EUROPEAN GEOTHERMAL PHD DAYS

EGPD 2025 SZEGED

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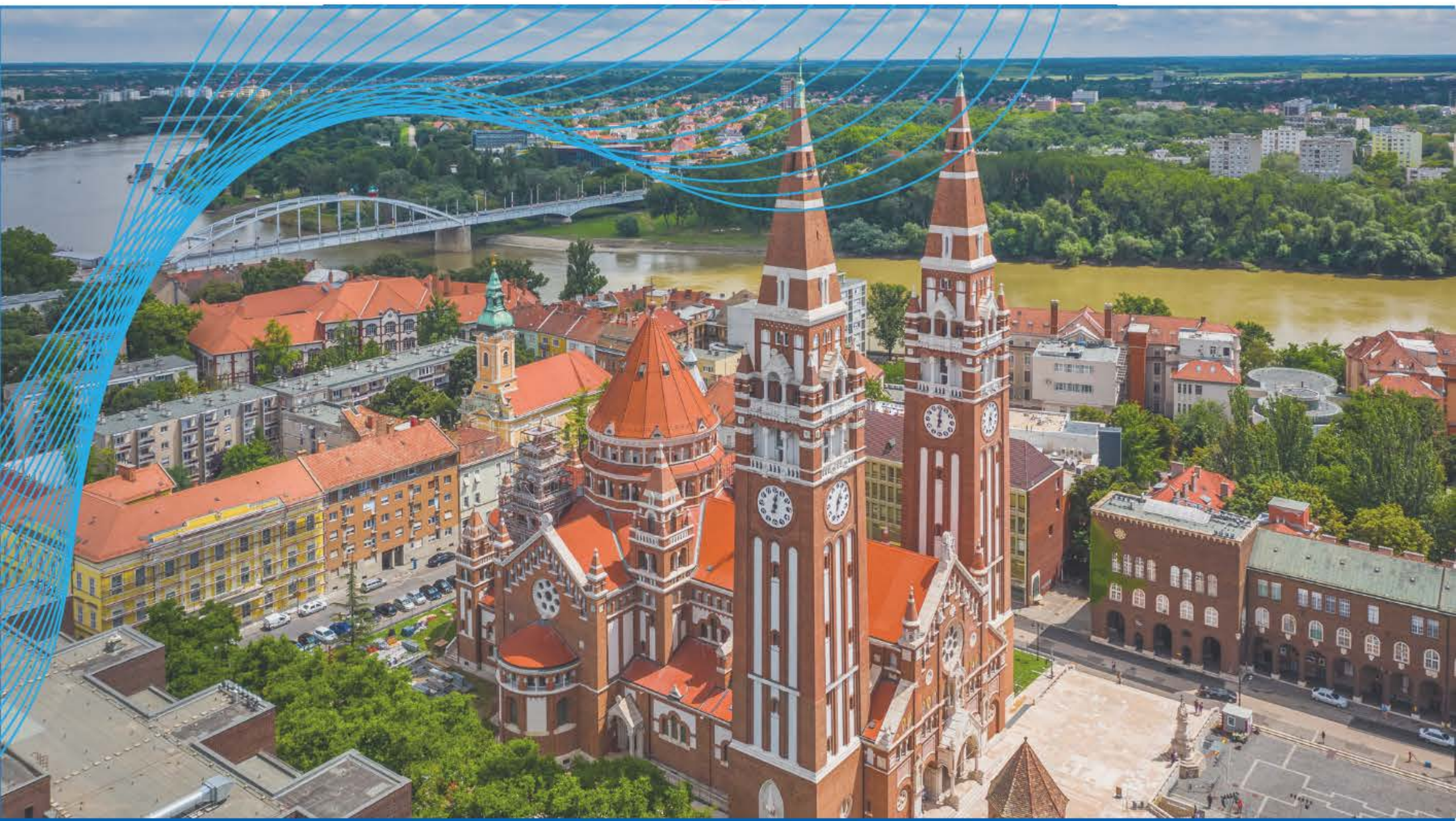

The 16th European Geothermal PhD Days

BOOK OF ABSTRACTS

8-11 April 2025 – Szeged, Hungary

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Foreword

Europe is struggling to cope with the challenges of the 21st century. In the absence of decisive action, Europe risks compromising its prosperity, environment, and freedom. In order to ensure a sustainable and competitive future, it is essential that Europe implements a robust industrial strategy that is firmly grounded in the sustainable and efficient production of energy and raw materials.

Geothermal energy, recognised for its reliable, weather-independent and renewable nature, aligns with this vision. Scientists specialising in geothermal energy, with their unique expertise in understanding underground resources and their interconnection with environmental issues, are fundamental to achieving this goal.

The diverse range of topics covered in this volume provides a comprehensive overview of the numerous opportunities associated with geothermal energy extraction and utilisation in almost all aspects of life. The scope of geothermal energy has expanded beyond mere energy generation to encompass the production of critical raw minerals, underground heat storage, and the utilisation of carbon dioxide as a working fluid, highlighting its vast potential across multiple sectors.

This volume has been co-authored by young researchers, who are following in the footsteps of the previous generation. At the same time, they are also tasked with developing novel solutions that are not yet known to the scientific community whilst meeting current societal, economic and environmental demands. Their fresh perspectives and commitment to innovation are crucial to addressing the evolving challenges of our time.

As geothermal potential varies from country to country, so does the level of knowledge and expertise. Collaboration between research centres can therefore produce significantly better results than isolated research. A similar conclusion can be drawn, regarding the future of the European Union, which, as in the example above, can only emerge from the current crisis with greater unity. This strategy must therefore be organised at the European level, with pioneering research and rapid implementation of innovative solutions.

To achieve this objective, young scientists will need to demonstrate the highest levels of professionalism. Moreover, they must help to promote geothermal energy and take the wind out of the sails of populism. With the hard work of today's PhD students, geothermal energy will become a major contender for energy diversification, and the Earth's heat will be integrated into the energy mix on a large scale. Geothermal energy is a crucial leap towards a sustainable future: let us be part of the change.

I wish you perseverance and good luck!

Dr. János Szanyi

On behalf of the Organising Committee

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Acknowledgements

We, members of the Organising Committee of **EGPD2025** warmly extend our deepest thanks to everyone who helped bring this event to life.

We would like to offer a very special thank you to all the **EGPD participants from last year's event** organised by TUDelft -Netherlands, whose trust in Hungary to organise and host this year's conference has been both an honor and an inspiration. Your confidence in Hungary and in the importance of nurturing collaboration across borders - has been truly meaningful, and we are grateful for the opportunity to continue the EGPD tradition.

We are deeply grateful for the generous contributions of our national and international sponsors. Their support has made it possible to organise the 16th European Geothermal PhD Days, and we are very thankful for their confidence in the geothermal sector.

We would especially like to recognise our sponsors for their vital role in making this conference a success:

- **Diamond Sponsors**: SZETÁV (Szegedi Távfűtő Ltd.), the National Research, Development and Innovation Fund (NKFIH), and Szeged Megyei Jogú Város
- **Gold Sponsors**: Mecsekérc Zrt., Zerlux Hungary Ltd., EGEC Geothermal, European Federation of Geologists, International Association of Hydrogeologists, Rotaqua Ltd., and Geo-Hőterm Kft.
- **Silver Sponsors**: Geomega, Geo-Log, and our other valued partners

We are sincerely grateful to the **members of the Scientific Committee**, who also served as our **keynote speakers**, for sharing their insights, experience, and enthusiasm with the next generation of geothermal scientists.

Special thanks go to the **University of Szeged** and our **local collaborators** for their tireless support in making this event a reality - from planning to hosting the various programs, your contribution has been vital.

To all **PhD students** and **early-career researchers** - your creativity, curiosity, and commitment to advancing geothermal energy are the heartbeat of EGPD. Thank you for your excellent contributions, your engaging presentations, and your willingness to learn and connect.

We also warmly thank the **general audience**, **invited guests**, and **industry professionals** whose presence and participation have enriched the spirit of this event.

As we close EGPD2025, we pass the torch with excitement and confidence to the organisers of **EGPD2026**. We wish you great success and look forward to seeing you carry the tradition forward with your ideas and energy.

Thank you all for being a part of EGPD2025.

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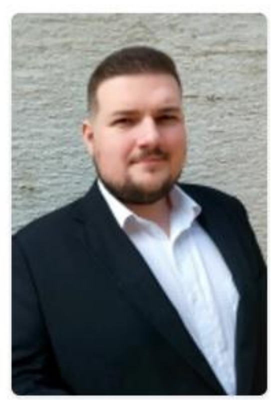

Tamás Zsolt Vári
PhD student
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Scientific committee and Keynote Speakers

A Scientific Committee will evaluate all presentations and select the best ones based on scientific quality, clarity, and presentation skills. The winners will receive the awards, recognizing their outstanding contribution to the conference. The awards will be announced during the closing session.

Co-presidents:

- Prof. Dr. Ladislaus Rybach – emeritus professor ETH Zürich
- Prof. Dr. Inga Moeck – University of Göttingen; Chair of Section Geothermics and Information Systems of LIAG

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- Prof. Dr. Inga Moeck – University of Göttingen
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Abstracts

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Feasibility and Performance Estimation of Innovative Shallow Closed-Loop Heat Exchange Systems in Volcanic Environments

Mohaman Dan Azimi[a], Eloisa Disipio[a], Giorgia Dalla Santa[b], Antonio Galgaro[a], Monia Procesi[c]

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[c] *National Institute of Geophysics and Volcanology (INGV-Roma), Via di Vigna Murata, 605. Topic: Shallow Geothermal*

Harnessing geothermal energy in volcanic environments through innovative closed loop systems offers a sustainable alternative for heat recovery while mitigating environmental and operational risks. This study explores the feasibility and thermal performance of a shallow coaxial borehole heat exchanger (CBHE) on Vulcano Island, Italy, a site characterized by thermal anomalies and volcanic activity. Using numerical modelling techniques, heat transfer dynamics, thermal outputs, and the environmental impact of the BHE system were analysed under operational conditions for 25 years. Results indicate that the system can achieve stable thermal outputs, with performance influenced by well geometry, operational parameters, and subsurface thermal conditions, with output temperatures stabilizing in pseudo-steady states within a short period of operation. The coaxial BHE demonstrates significant potential to sustainably extract geothermal energy while mitigating reservoir degradation and environmental risks. This work underscores the viability of shallow geothermal systems in volcanic settings, contributing to the global transition toward low-carbon energy solutions.

