Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Geothermal Potential Assessment of an Operating Mine: A Pilot Project Using the Goldex Mine Water (Val-d'Or, Quebec)

Emna Bouzaiene*, Félix-Antoine Comeau and Jasmin Raymond
Institut national de la recherche scientifique, 490 rue de la Couronne, Québec, QC G1K 9A9, Canada
Emna.bouzaiene@inrs.ca

Keywords: Active mine, underground workings, dewatering, field monitoring, open-loop system, Abitibi.

ABSTRACT

Decarbonizing Canada's mining sector has become a priority, as mines remain a major consumer of fossil fuels and a significant emitter of greenhouse gases. One promising solution is to harness the geothermal potential of the large volumes of water continuously pumped from active underground mines. While this opportunity has been widely studied in abandoned mines with operational systems already in place worldwide, active mines remain largely unexplored. Few studies have assessed the available geothermal resources at operating sites, and no pilot system has yet been implemented to demonstrate the feasibility of this approach under real conditions. This research aims to design, install, and validate the viability of a pilot-scale geothermal system at an active underground mine in Abitibi, a region in western Quebec with a rich mining history and world-class gold deposits. The system was successfully installed on the Goldex mine site and began operation in November 2025 using retention ponds for dewatering water, which was followed by a seven-day monitoring campaign. During this period, entering mine water temperature remained stable at approximately 11 °C, with an average flow rate of 12.5 GPM, ensuring steady operating conditions. The system delivered an average heating capacity of 9.68 kW, with peak values reaching 12.65 kW, producing a total of 1,626.9 kWh of thermal energy over the monitoring period. Results confirm the technical feasibility and short-term operational reliability of mine-water heat recovery under real conditions and provide a solid basis for extended monitoring and long-term performance assessment.

1 INTRODUCTION

A considerable number of theoretical and academic studies have been conducted to assess the geothermal potential of large volumes of water present in abandoned and flooded mines (Tóth and Bobok, 2007; Al-Habaibeh et al., 2018; Rudakov and Inkin, 2023). Moreover, geothermal systems utilizing mine water are already operational at several abandoned mine sites around the world, such as in Heerlen, the Netherlands (Verhoeven et al., 2014), Freiberg, Germany (Kranz and Dillenardt, 2009), and Springhill, Canada (Jessop et al., 1995). In active mines, the large volumes of water continuously pumped for mine dewatering offer a unique opportunity for geothermal energy recovery. This already mobilized resource can be harnessed without additional drilling or major new infrastructure (Abbasy, 2013). A promising approach consists of directing this water to a heat pump system to extract its thermal potential (Obracaj et al., 2022). This type of system, known as an "open-loop" configuration, relies on the direct pumping of groundwater from the mine. After heat extraction via heat exchangers, the water can be used for heating or cooling purposes.

Despite these promising prospects, active mines have yet to fully embrace this opportunity, leaving significant geothermal potential untapped. Few modelling studies have assessed geothermal resources in operating mines, and no documented pilot project has yet demonstrated the use of mine dewatering water for energy purposes. This gap highlights the need for applied research, which the present project aims to address. In the absence of real-world operational examples, mining companies remain hesitant to invest in such systems. Moreover, operating mines present technical challenges that simulations cannot accurately reproduce. Only experiments under real conditions can provide the knowledge needed to move from concept to implementation.

This paper presents the short-term operation and performance evaluation of an open-loop geothermal heat pump (GHP) system utilizing dewatering mine water from the Goldex mine (Quebec). The system configuration, along with the instrumentation layout and monitoring strategy implemented during the test period, is described in detail.

2 THE IMPLEMENTED GHP SYSTEM LOCATION

The Goldex mine is located approximately 4 km west of Val-d'Or, in the Abitibi region of western Quebec (**Figure 1**a). It is an underground gold mine operating since 2008, with production expected to continue until 2030. The mine infrastructure consists of two vertical shafts and an extensive network of ramps and drifts. Shaft #1 is located less than 300 m from the Thompson River, while Shaft #2 is situated approximately 600 m to the east.

