.

NECP

Slovakia currently does not have a standalone national strategy exclusively for geothermal energy. However, it is increasingly recognised as a key renewable resource, particularly for heating. The updated NECP (Slovak Ministry of Economy, 2023) identifies geothermal as a crucial low-carbon heat source, particularly for DH systems, but stops short of setting explicit quantitative targets. Rather the main strategic objectives outlined in the document that geothermal will be key to achieving are: 49% share of RES in H & C by 2030 and reducing reliance on imported fossil gas—particularly in urban heating where geothermal is seen as a viable alternative.

The plan also calls for simplified and streamlining permitting procedures for all renewable projects, specifically better integration with local spatial plans and improved use of EIA procedures.

For now support for geothermal is mainly provided through EU funding mechanisms, including the Recovery and Resilience Plan, Modernisation Fund, RePowerEU, and Just Transition Fund. There is also and state support for heat network upgrades and diversification which applies to exploration of geothermal energy resources with a view to making them available for energy purposes.

One recent example is the Ministry of Investment, Regional Development and Informatization (MIRRI) implementing the project *"Use of geothermal energy in the Košice basin"*, which will cover a quarter of Košice heat demand (MIRRI, 2024). The project received €56.2 million from the Just Transition Fund, which is part of the EU's Slovakia Programme designed to help regions in transition to a greener economy. The subsidy will support not only the construction of the production centre itself, but also a 15-kilometre long distribution line, which will help to cover the heat consumption of more than 170,000 customers. Furthermore, Programme Slovakia under MIRRI is promoting the search for and exploration of geothermal energy resources with a view to making them available for energy purposes.

For the first time ever, targeted support for the development of geothermal energy for energy purposes appeared in the Slovakia Programme (2021–2027)—the first demand-driven call for the measure for exploration and verification of geothermal energy resources. EUR 13 million are earmarked for exploration and verification of geothermal energy resources for energy purposes in the programming period (MIRRI, 2022).

Integrated geothermal H & C solutions

The H & C sector accounts for about 50% of the final energy demand in the EU, the vast majority of which is produced from the combustion of highly emitting fuels like coal, natural gas, and biomass.

The continued dominance and growth of solid biomass in the renewable H & C category shows that up to now, member states have failed to create support schemes inducing sufficient R & D and deployment support for immature technologies, like geothermal. Therefore, the technology-related cost savings created by higher deployment rates have not materialised in the sector.

Electric heat pumps have also come into focus as a key pillar of REPowerEU for phasing out imported natural gas. While individual units fit well into rural and low-heat density areas, networked geothermal can be more efficient and economical for small groups of buildings, like it is serving large heat pumps or DH in urban areas.

Meanwhile, demand for space cooling is on the rise with higher temperatures, mostly translating to higher demands on the grid for electricity in the summer months. However, data is even more limited and prioritization weaker than the heating sector.

Given this situation, local, sustainable, competitive alternatives are needed more than ever—and geothermal checks all of the boxes. In addition to the obvious climate, environmental and energy security benefits, geothermal has a significant long-term economic advantage to those sources as well: zero fuel cost and volatility, and low operational cost. Therefore, it is worth exploring further the opportunities and barriers for shallow, medium and deep geothermal:

- Shallow: Technically available almost anywhere, but requires a bottom-up, community-led approach. While no geothermal project is the same, the few that have been implemented can provide useful lessons and best practices for future projects.

- Medium: With the exception of low temperature DH or when the temperature demand is low, the geothermal heat output is usually combined with heat pumps in order to increase the temperature of the supply fluid. Synergies with cooling are easy to find, either by direct cooling ("geo cooling") or through reverse heat pumps. When implemented, these synergies can significantly improve the profitability of the operation.

- Deep: Usually considered below a depth of 2.5 km, this typically applies to DH systems, and by extension the buildings they are connected to, both of which must be upgraded in order to integrate low temperature renewables like geothermal. These are aging structures that must be modernized anyway if they are to remain as part of the decarbonized system of the future.

District Heating Networks

DHC networks will play a decisive role in the decarbonisation of Europe's heating sector by enabling the integration of renewable and waste heat on a larger and more centralized scale than individual methods that are less efficient if not impossible in densely populated areas. Therefore, it will be even more essential to master centralized, efficient heating systems to meet the needs of an increasingly urbanized European population.

DH systems can incorporate a variety of technologies including large scale heat pumps, CHP, biomass, waste and excess heat, solar and geothermal. Large heat pumps (25 kW and above) are especially versatile in their ability to use a wide range of low temperature heat sources.

The main energy sources which can be harvested via the means of large heat pumps include renewable heat sources, waste heat from industrial processes, urban excess heat (e.g. from service/residential sectors-supermarkets, underground metro, data centres etc.) and sewage water treatment facilities. Combined with efficient and intelligent buildings, large heat pumps open the way for high energy performance and the deployment of 4th and 5th-generation DH.

Large heat pumps in DH help reduce the overall electricity demands for H & C. In the context of electrification and sector coupling, they will further contribute to freeing up capacity for other sectors such as mobility and industry. Together with city-scale thermal storage, large heat pumps can absorb excess renewable electricity (for direct or postponed use) and modulate production to ensure grid balancing with a quick ramp-up/down of generation and provide weekly and even seasonal flexibility. Smart grids and digital control systems can further optimise the operation of these systems, while thermal storage systems and advanced insulation materials can improve overall performance.

The lower operating temperature of 4th and 5th- generation networks enhances system efficiency, lowers distribution heat losses, and increases integration of locally available renewable and waste heat resources. Developing these high-efficiency networks, especially in areas with dense heat demand, will enable a cost-efficient and technically viable decarbonisation of the European DHC sector.

According to the EED, Member States are required to submit annual statistics on DHC production and capacities. These data are collected using standardized methodologies to ensure consistency and comparability across countries.

The Fit for 55 package (European Commission, 2021) recognizes the role of DHC as a key solution to decarbonise heating and bring flexibility to the energy system and represents opportunities for the growth of the DHC market. The Renewable Energy Directive (European Commission, 2022) obliges Member States to increase the share of renewable and waste heat in DH systems and enable third party providers to access DH. Co-legislators also agreed on an overall binding renewable target of 42.5% in 2030, with a non-binding 2.5% increase bringing the target to 45%.

Although ETS II CO2 price is capped at 45 € per ton until 2030 to protect consumers, this is an important development to establish a level-playing field between boilers and larger installations already covered under the current ETS.

According to Article 16 of the EED (European Parliament & Council of the European Union, 2023c), an "efficient district heating and cooling system" must meet the following criteria:

- until 31 December 2027, using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat;
- from 1 January 2028, a system using at least 50% renewable energy, 50% waste heat, 50% renewable energy and waste heat, 80% of high-efficiency cogenerated heat or at least a combination of such thermal energy going into the network where the share of renewable energy is at least 5% and the total share of renewable energy, waste heat or high-efficiency cogenerated heat is at least 50%;
- from 1 January 2035, a system using at least 50% renewable energy, 50% waste heat or 50% renewable energy and waste heat, or a system where the total share of renewable energy, waste heat or high-efficiency cogenerated heat is at least 80% and in addition the total share of renewable energy or waste heat is at least 35%;

- from 1 January 2040, a system using at least 75% renewable energy, 75% waste heat or 75% renewable energy and waste heat, or a system using at least 95% renewable energy, waste heat and high-efficiency cogenerated heat and in addition the total share of renewable energy or waste heat is at least 35%;
- from 1 January 2045, a system using at least 75% renewable energy, 75% waste heat or 75% renewable energy and waste heat;
- from 1 January 2050, a system using only renewable energy, only waste heat, or only a combination of renewable energy and waste heat.

These progressively tightening, qualifying shares of renewables over time should send a clear signal for governments and companies to think long-term with H & C investments and promote the necessary renewable technologies.

Despite the wide consensus on the general interest of a broader deployment of modern and efficient DH heat pump systems, this solution represented only 12% of the EU's heating market in 2012 and the public awareness of its benefits remains low, especially in emerging DHC markets (Heat Roadmap Europe 2, 2013). Hungary and Slovakia, like many Eastern European countries, still use second or even first-generation heat networks that primarily rely on solid fossil sources with relatively high temperatures. This will be shown in more detail under the DH mapping section.

Hungary

In Hungary there are 214 DH systems, about two-thirds which are small (with peak load below 10 MW). There are 178 DH producers and 101 DH suppliers operating in 94 settlements. Many settlements have several separated (isolated) DH systems—for example, the Budapest DH supplier operates 9 separate systems. Approximately 30% of the DH heat sold to customers is produced by DH suppliers themselves ('in-house' generation), and around 70% is purchased from independent DH producers.

The Hungarian DH sector, despite the high number of suppliers, is quite concentrated: around 9 companies account for 70% of total DH supply (Budapest alone accounts for nearly 40% of Hungary's DH consumption). The vast majority of DH suppliers are owned by municipalities, although there are some operated by private companies. They are also quite diverse as far as heat sources (purchased or produced), the fuel mix (natural gas or renewables), tariff structure and customer base.

Close to 80% of heat is consumed by residential end-users, with the remaining 20% divided between industrial and commercial customers. Approximately 15% of the national housing stock (around 650,000 homes) is connected to DH networks (Orbán, 2018).

In Hungary, there is an important distinction between DH and municipal heating systems. Both distribute heat (hot water or steam) from a central location through a network of pipes to individual houses or blocks of buildings. The difference lies in their legal status, the composition of the consumer base served, and the regulation of DH prices.

- DH systems (operating in around 100 settlements) supply room heating and hot water mainly to residential consumers, mostly sourced by natural gas. These suppliers are heavily regulated, with operations under licence to the energy authority and DH prices set by the state.

- Municipal heating systems (about 25 systems) supply room heating to non-residential customers, such as public institutions operated by the municipality, and some commercial and industrial customers—mostly using geothermal energy. These suppliers are not subject to central state regulation, rather prices are set by the municipal company operating the system.

The DH heat generation fuel mix is diverse, spanning several different technologies and fuels, but the dominant source is natural gas, making up some 70%. Around 25% uses renewable sources—biomass (wood, wood chips and straw) (13%), geothermal (6%) and biodegradable municipal waste (about half of the total waste, 4%) and the remaining 5% by nuclear and non-degradable waste. The share of cogeneration (CHP) peaked at around 45% (Orbán, 2018).