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Predicting Thermal Performance of Aquifer Thermal Energy Storage Systems in Depleted Clastic Hydrocarbon Reservoir via Machine Learning: Case Study from Hungary

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This research introduces an innovative approach to converting depleted clastic sediment hydrocarbon reservoirs in Hungary into High-Temperature Aquifer Thermal Energy Storage (HT-ATES) systems, emphasizing the use of machine learning for optimization. Hungary's numerous depleted hydrocarbon fields, mostly comprising clastic formations, provide excellent potential for geothermal energy storage.

Initially, existing well logs and core data were used to construct detailed reservoir models. Advanced numerical simulations of heat transport and groundwater flow were performed within the Bekesi Formation, focusing on a dual-well system—one well dedicated to hot fluid injection and extraction, and another for managing cold fluids. Simulation tools included SGeMS, RockWorks, Python, MODFLOW, and GMS MT3DMS, targeting optimal brine injection sites by evaluating parameters such as thermal conductivity, porosity, and permeability. Additional core samples were analyzed to fill gaps in thermal conductivity data.

The core innovation of this research lies in applying machine learning, specifically the Random Forest algorithm, to optimize thermal recovery efficiency. Detailed numerical simulations were conducted on several wells, producing data used to train the Random Forest model. This model was then employed to predict and optimize thermal efficiency for all remaining wells within the hydrocarbon field. Expected results include accurately identified optimal injection locations, detailed heat transport analyses, precise estimates of heat storage capacities, and improved predictions of thermal recovery efficiency. This clear, data-driven approach demonstrates a sustainable pathway for repurposing depleted hydrocarbon reservoirs into effective thermal energy storage solutions.

Keywords: Aquifer Thermal Energy Storage (ATES), Machine Learning, Heat transport modeling, Groundwater flow, Geothermal energy, Depleted hydrocarbon reservoirs.

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CRM-geothermal: Raw materials from geothermal fluids

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The energy and digital transitions require a large amount of mineral raw materials, some of which are considered 'critical' by the European Union. These Critical Raw Materials (CRM) are predominantly imported from non-European countries where environmental and ethical standards may be less strict than in the EU. However, the EU has largely untapped resources at its disposal in geothermal fluids, some of which contain significant amounts of CRMs.

The EU-funded CRM-geothermal project therefore proposes to combine the extraction of mineral raw materials and geothermal heat, a renewable energy resource from the ground that is available 24 hours per day. The technology solution developed by CRM-geothermal will thus help Europe fulfil the strategic objectives of the EU Green Deal and the Agenda for Sustainable Development while reducing dependency on imported CRM.

Although Critical Raw Materials are known to occur in geothermal fluids, there are still many uncertainties concerning their occurrence in different geological settings and the sustainability of their extraction. The Horizon Europe-funded CRM-geothermal project therefore aims to :

- establish an overview of the potential for raw materials in geothermal fluids for a large range of elements across the EU and third countries;
- determine the source of selected CRM, their mobility and potential for sustained extraction from geothermal brines;
- develop and optimise innovative extraction technologies for selected CRM;
- assess the environmental-social-economic viability, create transparent and traceable value chains, and foster ethical sourcing of CRM;
- demonstrate for at least one CRM at the scale of a mini-plant and evaluate the system's sustainability.

CRM-geothermal is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Deep roots of a shallow super-hot geothermal system: felsic dyke swarm and tourmaline-quartz veins in a syn-tectonic extensional setting, Elba Island, Italy

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Hot to super-hot geothermal systems are associated with the occurrence of magmatic sources that influence the thermal state of the upper crust, increasing the geothermal gradient up to 100°C per km or more. Apart from the shallower part, new exploitation targets are then focused on the brittle-ductile transition due to the high temperature of the fluids (up to 350°C) and the possibility of finding fluids in supercritical conditions. The understanding of these environments can benefit from the analysis of analogous, fossil and exhumed geothermal systems, where fluid-rock interaction processes and the control of structures on the flow of geothermal fluids can be studied in detail through the analysis of outcrops.

In this presentation we show the results of a study carried out in an exhumed geothermal system that developed during the Late Messinian in a context of rocks belonging to a thermometamorphic aureole formed by a magmatic felsic intrusion (Porto Azzurro monzogranite, c. 6.4 Ma). This pluton caused overheating and the circulation of melts and geothermal fluids during the cooling phases, accompanied by the development of normal faults that led to the thinning of the lithosphere. The study area is the northern Tyrrhenian Sea (Tuscan Archipelago, Elba Island), where Neogene magmatic bodies were exhumed during the extensional tectonics that dismantled the Northern Apennines and allowed the opening of the Tyrrhenian Sea. The methodology for data collection and analysis was based on the integration of structural analysis of faults and veins with mineralogical, geochemical and fluid inclusion studies. The main results allow us to document the syn-tectonic formation of leucogranite dyke swarms and latest tourmaline-bearing quartz veins, which were tightly controlled by low- to middle-angle normal faults. The tourmaline-bearing quartz veins were formed by the circulation of 205 - 340°C geothermal fluids of relatively high salinity and magmatic origin.

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A holistic approach towards the integration of geothermal energy in remote communities

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Geothermal energy is increasingly considered as an energy alternative across off-grid indigenous communities in northern Canada. These communities primarily rely on diesel for electricity and a combination of oil, propane, wood, and diesel for heating. Burwash Landing, the seat of the Kluane First Nation government in Yukon Territory, Canada, is located on the shore of Łù'àn Män (Kluane Lake) at the base of the St. Elias Mountains and near a step-over in the Denali fault. A Play fairway analysis of southwestern Yukon highlights the geothermal favourability around Burwash Landing.

Over the past 15 years, Kluane First Nation has taken significant steps to reduce greenhouse gas emissions and drilled a community-led geothermal exploration borehole in 2012 (KFN-L; 387 m). KFN-L was drilled northeast of the Denali fault in Quaternary sediments. In 2021, the Yukon Geological Survey drilled a second exploration borehole (DRGW; 220 m) in bedrock to the southwest. This provided a unique opportunity to contrast geothermal context on either side of the Denali fault. The temperature gradients in KFN-L and DRGW are 45 and 35^{o}C km-1, respectively. Fibre-optic digital temperature sensing was used to produce high-resolution thermal conductivity profiles for each borehole. These results led to a heat flux estimation of ~ 90 mW m-2 at both sites. The field results were then combined into a coupled groundwater flow and heat transfer model to evaluate temperature at depth.

This poster presents the evaluation of the geothermal potential around Burwash Landing, considering the influence of the Denali fault on local geothermal resources alongside socio-economic factors. Both the local geology and socio-economic factors are combined to offer Kluane First Nation context-informed recommendations for the integration of geothermal energy into their energy budget.

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Evaluation of low-enthalpy geothermal energy potential in shallow alluvial aquifers of the Campania region (southern Italy)

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Low-enthalpy geothermal energy is a renewable and sustainable energy source that extracts heat from groundwater or underground. This energy type offers numerous benefits, including reliability, consistency, and reduced environmental footprint, if compared to traditional energy sources. In fact, low-enthalpy geothermal energy can realize high energy savings in climate control of buildings by means of heat pumps for thermal exchange. This work seeks to open a line of research dedicated to energy savings and contribute to achieve Goals 7 "Affordable and Clean Energy" and 11 "Sustainable Cities and Communities" of 2030 Agenda (UN, 2015), in the Campania region (southern Italy) where the use of this energy source is still underdeveloped.

The study focuses on the pyroclastic-alluvial aquifer across the Phlaegraean Fields and part of the Campania Plain area. This aquifer was chosen because: shallow water table, which is easily tapped through shallow wells; high urbanization, indicating the potential for use of this energy source; groundwater temperature varying in a wide range (16-80°C) across and beyond the caldera structure.

Along with a qualitative assessment of geothermal exchange potential, a preliminary thermogeological and hydrogeological characterization of the pyroclastic-alluvial aquifer of the Phlaegrean Field was carried out. The research process underwent several stages: implementation of a monitoring network through field surveys in the Campanian Plain (data acquisition on piezometric levels, temperature, and electrical conductivity of groundwater and pump testing); hydrostratigraphic framework reconstruction and hydrogeological/thermogeological parameters assigning; thematic map development (gradient maps, thermal conductivity, and groundwater flow velocity); creation of a geothermal exchange potential map based on prior data analysis. This work represents the starting point for promoting the use of low-enthalpy geothermal energy in the Campanian region, contributing to energy diversification, reducing reliance on fossil fuels, and promoting the transition towards a low-carbon economy. It also improves water resource management and tackling hydrogeological and climate.

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Evaluation and modeling of a High-Temperature Borehole Thermal Energy Storage (HT-BTES)

<u>Nicolas Gaston</u>[a, b], Laurent Mora[a], Thomas Recht[a], Hugo Viot[b]

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Thermal energy storage is essential for sustainable energy utilization due to the intermittent nature of renewables. Seasonal thermal storage enables energy collection during summer for winter use. Underground Thermal Energy Storage (UTES), particularly High-Temperature Borehole Thermal Energy Storage (HT-BTES), is a promising solution for increasing heating network flexibility and efficiency. Raising subsurface temperatures above 40°C enhances performance, though few systems operate at these levels. The European HeatStore initiative highlights the need for more demonstration sites to advance fundamental knowledge and integration strategies.

HT-BTES stores heat in the subsurface using borehole heat exchangers, where a fluid circulates through U-tube pipes buried 20–200 m deep. Due to high construction costs, feasibility studies rely on numerical simulations. Analytical models, such as line-source and cylindrical-source solutions, offer simplified predictions, while numerical models provide greater accuracy at a higher computational cost. TRNSYS Type 557 is commonly used for system-level modeling, combining finite difference methods with analytical solutions.

This study focuses on France's first HT-BTES demonstrator, operational since September 2022 near Bordeaux. It supplies heating and hot water to 67 homes using 60 boreholes (30 m deep) and stores solar energy from a 900 m^2 collector field. System performance is assessed using key indicators: solar fraction (~0.9 expected) and BTES efficiency (~0.5 expected), with comparisons to the Drake Landing Solar Community (Canada). A numerical model is developed to simulate the system, and validation is conducted using real operational data. This study uniquely combines experimental performance evaluation with numerical model validation, contributing to the development and optimization of HT-BTES technology.

