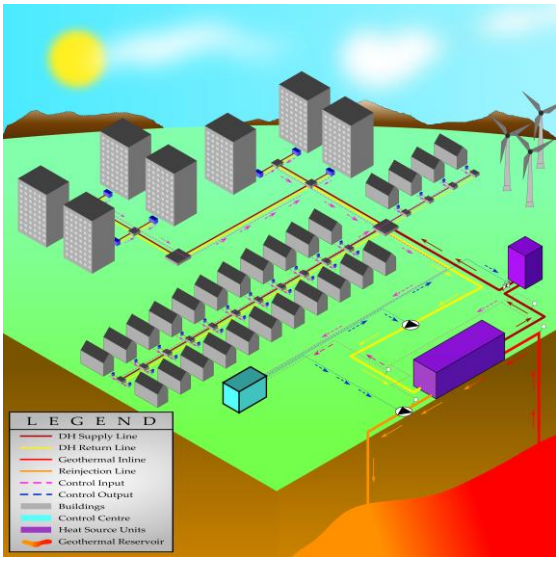


Source: S-GeoHeat / AEE INTEC

From Geothermal Sources to Smart Networks: Low-Temperature Geothermal Energy in District Heating

Hakan Ibrahim Tol, Lorenz Leppin

Decarbonising the heating sector is one of the greatest challenges of the European energy transition. District heating plays a key role in this context, particularly when operated at low temperature levels. Low-temperature systems allow renewable and industrial waste heat sources to be utilised directly, which would otherwise remain untapped in conventional high-temperature networks. Shallow geothermal energy is widely available in many regions, yet its use remains limited. Technical barriers and the need for heat pumps to raise temperature levels have constrained its potential.

The S-GeoHeat project addresses this challenge by combining the direct use of geothermal sources below 60 °C with targeted building refurbishment, the integration of industrial waste heat, and advanced digital monitoring solutions. This approach marks a paradigm shift: rather than adapting heat sources to demand, the network and consumption side are adapted to the quality of the available source. By linking geothermal energy, industry, and digital technologies, S-GeoHeat aligns local implementation with national and EU climate strategies.

Demonstration Sites: From Türkiye to Austria

S-GeoHeat develops three demonstration sites representing a broad spectrum of technical and geographical conditions for low-temperature district heating. Each site reflects a distinct context, yet all pursue the same objective: to demonstrate that geothermal and industrial waste heat sources can be utilised directly and intelligently.

The province of Samsun in Türkiye combines diverse renewable energy potentials with a strong industrial base and therefore serves as a strategic pilot region. In Havza, geothermal energy at approximately 54 °C is already used for heating and tourism, while in Ladik one of Türkiye's largest solar installations (57 MW) is located. Rapidly increasing industrial energy demand highlights the importance of waste heat recovery in the region.

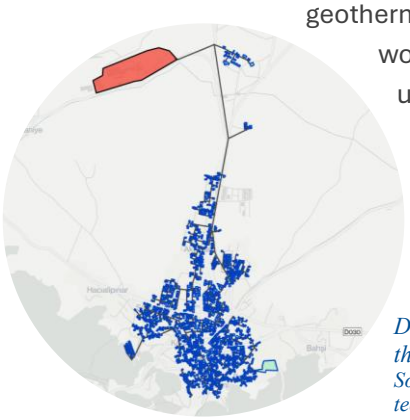
1) Havza – Direct Use of Shallow Geothermal Energy

The municipality of Havza in Samsun Province (Türkiye) operates geothermal wells delivering water at 53–56 °C with stable flow rates exceeding 150 l/s. These conditions enable the operation of a 55/25 °C district heating network without the need for additional heat pumps. The primary challenge lies on the demand side: buildings must be upgraded through renovation and optimised heat distribution systems to ensure thermal comfort at lower supply temperatures.