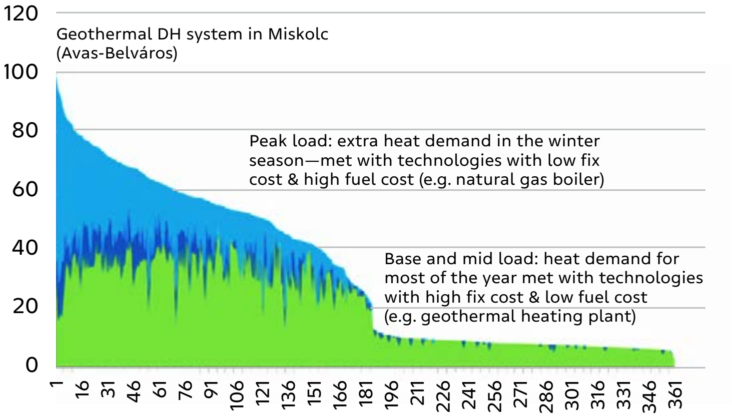
Gas boilers: simple DH technology dominant in Hungary with old, depreciated equipment, in some cases dating back to the 1970s–80s

- Gas engines: small, flexible equipment (1–2 MW), CHP, mostly installed in the 2000s, encouraged by the generous feed-in tariff system (in force until 2011)
- Biomass boilers: small to medium sized DH plants (2–20 MW), capital intensive equipment, requiring careful operation (fuel supply, fuel quality, firing technology etc.)
- Biomass CHPs: big (30–50 MW), capital intensive equipment, suitable for mixing fuels, operation characteristics similar to gas boilers
- Geothermal heating plants: small to large (1–60 MW) capital intensive, very low O & M costs, ideal for baseload operation
- Waste to energy: medium sized (20–50 MW) equipment (Budapest HUHA heating plant)

Hungary has a handful of large DH systems with significant shares of geothermal heat generation. The three biggest are in Győr (86 MW), Miskolc (78 MW) and Szeged (34 MW). These DH systems produce around 50% of their heat needs from geothermal sources (mainly the base load and mid load), and the other half from natural gas (meeting the peak load).

It is important to keep in mind that even in settlements with particularly favorable conditions, geothermal DH cannot achieve a significantly higher than 50% share. The reason is that while heat demand varies depending on the weather (peaking on colder days and falling on warmer days), geothermal heating plants are designed to operate at a constant load. For this reason, heating plants with lower capital costs and greater flexibility (primarily natural gas-fired) might also be needed for peak demand.

Figure 6: **Heat load and fuel mix in Miskolc DH system,** source: MIHO Kft. (cited by Tibor Orban: Present state of the Hungarian DH sector)



Exceptions to this are small municipal heating systems (typically with installed geothermal capacity of 1–5 MW) serving public institutions (which often retain their own gas boilers for emergencies) with greater heat inertia and therefore greater heat tolerance.

Pricing

For a long period, Hungarian DH prices were regulated at the municipal level. This decentralized approach allowed local governments to set prices independently, which led to significant variations and, in some cases, inefficiencies in pricing structures. Then in 2009, new legislation was introduced requiring review and approval by the Hungarian Energy and Public Utility Regulatory Authority (MEKH), marking the first step towards centralization of the pricing regime.

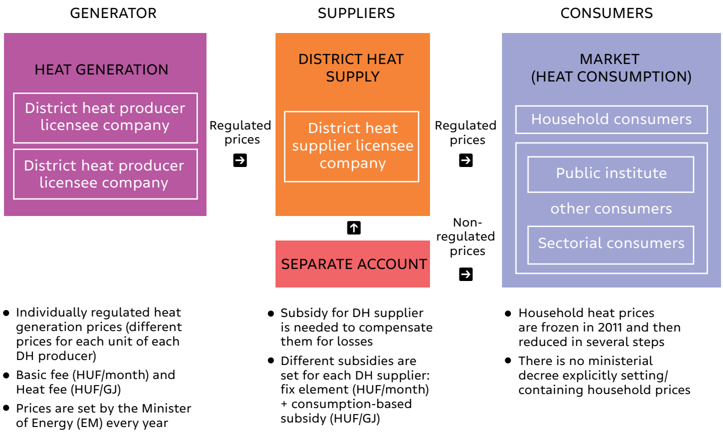
In 2011, a new amendment further expanded and centralized licensing and pricing powers beyond the residential sector to public institutions and DH producers (the price at which the producer can sell the district heat it produces to the DH supplier), while freezing residential prices before reducing them several times—by about 23%, similar to water, electricity and natural gas prices (Hungarian Parliament, 2011). This is the level they remain at today, since 2013.

DH producer prices consisting of heat and capacity charges are set using a traditional "cost-plus" method. Each year MEKH examines the data from the previous year's income statements and other data provided by licencees to determine the justified (i.e. officially accepted) costs and asset values on the basis of "comparative economic analyses." After its assessment, MEKH issues DH producer price recommendations and prices are announced by the Ministry of Energy by decree.

For a long time, DH producer pricing has been based on the principle of minimum cost: according to this, the sales price of all new DH producers is capped at the operating cost level of the cheapest producer in the given area (typically an old gas boiler). Meanwhile, price regulation for public institutions (local government, kindergartens, schools, hospitals, universities and other institutions performing public tasks) has been set on a cost reflective level since 2022.

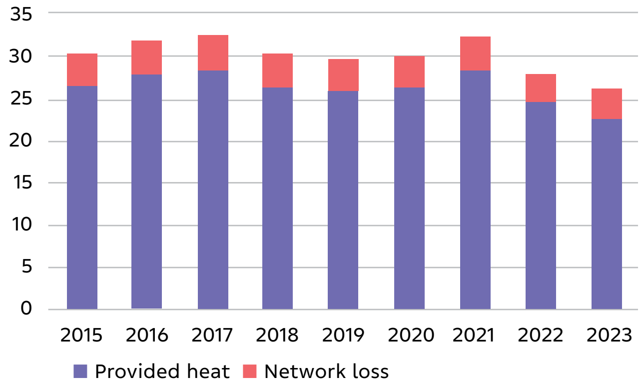
In addition to the official price setting, both DH producers and suppliers are subject to a profit cap, whereby any asset-based profit exceeding 2% must be invested in efficiency improvements or returned to consumers. Both residential and public DH prices are subject to 5% VAT compared to 27% for natural gas and electricity prices. A recent revision to the law (Ministry of National Development, 2011) established a new pricing methodology with a significantly higher profit cap (4.5%–9%), for new renewable DH producers, but it has not been applied to date.

Figure 7: **Hungarian DH sector,** source: Data of the Hungarian district heating sector 2023 published by Hungarian Energy and Public Utility Regulatory Authority and Association of Hungarian District Heating Enterprises, via REKK.



As a result of the strict price and profit controlled system, DH suppliers have been accumulating heavy losses over the past 12 years, becoming entirely dependent on state aid, mostly financed by industrial electricity consumers. According to one estimation, this amounted to a yearly average of EUR 100–130 million (REKK, 2023). The annual subsidization is still only sufficient for maintaining current services and does not allow for meaningful investment or development. The sector was hit hard by the spike in gas prices in 2022, which required a massive public bailout—some ten times the yearly average in the 2022–2023 gas year (REKK, 2023). Since then, national (network) DH production has seen significant declines.

Figure 8: **Hungarian DH consumption (PJ) in 2023,** source: Hungarian Energy and Public Utility Regulatory Authority and Association of Hungarian District Heating Enterprises.



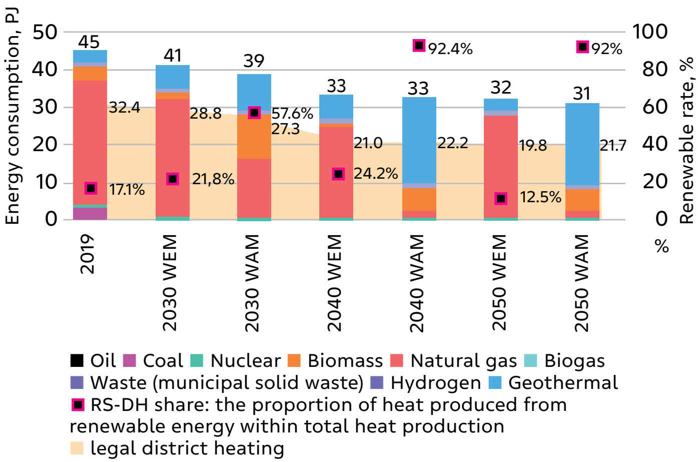
National strategy and support

The cornerstone of Hungary's National Energy Strategy 2030 (NES) is to reduce dependence on imported natural gas (Ministry of Innovation and Technology, 2020). The primary means for achieving this is the Energy Efficiency Obligation (EEO), which includes upgrading municipality DH systems up to 100,000 GJ (accounting for around 90% of the national DH supply) to the category of 'efficient DHC', establishing renewable energy, CHP, and waste heat as the main sources in the DH fuel mix.

Meanwhile, the NECP depends heavily on biomass to meet renewable targets, anticipating a 40% increase by 2030. However there have been doubts about the viability of this pathway, and the NES established a different set of priorities for greening DH, turning to geothermal and waste, while only allowing sustainably produced biomass to meet the remaining heat demand (NES, 2020). The implementation of the NECP for the DH sector requires the development of renewable energy-based DH capacity exceeding 1,000 MW, which is more than the total capacity of existing renewable DH facilities in Hungary. Even by conservative estimates, this programme would require an investment of at least HUF 300 billion, split between EU funds and state aid.

According to the NECP ambitious 'with additional measures' (WAM) scenario, the share of renewable energy sources in DH and derived heat supply would increase dramatically (more than threefold) by 2030 at a rate of 2.2% per year. In 2019, renewable-based heat production (biomass, geothermal energy and biodegradable waste) in DH derived heat supply barely exceeded 17%; by 2030 this share would rise to 57% and by 2040 to 92%.

Figure 9: **Hungary expected evolution of district heating and derived heat supply in WEM and WAM scenarios (2019–2050, PJ/year),** source: National Energy and Climate Plan, Hungary (2024 update).



