

Best Practices for Harnessing Energy from Geothermal Wastewater

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ABSTRACT

Reducing energy consumption and improving energy efficiency are key challenges in the context of global climate targets. Geothermal wastewater represents a largely untapped opportunity for heat recovery in both new buildings but also retrofit applications. This paper presents an innovative approach developed in Romania using geothermal probes immersed in concrete tanks filled with thermal wastewater. With case studies from aquaparks, university campuses, and wellness hotels, this system proves to be cost-effective, energy-efficient, and sustainable. It enables the recovery of up to 100% of residual geothermal heat, achieving a Coefficient of Performance (COP) of 6.5 to 7.

1. INTRODUCTION IN TO THE GEOTHERMAL POTENTIAL IN EAST EUROPE AND ROMANIA

The increasing demand for renewable energy and the parallel decline of fossil fuel viability requires new methods of energy reuse. Geothermal systems, particularly those generating thermal wastewater, often discard valuable low-temperature energy.

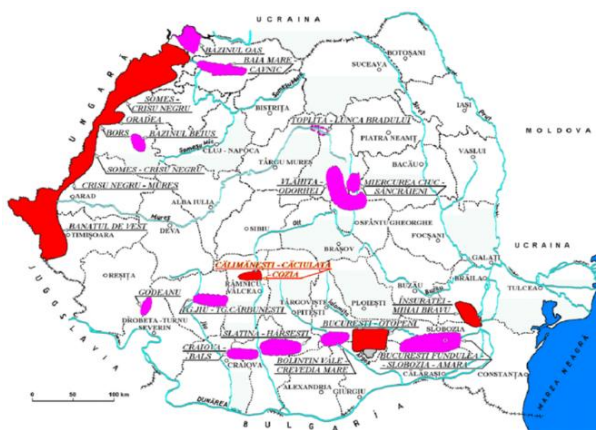


Figure 1: Romanian's geothermal energy potential (Antal et. al., 2020)

Europe's geothermal resources are concentrated in regions like Hungary, Germany, and Romania. In Romania, aquifers with temperatures up to 80°C are common, especially in Oradea and the western plain. Romania (Fig. 1), with its notable geothermal resources, has developed systems that capitalize on this waste stream through innovative technology involving geothermal probes in dedicated tanks (Neacsu et al., 2020).

These resources are currently used for heating pools, buildings, and in some cases district heating. However, the thermal water is typically discharged at 30–50°C, wasting a significant energy potential. Reusing this wastewater offers a strategic opportunity for sustainable energy systems (Menegazzo et al., 2022; Elshehabi and Alfehaid, 2025).

2. INNOVATIVE HEAT RECOVERY APPROACH

The traditional method of heat recovery, using stainless steel plate exchangers, suffers from corrosion and efficiency loss in geothermal conditions. Termoline team developed an alternative (Fig. 2): a concrete tank filled with used geothermal water, into which corrosion-resistant polyethylene (PE-Xa) probes are submerged. These probes connect to GSHPs that extract heat with minimal energy input. This approach reduces maintenance costs, eliminates corrosion, and maintains stable long-term performance (Khalil et al., 2024; Xue et al., 2024).

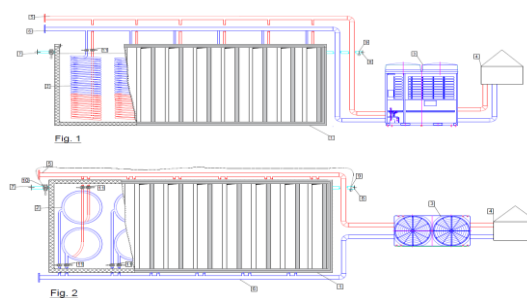


Figure 2: Sketch of the Innovative modular tank for waste geothermal water recovery

The modular design of the tanks allows for scalability and easy maintenance, while system performance is optimized by maintaining the primary circuit temperature around 20°C, resulting in exceptional COP values (Fig. 3).



Figure 3: Prototype of the innovative tank for waste geothermal water recovery

3. CASE STUDIES

To validate and demonstrate the practical performance of the innovative geothermal wastewater recovery tank, several large-scale projects have been implemented across Romania. These case studies span various building types and thermal demands, from public leisure facilities to educational institutions and healthcare infrastructure. Each project integrates a custom-designed concrete tank equipped with polyethylene (PE-Xa) geothermal probes, used to recover low-grade heat from thermally used geothermal water. The recovered heat is then supplied to ground source heat pumps (GSHPs), significantly improving energy efficiency and reducing discharge temperatures.

3.1 Aquapark Nymphaea Oradea

Aquapark Nymphaea in Oradea serves as the pilot site for the implementation of the innovative geothermal wastewater recovery tank. Previously operating with a conventional system based on stainless steel plate heat exchangers, the aquapark utilized geothermal water at approximately 70°C to heat its swimming pools. After primary use, the geothermal wastewater—still retaining a temperature of 30–40°C—was directed to a 900 kW ground source heat pump system for partial energy recovery.

The initial setup, however, resulted in discharge temperatures exceeding 20°C, due to high flow rates (over 24 m³/h) and sensor lag affecting precise control. To enhance system efficiency, the site has been retrofitted with a custom-built concrete tank housing corrosion-resistant polyethylene (PE-Xa) geothermal probes. This pilot installation is designed to significantly increase heat recovery, aiming to reduce the final discharge temperature to 5–10°C. As the first live application of the new system, Aquapark Nymphaea (Fig. 4, Fig. 5) provides critical performance data and operational insights that will inform future deployments.