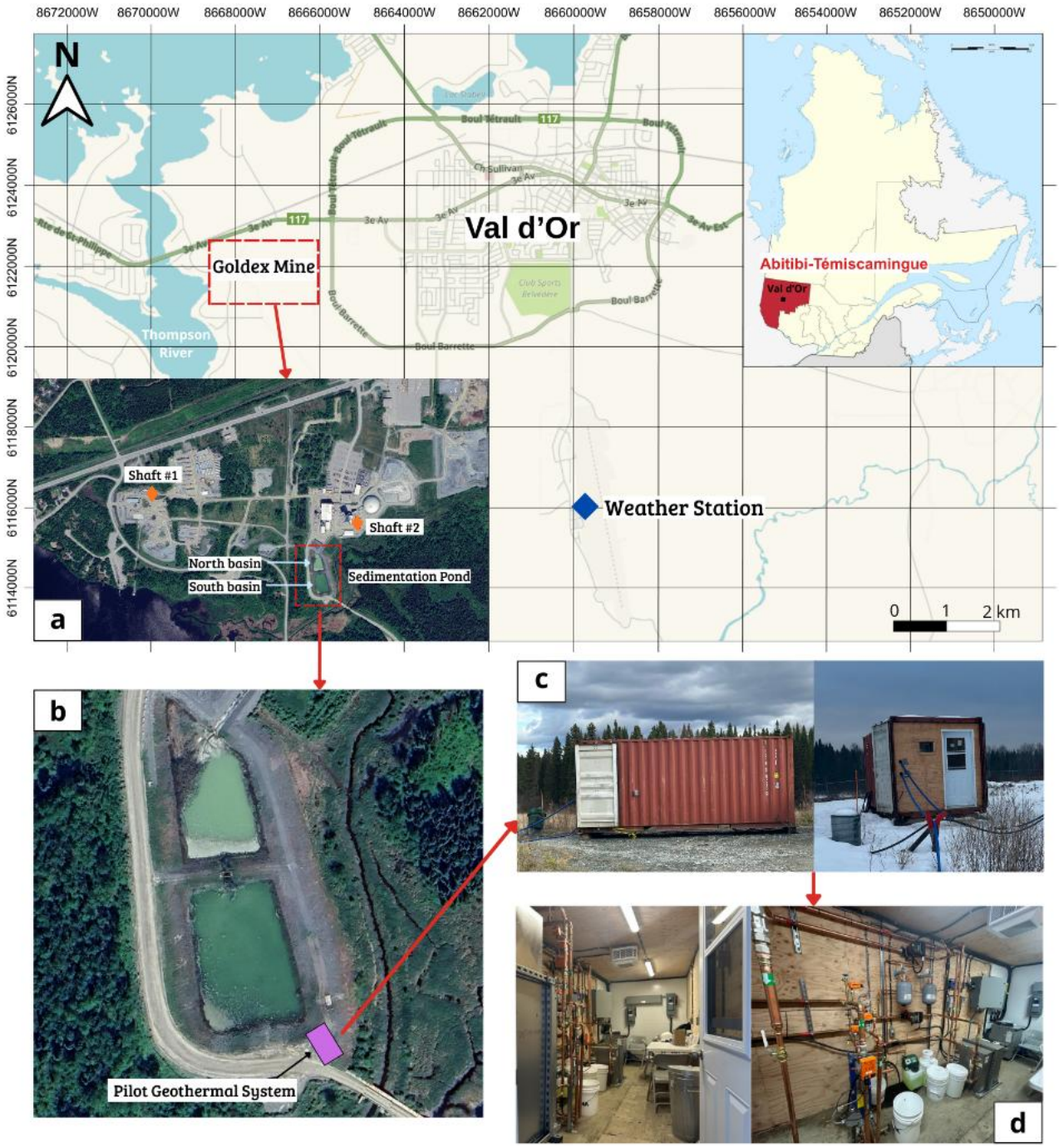


Figure 1. a) Location of the Goldex mine, b) location of the pilot system, c) photo of the container unit, d) photo of the GHP system.

The regional climate is characterized by cold winters and mild summers, with a mean annual air temperature of approximately 2.8 °C and total annual precipitation of about 784 mm (**Figure 2**). Consequently, heating demand

is significant for a large portion of the year. Approximately 2.1 million m^3 of natural gas is consumed annually for underground heating, primarily during winter times, between October and April (Agnico Eagle Mines Limited, 2021). In this context, the implementation of a GHP system offers the potential to partially offset natural gas consumption. To achieve this, the continuous use of dewatering water, pumped to maintain safe and dry underground operating conditions, represents a stable and reliable geothermal energy source. At the Goldex mine, groundwater collected in underground drifts undergoes three sedimentation stages before being pumped to the surface. Once at surface level, the water is directed to a sedimentation pond located near Shaft #2, which consists of two decantation basins (**Figure 1**b): The North Basin and the South Basin. The pond has a total storage capacity of approximately 12,000 m^3 and typically contains around 5,500 m^3 under normal operating conditions.

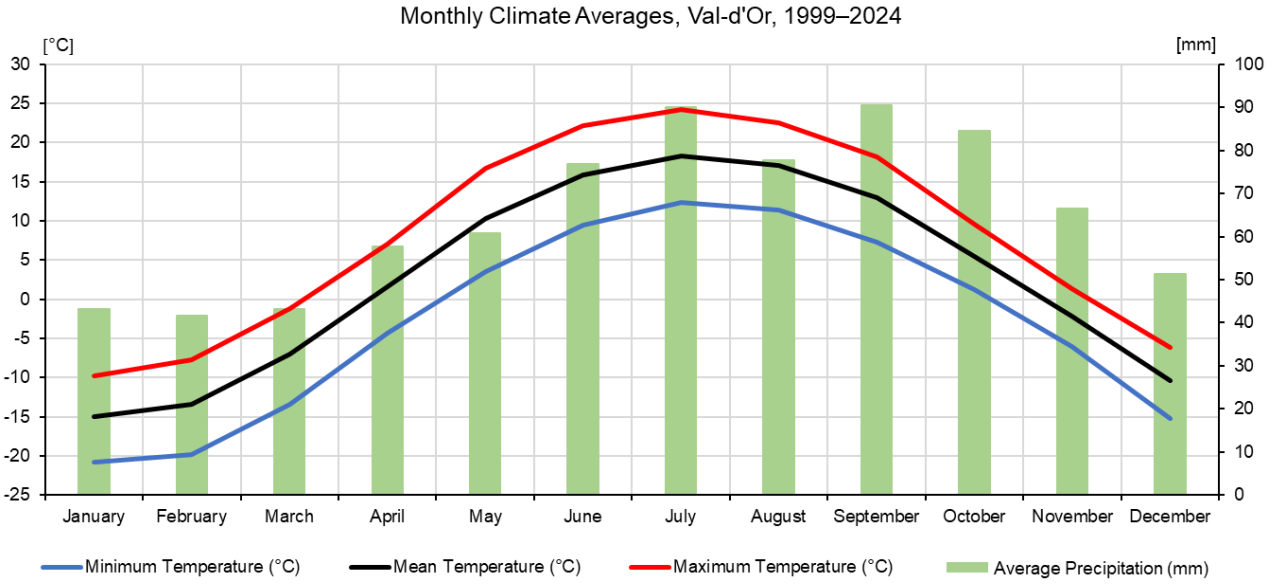


Figure 2. Monthly variation of average temperature and precipitation in Val-d'Or over the 1999-2024 period (Infoclimat, 2024).