In principle, renewable DH producers are also supported by the state through price regulation, but in practice this has been rather limited. Support for DH from renewable energy sources in Hungary has traditionally taken the form of non-repayable investment grants. However, since the European Commission suspended several EU funds (e.g. the Recovery and Resilience Facility and Cohesion Funds) to Hungary in 2022 due to rule of law violations, the resources available for greening and modernising DH have been extremely limited for several years.

Slovakia

Today there are over 200 DH systems in operation providing heat to around 1.8 million residents, which translates to 30% of Slovakia's total heat consumption. These systems were developed in the 1960s and 1970s to meet the increasing heat demand needs of rapidly growing urban areas. They primarily serve large residential, multi-family complexes, industrial zones and city centres. The number of connected consumers is expected to grow over the next 5–10 years by 1–2%. About 20% of DH heat is from renewables, predominately biomass.

It is common for cities to have public utilities—often municipal or state-owned—that are responsible for providing centralized heating to residential, commercial, and public buildings. They also maintain the necessary infrastructure and implement energy efficiency measures. A number of municipalities have committed to enhance DHC in their municipal development plans, including heat storing technologies to better balance supply and demand, increasing RES targets, prioritizing the integration of biomass and waste heat, awareness raising campaigns, new participation models, training and network platforms.

One of the Slovak flagship geothermal projects is the case of Galanta DH. The city of Galanta in the western part of the country has implemented geothermal heating to supply its residential and public buildings. By utilizing local geothermal wells, the project provides a sustainable heat supply to multiple buildings within the city. The system features multiple heating loops with different temperature levels and gradients, interconnected in a cascade design. Such configuration maximizes geothermal energy utilization, enhances the efficiency of the geothermal reservoir, and consequently extends its operational lifespan. This geothermal heating system has demonstrated cost-effectiveness, providing a replicable model for other Slovak towns with suitable geothermal resources. In 2007, a thermal spa was constructed and commissioned in Galanta, utilizing heat pumps to recover the remaining low-temperature heat from the water discharged from the station. The initiative is supported by local authorities and demonstrates how municipalities can successfully transition to renewable energy solutions for heating.

Municipalities like Košice and Zvolen have developed extensive DHC plans with decarbonization milestones over the next 20 years, focusing on increasing the RES share and reducing emissions from heat production. Košice is prioritizing the integration of biomass and waste heat from industrial sources. The city of Zvolen is actively pursuing the reduction of supply and return temperatures, a key measure for minimizing energy losses, enhancing the efficiency of existing DHC and connecting new buildings to the network.

The Slovak Association of District Heating (SZVT) leads awareness raising effortd and stakeholder engagement in the transition to RES-based DHC, using educational campaigns, workshops, and policy discussions. Small towns like Banská Bystrica are exploring innovative participation models, involving citizens through energy communities and collective 80 ownership of DHC systems. These approaches foster new business models and financing methods, such as cooperatives and crowdfunding. To improve the bankability of DHC projects, efforts are underway to increase access to EU funds, streamline permitting processes, and establish risk-mitigation tools for investors. Additional work is focused on standardizing technical and regulatory frameworks to attract private investment.

Pricing and Heat Purchase Agreements

The supply of heat is regulated by the Act on Thermal Energy under the Energy Policy of the Slovak Republic issued by the Ministry of Economy (Slovak Republic, 2004a). The Ministry of Economy sets the policy frameworks and regulations governing DHC production, distribution and supply of heat under the Heat Law.

In addition, the thermal energy sector is subject to the Act on Regulation in Network Industries (Slovak Republic, 2022). According to the Act, heat is considered a commodity and its price must be determined for a given regulatory period on the basis of a decree approved by the Office for Regulation of Network Industries (ÚRSO). ÚRSO oversees DH price regulation, tasked with monitoring pricing, ensuring service quality and preventing excessive profits. Under the cost-plus price regulation model, DH utilities must have their cost structures approved, taking into consideration energy consumption, pricing, efficiency improvements, and the share of RES in heat production. Large DHC systems undergo regular energy audits to assess system performance, identify energy losses, and realize opportunities for efficiency improvements. ÚRSO also supervises compliance with the rules governing the price of heat on an ongoing basis.

While ÚRSO does not directly dictate the contract terms, it influences pricing mechanisms, which indirectly shape heat purchase agreements (HPAs). For municipal or publicly supported projects, local authorities may participate in setting contractual frameworks for long-term heat supply and organise public tenders for suppliers (especially if public funds or infrastructure are involved).

There is no specific legal limit imposed by Slovak legislation on the duration of HPAs. However, typically this ranges from 5 to 20 years, depending on the size of the project, infrastructure investment, and financing arrangements. For geothermal heating projects, longer-term contracts (10–20 years) are common to ensure return on investment and provide stability for both suppliers and consumers. This is often aligned with payback periods for the geothermal infrastructure and financing conditions from public or EU funds.

NECP and support

The NECP establishes a policy framework for upgrading the DH sector with an ambitious target of increasing DH RES by 2.1% annually to 2030. There are numerous support measures made available to achieve these goals, mostly overseen by the Slovak Innovation and Energy Agency (SIEA), which manages both technical and financial support for H & C projects.

First, the state offers substantial operational support, including technical assistance and guidance for planning, feasibility studies, and stakeholder engagement to further streamline project development. SIEA carries out strategic energy planning at the municipal level. It also offers platforms for knowledge exchange, technical guidance, and best practices on integrating RES into DHC systems, including training for local governments and energy providers.

Several financial incentives were put in place to support the development and modernization of DH systems to be compatible with renewables. State subsidies and grants designed to reduce the upfront costs for innovative sustainable technologies provide a starting point. Slovakia leverages EU funding programmes, such as the Cohesion Fund and the European Regional Development Fund (ERDF), to finance large-scale DH projects transitioning to low heat RES. SIEA administers initiatives such as the Green Households Program, which provides subsidies to enhance energy efficiency and the use of RES in DHC systems. It also manages grant schemes at the municipal level.

Direct subsidies are available for connecting existing homes to DH, especially targeting households in urban areas, and switching from individual fossil-fuel-based heating systems to cleaner DHC solutions. There is also a biomass phase-out initiative to replace coal and non-renewable biomass with locally sourced renewable biomass. There are further operational incentives through the Operational Programme Quality of Environment to connect energy-efficient CHPs with DHC systems, exclusively for use of biomass or biogas. This is in addition to the tax reductions and incentives for low-temperature DH installation and infrastructure upgrades.

District Cooling Networks

In Europe, record breaking summer temperatures combined with rising consumer expectations for comfort are leading to growing demands for cooling. These demands are largely embedded in power consumption mostly met with building-bound units, typically in the secondary sector.

Despite this, many factors are working against more efficient district cooling systems. Similar to other renewables, the two biggest barriers are the high upfront capital and long-term uncertainty. To begin with, a proper framework recognising and addressing the cooling challenge is completely missing at the European level. Furthermore, the contribution of district cooling networks to the development of sustainable and resilient urban areas is not recognised. At the end of 2020, Member States delivered their first H & C strategies, and only 6 of the first 21 countries mentioned cooling demands (Toleikyte & Carlsson, 2021).

Geothermal energy can be effectively utilized for cooling applications through ground-source heat exchange systems. The core principle involves transferring excess thermal energy from the building or district cooling network into the subsurface via a closed-loop or open-loop geothermal system. In a closed-loop system, a circulating fluid absorbs heat from the network and carries it through buried pipes, where it is dissipated into the cooler ground. In an open-loop system, groundwater is directly extracted, used for heat exchange, and then returned to the aquifer. This process provides a reliable source of chilled water for cooling, particularly during peak summer demand, while also allowing the ground to absorb and store heat, which helps maintain long-term thermal balance. This regenerative aspect improves the seasonal performance of the geothermal system. There are two main technologies used to achieve this:

- Direct cooling (or "geo-cooling") is a solution using a direct cold source without a heat pump. The heat (or cold, in this case) is transferred through a heat exchanger.
- A reversed heat pump behaves as a refrigerating machine. The condenser becomes the evaporator and

the evaporator, the condenser. The heat is captured from the system and transferred through the heat pump to the geothermal resource. The evaporator temperature is defined by the cooling needs (usually 12°C for a cooling temperature of 7°C). The reinjection temperature is 20 to 30°C. With this technology cooling and heating work simultaneously in the heat pump.

Networked geothermal

A collective approach to replacing individual gas boilers in a cluster of buildings using networked geothermal ground source heat pumps can, in many cases, be more efficient and cost-effective than individual electric heat pumps. These projects can be implemented the fastest ÚRSO in 1–3 years—compared to DHC projects which typically taking 5–7 years to implement. Given the urgency of tackling the current energy security dilemma and lowering energy prices for residential and industrial consumers, networked geothermal opportunities should be examined more closely, especially substituting for natural gas.

Case study: Germany

Germany offers a relevant and instructive benchmark for Hungary and Slovakia due to its advanced DH infrastructure, strong climate policy framework, and increasing commitment to deep geothermal energy. Although the three countries differ in scale and market maturity, Germany shares a similar Central European climate, a comparable urban-rural settlement structure, and historical reliance on fossil-fueled DH systems.

More importantly, Germany demonstrates how legacy DH infrastructure can be modernized through targeted regulatory reform, financial incentives, and the integration of renewable technologies, including geothermal energy. Its goal of a climate-neutral DH sector by 2045, combined with real-world municipal initiatives (e.g. in Munich and Geretsried), showcases replicable strategies in governance, permitting reform, and local project design.

While Germany leads in geothermal innovation and policy integration, Hungary and Slovakia have comparable (if not more favourable) subsurface potential (particularly within the Pannonian Basin), making Germany's pathway a realistic and regionally adaptable model. Thus, Germany provides a practical and aspirational reference point—not only for technical transformation, but also for aligning DH systems with EU climate goals and cohesion funding frameworks.

Germany has positioned geothermal energy as a key pillar in its strategy to decarbonize the heating sector. With heat accounting for more than 50% of final energy use, and much of that still fossil-fuelbased, the German federal government aims to supply at least 50% of municipal heat demand from climate-neutral sources by the early 2030s (Clean Energy Wire, 2023 b). Deep geothermal energy is increasingly recognized for its potential to provide reliable, low-emission, and locally sourced heat—independent of weather and seasonality.

