Geneva's First Geothermal Plant in Development - A Pathway to Integrate Sustainable Heat into the District Heating System

Quiquerez, Loic; Mirjolet, Frédéric; Martin, François; Nawratil De Bono, Carole Frédérique

Geneva's First Geothermal Plant in Development - A Pathway to Integrate Sustainable Heat into the District Heating System

Loïc Quiquerez[1], Frédéric Mirjolet[1], François Martin[1] and Carole Nawratil de Bono[1].

[1] Service industriels de Genève, ch. Du Château-Bloch 2, 1219 Le Lignon, Switzerland

loic.quiquerez@sig-ge.ch

Keywords: Geothermal energy, district heating, medium-depth aquifers, Geneva.

ABSTRACT

This paper presents the development of the Satigny 2&3 geothermal doublet, part of Geneva's GEothermies program led by the Canton of Geneva and Services Industriels de Genève (SIG). Located in a key industrial zone, this is the first industrial-scale geothermal installation in the region targeting medium-depth aquifers. Designed for integration with the GeniTerre district heating network, the system will deliver 7 MW of thermal output — 2 MW through the direct use of geothermal heat via a primary heat exchanger, and 5 MW via a heat pump system connected to a secondary exchanger. The project also explores the potential for seasonal thermal storage, whereby excess summer heat could be injected into the reservoir and recovered during winter to enhance efficiency. With construction scheduled to begin in 2026 and commissioning expected in 2029, the Satigny doublet marks a major step in Geneva's renewable energy strategy and offers a replicable model for sustainable geothermal development in urban settings.

1. INTRODUCTION

In response to the global climate crisis and the growing demand for sustainable energy solutions, Switzerland has committed to transitioning toward a carbon-neutral energy system by 2050. This ambitious goal aligns with the country's energy strategy, which prioritizes renewable energy, energy efficiency, and the gradual phase-out of fossil fuels. Within this context, geothermal energy has emerged as a crucial component, providing a stable, clean, and sustainable source of heat.

The Canton of Geneva has embraced geothermal energy through the GEothermies program, launched in 2014 to deploy large-scale geothermal projects across the region. The Satigny 2&3 geothermal project, located in an industrial area, is one of the most ambitious of these initiatives. It represents Geneva's first industrial geothermal doublet targeting medium-depth aquifers. The system will contribute significantly to the regional district heating network "GeniTerre", while addressing Geneva's need for reliable, renewable heat sources.

This paper provides an in-depth exploration of the Satigny 2&3 geothermal project, detailing its geological, technological, and operational aspects.

2. PROJECT OVERVIEW

The Satigny 2&3 geothermal doublet is situated in the heart of Geneva's industrial zone, a key economic hub home to a wide range of energy-intensive industries (figure 1). The site's strategic location is advantageous for several reasons: it provides direct access to existing energy infrastructure, including the GeniTerre district heating network, and is positioned within an industrial zone managed by the Foundation for Industrial Land of Geneva.

The geothermal system will operate with a doublet configuration, consisting of two wells: a production well (Satigny-2) and an injection well (Satigny-3). These wells will enable geothermal energy extraction and reinjection, ensuring sustainable reservoir pressure management.