The GHP pilot system was installed at surface level in an insulated container (Figure 1c and 1d), a few metres from the South Basin (**Figure 1**b). Mine water is pumped from the North Basin to the geothermal system, where heat is extracted before the cooled water is discharged into the South Basin. This configuration allows continuous access to mine water while minimizing interference with existing mining operations.

3 SYSTEM CONFIGURATION AND COMPONENTS

The GHP operates in an open-loop configuration designed to extract heat from dewatering mine water and transfer it to a secondary closed circuit. The system comprises a primary mine-water circuit and a secondary heat-exchange loop containing a 30 % propylene glycol solution. The two circuits are thermally coupled through a plate heat exchanger rated for pressures up to 16 bars and temperatures between -10 and 180 °C. This configuration prevents direct contact between mine water and the geothermal heat pump, reducing the risk of clogging and corrosion. The secondary loop supplies a water-to-water heat pump with a nominal thermal capacity of approximately 7 kW, operating with entering fluid temperatures ranging from -4 to 32 °C. The recovered heat is then delivered to an air-handling unit equipped with an auxiliary electric heater to maintain stable thermal output during peak loads and released outside the container through an aluminum air duct afterwards.

Two variable-speed circulation pumps control the fluid flow within the secondary loop, while two fixed-diaphragm expansion tanks accommodate pressure variations.

In addition, the pilot system includes twelve ball valves that allow localized control of fluid circulation within the circuit (

Figure 3). These valves enable maintenance on individual components without the need to drain the entire system, simplifying intervention procedures and minimizing operational disruption.