Strategic Policy Framework and National Targets

Germany's geothermal policy is framed within the broader ambition of achieving climate neutrality by 2045. In 2023, the German government, through the Federal Ministry for Economic Affairs and Climate Action (BMWK), emphasized geothermal's strategic role in its heating transition. It set a target of 10 TWh of geothermal output from medium--depth and deep resources by 2030 and also 100 additional geothermal projects by this date (BMWK, 2022).

According to a national roadmap, developed by the Fraunhofer Society and Helmholtz Association, deep geothermal energy could potentially supply over 300 TWh annually, equivalent to 25% of Germany's current heat demand (Clean Energy Wire, 2023 b). The roadmap calls for clear national expansion targets, accelerated geological mapping, and capacity-building for a skilled geothermal workforce.

Germany has taken significant legislative steps to simplify and accelerate geothermal development. The 2023 legislative package includes three core instruments:

- Geothermal Acceleration Act, which grants geothermal projects the status of "overriding public interest," enabling faster permitting and prioritization within administrative processes (Watson Farley & Williams, 2023).
- Bureaucracy Reduction Act IV (BEG IV), which simplifies the regulatory treatment of near-surface geothermal projects (up to 400 metres), exempting them from the more complex provisions of mining law (ThinkGeoEnergy, 2023a).
- Amendments to the Water Resources Act, which introduce shorter approval deadlines for water-related permits in geothermal drilling and aquifer use, thus reducing long-standing bureaucratic bottlenecks (ThinkGeoEnergy, 2023 b).

Collectively, these reforms aim to mitigate development risk, increase transparency, and unlock the geothermal sector's potential by reducing time and complexity in project execution.

The 2021 revision of Germany's Renewable Energy Sources Act (EEG, 2021) reaffirms geothermal energy's place in the country's long-term climate and energy strategy, despite its relatively modest deployment compared to wind and solar. As Germany targets 80% renewable electricity by 2030 and climate neutrality by 2045, EEG 2021 supports geothermal exploitation primarily through continued feed-in tariffs (FiTs), rather than competitive auctions, recognizing the sector's high upfront risk and need for investor certainty.

While the Act does not introduce major new incentives specific to geothermal, it strengthens the strategic framework by integrating geothermal into the national low-carbon trajectory. The stability of the FiT mechanism under EEG 2021 helps maintain geothermal's viability, especially for deep geothermal projects used in CHPs, critical for decarbonizing heat in regions like Bavaria and Baden-Württemberg.

Though geothermal remains a niche source, its inclusion in the EEG ensures alignment with Germany's NECP and the Federal Climate Change Act. It signals the importance of dispatchable, baseload renewable sources to complement variable wind and solar generation. The Act thus lays a stable legal and economic foundation for geothermal development, though further reforms, especially in permitting and subsurface exploration, are needed to unlock its full potential.

Financial Support Instruments and Market Incentives

Germany supports geothermal deployment through a combination of national and EU-aligned instruments. The Renewable Energy Sources Act (EEG) provides a market premium model for electricity generated from geothermal energy, ensuring long-term revenue security (BMWK, 2024). In the heat sector, the state-owned KfW development bank offers subsidized loans and grants through programmes such as the "Renewable Energy—Premium" initiative, which supports DH infrastructure and renewable heat production, including geothermal systems (IEA, 2024 b).

These mechanisms aim to de-risk investments and encourage both public and private actors to enter the geothermal market. The government has also signaled a willingness to back additional guarantee schemes to reduce exploration risk, a persistent challenge in deep geothermal development.

In addition to regulatory streamlining, Germany has reinforced the economic viability of geothermal projects through the revision of its Renewable Energy Sources Act (EEG 2021). The updated framework introduced more favorable conditions for deep geothermal power generation by increasing the guaranteed feed-in tariffs and providing a market premium tailored to the higher capital intensity and longer development timelines of geothermal compared to other renewables like wind or solar (Rödl & Partner, 2021). The EEG also includes a "flexibility premium" and access to "innovation tenders," incentivizing geothermal projects that integrate heat production or storage systems. These instruments are especially valuable for municipal utilities, where geothermal electricity can be co-utilized for DH, enhancing overall system efficiency. The legal clarity provided under the EEG framework not only improves investment security but also increases the bankability of geothermal initiatives through long-term revenue guarantees. This combination of targeted financial support and regulatory transparency positions Germany as a leading EU Member State in aligning geothermal development with both energy transition and heating decarbonization objectives.

Technological Innovation and Project Development

Germany has emerged as a technological frontrunner in geothermal innovation, particularly in adapting systems to diverse geological contexts. One of the most prominent examples is the Eavor-Loop™ project in Geretsried, Bavaria, which represents Europe's first implementation of a closed-loop geothermal system. Unlike traditional hydrothermal approaches, Eavor's technology does not rely on naturally occurring aquifers or permeable rock formations. Instead, it circulates a working fluid through a sealed subsurface pipe system, using conductive heat transfer to extract thermal energy. This "radiator-style" approach offers minimal environmental risk, eliminates the need for hydraulic stimulation, and is highly scalable, making it suitable for regions of Germany without conventional geothermal reservoirs (AP News, 2023).

This innovation is part of a broader trend toward next-generation geothermal technologies that support the decarbonization of both electricity and heating sectors. In parallel, major municipalities such as Munich and Stuttgart are actively expanding their use of deep geothermal systems within their urban energy strategies. Munich's municipal utility, Stadtwerke München, aims to meet 100% of its DH demand from renewable sources by 2040, with deep geothermal expected to provide a significant share (Stadtwerke München, 2023). In Stuttgart, similar projects are being pursued in conjunction with municipal climate neutrality plans (BMWK, 2023a).

These developments are made possible by a combination of technological adaptation, long-term investment frameworks, and regulatory support. The successful integration of geothermal into urban heating networks demonstrates how geothermal energy, traditionally seen as geographically constrained, can be reimagined through engineering innovation and proactive public planning. Germany's project pipeline reflects a maturing geothermal sector, where commercial feasibility is increasingly being aligned with regional energy security and decarbonization goals.

Geothermal Permitting and Licensing

The regulatory framework for geothermal energy development in Germany is defined by a set of national laws that govern resource extraction, environmental protection, and spatial planning. Deep geothermal projects—those that involve drilling beyond 400 metres—fall under the jurisdiction of the Federal Mining Act (Bundesberggesetz), which stipulates that a company must obtain both an exploration license and an operational plan approval before commencing development (BMWK, 2023 b; Watson Farley & Williams, 2023). The exploration licence grants the right to investigate subsurface geothermal potential within a defined area and time frame, while the operational plan outlines the technical, safety, and environmental protocols for resource utilization.

In addition to mining law, geothermal developers must comply with the Federal Water Act (Wasserhaushaltsgesetz), which regulates groundwater abstraction and reinjection, particularly in closed-loop or hydrothermal systems. Projects that interact with surface or groundwater typically require a water usage permit, and those with significant environmental implications may be subject to an Environmental Impact Assessment (EIA) under German and EU legislation (BMUV, 2022). Furthermore, a construction permit is necessary under the Federal Building Code (Baugesetzbuch) to ensure the proposed installation aligns with municipal zoning and land-use plans (BMWK, 2023 b).

Recognising the need to accelerate renewable heat deployment, Germany has recently introduced targeted reforms to streamline geothermal permitting. The Geothermal Acceleration Act (*Geothermie-Beschleunigungsgesetz*) elevates geothermal energy to a status of "overriding public interest," which prioritises such projects in administrative decision-making and facilitates faster permitting (Clean Energy Wire, 2023a). This legal shift is intended to reduce delays, clarify institutional responsibilities, and support the integration of geothermal into municipal heat planning. Additional reforms include the simplification of near-surface geothermal permitting under the Bureaucracy Reduction Act IV (ThinkGeoEnergy, 2023a), and updated timelines for water law approvals (ThinkGeoEnergy, 2023 b). Plans for further digitalisation of licencing processes are also underway, aimed at improving transparency and reducing administrative burdens.

Together, these legal provisions and reforms constitute a progressively enabling environment for geothermal energy development. Germany's approach provides an important regulatory reference point for Hungary and Slovakia, where fragmented permitting processes and unclear administrative pathways continue to constrain geothermal investment. By establishing clear legal procedures, consolidating institutional roles, and aligning geothermal licencing with national decarbonisation goals, Germany illustrates how regulation can be a catalyst rather than a barrier for renewable heat innovation.

Challenges and Remaining Barriers

Despite this progress, several challenges persist. Public opposition related to seismic risks and groundwater safety can delay or derail projects, particularly in densely populated areas. Access to detailed and up-to-date subsurface geological data remains limited, complicating feasibility studies and financing. Furthermore, there is a growing need for trained professionals and technical experts as project pipelines expand (IEA, 2024).

To overcome these barriers, the German government invests in national geological mapping programmes and plans to expand vocational training specific to geothermal and drilling engineering. These complementary measures are essential to ensuring a sustained and equitable geothermal scale-up.

Germany's geothermal strategy explains how coordinated policy, regulatory reform, and public investment can catalyse the transition toward climate-neutral heating. Its legal recognition of geothermal as a public interest, streamlined permitting procedures, and robust financial instruments represent international best practices. While challenges remain in social acceptance and data availability, Germany's trajectory illustrates the transformative potential of geothermal energy when supported by an enabling governance framework.

Germany's District Heating System in brief

Germany's DH landscape is extensive and evolving rapidly in response to climate policy objectives. The country operates over 4,100 DH systems, spanning approximately 34,000 km. As of 2023, 14% of households are connected to these networks, accounting for a similar share of total building heat demand.

Historically, German DH has relied heavily on CHP plants fueled by natural gas (42%), hard coal (39%), and lignite (12%), with only about 17.8% of heat sourced from renewables. However, the national goal is to achieve a climate-neutral DH sector by 2045. To this end, the German government and municipal utilities are investing in alternative technologies, such as large-scale heat pumps, geothermal systems, and solar thermal collectors, and integrating industrial waste heat.