Figure 4: Aquapark Nymphaea Oradea outside view



Figure 5: Aquapark Nymphaea Oradea technical room – GSHPs

3.2 Smart Campus University Oradea I and II

The Smart Campus of the University of Oradea spans a total area of 143,200 m², with over 44,000 m² of built space originally heated using geothermal water extracted at 77°C. In its initial configuration, the buildings were equipped with radiator-based heating systems, leading to the discharge of geothermal wastewater at relatively high temperatures of 40–50°C—representing a significant loss of recoverable thermal energy.

To address this inefficiency, a retrofit was undertaken across six buildings totalling 18,000 m², replacing radiators with radiant ceiling systems capable of both heating and cooling. As part of this upgrade, two thermal power plants—one for Campus I and one for Campus II—were constructed and equipped with ground source heat pumps (GSHP). These systems utilize the thermally used geothermal water, previously discharged as waste, as their primary energy source (Fig. 6). The integration of the innovative recovery tank with geothermal probes in each thermal plant allows the system to capture residual heat more effectively and reduce discharge temperatures, significantly improving energy efficiency and enabling year-round climate control across the campus.



Figure 6: Smart Campus University Oradea

The two thermal plants installed at the University of Oradea's Smart Campus are each equipped with ground source heat pumps: a 700 kW system for Campus I (Fig. 7) and a 400 kW system for Campus II I (Fig. 8). Both installations utilize the innovative concrete tank technology, each fitted with PE-Xa geothermal probes, to recover energy from thermally used geothermal water discharged after primary use in the building heating systems.



Figure 7: The installation of the innovative recovery tank Smart Campus University Oradea I



Figure 8: The recovery tank at Smart Campus University Oradea II

These tanks collect geothermal wastewater previously released at 40–50°C and enable a second-stage energy extraction before final discharge. The recovered water exits the system at significantly reduced temperatures—between 10°C and 15°C—allowing for the recovery of 30–35°C of otherwise wasted thermal energy.

The GSHPs operate at an average primary inlet temperature of around 20°C, with the secondary circuit delivering between 35°C and 37°C. This optimized temperature differential ensures a high Coefficient of Performance (COP) in the range of 6.5 to 7, confirming the system's superior efficiency and its role in decarbonizing campus operations.

3.3 Hotel Perla Wellness & SPA

Hotel Perla Wellness & SPA operates with a thermal demand of approximately 450 kW and utilizes its own geothermal well, supplying water at 36°C primarily for heating indoor pools. To maximize energy efficiency, the system has been upgraded with a concrete tank equipped with PEHD geothermal probes that collect geothermal wastewater at 28–30°C after its initial use (Fig. 9). This recovered thermal water serves as the primary energy source for a 300 kW ground source heat pump system, which supplies heat both for the pool water treatment systems (operating at 36–38°C) and for the hotel's internal spaces.

As part of the retrofit process, the hotel was equipped with a low-temperature radiant ceiling system made of plasterboard, allowing for efficient heating and cooling with a maximum working temperature of 40°C. This configuration not only enhances occupant comfort but also ensures high energy efficiency by enabling optimal

heat pump performance using moderate-temperature geothermal wastewater.



Figure 9: The geothermal wastewater recovery tank (left) and the inside pool of the hotel (right)

4. ADVANTAGES AND TECHNICAL INSIGHTS

The concrete tank design eliminates metal corrosion and ensures durability. Deposits from geothermal water do not clog the system, unlike traditional exchangers. The tanks are scalable and can be adapted to different capacities. Efficiency remains high even under mineral accumulation due to optimized spacing and fluid dynamics.

5. ENVIRONMENTAL AND ECONOMIC IMPACT

By enabling the recovery of 50–100% of the residual thermal energy present in geothermal wastewater, these systems significantly reduce the need for conventional heating inputs, thereby drastically lowering the total energy demand of the buildings they serve. This recovered heat—once lost during conventional discharge—is now efficiently harnessed through advanced GSHP systems operating with a Coefficient of Performance (COP) between 6.5 and 7.0. In practical terms, this means that every unit of electricity consumed by the heat pump system generates up to seven units of usable thermal energy, resulting in exceptionally low operational costs.

Furthermore, when the electricity powering these systems is derived from renewable sources such as solar or wind, the entire heating process becomes virtually carbon-neutral. Unlike fossil fuel-based systems, which are bound to high emissions and volatile costs, this geothermal wastewater recovery approach aligns fully with EU climate and energy goals by providing a stable, clean, and scalable heating solution.

As urban energy policies increasingly prioritize sustainability, the integration of these systems into both new and existing infrastructure offers a viable pathway toward zero-emission building stock and long-term energy resilience.

5. CONCLUSION

In the context of rising energy costs and the urgent need to decarbonize the built environment, implementing advanced heat recovery systems from geothermal wastewater is not just a technical upgrade—it is a

strategic necessity. Solutions like the concrete tank with geothermal probes enable significant reductions in energy consumption and operating expenses, while also contributing to environmental targets.

Equally important is the role these systems play in enhancing energy independence, reducing reliance on imported fuels, and stabilizing long-term energy supply. In regions where geothermal water is available, it is essential to exploit this resource to its full potential. Maximizing energy recovery through optimized, innovative systems ensures that every unit of geothermal energy is used efficiently, delivering both economic and ecological value.

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