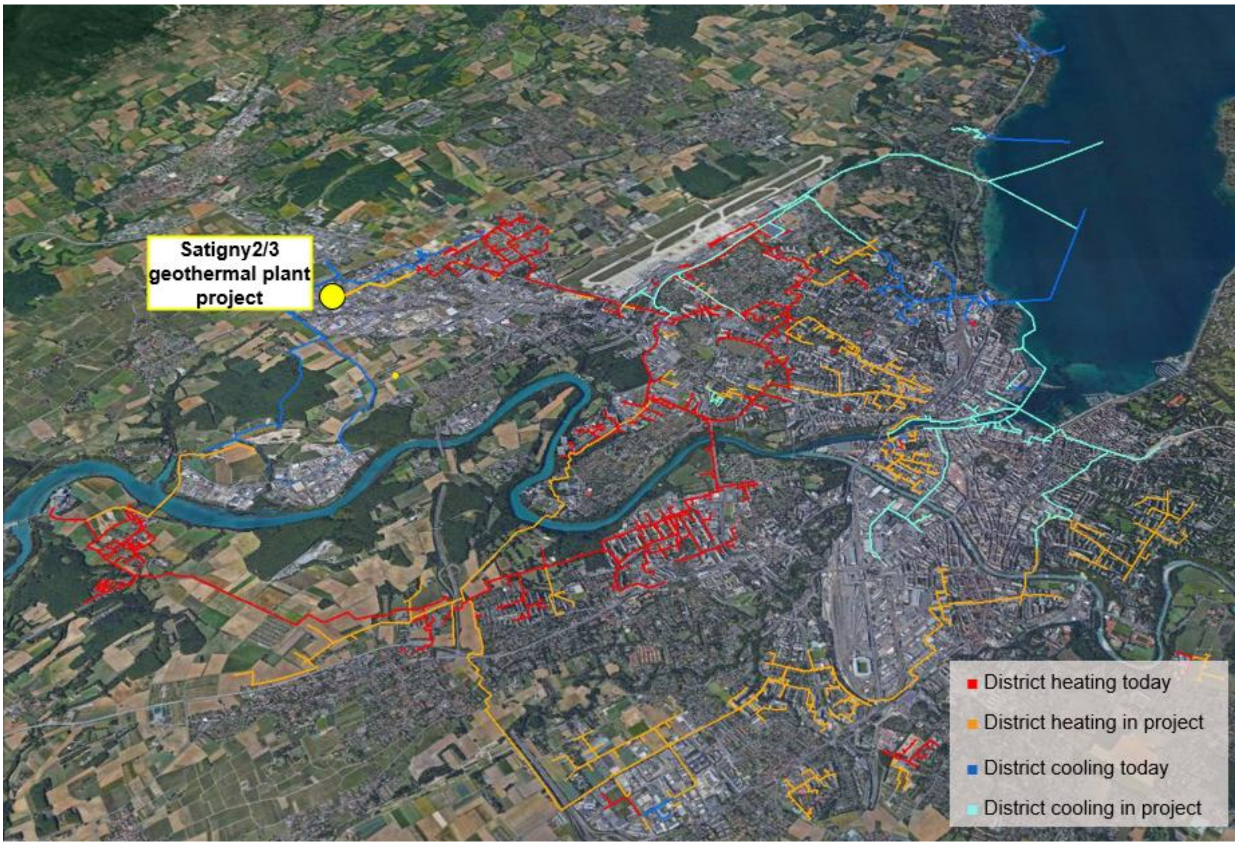

Figure 1: localisation of the Satigny 2&3 project and the district heating network

Construction of the well site is expected to begin in spring 2025. The spud date for the first drilling is scheduled for summer 2026. The drilling phase, which includes acidizing and testing, is estimated to take approximately 4 months. The first kilowatt-hour (kWh) of heat is expected to be delivered by 2029.

3. GEOLOGICAL TARGETS AND DRILLING STRATEGY

The Geneva Basin lies between the Jura Mountains to the northwest and the subalpine units to the southeast. Within this tectonic setting, promising aquifers are located at depths between 500 and 2,500 meters, primarily in karstified and/or fractured limestones belonging to the Mesozoic carbonate units.

The Satigny 2&3 project site lies within one of the most promising geothermal corridors in the Geneva Basin, marked by the presence of the Satigny Fault and a complex sequence of Mesozoic sedimentary formations (see Figures 2 and 3). Previous geological investigations — including a prospecting well drilled in 2018, borehole logging, 2D and 3D seismic surveys and hydrogeological modelling — have confirmed the site’s potential and allowed for a robust characterization of the subsurface conditions.

The primary reservoir target is the Malm formation, a karstified and fractured unit composed of limestone and dolomite, located at depths between approximately 700 and 1,300 meters. This formation is known for its high permeability and is expected to provide favourable conditions for geothermal heat extraction, with estimated temperatures exceeding 50°C.

A secondary target has also been identified in the Cretaceous carbonates, which could serve as a backup reservoir. While expected temperatures are lower (around 33°C), the potential flow rates may be comparable or even superior to those of the Malm formation.