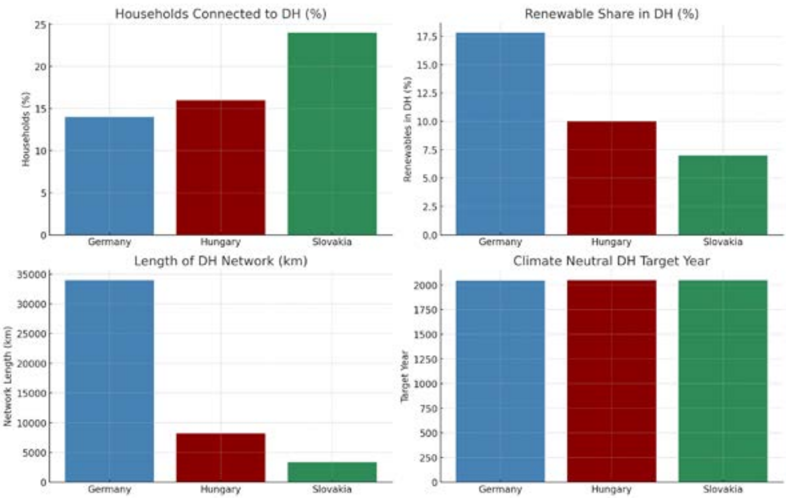
Regional disparities are significant. Cities like Flensburg, Munich, and Hamburg have DH penetration rates above 30%, while others like Cologne lag behind. Projects like the Eavor-Loop™ in Geretsried illustrate Germany's leadership in geothermal innovation, and municipal plans in Munich aim to transition 100% of DH supply to renewables by 2040.

The cross-country comparison between Germany, Hungary and Slovakia can be summarised as follows:

- **Germany** has a more expansive network and a moderate share of renewable inputs, with an ambitious climate neutrality target for 2045.
- **Hungary** has slightly higher DH household penetration (16%) but lower renewable integration (~10%). Its systems are often gas-dominated, though geothermal expansion is underway.
- **Slovakia** has the highest DH penetration among the three (24%), yet the lowest renewable share (7%). Most systems rely on fossil inputs, with slow uptake of renewables.

Figure 10 visualizes differences across four DH system key metrics: household coverage, renewable integration, network size, and climate targets.

Figure 10: **Comparison of District Heating Systems, Germany, Hungary, Slovakia,** sources: Data compiled from BMWK (2023c), Clean Energy Wire (2023 b), Solarthermalworld.org (2023) for Germany; STRATEGO Project (2015) and Hungarian Energy and Public Utility Regulatory Authority for Hungary; and Heat Roadmap Europe (2018), Slovak National Heat Study, and IEA (2024) for Slovakia.



Geothermal DH Mapping for Hungary and Slovakia

Data and resources

Hungary's geothermal data is provided by: 1) OGRe—Geothermal Information Platform. It includes interactive maps showcasing geothermal wells, temperature gradients, and potential areas for geothermal development. 2) Geothermal Atlas of Hungary. Developed by researchers at Stanford University, this atlas offers detailed isothermal maps of Hungary, illustrating temperatures at various depths (e.g., 50°C, 60°C, 70°C, 90°C). It highlights regions with significant geothermal potential, particularly in southeastern counties like Csongrád and Békés.

For Slovakia, the data sources are more limited. Mapping efforts are being led by the State Geological Institute of Dionýz Štúr (ŠGÚDŠ). The Heat Roadmap Europe project provides maps identifying regions in Slovakia with high synergy between excess heat sources and heat demand which will be instrumental in planning efficient DH expansions.

Heatmap of the geothermal DH systems

This section presents a heatmap analysis of geothermal DH projects in Hungary and Slovakia. The visualisation supports comparative assessment across locations, based on both technical and operational indicators, while addressing earlier limitations related to score scaling and interpretation.

The selection of the two geothermal DH projects in Hungary and three in Slovakia was guided by their representativeness, strategic relevance, and analytical value. These locations reflect varying stages of development, from established systems to more recently expanded networks, offering a diverse picture of geothermal deployment in the region. Geographically, they are situated in geologically favourable zones—particularly the Pannonian Basin—known for its geothermal potential. Technically, the projects vary in size, depth, and network scale, enabling comparative analysis. Their inclusion also stems from their relevance to national and EU energy strategies, including REPowerEU, and the availability of reliable data. Such mapping exercises enable cross-border benchmarking, helping to identify shared opportunities and barriers while highlighting successful models that may be replicated across similar contexts in Central and Eastern Europe.

Methodology

The data was sourced from the Geothermal DHC project database (Pinna et al., 2023), a project dedicated to promoting geothermal energy in multivalent DHC networks. The data selected for this geothermal H & C Systems exercise includes various indicators describing the scope, technological readiness, and infrastructure characteristics of each geothermal DH project. To construct the heatmap, the following key variables were used:

Variable Name—Description

Composite Size Score: Combined metric reflecting human reach, technical scale, and DH network length (scaled 5–10). It reads as follows:

- Technical Scale Score: Reflects the energy production or technical design scale of the geothermal system, including installed capacity in MWh.
- Human Reach Score: Estimates the number of people or facilities served by the DH system.
- DH Length Score: Represents the pipeline length, providing insight into network expansion and urban integration.

Enthalpy Score: Resource temperature or quality proxy, scaled typically between 5–10. TRL: Technology Readiness Level (on a 0–9 scale). DH Generation Score: Reflects the geothermal system's role in generating district heat (score 5–10). Admin Support: Level of administrative/policy support for the project (subjectively scored 5–10). Final Score: Composite average of the above variables to provide an overall evaluation.

To enable meaningful comparisons while ensuring no project was represented by a zero (which could misleadingly imply irrelevance or inactivity), the numeric variables were normalized to a 5–10 scale using the formula:

Adjusted Score = 5 + 5 × (value−min/max−min)

This ensures that even the lowest-scoring projects are presented with a baseline value of 5, making it clear they are operational while still allowing for relative comparison. The technology readiness level (TRL) value was preserved in its original raw form, allowing its true 0–10 scale to remain visible and interpretable.

Next, we build the representation of the DH system scores. The heatmap is created using the Seaborn visualisation library in Python, presented as Figure 11. Each row in the heatmap corresponds to a specific geothermal DH project, while each column represents a selected indicator. The colour intensity indicates relative performance: darker shades imply higher scores, while lighter shades indicate lower scores.

Table 2: **Standardized scores of the geothermal DH systems for selected Hungarian and Slovakian locations,** own elaboration.

Location	Country	Size Score	Enthalpy Score	Capacity (MWth)	TRL	DH Gen. Score	Admin Support	Final Score
Galanta	Slovakia	6.5	2.0	7.0	9.0	3.0	6.0	5.5
Sereď	Slovakia	7.8	2.0	1.4	9.0	3	6.0	5.47
Šaľa	Slovakia	6.2	2.0	6.2	9.0	3	6.0	5.42
Hódmező-vásárhel	Hungary	8.2	2.0	20.0	9.0	2.0	6.0	6.2
Mórahalom	Hungary	7.3	2.0	1.5	9.0	4.0	6.0	5.55

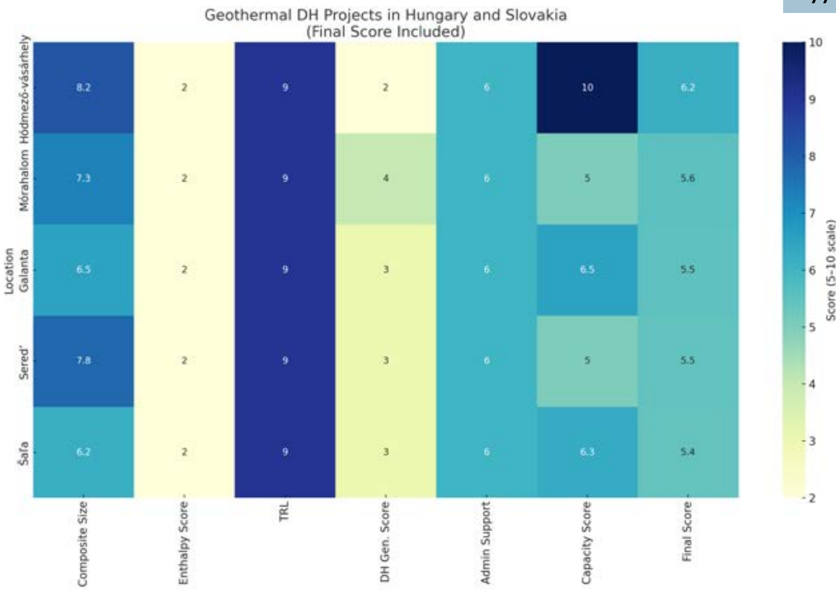
This heatmap presents a standardized comparison of geothermal DH projects across selected Slovak and Hungarian locations. Each row corresponds to a project site, while each column represents a key performance dimension: human reach, technical capacity, DH pipeline length, system depth, and technology readiness level (TRL). All indicators, except TRL, are normalized on a 5–10 scale to prevent misrepresentation of active systems and to allow fair comparison. TRL is displayed in its raw value (1–10 scale) to reflect technological maturity. Color intensity illustrates the relative performance.

This heatmap offers several layers of insight:

- Projects with consistently dark rows demonstrate balanced high scores across most or all indicators.
- Variations in shading across columns help highlight specific strengths or weaknesses—for instance, a project may score high in depth and TRL but lower in human reach or network length.

- TRL values, shown in raw form, illustrate which systems rely on fully mature technologies and which ones may be more experimental or emerging.
- Comparing rows across the two countries reveals how project development and geothermal DH integration differ contextually between Slovakia and Hungary.
- The visualization highlights performance disparities and helps identify strengths, weaknesses, and development patterns across the region's geothermal DH landscape.

Figure 11: **Comparative heatmap of geothermal DH projects in Hungary and Slovakia,** own elaboration.



This method improves interpretability while preserving the nuance of each location's geothermal DH profile. It provides a clear, evidence-based tool for benchmarking, strategic development, and investment planning in regional low-carbon heating infrastructure.

The developed heatmap provides a multidimensional assessment of selected geothermal DH projects in Hungary and Slovakia. It visualizes six core criteria—composite system size, geothermal resource quality (enthalpy score), TRL, DH generation capacity, administrative support, and installed thermal capacity—each normalized to a 5–10 scale (except for TRL, which remains in raw format). The Final Score is a calculated average of these indicators and serves as a synthesized measure of project maturity, strategic readiness, and development potential.

Visual Insights

Projects with darker shades across all rows in the heatmap represent high-performing systems across the selected dimensions. The final column, "Final Score," consolidates this information into a single value, helping to identify projects that not only perform well in one or two categories but consistently across the board. For instance, projects located in more mature geothermal regions such as Hódmező-vásárhely (HU) or Sered (SK) exhibit balanced strength in size, technology readiness, and administrative support, indicating a strong overall strategic position.