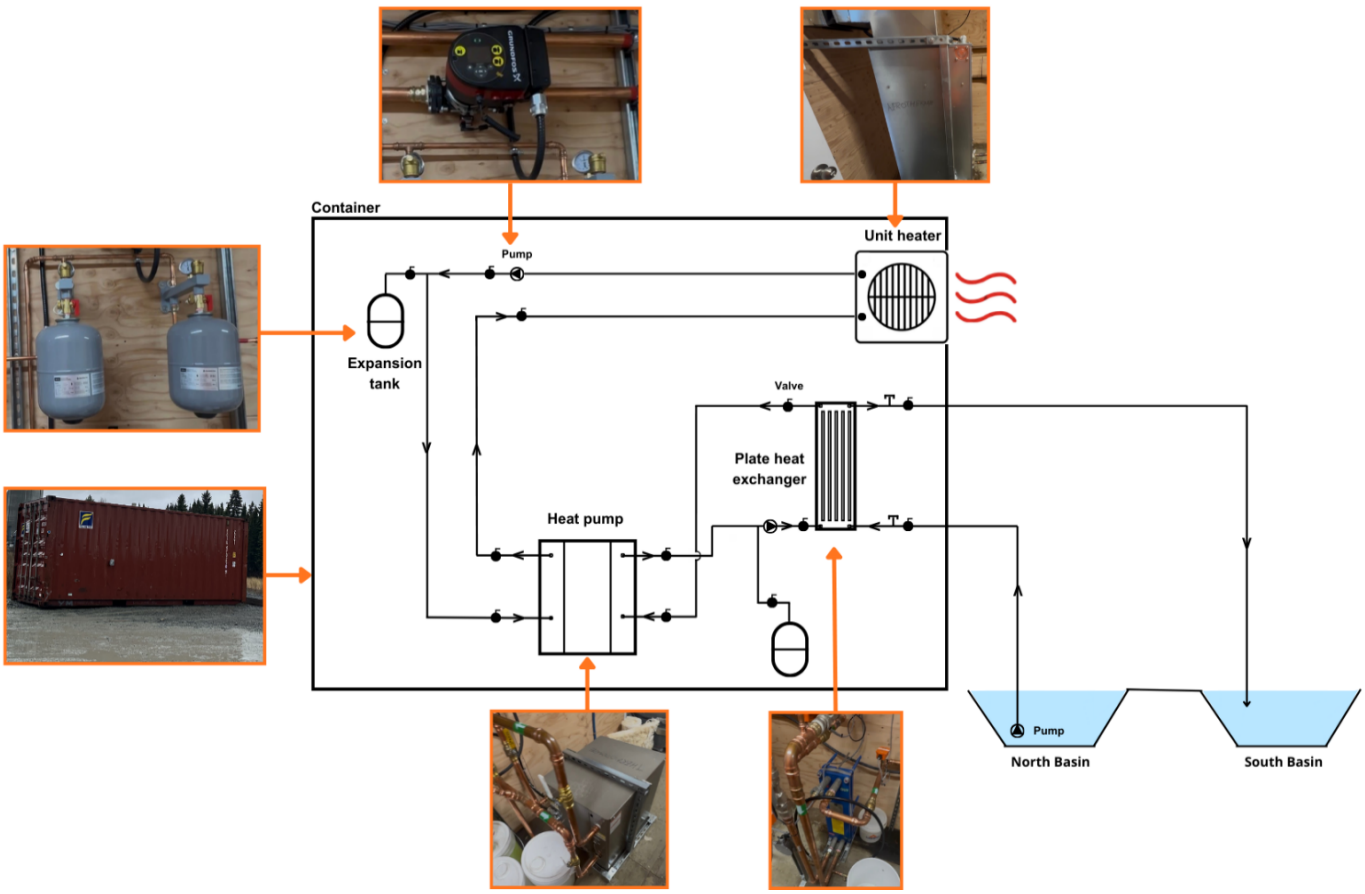


Figure 3. Simplified schematic diagram of the pilot system operation and main components.

4 MONITORING PLAN AND DATA ACQUISITION

The components used for monitoring the pilot system include six immersion temperature sensors installed at the inlet and outlet of the plate heat exchanger, the heat pump and the air heater (Figure 4a). These sensors passively detect temperature without emitting any signal. They operate within a measurement range of -50 to 150 °C, with the accuracy of ±0.2 °C for fluids at 25 °C and a resolution of 0.000001 °C. Their time constant in water ranges between 7 and 9 s. The probes are made of austenitic stainless steel, which ensures corrosion resistance.

Three ultrasonic flowmeters (Figure 4b), one per circuit, are installed to measure flow rates. They offer a resolution equal to the minimum detectable flow of 0.2 % of full scale. For water at 20°C (0 % glycol), the flow measurement accuracy is ±2 % of the measured value over 20-100 % of full scale and ±0.4 % of full scale over 0-20 % of full scale.
For glycol-water mixtures (0-60 % glycol), the accuracy becomes ±5 % of the measured value over 20-100 % of full scale. The flowmeter located upstream of the plate heat exchanger helps determine when cleaning is required, as scaling on the plates would slow fluid circulation and cause a decrease in the flow rate.

A pressure gauge is installed at the outlet of the plate heat exchanger on the primary circuit, and two sampling valves are placed on the same circuit to collect water samples for geochemical analysis.

The system also includes a power consumption meter to quantify the energy used by the heat pump (Figure 4c). It measures voltage, current, and power with the accuracy of 0.2% (ANSI C12.20 2015 Class 0.2) and a resolution based on 32-bit floating-point processing, covering voltage channels from 80 to 346 V line-to-neutral (up to 600 V line-to-line) and current measurements up to over 4,000 A.

The entire monitoring system is connected to a digital controller installed in the control cabinet (Figure 4d), which communicates with the Strato Enterprise Workstation, a BACnet server that centralizes data acquisition. This system allows for continuous monitoring and remote access to all measured variables, including temperatures, flow rates, and electrical consumption of the heat pump. Data acquisition was done with a time step of one minute over a seven-day monitoring period.