District heating network of the Havza study area (TR). Source: AEE INTEC, arteria technologies

2) Ladik – A Geothermal-Industrial Hybrid Model

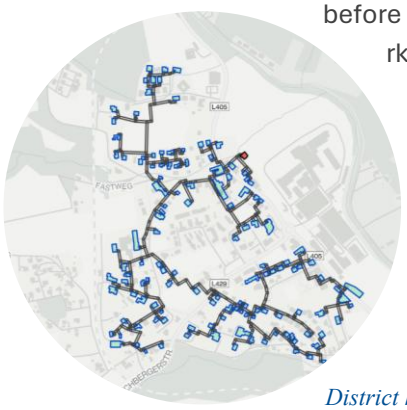
In Ladik, local geothermal sources provide temperatures between 28 and 38 °C, which are insufficient for direct district heating use. Within S-GeoHeat, a theoretical study examined the combination of low-grade geothermal energy with industrial waste heat from the nearby Akçansa cement plant. This hybrid concept could potentially raise supply temperatures to approximately 55 °C, suitable for low-temperature district heating. Although direct implementation is not planned for Ladik, the study demonstrates how industrial symbiosis can unlock geothermal resources that would otherwise remain unused.



District heating network of the Ladik study area (TR). Source: AEE INTEC, arteria technologies

3) Rohrbach – Digital Twin for Smart Operation

The Rohrbach site in Upper Austria is not geothermal-based but plays a central role in testing digitalisation strategies for district heating. Controllers transmit live data at five-minute intervals to a digital platform forming the basis of a digital twin. This environment allows the testing of AI-supported substations, supply temperature optimisation strategies, and blockchain-based monitoring solutions before implementation in Türkiye.



District heating network of the Rohrbach study area (AT). Source: AEE INTEC, arteria technologies

Network Design: Efficiency Begins with the End User

The success of low-temperature networks depends not only on the heat source but also on distribution infrastructure and the demand side. In Havza, where higher source temperatures are available, smaller pipe diameters can be used. In Ladik, longer transmission distances and hybrid heat supply require larger pipe dimensions to maintain system stability.

Building renovation quality is equally critical. Well-insulated buildings equipped with modern heating systems reduce peak loads and allow smaller pipe dimensions. Poorly renovated buildings increase heat demand and require more robust networks. Domestic hot water storage at substations further mitigates demand peaks, stabilises flows, and relieves stress on the system.

The findings highlight that building refurbishment and storage integration are not isolated measures but strategic levers for cost reduction, network optimisation, and improved overall efficiency.

Sustainability and Scalability

Long-term sustainability forms the foundation of the project. In Havza, three-dimensional geological modelling, predictive reservoir simulations, and optimised tracer and inhibitor tests[1] establish a reliable basis for sustainable extraction and reinjection. These measures, supported by comprehensive field investigations, ensure the long-term viability of geothermal operations.

In Ladik, a detailed energy balance of the cement plant demonstrated how industrial waste heat can be integrated into the system using realistic load profiles. The combination of geothermal energy and industrial waste heat stabilises the system and ensures a consistent 55 °C supply temperature. Simultaneously, the cement plant benefits from improved energy efficiency and reduced CO_2 emissions, illustrating cross-sectoral synergies.

Scalability is assessed across the three demonstration sites, while digital control strategies are tested on a dedicated platform. A blockchain-based monitoring system collects data from critical sensors[2] throughout the system, processes it, and provides

secure, role-based access for operators, authorities, and investors. The result is a transparent, adaptive, and replicable framework that addresses both technological and regulatory requirements and can be transferred across Europe.

Conclusions

S-GeoHeat demonstrates that shallow geothermal energy, combined with targeted building refurbishment, industrial hybridisation, and digital tools, provides a direct and reliable basis for low-temperature district heating. Measures on the demand side are as important as the characteristics of the heat source itself.

Through waste heat integration in Ladik, reservoir and reinjection modelling in Havza, and real-time digital control in Rohrbach, the project pursues a holistic approach that integrates resource management, network design, and operational control. It clearly illustrates that decarbonisation cannot be achieved solely by expanding renewable sources but requires intelligent combinations, cross-sector integration, and digitalisation.

The three demonstration sites confirm not only technical feasibility but also scalability across diverse regional contexts. Together, they provide a replicable model for future district heating systems, simplified, sustainable, and aligned with European climate objectives, offering guidance to investors, utilities, and municipalities alike.

[1] Tracer tests analyse flow paths and hydraulic connections between production and reinjection wells by introducing tracer substances into the geothermal fluid and monitoring their movement. Inhibitor tests evaluate and optimise chemical additives that prevent scaling and corrosion within the geothermal system, ensuring stable long-term operation.

[2] A sensor is considered critical when installed at key measurement points whose data are essential for safe and efficient system operation, such as wells, pumping stations, heat exchangers, or network transfer points.

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Further information and links in the e-paper

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Sources and further information

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