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Mathematical Models for Simulating Geothermal Lithium Co-Production

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The presence of lithium (Li) in geothermal brines, driven by increasing demand, offers potential for co-producing geothermal energy and Li. However, the long-term viability of this co-production, especially in heterogeneous and fractured reservoirs, is not well understood. We aim to develop simulation tools to study thermal energy and Li concentration in reservoirs and produced brine over the lifespan of an engineered system, using experimental constraints on Li behavior. Focusing on the low-enthalpy system, our model will couple single-phase flow, heat transfer, and reactive transport. It includes partial differential equations (PDEs) for flow, solute transport, and heat transfer; algebraic equations for equilibrium processes; and differential equations for kinetic reactions. Equilibrium constraints and constitutive relationships complement the governing PDEs. Equilibrium reactions are solved via Gibbs minimization, while kinetic reactions are simplified through partial equilibrium assumptions. The model will be implemented in the open-source software framework PorePy developed at UiB. Fractures are modeled as two-dimensional objects in a three-dimensional porous rock matrix, with governing equations formulated in a mixed-dimensional setting. Mass conservation, solute transport, and energy conservation equations are defined across matrix, fracture, and fracture intersection domains, coupled through constitutive laws on the interfaces between these domains.

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A methodology to evaluate the ‘geothermal reinjection potential’, demonstrated in the Pannonian Basin

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The sustainable use of thermal water resources requires the reinjection of heat-depleted water. Since in the case of siliciclastic aquifers this is often associated with operational issues, and geological risk factors, special attention should be paid to overcome the challenges.

The goal of this research was to introduce a methodology applicable to evaluate the risks and the possibilities for reinjection in sedimentary environments. To this end, the parameter of “geothermal reinjection potential” was introduced and defined as the probability that the reinjection will be successful from a geological point of view. Reinjection potential is proposed to be evaluated similarly to the geothermal potential in the exploration phase. For its quantification, a newly developed evaluation scheme was also created. Furthermore, a structured workflow was developed for a multi-scale scientific investigation, with proposed scale-dependent and problem-source-focused approaches and methods. The workflow was demonstrated in sedimentary subbasins of the Pannonian Basin.

Regional hydraulic evaluation in the Zala study area revealed quasi-hydrostatic conditions in the shallow-water Pannonian siliciclastic aquifers. Detailed reservoir analysis using multiple seismic interpretation techniques (RMS amplitude map generation, spectral decomposition) as well as sedimentary facies correlation in well-logs revealed 100 m scale heterogeneities in the deltaic formation. Interaction of clogging processes was revealed in the Mezőberény study site (Béskés Basin), caused predominantly by microbial activity (phenol-degrading aerobic Pseudomonas bacteria) and secondarily by mineral precipitation (calcite and iron(III)hydroxides. Based on the outcomes, reinjection was determined for the investigated elevation interval ([-700 m] – [-1200 m]) in the Barlahida seismic block, also by creating a reinjection potential map.

The demonstrated methodology with the multiscale scientific analysis, risk and probability of success quantification and creation of reinjection potential maps can contribute to decision making, through a better understanding of geological risks related to reinjection, while indirectly increasing the success of reinjection projects.

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Evaluation of a stochastic method to make decision about investing in ATES in complex subsurface settings

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Aquifer thermal energy storage systems are gaining popularity worldwide. While its potential has been extensively proven in traditional homogenous, productive sandy layers, investing in more complex subsurface settings has greater financial risk. This is related to uncertainty about the hydraulic feasibility and thermal efficiency of the system. For instance, preferential flow paths in fractured rocks are challenging to predict but can quickly transport stored thermal energy away. This uncertainty leads to a great untapped potential of thermal energy storage. Decisions about the investment must be made based on sound scientific approaches that have two main characteristics. First, uncertainty about the prediction should not be neglected. Second, we should be able to communicate the risk to the decision maker and propose mitigation measures to reduce risks.

In this light, we evaluate a stochastic method based on global sensitivity analysis and uncertainty quantification through kernel density estimation. It focuses on determining the potential of a low-transmissivity aquifer for ATES on a Ghent University campus. Despite its low productivity and therefore higher investment cost related to many drillings, it was shown financially more interesting than BTES. The main challenge is quantifying hydraulic feasibility. The hydraulic feasibility was first estimated based on the stochastic method, both for a risk-taking and risk-averse decision maker. Second, in the context of a Living lab at Ghent University, an investment could be made to verify the feasibility based on field data. In the future, thermal feasibility should be studied but is not expected to be a limiting factor for low-transmissivity settings. This approach aims to convince policymakers to invest in a more challenging subsurface setting for ATES. To promote the applicability of the results, a decision tree was made. As such, it could be an example study for more informed decisions about ATES investments in the future.

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Geological Characterization of the Reitbrooker Formation in Northern Germany as a Potential Medium-Depth Geothermal Reservoir

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The calcarenites of the Reitbrooker Formation represent a promising yet largely underexplored geothermal reservoir. Numerous hydrocarbon exploration wells have intersected these deposits. In certain locations, they were used for wastewater disposal, demonstrating their considerable porosity and permeability. This study aims to reassess existing well data and seismic surveys to evaluate the geothermal potential and geological characteristics of the Reitbrooker Formation.

Preliminary findings identify a marl zone at the base of the formation, which defines the contact with the underlying strata and the overlying arenites. This marl zone is clearly recognizable in geophysical logs and can be correlated over extensive areas. Higher stratigraphic arenites are expected to exhibit increased porosity. Additionally, a distinct lateral facies transition is observed, with more distal arenites in the north grading into more proximal glauconitic sands towards the south. The thickness of the arenites, preserved beneath the Paleocene transgression, exhibits substantial spatial variability. In certain regions, the Upper Arenite/Sandstone reaches thicknesses of up to 275 meters, whereas in other areas, the arenites are entirely absent. The distribution and preservation of these arenites in the basin were strongly influenced by salt tectonic processes and regional subsidence. Seismic data reveal that salt structures developed independently during deposition, with sediment accumulation occurring in post-kinematic, pre-kinematic, and syn-kinematic settings relative to these structures. Consequently, significant variations in thickness and depth are observed across the basin.

In conclusion, the preservation and current distribution of the arenites result from multiple geological processes acting at different scales. Locally, halokinesis plays a dominant role in shaping the reservoir architecture. To assess the geothermal potential comprehensively, numerical methods will be employed. The findings of this study will contribute to a broader understanding of the geothermal viability of the Reitbrooker Formation and support future exploration efforts.

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Key Factors Influencing Borehole Thermal Energy Storage (BTES) Systems and Their Worldwide Distribution

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Borehole Thermal Energy Storage (BTES) systems have emerged as pivotal low-carbon solutions for seasonal thermal energy storage in the transition to sustainable energy systems. This work presents a comprehensive analysis of 75 documented BTES installations worldwide. Advanced Geographic Information System (GIS) tools have been employed to create the first geodatabase of BTES installation locations and characteristics, a pioneering achievement in the field.

The study elucidates the operational principles of BTES systems, categorizes them by temperature and energy source, and examines key design factors such as array geometry, charging and discharging rates, and thermal conductivity. Several graphs effectively demonstrate the real-world performance of operational BTES plants. Additionally, this research analyses and compares various numerical modelling software used in BTES design, evaluating their performance, accuracy, and utilisation. Incorporating additional data remains essential to expand current knowledge and fully harness the potential of open-access information.

This research delivers novel insights into both the theoretical and practical aspects of BTES technology. It provides valuable contributions with wide-ranging applications and implications for both researchers and companies. By promoting the integration of open-access data and encouraging technological advancements, this work significantly advances our understanding of BTES systems and supports their continued deployment and optimization within sustainable energy solutions.

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Effects of reservoir heterogeneity on the extension of the protection area around geothermal wells

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Sustainable geothermal energy utilization requires the accurate delimitation of protection areas (PA) around geothermal wells. Although the definition of protection area is different in every country, there are similar methodologies using groundwater travel times or studying the extent of the temperature anomaly. The assumption of a homogeneous medium is generally applied in modelling well protection area, although heterogeneity can have a significant effect on size of PA.

In this study, we investigated the effect of permeability heterogeneity on the size of well protection area in synthetic models and in a case study. In the synthetic simulation set, a simplified two- and three-dimensional finite element model of an injection well were compiled in COMSOL Multiphysics software to study the concentration and thermal front at given times (according to Hungarian legislation), where the confined heterogeneous geothermal reservoir is represented by a stochastic permeability distribution. To emphasize the practical relevance of the synthetic results, the effects of reservoir heterogeneity were investigated in a real geothermal setting near Berettyóújfalu as well, where a 3D hydrodynamic model of the heterogeneous hydrogeological environment (Újfalu Formation) is developed in FEFLOW software. To determine the horizontal and vertical heterogeneity scale of Újfalu Formation, sweetness seismic attribute and gamma ray logs were used, respectively. The numerical results indicate that a larger protection area is expected compared to the homogeneous approach, because water travels 25–75% further (depending on the heterogeneity scale and time) in heterogeneous media than in homogeneous media. This impact should be taken into account both in designing new and optimizing existing geothermal systems.

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Towards Sustainable Mineral Extraction: The Role of Geothermal Reservoirs in Critical Material Recovery

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The extraction of critical materials from geothermal reservoirs represents a promising strategy for sustainable resource recovery while harnessing geothermal energy. This study explores the intersection of geothermal technology and geological modeling in optimizing the extraction of valuable elements from geothermal fluids. By focusing on geothermal reservoirs in Italy, we aim to characterize the fluid composition, mineral precipitation processes, and thermodynamic conditions that influence resource viability.

A key challenge in this field is developing efficient and environmentally responsible extraction techniques. Our research addresses these challenges by integrating geochemical analysis, numerical simulations, and field data collection to refine predictive models. Additionally, we investigate how reservoir temperature, pressure, and rock-fluid interactions impact the concentration and mobility of critical materials, such as lithium, rare earth elements, and other strategic metals.

Preliminary results from ongoing data collection in Italian geothermal sites reveal variations in fluid chemistry and mineral deposition patterns, emphasizing the need for site-specific modeling approaches. Furthermore, we assess the feasibility of integrating geothermal energy production with mineral extraction technologies, reducing operational costs and minimizing environmental impact.