In contrast, systems not included in this analysis, such as Veľký Meder (SK) or Szarvas and Miskolc (HU) may have promising technical parametres or resource potential but score lower in administrative support or DH network generation, indicating specific barriers to full deployment. These disparities suggest where policy support or infrastructure investment could have the most catalytic effect.

Final Score as an Analytical Tool

The Final Score, presented in the last column of the heatmap, is not intended as a rigid ranking but as a comparative benchmarking tool. It provides a snapshot of how each geothermal DH system performs relative to others within the same policy and geographical context. The average-based methodology ensures that no single indicator dominates the evaluation, allowing for a more nuanced representation of multifaceted projects.

This score helps to prioritize sites for further development or EU funding support (e.g., through REPowerEU or Cohesion policy instruments), as well as identifying replicable models in more advanced locations. It can be also used to target policy efforts towards underperforming but high-potential regions (e.g., locations with good geothermal resources but low TRL or weak administrative engagement).

Cross-Border Patterns

The results of the composite scoring and visual heatmap analysis reveal notable cross-country differences and complementarities between Hungary and Slovakia in their geothermal DH potential. Hungarian sites generally achieve higher composite scores, which is primarily driven by more established DH integration, greater administrative and institutional support, and higher installed thermal capacities. Locations such as Hódmező-vásárhely and Mórahalom illustrate how geothermal can be effectively mainstreamed into urban heating strategies when underpinned by strong governance and long-term investment planning.

In contrast, Slovak sites show more variation in performance. While some locations like Galanta and Šaľa exhibit robust technical readiness and favourable geological conditions, they are often constrained by lower administrative engagement and the absence of a clearly defined national geothermal development strategy. Despite these institutional gaps, Slovakia's emerging projects demonstrate encouraging potential for upscaling, particularly when supported by targeted policy intervention and regional cooperation. The relatively lower scores in Slovakia should therefore not be interpreted as a lack of geothermal resource, but rather as an opportunity for capacity building and policy support.

This comparative approach underscores that geothermal development is not solely a function of geological endowment but is equally shaped by political will, infrastructure maturity, and policy coherence. By using a multi-variable composite heatmap—integrating technical depth, installed capacity, DH connectivity, administrative support, and technological readiness—this project delivers a tool that helps prioritize investment and planning efforts across the two countries. The visual representation of these scores not only enhances comparability but also provides a transparent basis for decision-making.

Strategically, the heatmap-based scoring reinforces the importance of aligning technical and institutional conditions to fully leverage geothermal potential. It can serve multiple purposes: as an evidence base for energy and climate policymaking; as a decision support tool for local authorities and investors; and as a mechanism to guide regional coordination. While geothermal is inherently a local resource, its successful deployment requires synchronized efforts across governance levels. The contrast between Hungary's more advanced integration and Slovakia's emerging ecosystem highlights both the challenges and opportunities for coordinated cross-border progress in sustainable DH.

Strategic Implications

The development and application of a heatmap-based composite scoring methodology carries significant strategic value for the advancement of geothermal DH in Hungary and Slovakia. By integrating multiple dimensions—such as technical potential (e.g. resource temperature, depth), installed thermal capacity, DH infrastructure length, administrative support, and technological readiness—the scoring framework enables a more holistic and data-driven assessment of each site's viability. This, in turn, strengthens the foundation for evidence-based policy planning by providing national and regional authorities with a clear, comparative understanding of where geothermal efforts are most promising or where additional support is required.

Furthermore, this approach informs location-specific investment strategies by identifying not only the highest-performing sites, but also those that may be strategically important despite current limitations. For example, a site with moderate technical scores but strong institutional backing could become a testbed for rapid upscaling if targeted support mechanisms are introduced. The visual heatmaps derived from this method enhance transparency, allowing policymakers, municipalities, and investors to evaluate geothermal DH potential more objectively across different regions.

Importantly, the composite scoring tool supports regional cooperation by highlighting both shared strengths and development gaps between Hungary and Slovakia. It enables a joint narrative for regional planning, where lessons learned in high-performing areas can be transferred to less developed ones. This is particularly relevant in the Central and Eastern European context, where countries share similar legacy infrastructures and climate commitments, but differ in the maturity of their geothermal ecosystems.

Ultimately, the findings reinforce the notion that while geothermal energy is rooted in local geological conditions, its successful integration into national energy and climate strategies hinges on a convergence of technical feasibility, institutional will, infrastructure preparedness, and stakeholder coordination. The composite heatmap tool not only guides current deployment but can also be adapted as a monitoring framework to track progress over time, refine priorities, and optimize public and private resource allocation.

Roundtable and Expert Survey

The first Hungary–Slovakia Geothermal Roundtable was held on December 3, 2024, during the Central European Energy Conference (CEEC) in Bratislava, Slovakia. The roundtable included the active participation of government representatives, regulatory authorities, industry leaders, and project developers. Immediately after this convening, a follow-up survey was distributed to all participants (about 20 individuals) to further contribute to the consultation and research process. In the end, seven expert responses were collected. While the number may appear modest, it is very representative of the room since there were multiple people from the same entity.

The survey was intended for expert and high-level stakeholders, ensuring that the insights gathered reflect in-depth, practice-based knowledge rather than general opinions. It was designed as a diagnostic tool to capture the perspectives of geothermal energy experts in Hungary and Slovakia. Its primary aim was to identify key barriers and enabling conditions for geothermal development across strategic, financial, technical, and institutional dimensions. The questions were structured to assess national policy alignment, investment frameworks, infrastructure readiness, and regulatory challenges. Particular attention was given to practical implementation issues such as project permitting, reinjection obligations, and DH compatibility. By also exploring knowledge gaps, cascading use potential, and stakeholder perceptions of geothermal energy's role relative to other low-carbon heating options, the survey sought to build a grounded understanding of what currently constrains, or could accelerate, the growth of geothermal energy in the region. The expert responses serve as a qualitative evidence base to inform future planning, policy reform, and cross-border cooperation.

Each response provides valuable input on regulatory frameworks, investment models, technical challenges, and policy needs. The results should be interpreted as a qualitative snapshot of sectoral priorities and used to inform further dialogue, strategic planning, and regional cooperation in geothermal development. The responses were taken anonymously. The survey was created using Google Forms and distributed digitally.

Stakeholder Insights on Geothermal Development in Hungary and Slovakia

Regulatory frameworks remain a critical area for improvement. Stakeholders emphasized the need for strategic national planning, risk-sharing mechanisms (especially for unsuccessful drilling), and streamlined licensing procedures. Transparent and predictable regulatory environments, as seen in more advanced markets like Poland and Germany, were highlighted as best-practice models. E.g.:

Governments can de-risk geothermal projects by introducing guaranteed loans, cost-sharing mechanisms, or other financial incentives that attract private sector involvement. In addition, better accessible subsurface data and knowledge exchange platforms among the countries is a crucial step for better planning both in-country and cross-border projects.

From a technical standpoint, challenges include the geographical distance between geothermal resources and urban demand centres, reinjection feasibility, and the high-temperature requirements of legacy DH networks. While some respondents noted relatively few technical barriers, others identified financing and access to drilling technology as bottlenecks. E.g.:

There are no big technical challenges in connecting geothermal to the DH systems. Slovakia has a few working and a new one in preparation (Košice). The challenge is in continuous support of gas and biomass that makes geothermal less attractive for heat distributors / producers.

The cascading use of geothermal energy—where residual heat is utilised across multiple sectors—was widely endorsed as a method to improve project economics and efficiency. This approach could significantly enhance return on investment, particularly for geothermal electricity and heating projects. E.g.:

There is a lot of excess heat produced in geothermal power production. A couple of points:

Water that has already run through a turbine and would otherwise need to be cooled before reinjection can instead *be put to productive use. Whether or not it is used, the excess geothermal heat exists, and can be a reliable source for district heating. Facilities that integrate power generation with heat become more competitive by monetizing heat that would otherwise be wasted. Using cascading heat improves the return on investment for each well drilled.*

Investors and lenders will likely view projects with multiple revenue streams (heat and power) as lower risk. Unlike standalone district heating systems that rely on seasonal demand, geothermal heat cascaded from power plants provides multiple demand streams, which could potentially make combined heat and power facilities more financially stable. Beyond district heating, cascading uses of geothermal heat can also support industrial processes by boosting heat for metals manufacturing, drying processes, hydrogen production, and direct air capture. It can also provide heat for lower temperature needs like greenhouses, de-icing roads, and aquaculture.

Opinions on government awareness and support for geothermal's long-term benefits were mixed. While some indicated growing recognition, others reported a lack of strategic consideration for geothermal's economic, environmental, and energy security potential. E.g.:

There is a big lack of understanding of the geothermal potential amongst the government and governmental employees.

Geothermal energy remains under-assessed in comparison to gas and biomass in the heating sector. Most experts confirmed that formal comparative analyses—such as those assessing networked geothermal systems versus individual gas boilers or heat pumps—are largely absent. As such, geothermal is not yet on equal policy footing with other heat sources. E.g.:

The geothermal sector presents high investment risk in the early stages and faces different challenges than the gas or biomass CHP in the DH sector. The assessments of networked geothermal and gas sources is standard and will continue to happen in the context of the largest geothermal project in the country. The geothermal investment will increase the share of geothermal energy (and RES) in the energy supply mix of the heating plant.

Risk mitigation was consistently cited as the most pressing need for the sector. Proposals ranged from government-backed guarantees for initial drilling to the creation of national risk funds. Better access to geological data and the development of centralized digital databases were also seen as necessary steps toward de-risking investment. E.g.:

A electronically processed database of existing geological data (there is plenty of data in the Slovak ŠGÚDŠ archive). Risk mitigation through financial incentives from government that can be repaid in case of successful wells. National programme for exploratory drilling.

When asked about funding, experts cited national environmental and modernization funds, as well as EU instruments such as Structural and Cohesion Funds and the Just Transition Fund. However, uneven awareness suggests the need for better outreach and capacity-building to help stakeholders navigate available financial instruments. E.g.:

National: Environment and Energy Efficiency Operative Program (85% ERDF funds), any EU funds (Just Transition Fund and EIB loans).