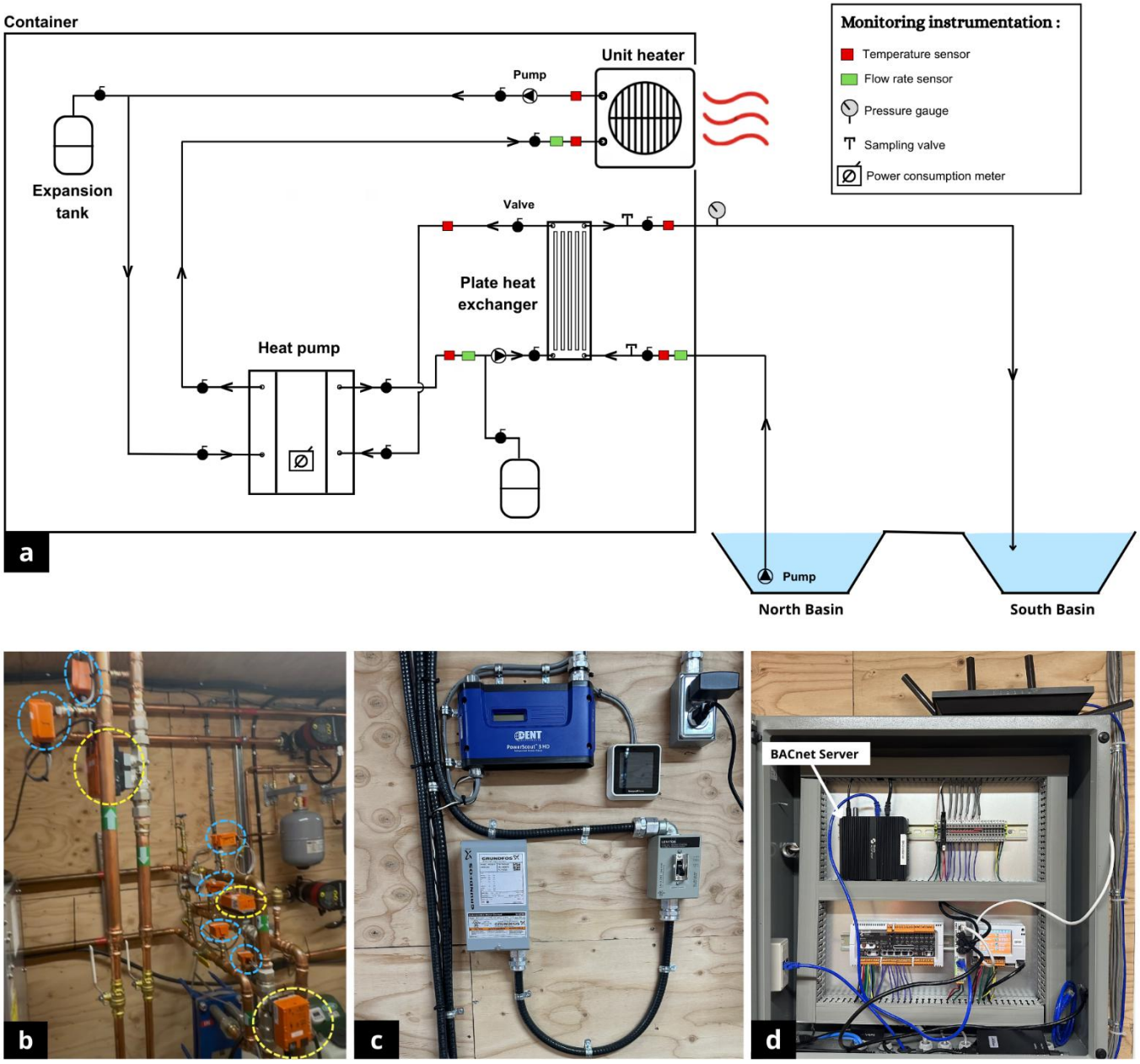


Figure 4. a) Components and monitoring instruments of the pilot geothermal system designed by Induktion, b) the temperature sensors (circled in blue) and the flowmeters (circled in yellow), c) the power consumption meter, d) the control cabinet housing the digital controller and the BACnet data acquisition server.

5 THERMAL ENERGY ASSESSMENT

Temperature and flow measurements will be used to calculate heat exchanges within the pilot system and to determine the total recoverable thermal energy (Figure 5). The thermal power extracted or transferred to a fluid

passing through a plate heat exchanger or a heat pump can be expressed as follows (Kavanaugh and Rafferty, 2014):

$$Q\ (\mathrm{W}) = Q' \times \rho \times C_{\mathrm{p}}(T_{\mathrm{in}} - T_{\mathrm{out}}) \tag{1}$$

where Q (W) is the thermal power, Q' ($m^3 \cdot s^{-1}$) is the volumetric flow rate, ρ ($kg \cdot m^{-3}$) is the density, C_p ($J \cdot kg^{-1} \cdot K^{-1}$) is the specific heat capacity, and T_{in} and T_{out} (K) are the inlet and outlet temperatures of the fluid.

This equation will be applied at different stages of the system, with subscripts adjusted according to the fluid type and circuit position. For instance, Q_w refers to the power extracted from mine water, Q_{gly} to the power transferred to the heat carrier fluid (water/propylene glycol mixture), Q_{hp} to the power produced by the heat pump, and Q_{air} to the heat released into the air by the air heater.