This research contributes to advancing knowledge in sustainable resource extraction and geothermal utilization, offering insights into innovative strategies for optimizing critical material recovery. The findings will support policymakers, researchers, and industry stakeholders in developing effective frameworks for sustainable mineral extraction from geothermal reservoirs.

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Revitalization of oil wells using Aquifer Thermal Energy Storage – case study Dugo Selo, Croatia

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The Republic of Croatia has a well-established history of hydrocarbon exploration, with approximately 4,500 wells drilled, and around 3,500 of which are documented in the Croatian Hydrocarbon Agency's database. After nearly seventy years of oil and gas operations, many reservoirs have experienced significant production declines due to resource depletion, increased water content, or pressure drops. These conditions offer an opportunity to repurpose temporarily abandoned wells, particularly for geothermal energy extraction or Aquifer Thermal Energy Storage (ATES) systems.

ATES is an innovative method of storing thermal energy by injecting and extracting groundwater or brine from permeable geological formations, helping to address the seasonal imbalance between heat demand and supply. Despite over 2,800 successful ATES projects worldwide generating more than 2.5 TWh of thermal energy annually, the technology remains underutilized. In Croatia, ATES systems are not yet developed, but one potential approach for their implementation could be through the revitalization of existing deep wells.

This study investigates the feasibility of implementing ATES systems in Croatia by analyzing deep, non-decommissioned wells in the Pannonian basin and Sava sub-depression. A production and reservoir engineering case study was conducted in the Dugo Selo oil field, chosen due to its proximity to an urban heat market, almost depleted oil reserves and available wells. Study identified five water-saturated sand layers in the Abichi formations at depths of 800 to 1,300 meters, which are shallower than the currently exploited oil-saturated sandstones.

ATES systems represent a key opportunity for integrating renewable energy into Croatia's heating and cooling sector, contributing European Union goals for utilization of renewable energy.

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Analyzing The Performance of Geothermal Companies in Meeting Commitments to Reduce GHG Emissions

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Geothermal energy is a key renewable energy source with significant potential to mitigate greenhouse gas (GHG) emissions. Indonesia, with an estimated geothermal potential of 2.356 MW, is the world's second-largest producer after the United States. Despite its renewable status, geothermal energy is not entirely emissions-free due to non-condensable gases (e.g., CO_2 and CH_4) released during steam production, deforestation during land use, and harmful by-products like scaling and hydrogen sulfide gas. This study analyzes the impact of geothermal energy on emission reduction and evaluates the progress of geothermal companies in Indonesia toward sustainability goals. By utilizing Indonesia's geothermal potential of 2.356 MW, this research estimates an annual carbon emission reduction of 16.34 million tons, achieved by replacing coal-based energy (0.9 tons CO_2/MWh) with geothermal energy (0.02 tons CO_2/MWh). This reduction represents a significant contribution to Indonesia's climate targets and global efforts to combat climate change. A qualitative research method was employed, using data from annual reports of geothermal companies and relevant articles. The findings highlight both achievements and challenges in the sector, including the need to mitigate non-condensable gases, reduce deforestation, and manage harmful by-products. Recommendations are provided to address these challenges and enhance the sustainability of geothermal energy production. This study underscores the critical role of geothermal energy in Indonesia's energy transition and its potential to serve as a model for other countries. This analysis can provide strategic advantages for both companies and policymakers, particularly in leveraging vast geothermal resources for sustainable development.

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Innovative earth-to-air heat exchanger solutions for space heating and cooling

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The growing demand for energy and the alarming rise in global CO2 emissions have shifted significant focus toward the advancement and adoption of renewable energy sources and energy-efficient systems. In the building sector, Heating, Ventilation, and Air Conditioning (HVAC) systems account for the largest share of energy demand, constituting approximately 50% of the sector's total energy consumption and contributing to 10–20% of global energy consumption. Geothermal energy can be utilized for HVAC systems through the application of an Earth-to-Air Heat Exchanger (EAHE) system. These systems have gained significant attention in recent years as an energy-efficient solution for space heating and cooling. By utilizing the ground's stable temperature to pre-condition air before it enters a building, these techniques help to reduce the energy demands of conventional HVAC systems. This work is analyzing several applications of this technology to give a short view of one of the shallow geothermal energy uses for sustainable buildings.

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High Enthalpy Geothermal Energy (Thermal & Electric) in Solid Oxide Electrolysis Cells (SOEC) for Green Hydrogen production; A Systematic Review

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The global transition to a carbon-free economy necessitates the development of highly efficient and scalable hydrogen production technologies. Solid Oxide Electrolysis Cells (SOECs) have emerged as a promising high-temperature electrolysis technology due to their superior energy conversion efficiency, high hydrogen production rates, and ability to utilize both thermal and electrical energy. However, the high operating temperature requirements (typically 700 –1000°C) pose challenges related to energy consumption and system durability. High-enthalpy geothermal energy, which provides both stable baseload electricity and high-temperature heat, presents a unique opportunity to enhance SOEC performance and efficiency while reducing operational costs.

This systematic review explores the potential of integrating high-enthalpy geothermal resources with SOEC technology for large-scale green hydrogen production. The study evaluates key thermodynamic and electrochemical parameters, including specific thermal and electrical energy consumption, system efficiency, and degradation mechanisms in SOECs when coupled with geothermal power and heat. A comprehensive analysis of direct heat utilization strategies, hybrid thermal-electric operation, and waste heat recovery from SOEC systems is conducted to determine optimal integration pathways. Further, the review examines materials and design considerations, focusing on high-temperature resilience and long-term stability to enhance SOEC durability in geothermal-assisted operations.

By synthesizing existing research and identifying knowledge gaps, this review provides actionable insights into the feasibility, challenges, and future directions of geothermal-SOEC integration. The findings aim to inform industrial applications, policy frameworks, and future research on renewable hydrogen production, contributing to global net-zero and energy transition goals.

This review serves as a foundation for advancing SOEC-based hydrogen production, promoting the synergistic utilization of geothermal energy for sustainable and cost-effective decarbonization pathways.

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Geothermal Environmental Impacts and Mitigation Optimizing water reinjection in the Szentes Geothermal Field, Hungary

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Effective water reinjection is crucial for maintaining geothermal reservoir performance, particularly in poorly consolidated sandstones, which are common targets for geothermal projects in Hungary. Reinjection challenges often lead to pressure decline and reduce geothermal productivity. This study aims to improve reinjection strategies in the Szentes Geothermal Field by developing a multi-scale petrophysical modeling approach that addresses geological heterogeneity and enhances flow simulations. Geological modeling is often hindered by limited data, making it challenging to accurately characterize subsurface reservoirs. This research utilizes existing well logs and petrophysical parameters to analyze sedimentary facies and their petrophysical properties. Planned micro-CT measurements will help build a framework incorporating variations in grain size, porosity, mineralogy, and diagenetic processes—factors that influence hydraulic conductivity, porosity, and flow. These are critical for identifying suitable formations for water production and reinjection. This approach improves flow simulations in data-limited areas by enhancing facies characterization and identifying flow units that influence reinjection. It also aids in recognizing architectural elements and hydrofacies that govern subsurface heterogeneity, essential for building accurate flow models. As part of the TRANSGEO project, which investigates repurposing abandoned hydrocarbon wells for geothermal production in Central Europe, this study contributes to optimizing the use of existing infrastructure for sustainable geothermal energy at the Szentes Geothermal Field by improving the understanding of its subsurface conditions. The insights gained will help address technical challenges in the repurposing process. Additionally, the methodologies developed will contribute to overcoming limitations in modeling geothermal fields with limited data, supporting sustainable geothermal development in Hungary and globally.

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Geological evolution and geothermal potential of the Mačva region (Serbia, Pannonian Basin System)

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The Mačva region is located in Western Serbia, in the boundary area between the Dinarides and the Pannonian Basin. It can generally be considered as the southern part of the Mačva-Srem subbasin between the Cer and Fruška Gora mountains created at the end of the Lower Miocene by regional tectonic subsidence as a part of the back-arc extension processes pertaining to the formation of the Pannonian Basin System. Mačva is a frontier area for geothermal exploration, with 12 boreholes completed in the 1980s. Borehole data and previously published neotectonic maps have been used to map the central Belotić High bounded by two major faults, and depressions to the north and south.

Mačva has the highest heat flux values in Serbia (~130 W/m2). This probably has two reasons: the lithosphere is fairly thin because of intense Miocene extension; and the presence of a near-surface granitoid intrusion causes additional heating. The Triassic carbonate unit is a karst-type aquifer, and practically a geothermal reservoir. Thick Miocene sedimentary cover serves as the seal. Thermal fluids convect from the Cer Mt. northwards up to the Belotić High, where the cover is drastically thinner and more conductive, and here the geothermal energy can be exploited.

The measured temperatures are about 0 C with a high probability of encountering those up to 100 C which means that the hydrothermal system is suitable for snow melting, central heating, food processing, and chemical industry. After comparison with other systems, and especially the similar Ciglena system in Croatia, the Organic Rankine Cycle is determined to be the recommended method for energy exploitation.

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Scale Formation and Treatment in Indonesian Geothermal Wells: A Multi-Field Comparative Analysis

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This study examines scale formation mechanisms, detection methodologies, and treatment strategies in production wells across Patuha, Salak, and Kamojang geothermal fields in Indonesia. Our comprehensive methodology integrated Hewitt-Robert flow pattern mapping, PTS survey analysis, geochemical sampling, PHREEQC thermodynamic modeling, and XRD mineral characterization to evaluate scaling phenomena. Results revealed that annular flow consistently correlates with scale precipitation at flashing zones, typically occurring at casing diameter transitions. We identified distinct scale compositions: calcite in Patuha (CSI of 2.54), amorphous silica at Salak, and quartz with magnetite at Kamojang. Well integrity testing using Go-Devil operations and sample catchers precisely located scale accumulation at depths of 1458.27 m (Patuha), 4600 ft (Salak), and 900.74 m (Kamojang). Economic evaluation demonstrated the broaching method's superior cost-effectiveness for silica scaling in systems with deviation angles below 50°, requiring only $42,690 compared to conventional methods ($628,147-$1,195,339). This approach restored production from 28.71 to 31.50 tons/hour with a 3.3-month payback period, significantly outperforming alternative treatments requiring 4-10 years for cost recovery. This research challenges assumptions that vapor-dominated systems are less susceptible to scaling and establishes a methodological framework applicable across diverse geothermal fields. Our findings provide evidence-based guidance for treatment selection based on scale characteristics, well geometry, and economic considerations, demonstrating how strategic scale management extends well productivity while reducing operational costs, thus enhancing sustainable geothermal resource development worldwide.