Finally, geological exploration is currently financed through a mix of private equity and public support. While Slovakia relies more heavily on private investments, Hungary has implemented state-supported exploratory programs in selected regions, particularly those eligible for EU cohesion funding. E.g.:

State financed exploration campaigns for less explored areas (including field seismic surveys perfored by the National Geological Survey).

Private sources, a combination of private and public sources (e.g. local government) and now also the European funds (JTF, ERDF) and the state budget. The ambition is to increase state support in this area.

Overall, the survey underscores the importance of coordinated regulatory reform, targeted risk-sharing policies, and strategic investment in workforce and data infrastructure to unlock geothermal energy's full potential in Slovakia, Hungary and across the region.

Conclusions and Recommendations for mainstreaming geothermal H & C solutions in Hungary and Slovakia

Hungary and Slovakia stand at a critical juncture in their heating transition. Both countries possess abundant geothermal resources, well-developed DH infrastructure, and rising political and economic incentives to reduce reliance on fossil fuels. However, without clear and coordinated action, the countries risks missing a narrow window of opportunity to modernize their H & C sectors in line with EU decarbonization targets.

Moreover, there is limited national experience with 4th and 5th-generation DH systems which operate at lower temperatures, enabling higher renewable and waste heat integration. They are also optimized for flexible and digitalized management. This report, therefore, highlights the need for capacity-building, data transparency, and integrated spatial planning tools to support a modernized, decarbonized H & C sector.

This report has shown that geothermal energy—particularly when deployed through DH networks—is not only feasible but highly strategic. Hungary's experience, including the large-scale geothermal transition underway in Szeged, demonstrates that deep decarbonization of municipal heating is possible. Slovakia, while still early in its geothermal journey, has promising pilot projects and access to substantial EU modernization funds that could unlock rapid progress. Both countries can learn from successful European models while leveraging their unique geological assets.

To accelerate the mainstreaming of geothermal, targeted policy reforms are needed: streamlined permitting, risk-sharing instruments for exploration, dedicated funding allocations, and stronger integration of heat planning into national energy strategies. Equally, transparency in public subsidies and tariff systems will be essential to ensure that cost advantages of geothermal heating are passed on to consumers. This requires vastly improved knowledge and synergy of information between key stakeholders and decision-makers, including qualified ministry and local authority staff, H & C companies, technicians, Energy Service Companies, and the regulatory body.

By aligning national actions with EU priorities, and by making full use of available financial instruments and best practices, Hungary and Slovakia can transform their geothermal potential into a clean, secure, and affordable heating reality. Doing so will not only reduce emissions and increase energy sovereignty but also future-proof their urban energy systems for generations to come.

The DHC industry needs to be constantly innovating to create a more sustainable and efficient energy system for the future. This means shifting towards the adoption of fourth-generation DH (4GDH) or low-temperature DH to replace third-generation DH (3GDH) networks. This new technology offers numerous benefits, including reduced heat losses and lower thermal stress.

A primary concern in DH implementation is affordability, particularly for vulnerable households. DH pricing structures can have a significant impact on household budgets, especially among low-income groups. This is why the projects should include socioeconomic assessments to better understand the social and economic realities of the communities they serve. This is an essential framework for aligning DH projects with affordability, equity, and broader societal goals. Without such considerations, there is a serious risk of exacerbating energy poverty, a condition in which households cannot afford adequate heating. Even technically optimized systems may become inaccessible if pricing models do not account for the financial capacities of users, making affordability analysis a vital step in the planning process.

Closely related is the issue public acceptance. Socioeconomic analysis provides the data needed to design fair and inclusive tariff structures that reflect the diversity of the population. When groups such as the elderly, renters, or low-income families are disproportionately burdened by DH costs or policies, resistance to project implementation often follows. Assessments that identify these disparities early on can prevent backlash, improve community trust, and promote broader adoption.

Beyond consumer concerns, DH projects also carry the potential to support job creation and local economic development. However, these benefits do not materialize automatically—they must be planned and measured. Socioeconomic assessments can quantify employment impacts, highlight opportunities for local hiring, and contribute to a just transition by ensuring that economic gains from DH systems benefit the communities they serve.

Furthermore, socioeconomic assessments play a key role in aligning DH projects with long-term policy goals. Objectives such as reducing inequality, improving public health, and advancing the Sustainable Development Goals (SDGs) are increasingly embedded in national and EU-level energy and climate strategies. Demonstrating a positive social impact not only enhances the legitimacy of DH projects but also increases their eligibility for public funding and international support. EU funding instruments like Horizon explicitly prioritize projects that integrate social inclusion and impact considerations.

In addition, consumer behavior and demand forecasting are critical elements of effective DH system design. Factors such as household income, housing conditions, and energy use habits all influence heat demand and connection willingness. Failing to incorporate these variables can lead to over-dimensioned systems or underutilization, undermining both financial and environmental objectives. Socioeconomic data enables more accurate modelling and more resilient infrastructure decisions.

Evidence from leading cities supports the integration of these assessments. For instance, Hanover in Germany, has been proactive in expanding and decarbonizing its DH network. Their approach emphasizes not only technical and environmental considerations but also socioeconomic factors to ensure equitable access and community support. Similarly, Vienna has successfully connected its social housing sector to DH networks, using pricing models that protect low-income residents. These cases demonstrate how social impact considerations can be a driving force in successful, inclusive DH expansion. Thus, socioeconomic assessments are not peripheral to DH. They ensure that systems are accessible, supported by the public, economically beneficial, and aligned with the social objectives of sustainable development. As more cities and countries turn to DH as a key solution in the climate transition under the growing pressure of urbanisation, embedding social analysis in every phase of planning will be essential for success.

As district energy solutions are cost-effective in the long run but capital intensive upfront, reliable data and detailed knowledge for long-term planning are critical, considering trends in heat demand, the building stock and availability of heat sources.

Both the EED and the RED should promote and encourage a comprehensive data collection infrastructure and methodology to help Member States and local authorities to plan and carry out the heat transition. A holistic, integrated long-term strategic approach between buildings, heat networks and heat pumps is needed at the national level to enable low temperature systems fit for geothermal.

Further uptake of renewables in DH needs careful design, support and regulatory schemes. DH market and support structures are typically heterogeneous, not only varying amongst Member States but also within a country due to the divergent regional/municipal characteristics of the DH systems. However, CEE DH systems are facing similar challenges that must be urgently addressed: disconnections, dominance of fossil fuel-based heat generation, ageing infrastructure and declining competitiveness.

Alternatively, shallow geothermal systems, such as ground--source heat pumps, provide a fast, decentralized solution to reduce dependence on imported fossil fuels in Slovakia and Hungary. By harnessing stable underground temperatures for H & C, these systems enhance energy security and buffer households and businesses against volatile energy prices. Their relatively quick installation times and suitability for both urban and rural settings make them an effective short-term response to current energy challenges in the region.

In conclusion, both Hungary and Slovakia recognize that geothermal energy must play a strategic role in decarbonizing their H & C sectors. This comparative analysis makes clear that mainstreaming geothermal is not only an environmental imperative but also a practical path to enhance energy security and meet EU climate commitments in both countries. Even in Hungary, geothermal currently accounts for only around 6.5% of gross heat production and Slovakia's vast geothermal potential remains largely untapped—by one estimate, roughly 98% of it is still unused. With heating in both nations still heavily reliant on fossil fuels, expanding geothermal use offers a critical opportunity to reduce carbon emissions and dependence on imported gas. High-level policy momentum is gathering behind this vision: the Hungarian government's new National Geothermal Strategy aims to double geothermal output by 2030, and at the European level there is a push for action, exemplified by the EU Council's recent call for a comprehensive strategy to decarbonize H & C accompanied by a dedicated European Geothermal Action Plan. Geothermal energy, with its ability to provide efficient, renewable heat, is thus increasingly seen as a cornerstone for a sustainable heating future in both Hungary and Slovakia.

Yet, the road to fully mainstreaming geothermal in these countries is impeded by common challenges. Both face complex, fragmented regulatory environments that can stifle investment and slow project development. In the past, geothermal projects had to navigate multiple overlapping laws (from mining to water and environmental regulations), often handled by different authorities—a situation that breeds contradictory requirements, lengthy permitting, and bureaucratic delay. Such regulatory complexity, combined with burdensome administrative procedures, has discouraged investors and developers.

Financing barriers are equally significant: geothermal installations entail high up-front costs, especially for drilling and resource exploration, and these costs are compounded by the risk that a drilled well may not yield a viable resource. Geothermal development is still viewed as high-risk by financiers, given that exploration and drilling can be very costly with no guaranteed success. The lack of readily available insurance or risk mitigation instruments (for example, insurance for drilling failures) further exacerbates investors' hesitancy. Moreover, legacy infrastructure and market conditions in both countries present hurdles. Existing DH systems and buildings are often geared toward high-temperature supply, meaning that without significant network upgrades or building renovations, the lower-temperature heat from geothermal sources cannot be fully utilised.

In Szeged, Hungary, for example, the geothermal DH network has reached the capacity allowed by current building radiator technology—expanding geothermal use would require retrofitting buildings for lower-temperature heating. Likewise, decades of reliance on cheap fossil fuels have left a legacy of pricing and subsidies that can undermine geothermal's competitiveness: in Hungary, centrally regulated heat prices and subsidized natural gas have meant that geothermal's lower operating costs do not translate into savings for consumers, dampening any financial incentive to switch or invest in efficiency.

Both countries also grapple with limited human and institutional capacity in the geothermal sector—there is a shortage of specialized expertise in areas like geothermal drilling, project design, and even within permitting authorities. This skills gap can slow down project execution and reduce confidence in managing geothermal operations. In sum, regulatory complexity, financing hurdles, entrenched fossil-fuel infrastructure, and capacity deficits form a set of intertwined challenges that Hungary and Slovakia must address to unlock the full potential of geothermal energy.