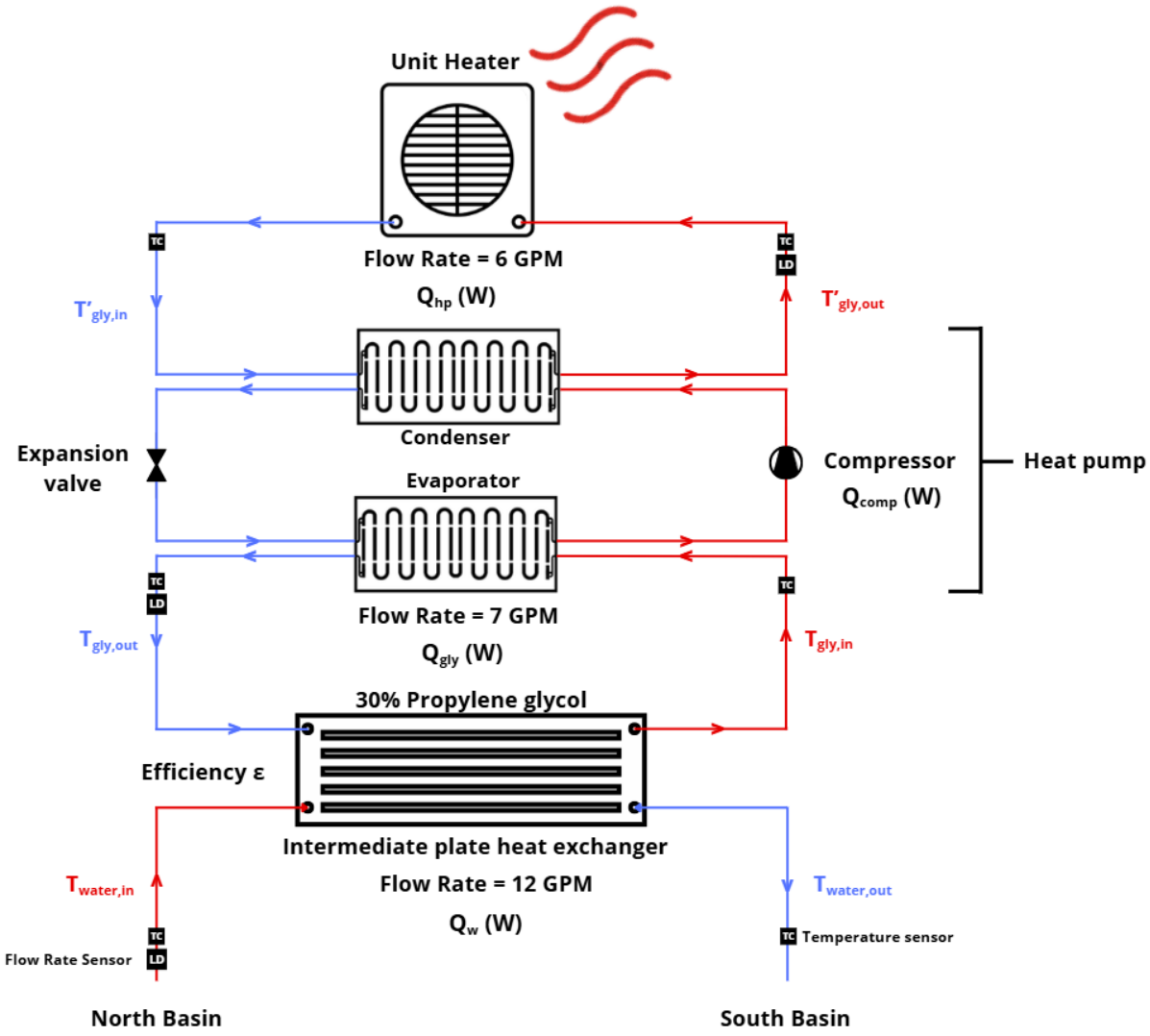


Figure 5. The thermal exchanges within the pilot GHP system.

6 RESULTS AND DISCUSSION

The pilot geothermal system was installed in November 2025 and operated continuously for seven days, from 18 to 24 November 2025. During this period, the monitoring system recorded temperature and flow rate data, enabling evaluation of operational stability and quantification of the thermal energy produced.

The inlet temperature remained relatively stable during the test period (Figure 6), ranging from 10.1 to 13.0 °C. The outlet temperature followed a similar trend, varying between 7.9 and 10.6 °C. Moderate daily fluctuations were observed, with a slight increase from 19 to 21 November and a small decrease on 23 November.

The temperature difference (ΔT) across the heat exchanger remained stable, fluctuating between 2.0 and 2.5 °C. The stable ΔT suggests consistent heat transfer performance throughout the monitoring period.

Overall, the results confirm reliable and stable heat extraction from the mine water source.

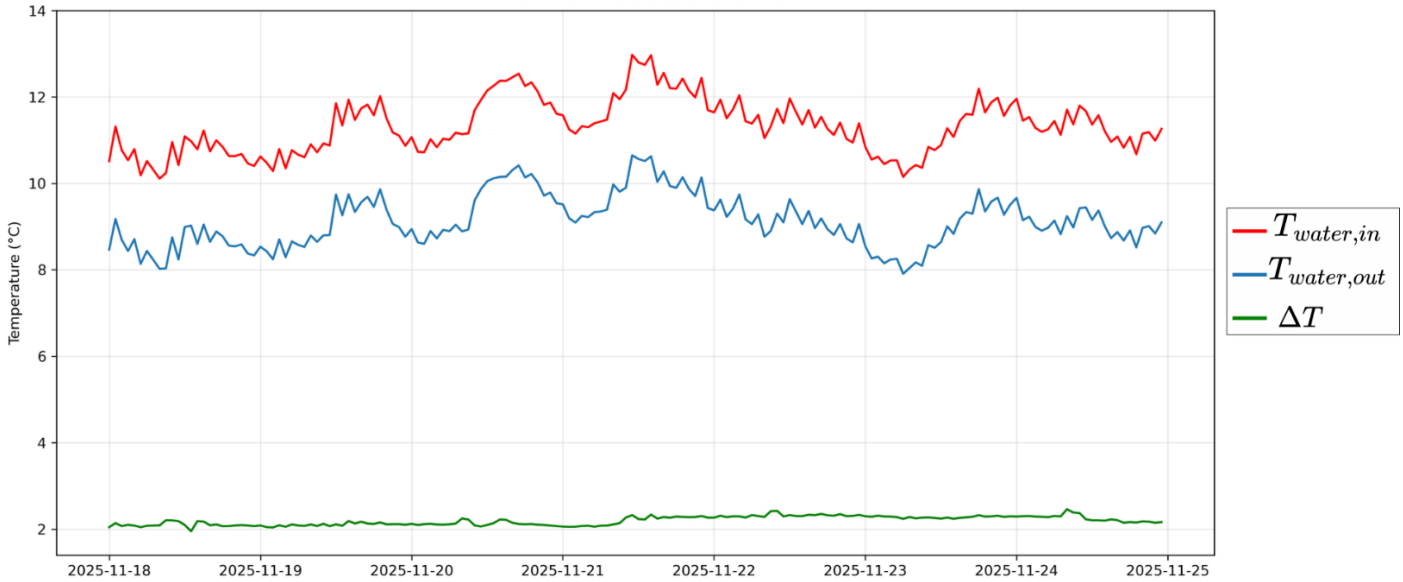


Figure 6. Mine water inlet and outlet temperatures.

The source-side flow rate varied between 11.8 and 13.4 GPM during the test period, while the load-side flow rate ranged from 9.1 to 10.7 GPM (Figure 7). Temporary reductions observed on 19 and 20 November resulted from adjustments to the circulation pumps on both loops. The flow rates were briefly reduced from 12 to 11 GPM to assess whether a lower flow could increase the temperature difference across the heat exchanger. Following this test period, the pumps were reset to 12 GPM, which prevented short cycling and ensured stable operation. Overall, both loops operated within narrow flow ranges.