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Thermo-Economic Analysis of BHE working with CO_2 Mixtures

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CO_2 has gained a special attraction as a geothermal working fluid as it has benefits such as a self-sustaining thermosyphon effect, leading to higher efficiency and a reduced component size, along with the additional benefit of long-term geological storage. Many comparative studies of CO_2 over water as a working fluid have been conducted to identify the pros and cons of both fluids. In this work, it was aimed to compare CO_2 mixtures over pure CO_2 in the form of thermo-economic analysis. Selection of additives for a certain system is quite comprehensive, and additives for a certain system depend on the system itself. Apart from that, property software in use, such as CoolProp and Refprop have only a limited number of predefined mixtures that can calculate accurate properties. In the absence of BIP (Binary Interaction Parameter) property software does not guarantee accuracy. In this work the one of predictable activity coefficient models, COSMO-SAC (Conductor like Screening Model-Segment Activity Coefficient) was used to obtain BIP and thermophysical properties for some extent.

Simplified HOCLOOP (Horizontal Closed Loop) model which was modeled in python-based Environment is used to evaluate CO_2 mixtures. Thermophysical properties of CO_2 mixtures were calculated using CoolProp with own BIP calculated with predicted VLE data and also some BIP which were found in literature. A well with Thermo- economic analysis was conducted and LCOE (Levelized Cost of Exergy) for each additive is compared.

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Soil and soil-gas surveys for geothermal exploration at Cumbre Vieja volcano, La Palma, Canary Islands

Alba Martín-Lorenzo[a,c], Nemesio M. Pérez[a,b], Gladys V. Melián [a,b], María Asensio-Ramos[a], Pedro A. Hernández [a,b], Eleazar Padrón [a,b], Paolo Basile[c] and Luca Xodo[c].

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The most common geochemical surveys for geothermal characterization involve water and gas sampling from natural discharges. However, in areas with few surface manifestations or unknown field extents, soil and soil-gas surveys can be valuable. These surveys help identify permeable zones, potential upflow or boiling areas, and system boundaries, often complementing geophysical surveys for a more comprehensive understanding.

A soil and soil-gas survey for geothermal exploration was conducted at Cumbre Vieja volcano, which lacks visible volcanic gas emissions or hydrothermal alteration zones. We categorized such surveys into four types based on sampling density: 1) Regional (1 site/km^2), 2) Regular (≈5 sites/km^2), 3) Detailed I (10–100 sites/km^2), and 4) Detailed II (>500 sites/km^2). Our survey at Cumbre Vieja falls under the regular category, with 1200 sampling points over 220 km^2 (~5.5 sites/km^2). Similar surveys have been conducted in the Canarian archipelago (Rodríguez et al. 2021).

At each site, we measured in-situ soil CO_2 efflux and ^{222}Rn activity in soil gas. Additionally, soil gas samples were collected at 40 cm depth for chemical and isotopic analyses. Simultaneously, soil samples were taken from the base of the B Horizon (30–50 cm), dried, sieved (80 mesh), and leached to analyze key volatiles (Hg^0, As, B, NH_3) fixed in the organic-clay fraction.

This study presents preliminary results from the Cumbre Vieja survey, contributing to the understanding of geothermal potential in areas with no surface manifestations.

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Thermo-Economic Analysis of Water-based and CO_2-based Geothermal-driven District Heating Networks

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The introduction of geothermal-based district heating networks plays a crucial role in pursuing the environmental goals set by policymakers. By harnessing the heat resources available in existing geothermal reservoirs, these systems enable the development of highly efficient and environmentally sustainable heating infrastructures, significantly contributing to the reduction of greenhouse gas emissions. Furthermore, the development of district heating networks could provide a more cost-effective transition to renewable energy sources for end-users than the individual heat pump installation. In this framework, the present work aims to evaluate and compare the performance of two different district heating network layouts: a water-based and a CO_2-based network. While water-based district heating networks are well-established and have been implemented in various locations across Europe, the CO_2-based concept represents an innovative approach that could offer significant advantages when integrated with a geothermal reservoir. This network consists of two pipelines, one containing saturated liquid and the other saturated vapor, operating at relatively low temperatures (0°C to 30°C). Heat is supplied to end users by compressing the saturated vapor to achieve the required outlet temperature through a standard heat pump, enhancing the flexibility of the system and allowing the network to operate with very cold and shallow geothermal reservoirs. With reference to an existing geothermal reservoir in Gavorrano (southern Tuscany, central Italy), a complete thermodynamic and economic analysis has been performed for both the layouts and the resulting Levelized Cost of Heat (LCOH) has been finally compared between the two solutions.

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Thermal Properties and Flow Unit Characterization of Nubia Formation Sandstones: Implications for Shallow Geothermal Applications at Gebel Abu Hasswa, Southwest Sinai, Egypt

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The present work evaluates the thermal and reservoir properties of Nubia Formation sandstones at Gebel Abu Hasswa, southwestern Sinai, Egypt, with specific focus on their potential for shallow geothermal applications. Fifty-one samples were collected from different lithofacies across the Paleozoic section, comprising the Araba, Naqus (Nubia C and D), Abu Durba, Ahemir, Qiseib (Nubia B), and Malha (Nubia A) formations. Petrographical investigation confirmed that the samples are predominantly quartz arenite facies, which typically exhibit favorable thermal conductivity characteristics for ground-source heat exchange. An X-Ray Diffraction (XRD) analysis revealed quartz as the main mineral, with calcite, hematite, and kaolinite as minor constituents. Various diagenetic processes, including compaction, recrystallization, dissolution, and cementation (silica overgrowth, ferruginous, and calcareous), significantly impacted the thermal transmission properties of the formation. Acoustic velocity measurements on both dry and wet samples demonstrated that diagenesis increased compressional and shear wave velocities, which correlate with thermal conductivity behavior in porous media. The hydraulic flow unit (HFU) discrimination identified five distinct flow units, while electrical flow unit (EFU) analysis detected only three units. This discrepancy, attributed to iron oxide cementation, has important implications for the heat transfer efficiency in shallow geothermal applications, as it affects fluid circulation patterns and thermal exchange rates. The study concludes that diagenetic processes primarily control the thermal-hydraulic characteristics of these sandstones, with significant implications for designing ground-source heat pump systems in the region. Empirical equations derived from acoustic measurements provide valuable predictive tools for estimating thermal properties, essential for modeling heat exchange efficiency in shallow geothermal installations. These findings contribute to the understanding of sandstone formations as potential thermal reservoirs for sustainable heating and cooling applications in arid regions like the Sinai Peninsula.

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Characterization of clays distribution linked to reservoir qualities of geothermal plants in the Rhine Graben, northeastern France

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The tectonic and sedimentological history of the Rhine Graben has favored geothermal exploitation, particularly in northeastern France. Since the late 20th century, geothermal exploration has dominantly targeted granitic basement and its non-conformable interface with Lower-Triassic sediment, where the Buntsandstein Group records significant structural and mineralogical heterogeneities.

Hydrothermal clays in the granitic basement, primarily illite and illite-rich illite/smectite mixed-layers (± chlorite), have been well-characterized. In sedimentary deposits, distinguishing diagenetic from hydrothermal clays is pivotal for their use as key markers in hydrothermal fluid circulation pathways. Mineral paragenesis, crystal chemistry, and textural properties will be investigated for this purpose. Given the complexity of fault and fracture networks and sedimentological facies variations, characterization cannot be separated from the sedimentological and structural approach. In addition to determining the origin of clay minerals, clay textural properties will have a direct impact on reservoir quality by controlling porosity and permeability, as well as the evolution of the reservoir properties during exploration as it may affect fluids dynamic.

This study aims to refine techniques for characterizing clay minerals variations using short-wave infrared spectroscopy. By employing a field spectrometer, we seek to establish a calibration method to enhance well monitoring and target permeable zones more effectively.

This project is based on the analysis of over 1250 m of core and cuttings from three geothermal wells (EPS-1, GRT-1, GRT-2) from Soultz-sous-Fôrets and Rittershoffen plants. Semi-quantitative infrared data is collected using TerraSpec 4, a field spectrometer, while mineralogical compositions are determined by X-Ray Diffraction (XRD) and refined by the Rietveld method. Clay mineral qualitative analysis is conducted through XRD, SEM analyses, and other laboratory methods.

These advanced characterization techniques will enhance understanding of permeability controls in the Buntsandstein and contribute to conceptual geothermal modeling, ultimately improving geothermal reservoir assessment and management.

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Coupling Geophysical Data and Numerical Models for Thermohydraulic Characterization in Fault Zones: Benchmarking Analyses

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Intending to achieve the European objectives of the energy transition, Spain has been investigating its renewable energy resources, with particular emphasis on geothermal reservoirs and their potential. This is notably the case in regions such as the Canary Islands and Catalonia, along with the Pyrenees near the French border. Focusing on the Vallès Basin (close to Barcelona, NE of Catalonia region), an extensive campaign of geological and geophysical data acquisition, previously carried out by the UB team, has enabled the construction of a conceptual model based mainly on the interpretation of Seismic, Gravimetric, and Electromagnetic data. As a result, the Vallès Reservoir has been characterized as a fault-controlled system. Nevertheless, critical aspects like temperature gradient and mechanisms governing fluid flow through fractured media remain unresolved.

My PhD project focuses on the investigation of geothermal reservoirs through the integration of geophysical data with Thermohydraulic (TH) simulations, employing a Finite Element approach to solve the coupled equations of Darcy's law, energy conservation, and mass balance. This methodology facilitates the numerical analysis of various hydrothermal systems, particularly those controlled by faults. The application of precise boundary and initial conditions, combined with accurately defined petrophysical properties, is essential for the development of robust numerical models. The conceptual model plays a pivotal role, with permeability emerging as the most critical parameter. Recent studies suggest that permeability treated as time-dependent could be higher than previously estimated, potentially enhancing fluid circulation within the crust and triggering thermal convection.

In this study, we present preliminary results that include benchmark analyses from prior investigations, aimed at calibrating our methodological framework. Additionally, we discuss simulations that account for different degrees of structural complexity within the fracture zone. Finally, the numerical results are compared with magnetotelluric electrical resistivity models to assess their consistency and enhance our understanding of subsurface dynamics.