Encouragingly, a number of emerging opportunities and supportive trends can help overcome these barriers. Evolving EU directives and national policies are beginning to create an enabling environment for geothermal expansion. Notably, the integration of H & C planning into policy frameworks stands out as a key lever. Both countries are influenced by European initiatives that mandate or encourage strategic heat planning at the municipal level. Slovakia, for instance, now tasks its cities and municipalities with integrating DH (and by extension renewable thermal sources) into urban planning and zoning, designating areas for heating networks and even enforcing connection of new buildings to efficient systems. This kind of forward-looking planning, driven by EU climate and energy directives, ensures that geothermal options are considered in city development and that infrastructure is gradually steered toward sustainability. A powerful example of what comprehensive heat planning can achieve is seen in Germany's recent policy moves, which Hungary and Slovakia can look to for inspiration. Germany's new Heat Planning Act and revised Building Energy Act together set an ambitious course: all large municipalities (over 100,000 people) are mandated to draft detailed heat transition plans by 2026 (smaller ones by 2028), and existing DH networks must incorporate at least 30% renewable or waste heat by 2030, rising to 100% by 2045. These laws, aimed at achieving a climate-neutral heating sector by 2045, provide clarity and long-term certainty for investors and local authorities alike. In effect, Germany's example shows how high-level commitments can be translated into concrete requirements and timelines for action—a blueprint that could be adapted in the Hungarian and Slovak contexts. There is much that other EU countries can learn from this approach, especially the way it combines regulatory mandates with supportive funding (the German government, for instance, is allocating €500 million to assist municipalities with heat planning.

Additionally, the broader availability of EU funding and international support is an opportunity that both Hungary and Slovakia are beginning to leverage. European climate and recovery funding mechanisms are increasingly aligned with the goal of decarbonizing heating. The EU's Recovery and Resilience Facility, the Cohesion Policy funds, the Modernisation Fund, and the Just Transition Fund all present avenues to co-finance geothermal projects—provided that these projects are prioritised in national and regional plans. Indeed, we see promising signs: the Just Transition Fund in Slovakia, for example, is poised to support the connection of geothermal sources to the DH network of Košice (the country's second-largest city), a flagship project blending EU support with local initiative. Hungary, for its part, has utilised the Environment and Energy Operational Programme to co-fund geothermal installations and is expected to tap further EU funds (including its Recovery Plan and Modernisation Fund allocations) to scale up geothermal heating. International financial institutions are also in play—both the European Investment Bank and the European Bank for Reconstruction and Development have mandates to finance green energy infrastructure, and while neither has yet invested in geothermal in Hungary or Slovakia, both banks have extensive experience funding DH upgrades and geothermal projects in other countries. With the right project pipelines and policy support, there is significant potential to attract such investments into the region. In short, the confluence of stronger EU policy signals, availability of funding, and successful case studies from around Europe (from Germany's heat transition plans to pioneering geothermal DH projects in countries like France and the Netherlands) creates a favourable landscape for Hungary and Slovakia to accelerate their geothermal trajectories. The coming years are a window of opportunity in which proactive engagement with these European directives, funds, and examples can substantially boost geothermal development in both nations.

Realizing this potential will require targeted policy reforms, capacity-building, and coordinated investments—in other words, a concerted effort by policymakers and stakeholders to tackle the known obstacles. Both countries would benefit from streamlining and strengthening their policy frameworks for geothermal energy. This means, foremost, simplifying regulations and permitting procedures so that developers face a clear, predictable process. International best practices suggest moving toward a unified, "one-stop-shop" approach: successful geothermal markets often have a single comprehensive geothermal law and one lead agency handling licensing and oversight. Establishing such a specialized framework—rather than forcing projects to navigate a maze of mining, water, and environmental permits from different authorities—would significantly reduce delays and uncertainty.

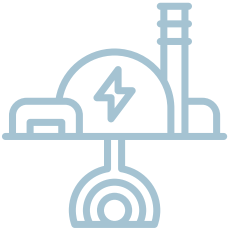
Hungary and Slovakia should consider adopting dedicated geothermal legislation or regulatory provisions that consolidate responsibilities and set clear timelines for permit decisions, while still upholding environmental and safety standards. Alongside regulatory reform, there must be a focus on financial de-risking and support schemes tailored to geothermal's unique profile. Geothermal projects need upfront capital and face resource risk, so public interventions can be decisive in making them bankable. Both governments should look at introducing or expanding risk mitigation facilities (for example, insurance funds or guarantee schemes for drilling) and providing targeted subsidies or low-interest loans for geothermal exploration and well development. Such measures would help crowd-in private investment by sharing the early-stage risks that private developers alone are often unwilling to bear. In fact, countries that have succeeded in scaling geothermal typically offer effective financing and insurance schemes that reflect the special needs of geothermal investments. Hungary's new strategy, which foresees a state-backed geothermal investment fund and loan facility, is a step in this direction, and Slovakia could develop similar instruments, potentially in partnership with EU financial institutions.

To tackle the geothermal project costs, our recommendations include the implementation of a comprehensive cost analysis focused on the financial assessment of geothermal energy in both Hungary and Slovakia. This analysis should evaluate key economic indicators such as capital investment, operational and maintenance costs, lifetime energy output, and return on investment. It should also consider the availability of public subsidies, EU funding instruments, and potential carbon pricing impacts. Essentially, the assessment should compare geothermal systems against other renewable energy sources, such as solar, biomass, and wind, under current and projected market conditions. The outcome will help policymakers and investors understand the relative cost-effectiveness and strategic value of geothermal energy within the broader national and regional energy transition strategies.

Building up human capital is another essential pillar: both nations should invest in training programmes and institutional capacity so that there are enough skilled geoscientists, drilling engineers, project managers, and local officials well-versed in geothermal technology and regulation. This capacity-building extends to raising awareness and technical know-how at the municipal level as well—local authorities will be on the front lines of implementing DH projects and integrating geothermal into urban energy plans, so they must be equipped with expertise and resources. Initiatives like knowledge exchanges, twinning of cities or utilities, and inclusion of geothermal modules in university and vocational curricula can all contribute to a stronger knowledge base. Finally, coordinated investment planning is needed: rather than piecemeal projects, Hungary and Slovakia should develop coherent investment roadmaps for geothermal heat, identifying priority regions (e.g. areas with the best resources or pressing coal-to-heat transition needs), and ensure that upgrades to heating networks go hand-in-hand with geothermal resource development. By aligning national budgets, EU funds, and private sector contributions around these roadmaps, both countries can achieve economies of scale and more impactful deployment. In essence, a combination of clear policy direction, risk-sharing finance, skilled people, and strategic investment coordination will be required to transform geothermal from a niche activity into a mainstream component of the heating sector.

Crucially, Hungary and Slovakia do not have to undertake this journey in isolation—there is much to be gained from regional cooperation and mutual learning. The similarities in their situations invite a collaborative approach. Both countries share not only geographic proximity but also a common interest in reducing fossil fuel dependence and similar challenges in developing geothermal projects; this creates a natural synergy for partnership. Increased cross-border engagement can accelerate progress by pooling expertise, sharing lessons learned, and even jointly advocating for supportive policies or funding at the EU level. Stakeholders in both nations have already recognized this:

recent forums have brought together Hungarian and Slovak officials, industry players, and experts to exchange experiences and identify areas of common interest where cooperation can help "mainstream" geothermal project pipelines. By establishing regular dialogues—for example, joint working groups or bilateral agreements on geothermal energy—the two countries can compare approaches on regulation (learning from each other's regulatory successes or pitfalls), coordinate on research (such as sharing geological data and exploration results, especially in border regions of the Pannonian Basin that span both territories), and even develop cross-border projects if suitable resources are found near their frontier. Collaboration could also mean jointly building the market for geothermal by coordinating demand—for instance, if one country develops a strong service industry in geothermal drilling or pump manufacturing, it can serve projects in the neighboring country as well, reducing costs for all. Furthermore, a unified voice from Central and Eastern Europe on the importance of geothermal can carry more weight in Brussels; Hungary and Slovakia together can advocate for robust EU support, be it in the form of dedicated geothermal funds or inclusion of geothermal in regional energy initiatives. Ultimately, by learning from each other's experiences and aligning their efforts, Hungary and Slovakia can bolster each other's progress. This spirit of partnership will help ensure that geothermal energy moves from the margins to the mainstream of their H & C. Such a development would not only enable both countries to meet their national renewable energy and climate targets but would also contribute to a more resilient and sustainable energy future for the entire region. The overarching message is clear: through strategic vision, policy action, and collaborative effort, geothermal heat can be scaled up to become a cornerstone of clean heating in Hungary and Slovakia, driving both countries toward a decarbonized and secure energy era.



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ANNEX

Google Form:
https://docs.google.com/forms/d/1P8uhvSqrCfO4ND-p_2PEX3O_aMkSfNzPnpAcIDmG9LnU/edit

Hungary and Slovakia Geothermal Roundtable

Experts Questionnaire

We would like to know more about your thoughts on geothermal development in Hungary and Slovakia concerning the geothermal roundtable during the CEEC in Bratislava in November 2024. The answers will be collected and processed anonymously, and a summary will be made available to you. Eight open questions aim to continue the roundtable discussion on district heating, levelling the playing field, and project financing for geothermal development. The last three questions are the respondents' metrics. Answering the questions should take no longer than 5–10 minutes.

Thank you for sharing your thoughts and filling out this questionnaire.

*** Indicates required question**

District Heating in focus

Evaluating the competitiveness of geothermal technology.

1. What does the geothermal sector need in your country in terms of a regulatory framework to improve the investment case?

Your answer

2. What are the technical challenges for introducing the geothermal resource to the DH systems in your country?

Your answer

Leveling the playing field for geothermal investment

Active and planned policy tools to encourage the investment case.

3. How might the cascading use of geothermal resources improve the business case for electricity and DH projects?

Your answer

4. Are the long-term economic, environmental, and security benefits of geothermal taken into consideration by the government?

Your answer

5. How does geothermal compare to natural gas and biomass CHP in the DH sector? Are there assessments of networked geothermal *vs.* individual gas boilers and heat pumps?

Your answer

Project financing

Role of risk-mitigation schemes, public funds, and national and private banks

6. What level of risk mitigation is needed for geothermal development in your country?

Your answer

7. Which EU or national funds are geothermal projects qualified for and encouraged to apply for?

Your answer

8. How is the geological exploration of geothermal financed in your country? What business models do you use?

Your answer

Experts information

*Which country of geothermal development do you represent?

Hungary
Slovakia
Other:

*Which sector of geothermal development do you represent?

Government representative
National agency
Geothermal or mining operator
District heating company
Technical expert
Policy expert
Other:

*Do you have direct working experience with geothermal project development in your country?

Yes
No