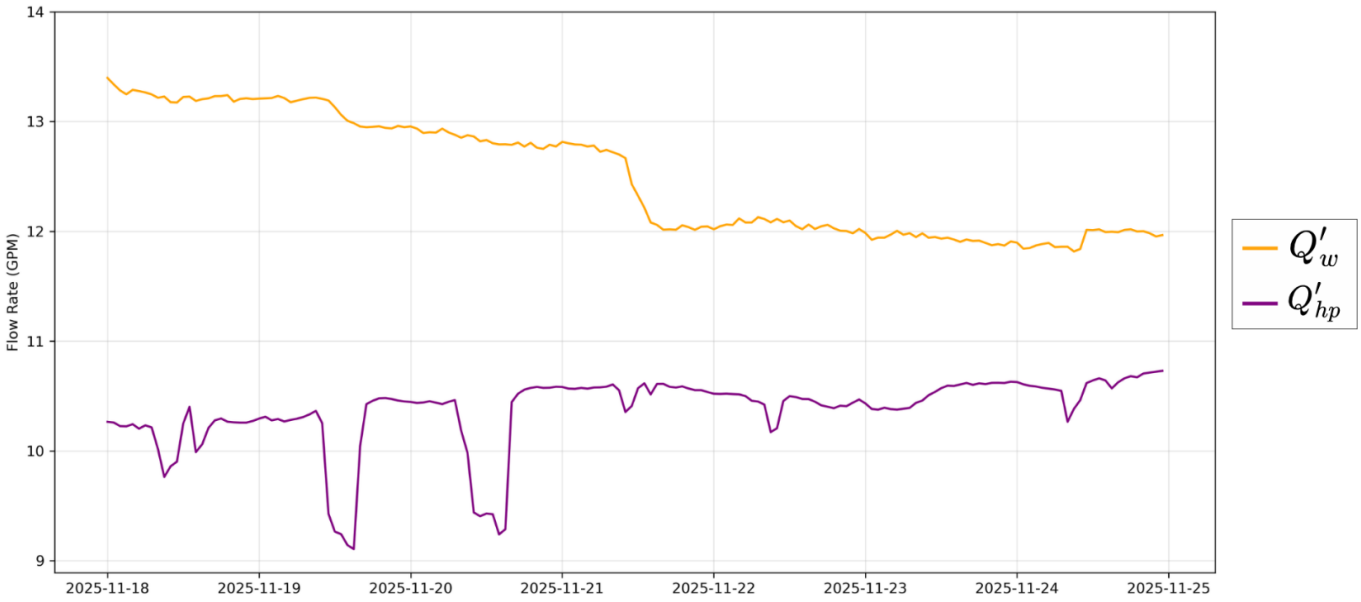


Figure 7. Flow rates measured at the inlets of the plate heat exchanger (orange) and the unit heater (purple).

Due to a malfunction of the power consumption meter, the electrical consumption of the heat pump could not be measured during this initial test. Consequently, the coefficient of performance (COP) was estimated using the manufacturer's performance charts, based on the measured inlet glycol temperature to the heat pump (Figure 8). The estimated heating COP remained relatively stable over the 7-day monitoring period. For inlet glycol temperatures ranging from 7.1 °C to 10 °C, with a mean of 8.4 °C, the COP values varied between 4.03 and 4.25, resulting in an average of approximately 4.13. This corresponds to a variation of around 5%, indicating consistent operating conditions and stable thermal performance.

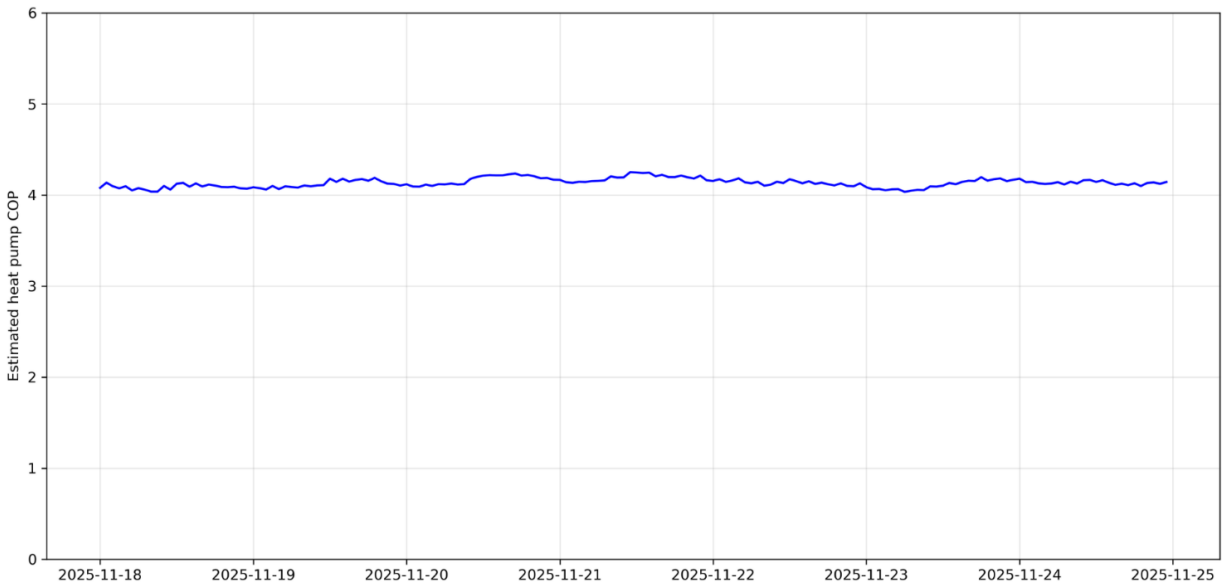


Figure 8. Estimated COP of the heat pump.