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Hungary
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Hydrogen Sulfide Exposure: Health Impact from Geothermal Power Plants – A Scoping Review

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Geothermal power plants extract fluids from deep underground, releasing gases and pollutants into the atmosphere. Hydrogen sulfide (H_2S) is often linked to geothermal power plants. Research has focused on its potential health effects, especially concerning respiratory diseases. This scoping review aims to investigate the health effects associated with exposure to hydrogen sulfide (H_2S) from geothermal power plants. PubMed, Scopus, and Web of Science databases were searched for published articles. Included in the review were studies that assessed the health impact of H_2S exposure. Review articles and articles that lacked outcome data were excluded. The review was limited to English-language articles published between 2014 and 2025. A search was conducted, yielding 47 articles, which were then filtered according to inclusion and exclusion criteria down to 3 articles. The findings indicate a weak association between short-term exposure to H_2S and certain mortality and morbidity outcomes, with notable differences between genders. The most consistent health impacts were observed for respiratory diseases, with evidence of exposure-related trends. However, no positive associations were found for cancer or cardiovascular diseases, highlighting the need for further research to clarify the etiology of health effects related to geothermal emissions. To mitigate these potential impacts, practices such as the reinjection of used geothermal fluids and improved emission control technologies should be encouraged as part of a sustainable geothermal development strategy.

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Innovative Method Integrates Play Fairway Analysis supported with GIS and Seismic modeling for Geothermal Potential evaluation in a Basement Reservoir

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The growing demand for clean and sustainable energy sources has prompted the investigation of numerous renewable and ecologically friendly options. Among these, geothermal energy is particularly noteworthy because of its widespread availability, compact size, and consistent, weather-independent power production. A geothermal play fairway analysis (GPFA) model was created for the study area, which is located in Békés county, southeastern Hungary. The GPFA model approach in the current study is the first model developed in Hungary to achieve three main goals. Firstly, to quantitatively assess the geothermal potential, secondly, to identify the most favorable areas for geothermal exploration and development, and thirdly, to evaluate the corresponding risk levels in the study area. The study focuses on identifying and assessing three main risk components associated with exploitable geothermal systems in the study area. The risk parameters consist of the heat source, reservoir fracture permeability, and seal. Advanced 3D seismic interpretation, geographic information system (GIS), and 3DHIP (heat in place) calculator techniques are used to evaluate subsurface structural and thermal models. Two phases of seismic interpretation are used; conventional interpretation phase focused on conventional seismic data interpretation and advanced attribute generation phase where various seismic attribute cube volumes are generated. Common Risk Segment Maps (CRS) for each risk parameter are created by combining data from all the elements contributing to that risk using GIS toolbox. The resulted CRS maps of the study area three risk parameters are summed to produce a Composite Common Risk Segment Map (CCRS) map. Based on the constructed CCRS map and the developed GPFA model, the study area holds valuable untapped geothermal potential, poses varying risk levels associated with geothermal exploration and development. The amount of risk resulting from the three risk components is not equal, and the reservoir fracture permeability is the main risk factor. The GPFA model is successfully narrowed down an expansive exploration area of around 350 km2 to just 4 highly promising targets with high geothermal favorability and low risk as future drilling targets. The constructed 3D thermal capacity model indicates that the average heat content in the study area is estimated to be 65450 Petajoules per square kilometer (PJ/km2), with a recoverable heat energy of 6090 megawatt thermal per square kilometer (MWth/km2). The recoverable heat for the four selected targets is estimated under different production scenarios: a 30-year plan, a 20-year plan, and a 10-year plan and it ranges from 7.5 to 32 MWth/km2, 11 to 48 MWth/km2, 22.2 to 96.8 MWth/km2 respectively. The findings of this study have made important contributions to the field of geothermal exploration approaches and offer valuable insights for making well informed decisions about sustainable energy development in the study area.

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The influence of geological conditions on the performance of working fluids in Enhanced Geothermal Systems – case study of Gorzów Block in Poland

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The Enhanced Geothermal Systems technology development is one of the fastest growing field of geothermal research in the world, as well as in Poland. The geothermal potential in Poland is well recognized, but no EGS installation yet exists. For this reason, some geological criteria for EGS reservoir were chosen as a basis: the minimum depth of at least 4 km, the temperature above 150°C, the minimum specific rock thickness of 300 m and low permeability and porosity. The researchers (Wójcicki et al., 2013; Bujakowski et al., 2015; Sowiżdżał et al., 2013, 2021, 2022a, 2022b; Sowiżdżał & Semyrka, 2016; Gładysz et al., 2024) selected a few potential locations with the best conditions: the Gorzów Block (volcanic rocks), the Sudetes (crystalline rocks), the Szczecin Trough, Mogilno-Łódź Trough and Upper Silesian region (sedimentary rocks). Also, the mentioned areas correspond to the highest terrestrial heat flow density and highest temperatures measured at the depth of 2000 m in Poland (Szewczyk & Gientka, 2009; Szewczyk, 2010). In this research, the Gorzów Block was selected to focus on. The area is well recognized by seismic research and drilling works connected to the crude oil. The thickness of the volcanic rocks in Gorzów Block can reach even 1800 m or more – at the depth of 4950 m of Ośno-IG 2 well the Permian rocks were not drilled through. Also, at the depth of 4300 m the approximate temperature can reach 160°C. The type of rocks that build the reservoir, its temperature and pressure as well as overburden rocks and the well construction affect the performance of the working mediums, which are water and supercritical carbon dioxide.

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A Micro- to Laboratory-Scale Investigation of Physical Clogging Processes During Geothermal Tail Water Reinjection in the Pannonian Basin

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Reinjection of geothermal tail water is essential for the long-term sustainability of geothermal energy systems, yet in porous reservoirs such as those in Hungary's Pannonian Basin, it is severely constrained by physical clogging. This research investigates the mechanisms and controlling factors of physical clogging during reinjection, through an integrated workflow that spans micro- to laboratory-scale experiments and digital simulations.

We optimized micro-CT (μ-CT) imaging resolutions (1–5 μm) to characterize pore-scale structures in sandstone samples from the Dunántúli Group. Resolution thresholds were established, with 2 μm identified as the minimum for accurately capturing pore connectivity in most samples. Core flooding experiments were conducted on both natural and cost-effective artificial sandstone cores to simulate geothermal injection conditions. To extend these findings, Digital Rock Physics (DRP) simulations were applied to model fluid flow, particle transport, and clogging development.

The results reveal that even porous and permeable rocks may experience severe clogging due to grain-scale heterogeneity and fines migration. DRP simulations demonstrated that clogging predominantly occurs within the first 1–1.5 mm of flow paths, with post-clogging flow velocities decreasing by up to a factor of seven. Artificial cores successfully replicated natural clogging behavior, confirming their suitability for controlled reinjection studies.

This study is the first to combine μ-CT imaging, DRP, and core flooding for investigating geothermal reinjection in the Pannonian Basin. It provides critical insight into subsurface clogging zones and delivers a reproducible, scalable framework for optimizing reinjection strategies in porous geothermal reservoirs.

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Buntsandstein as a target horizon for medium deep geothermal systems – Feasibility study for Göttingen, Germany

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Due to the high initial cost of deep geothermal systems, municipal energy providers are focusing on shallower alternatives with lower investment costs and lower exploration risk. In Germany, multiple medium deep hydrothermal systems were implemented within the last decades, providing a reliable and sustainable heat source even in non-favourable geothermal regions. As these are typically underexplored regions, medium deep projects often suffer from a lack of data and thus a high geological uncertainty in the pre-exploration phase. The added challenge of these systems often operating on the cusp of economic viability has led to a reluctant rollout of the technology.

Based on a 2D seismic survey in the city of Göttingen from 2015, conducted by the University of Göttingen, a feasibility study was conducted by the Stadtwerke Göttingen AG to investigate the sandstones of the Middle Buntsandstein as a target horizon for a hydrothermal doublet. While the initial prognosis was promising, such a system in combination with a high-performance heat pump to serve the existing high-temperature district heating network, is currently not financially viable.

This study explores future changes of the technical and financial boundary conditions which could lead to an economic feasibility. We consider the geologic uncertainty, including data from an analogue study of the Buntsandstein, technical modifications of the district heating network, such as shifts in grid temperature and new concepts, like the integration in a so called EnergyHub.

Influence of the Peclet Number on Heat Transfer in Geothermal Boreholes: Experimental Analysis

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In closed-loop geothermal systems, the presence of underground water flow can significantly impact system performance. Specifically, groundwater movement can replenish heat in the surrounding rock, counteracting depletion caused by heat exchange with the borehole. As part of the European Horizontal Closed LOOP (HOCLOOP) project, a finite element method (FEM) analysis was conducted to study the long-term heat transfer dynamics in a rock formation subjected to an underground flow. To validate the numerical model, an experimental campaign was designed to assess the thermal response of the rock formation to heat exchange with the geothermal well, taking into account convective heat transfer effects, quantified by the Peclet Number. A dedicated test section was developed to allow detailed investigations of heat transfer mechanisms between the rock and the well, enabling variations in both the well's heat injection rate and the groundwater flow rate in its vicinity. This work presents the design and installation of the laboratory test bench at the Department of Industrial Engineering, University of Florence. Additionally, it discusses the FEM analysis, the experimental methodology, and the results obtained, providing insights into the thermal behavior of geothermal boreholes in the presence of underground flow.

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Enhancing Geothermal Assessments with Distributed Thermal Response Testing (DTRT)

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Conventional thermal response tests (TRT) assume homogeneous ground conditions, measuring only the inlet and outlet fluid temperatures of a borehole heat exchanger (BHE) during heating. This method neglects vertical variations in thermal properties and groundwater flow effects if numerical models are not applied, resulting in imprecise or unreliable geothermal parameter estimates for long-term performance. TRT measurements are also time-consuming and require significant energy consumption due to continuous fluid circulation.

Distributed Thermal Response Tests (DTRT) overcome these limitations by using optical fiber technology to measure temperature variations along the entire borehole depth. Distributed Temperature Sensing (DTS) enables detailed thermal characterization, capturing geological heterogeneity and groundwater movement effects on heat transfer. Advanced DTRT methods use actively heated fiber optic cables with integrated heating wires instead of circulating fluid, reducing both energy consumption and test duration. Enhanced Thermal Response Tests (ETRT) with hybrid optical cables provide reliable thermal conductivity values with minimal energy use.

We performed DTRT using the Distributed Temperature Sensor Silixa XT-DTS, available at the Faculty of Civil Engineering and Geodesy in Ljubljana, on a 100 m deep borehole (GCF-1). The subsurface consists predominantly of marly silt with partial sand content. A fiber optic cable embedded between U-tube pipes and cement grout enables direct contact with the grout for a representative temperature profile. After thermal equilibrium is achieved, heat injection is applied through fluid circulation with constant flow and power. The data collected is used to estimate ground thermal conductivity, borehole thermal resistance, and specific heat capacity.

Future work includes establishing a natural laboratory in a new geoprobe in SE Slovenia to monitor temperature distribution with depth under climate variability. We will also quantify the in situ thermal diffusivity of Miocene clastic rocks influenced by a nearby geothermal heat pump system.

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Between Potential and Legal Burden : Analyzing the Policy Challenges of Geothermal Exploration in Indonesia

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Indonesia, holding 40% of the world's geothermal reserves (23.9 GW), has substantial potential to lead in renewable energy. However, legal and operational challenges hinder its geothermal exploration. The Sarulla Geothermal Case (2016) exemplifies delays due to regulatory ambiguities, causing a 12-year postponement. Similarly, the Dieng Plateau Geothermal Case (2016) showcases how environmental concerns led to project halts, despite its energy potential. Additionally, indigenous land rights are a persistent issue, as seen in the Mount Talang Geothermal Case (2018), where local communities opposed exploration on customary lands. The Gunung Slamet Geothermal Case (2020) highlights similar conflicts. Fiscal challenges, like those in the Patuha Geothermal Case (2014), demonstrate how inconsistent regional tax policies create financial risks that deter investors. These cases reflect the gap between Indonesia's geothermal potential and the inability to harness it due to socio-political and legal challenges.

This study employs a doctrinal and literature-based legal analysis method, analyzing relevant legal provisions, judicial decisions, and scholarly articles to identify the barriers to geothermal development in Indonesia. A comparison with New Zealand's legal framework, which offers a more streamlined and efficient approach, helps to uncover potential solutions.

The analysis reveals that Indonesia's geothermal sector is hindered by fragmented regulations, unclear land rights, and fiscal uncertainty. Customary land rights, as outlined in Article 18B(2) of the 1945 Constitution and Law No. 5/1960 (Article 16), complicate projects, as demonstrated by the Mount Talang Geothermal (2018) case. The multi-stage licensing process in Law No. 21/2014 (Articles 17-23) and Government Regulation No. 7/2017 contributes to delays. Inconsistent taxation under Law No. 28/2009 (Articles 91-94) increases financial risk, as seen in the Patuha Geothermal Case (2014). In contrast, New Zealand's Resource Management Act (1991) offers a more efficient system for geothermal exploration. This study recommends integrating licensing processes and clarifying customary land governance to promote geothermal development in Indonesia.

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Estimation of the Power Output of Geothermal Power Plants: A Review of the Geothermal Energy Potential in Nigeria

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Surface phenomena that hint at the presence of viable geothermal energy can be found in various locations in Nigeria. None of these locations have been explored extensively to determine the feasibility of sustainable geothermal energy development for electricity generation or direct heating. In this context, the present study aims to provide insight into the potential of such development based on the enthalpy estimation of geothermal reservoirs. This particular study was conducted to determine the power output from a geothermal resource given an estimated enthalpy of the geothermal fluid, and flow rate. The process route chosen for this study is the single-flash geothermal power plant because of the temperature and unique properties of the geothermal fluid (a mixture of hot water and steam as a liquid under high pressure). To support food security efforts in Africa, this study proposes the cascading of a hot water stream from the flash tank to serve direct heat purposes in agriculture for food preservation, before re-injection to the reservoir. The flowrate of the geothermal fluid to the flash separator was chosen as 3125 tonnes/hr. The power output from a single well using a single flash geothermal plant was evaluated to be 11 MW. This result was obtained by applying thermodynamic evaluations, including material balance, energy balance, and enthalpy calculations. This particular study is a prelude to a robust model that will predict the power output of geothermal power plants based on the enthalpy of geothermal fluid, size of the geothermal resource, and different plant designs with high accuracy using data from primary sources. The knowledge gained from the study will promote best practices in geothermal engineering and emphasize appropriate planning for, and implementation of, geothermal plants in Nigeria and across the world.

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Deep geothermal exploration in Hungary and its associated problems in siliciclastic reservoirs

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In the Pannonian Basin, both the high heat flux (110 mW/m2) and the geothermal gradient (45 °C/km) exceed the continental average (e.g. Lenkey et al. 2021). Although these favourable conditions have not been exploited for a long time, in recent years, several concessions on geothermal exploration have been opened and Goldminco Ltd has successfully applied for three blocks. The block near Nagykanizsa, in SW Hungary is particularly promising as it offers two possible geothermal reservoirs: Upper Miocene (Pannonian) sandstones and Triassic platform carbonates.

These reservoirs present unique challenges: (1) the Upper Miocene siliciclastic reservoir is known to cause surface movement (Békési et al. 2022) and present permeability problems (Markó at al. 2021), while (2) the Triassic platform carbonates are relatively unexplored and located at 2-3000 meters depth. However, due to its depth and as a result temperature, it could make an ideal prospect for an ORC power plant if a suitable water yield can be found. Exploration for carbonates is ongoing, and a geological model is being built to pinpoint the best location for a first exploration well.

North of Nagykanizsa, due to the depth of the basement rocks, the Upper Miocene (Pannonian) sandstones present an alternative reservoir for city heating purposes. Due to poroelastic effects, siliciclastic reservoirs are prone to compaction over time when water is being produced from the reservoir. We are making simple finite element models in COMSOL Multiphysics to understand these processes. Firstly, a three-layered confined aquifer model is simulated to sink to 3000 m depth in 20 million years to study structural mechanical effects on the rocks. Secondly, Darcy's law is applied to the model with a well in the middle to simulate water withdrawal effects in the pressure field. Thirdly, these two models are combined to simulate poroelastic effects and observe compaction around and above the production well.

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Sponsors and Partners

The District Heating Company of Szeged (SZETÁV) is a municipally owned SME that operates the district heating and cooling system in Szeged, Hungary. It supplies heat and domestic hot water to 27,256 households and 433 public buildings in the city. The district heating system consists of 23 heating circuits with a total installed capacity of 204 MW, providing a total energy output of 843,700 GJ per year. Since 2018, SZETÁV and its partners have been undertaking a large-scale project to integrate geothermal energy into the system. This €63-70 million development, co-financed by the EU and private investment, involves drilling 27 wells (9 extraction and 18 injection) to depths of 1,700-2,000 meters. The extracted 90°C thermal water is transported through 30 km of new pipelines to heating plants where heat exchangers transfer the energy to the district heating network. Upon completion, the project is expected to replace nearly 20 million cubic meters of natural gas annually with approximately 600,000 GJ of geothermal energy. This will reduce the city's greenhouse gas emissions by an estimated 35,000-39,000 tons per year, improving air quality and energy security. The goal is to make the district heating system 60% less polluting and more economical to operate.

The University of Szeged and the City Council jointly decided to utilise geothermal heat for their district heating systems. This collaboration is seen as a positive example of synergy between the academic institution and the municipality. The geothermal system in Szeged also serves as a demonstration site for higher education, offering opportunities for professional internships, theses, and PhD work. Furthermore, the Danube GeoHeCo project, which is testing geothermal-based district cooling at SZETÁV's headquarters, will also function as a research facility for students, graduates, and young researchers from the University of Szeged. This initiative aims to optimise the use of geothermal energy and promote education on renewable energy technologies. The District Heating Company of Szeged's large-scale transition to geothermal energy offers several key lessons and serves as a strong example for other cities in Hungary looking to adopt this sustainable heating solution.

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The National Research, Development and Innovation Office (NKFI Office) has been a defining governmental institution in Hungary's innovation ecosystem since 2015. As a central office operating under the direction of the minister responsible for science policy, it is the most significant state public funding organisation in the field of R&D&I, bringing together the expertise of more than 200 employees to strengthen Hungary's competitiveness by promoting research and innovation.

The primary way the NKFI Office supports innovative businesses in creating higher added value, universities and other research institutions in expanding their R&D&I capacities, and in achieving research results that can benefit society and the economy, as well as – on the basis of excellence – researchers and research communities in their internationally recognized research important for the country, is through a system of research, development, and innovation competitive tenders financed from the National Research, Development and Innovation Fund.

The priority target areas of the NKFI Office's funding activities are: supporting the innovation activities of market players and the market utilisation of results; connecting the actors of the R&D&I ecosystem through the promotion of professional collaborations; ensuring the long-term supply of researchers; and facilitating the integration of Hungarian researchers into the international scientific community. To ensure the efficient, transparent, and effective use of the NKFI Fund's resources, the NKFI Office operates a multi-level tender evaluation system with the participation of experts and professional bodies from the academic and business sectors. It monitors and tracks the appropriate and compliant use of grants, evaluates the professional results of projects, and measures their social, economic, and intellectual impacts.

In addition to its tasks related to the tender system, the NKFI Office supports the achievement of the Government's R&D&I policy objectives through various means. It participates in the development and implementation of R&D&I strategies, the development of the innovation ecosystem, the dissemination of an innovation-friendly mindset, and is involved in the professional tasks of international and European integration collaborations with an R&D&I focus.

Szeged Megyei Jogú Város

Szeged has firmly established itself as a leading city in geothermal energy utilisation within Europe, proudly hosting the European Union's largest municipal geothermal heating system. The city's unwavering commitment to harnessing its underground thermal resources has resulted in significant reductions in natural gas consumption and greenhouse gas emissions, contributing substantially to environmental sustainability. Moreover, the residents of Szeged are already experiencing the tangible benefits of this transition through reduced heating costs and enhanced energy security. Szeged's comprehensive and successful implementation of geothermal technology serves as a valuable model and a practical blueprint for other cities across Europe and beyond that are striving to transition to sustainable heating solutions and diminish their reliance on fossil fuels. Experts in the field recognize the "Szeged model" as highly replicable, given that approximately 25% of the EU population resides in areas with sufficient geothermal resources to support similar initiatives. Szeged's dedication to geothermal energy offers long-term advantages, providing a sustainable, environmentally responsible, and economically sound heating solution for the city. This commitment not only enhances energy independence and security, making Szeged more resilient to the volatilities of global energy markets, but also contributes to a greener future for the city and sets a commendable example for other urban areas navigating the transition towards a low-carbon economy. The continuous development, expansion, and optimisation of Szeged's geothermal infrastructure will undoubtedly ensure its long-term viability and enduring benefits for the city and its residents.