The thermal power extracted from the mine water Q_w during the test period ranged from 6.8 kW to 7.8 kW (Figure 9), with an average of approximately 7.2 kW. The delivered thermal power Q_{hp} varied between 9.3 kW and 10.5 kW, with an average of 9.7 kW. Short-duration peaks above 10.4 kW were observed on 20, 21, and 24 November. Throughout the monitoring period, Q_{hp} consistently exceeded Q_w, with an average difference of approximately 2.4 kW, corresponding to the compressor electrical input.

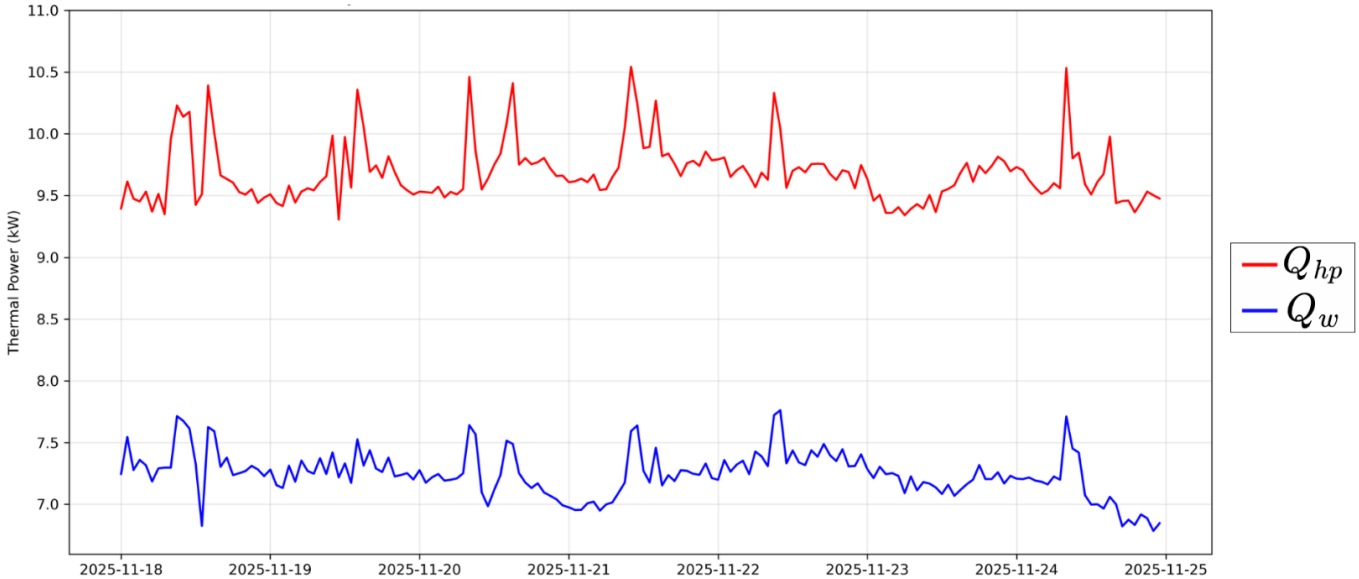


Figure 9. Comparison of extracted and delivered thermal power.

Over the 7-day test, a total of 1,217.1 kWh of thermal energy was extracted from the mine water, resulting in 1,626.9 kWh of heating energy produced.

Following the 7-day monitoring period, the system was shut down for the winter season due to the harsh climatic conditions in Val-d'Or, where ambient temperatures can reach approximately -20 °C. The outdoor pipe connecting the pump to the heat exchanger is not insulated because this is a pilot unit and there is a risk of freezing that could lead to pipe rupture or damage to the plate heat exchanger. The system will be restarted in April 2026 and operated until November 2026. Based on the initial operational test, several system improvements will be implemented for the next campaign, including calibration of the power meter to obtain direct measurements of the heat pump electrical consumption, enabling accurate determination of the system COP.

7 CONCLUSION AND PERSPECTIVES

This study presented the design and successful implementation of an open-loop geothermal system in an active mine. Data collected during the 7-day continuous monitoring demonstrated that mine water represents a reliable geothermal resource. Future work will involve extending operation of the system to evaluate seasonal performance and quantify the system's contribution to reducing greenhouse gas emissions and lowering energy costs. The results will provide mine operators with concrete data and practical technical recommendations to support the integration of geothermal energy from the early stages of mine development. Beyond the experimental phase, the project will include a numerical modelling component to simulate the thermal and hydrogeological behaviour of the whole system throughout the mine's life cycle, from operation to closure, enabling long-term planning and optimization of geothermal energy recovery.

Acknowledgements

This research was funded by the Fonds de recherche du Québec - Nature et technologies (FQRNT), under the program *Développement durable de l'industrie minière*, and Mitacs. We acknowledge Agnico Eagle for providing access to the Goldex mine and for their collaboration during the project. Induktion contributed expertise in the design and installation of the pilot system, while Blais Industries ensured its performance and reliability.

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