The City Council of Szeged has been a key supporter of the city's transition to geothermal energy. In 2015, it appointed a new expert team to manage SZETÁV, the District Heating Company of Szeged, with the specific goal of integrating renewable energy sources, including geothermal, into the city's district heating system. The Mayor of Szeged has also publicly stated that the investment in geothermal energy allows the city to provide sustainable and environmentally friendly heating for thousands of families, reducing the amount of gas used for district heating by half and significantly decreasing pollutant emissions. The municipal government has actively made efforts to utilise geothermal energy for its district heating system, recognizing that it was the largest CO_2 emitter in the city relying on natural gas. The fact that Szeged is considered an excellent site for geothermal utilisation is also attributed to having a supporting municipality.

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The University of Szeged is a prestigious higher education institution in Hungary with rich tradition, committed to quality education on all levels including Bachelor's, Master's, Doctoral programmes, higher-level vocational and postgraduate specialist trainings, to basic and applied research and development, the fine and performing arts, as well as to quality health care, social responsibility, and the development of entrepreneurship.

In line with its tradition, education at the University of Szeged ensures the unity of high-level theoretical foundation and practice, the latter based also on external partnerships. The University is committed to the continuous improvement of the content of education, both in multilevel and multilingual education, in line with scientific progress, the development of information technologies and the needs of society.

The purpose of the University of Szeged is to issue quality degrees meeting labour market demands and to make sure that its graduate students would be sought-after by both national and international employers. The University provides educational conditions leading to highly prestigious degrees, which at the same time promote the academic development of its students. The Institution plays an important role in the organisation of students' lives by providing opportunities that promote their intellectual development and the maintenance of equal opportunities among them.

The University of Szeged's mission and goal is to cultivate science, to conduct internationally competitive research, and to ensure its position as a research university. Its research and creative activities, as part of international and domestic programmes, include basic and applied research, artistic creation, as well as product and service development. The social and economic exploitation of the University's research results, supported by innovative solutions, contributes to the Institution's role as a knowledge-intensive engine in the innovation ecosystem and in regional economic development.

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The Árpád Group's horticulture is one of Hungary's largest vegetable farming enterprises. Initially, open-field and hotbed cultivation took place, followed by the construction of greenhouses starting in the late 1960s, which was truly boosted by the thermal water found during test drillings for the oil industry. Currently, in addition to Árpád-Agrár Zrt., the horticultural sector includes the companies Árpád Masterplant Kft. and Szentesi Paradicsom Kft. The new developments rightly reflect that the leaders of the Árpád Group follow the example of their predecessors, encouraging their gardeners and specialists to cooperate, the results of which are constantly tangible. The total area of cultivated land of the group is 4751 hectares, on which wheat, corn, barley, sunflower, soybean, alfalfa, sorghum, and clover grow.

One of the most important mottos of the group is: "good quality goods start with good raw material management," because clean, fresh, healthy food and drinking water represent the basic elements and survival of humanity, and Árpád Agrár Zrt. undertakes a role and responsibility in their production in the long term, with the dedication and intention to continuously increase the number of employees and contribute to the social and economic development of society, in addition to producing excellent goods.

Mecsekérc Zrt.'s activities are diverse and complex, ranging from environmental protection and geological research to general contracting and laboratory testing services. The company participates in key projects, such as nuclear power plant capacity maintenance programs, radioactive waste storage construction works, the remediation of environmental damage caused by uranium mining in the Mecsek region.

Mecsekérc Zrt. provides a wide range of services, including specialised civil engineering, landscaping and reclamation, monitoring and laboratory testing, and hydrogeological modelling. The company has significant experience in environmental protection and reclamation, particularly in managing the long-term effects of mining activities.

The company's name is recognized both in Hungary and internationally, and it employs state-of-the-art technologies in environmental protection and reclamation processes. Mecsekérc Zrt. also operates an Accredited Testing Laboratory, which functions in the fields of sampling, radiometry, chemistry, environmental geology, and soil mechanics.

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Zerlux Hungary Kft. is a company with diverse activities, with a strong emphasis on technological solutions for the oil and gas industry, as well as manufacturing in the mining and construction sectors. The company is involved in research, development, design, and manufacturing, particularly in the field of downhole video camera and laser technology. They offer specialised solutions for downhole technologies, including high-temperature fiber optics, hybrid downhole camera families, coiled tubing lens cleaning, high-temperature memory, and side and downward-looking cameras.

Subsurface AS and Zerlux Hungary Kft. established the joint company Zerlux AS with the aim of research and development specifically in designing, manufacturing, and commercializing advanced laser-optic down-hole laser tools and smart down-hole mechanical tools for offshore and onshore applications in the oil and gas industry.

The European Geothermal Energy Council (EGEC) is a not-for-profit organisation promoting all aspects of the geothermal industry. Founded in 1998, its objective is to facilitate awareness and expansion of geothermal applications across Europe by shaping policy, improving investment conditions and steering research.

It has over 200 members from 30 countries, ranging from developers to equipment manufacturers, energy providers, national associations, consultants, research centres, geological surveys, government agencies, departments and public authorities. This allows EGEC to represent the entire geothermal sector.

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European Federation of Geologists

The European Federation of Geologists (EFG) is a not-for-profit organisation instituted to ensure competent and ethical practice among geoscientists in Europe while representing the profession across the continent. EFG aims to be recognised as an independent, trustworthy and reliable international organisation that contributes to the protection of the environment, public safety and the responsible use of natural resources.

Its mission is to promote excellence in the application of geoscience across Europe, to represent the professional European associations of geoscientists and to create public awareness of geoscience's importance to society. Professional geologists contribute to public safety, sustainable development, the responsible use of natural resources, wealth creation and the effective prediction, prevention and mitigation of natural hazards through cooperation with other experts and effective communication with the public.

International Association of Hydrogeologists
the World-wide Groundwater Organisation

The International Association of Hydrogeologists (IAH/AIH) is a scientific and educational charitable organisation for scientists, engineers, water managers and other professionals working in the fields of groundwater resource planning, management and protection. Founded in 1956, it has grown to a world-wide membership of more than 4000 individuals. IAH aims to be a leading international society for the science and practice of hydrogeology and to be a globally recognised information source and facilitator for the transfer of groundwater knowledge. We endeavour to raise awareness of groundwater issues and work with national and international agencies to promote the use of groundwater to ensure ready access to safe drinking water. IAH also promotes the protection of aquifers against pollution, the improvement of aquifer storage and the management of groundwater resources to assure the sustainability of groundwater-dependent ecosystems.

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ROTAQUA

ROTAQUA Ltd. was founded by the Mecsek Ore Mining Company (MÉV) from its Exploration and Drilling Branch in spring of 1990. The ancestor organisation implemented the exploration and drilling works connected to the Hungarian uranium prospecting which covered the whole area of the country except the deep basins filled up by young sediments.

The MÉV considered strategic area to hold at least a part of the drilling equipment and the experienced staff, therefore it and 20 former employees with pecuniary contribution founded the ROTAQUA Ltd. in which the MÉV became the majority shareholder.

With the development of the equipment (purchase of up-to-date western manufactured drilling rigs instead of the inherited Russian made ones) and focussing on the quality, the company reached market leader position (35%market share) in its main activity area (geological exploration). We have a fleet of 20 modern drilling rigs, and excellent, high qualified experts.

GEO HŐTERM KFT.

Cooperating closely with Szeged District Heating Company (SZETÁV), Geo-Hőterm Kft. plays a significant role in the transition of Szeged's district heating to a geothermal base. The company is realizing several projects with EU and governmental funds which aim to realize geothermal heat supply to the Szeged heat districts. Their main responsibilities are construction, operation, and maintenance of geothermal systems. These activities include drilling and development of geothermal wells, design and installation of geothermal heating systems, installation of heat pump systems, ensuring the efficient and safe operation of the systems, maintenance of wells and mechanical systems.

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Geomega Ltd. is a Budapest-based geological-geophysical service company, providing a wide range of quality services in the field of shallow engineering geophysics as well as subsurface- and hydrocarbon exploration. The largest value of the company is considered to be the intellectual capital of highly qualified employees as well as their unmatched geophysical instrumentation.

The company's main services include the implementation of engineering and shallow geophysical measurements as well as various subsurface geological exploration activities, e.g.: geotechnical surveying, environmental and geological exploration supporting remediation works, drilling of shallow boreholes, geothermal exploration, archaeological-geophysical investigations.

Geo-log Environmental and Geophysical Ltd. offers an exceptionally wide range of wireline services and engineering geophysics to characterize subsurface geology and to provide downhole information about wells and boreholes. Their services are explicitly vital for geothermal research projects, geotechnics, groundwater and karst aquifer exploration, mining and exploration geology.

They are specialised in wireline open hole/cased hole logging, well and borehole camera inspection, well testing, borehole seismic surveys, slickline operations, downhole and surface fluid sampling, engineering geophysics and special borehole measurements.

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The Hungarian Geothermal Association (MGtE) was established in 1995 by the will of 28 founding members. We currently have 85 members, who are partly natural persons (active employees, retirees, and students), and partly legal entities (municipalities, nonprofit organisations, and other legal entities).

The Hungarian Geothermal Association – as stipulated in its articles of association – is a professional scientific, environmental, educational, and cultural organisation founded in Hungary. MGtE is a non-political, non-governmental, and non-profit organisation that primarily does not engage in economic or entrepreneurial activities.

Among the non-economic activities, the publication of the Földhő Hírlevél (Geothermal Newsletter) since 2004 stands out, as well as the organisation of geothermal conferences, also since 2004.

The Hungarian Geothermal Association has participated in the review of draft legislation on several occasions, and in the critical review of already adopted legislation. If necessary, we have formulated positions, statements, or announcements on the status, tasks, and opportunities of geothermal energy utilisation.

The Hungarian Mining Association represents the employer interests of mining companies and mining-related businesses. This means it actively addresses issues affecting employers, such as labour regulations, wages, working conditions, and employment terms. The organisation also represents the professional interests of the mining industry, including mining technologies, safety standards, environmental considerations, and industry regulations.

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