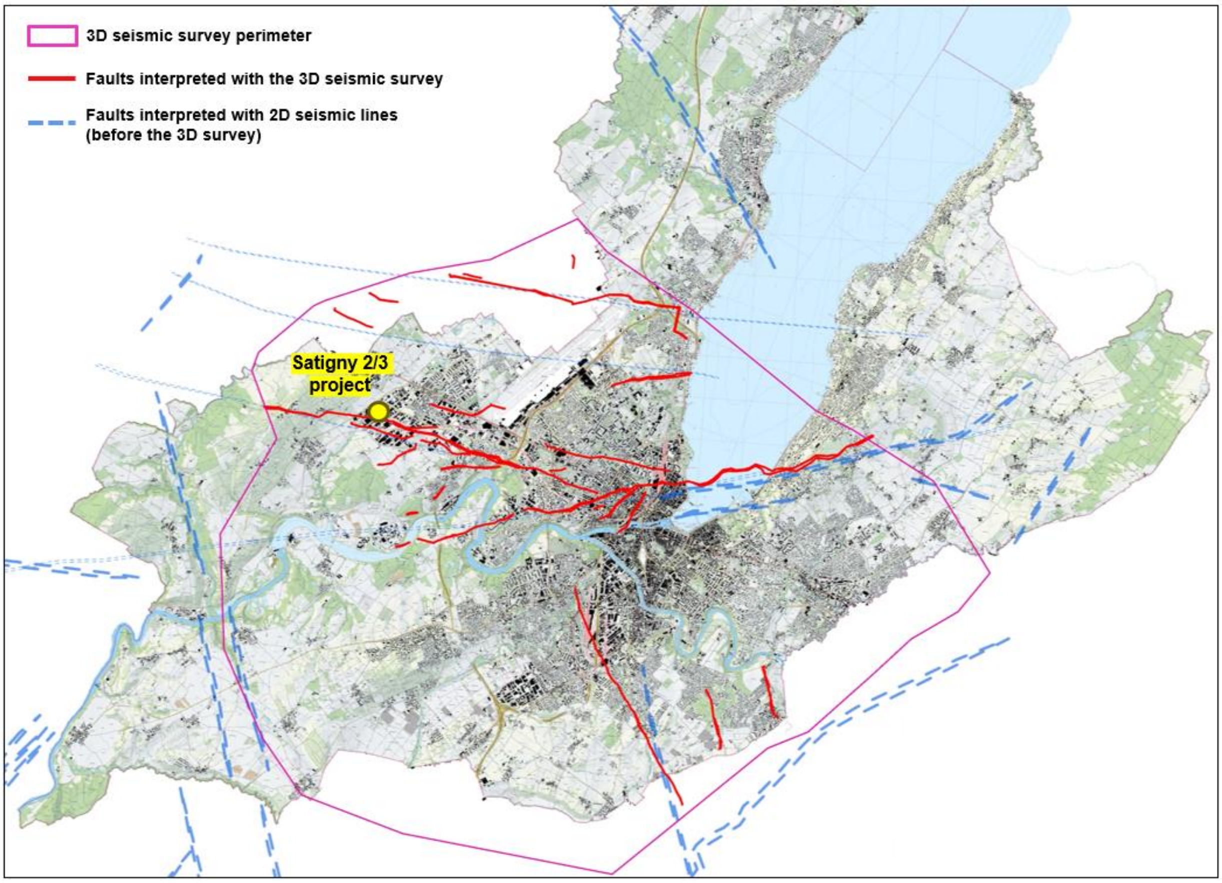

Figure 2: Localisation of the Satigny 2&3 project and major geological faults

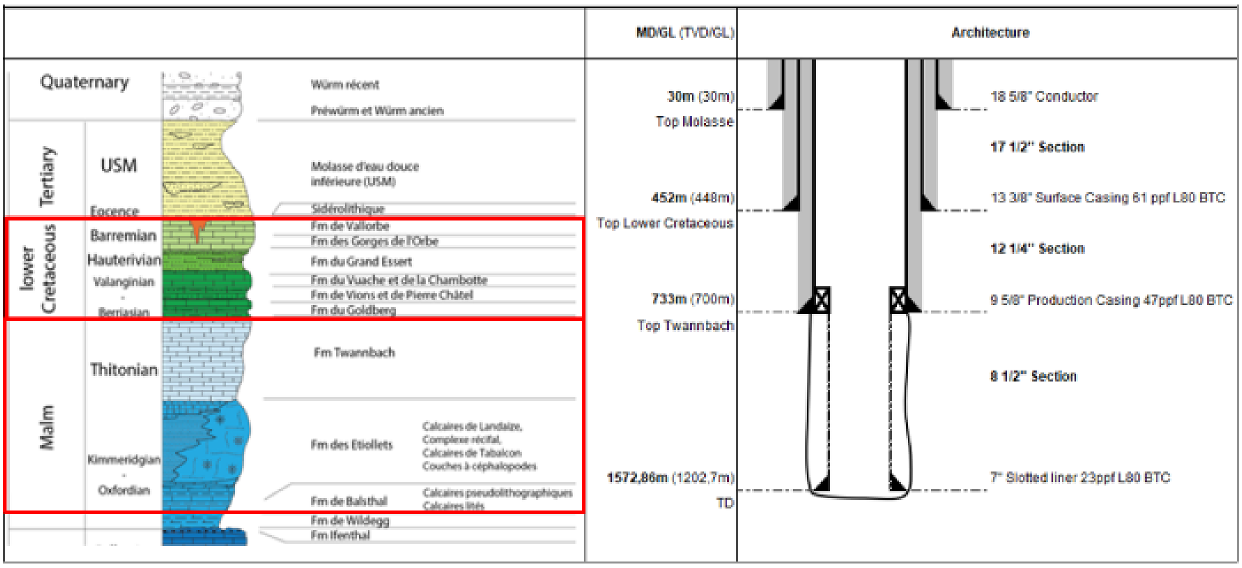

Figure 3: Lithostratigraphic section and drilling architecture at the site location
(the targeted reservoirs are highlighted in red)

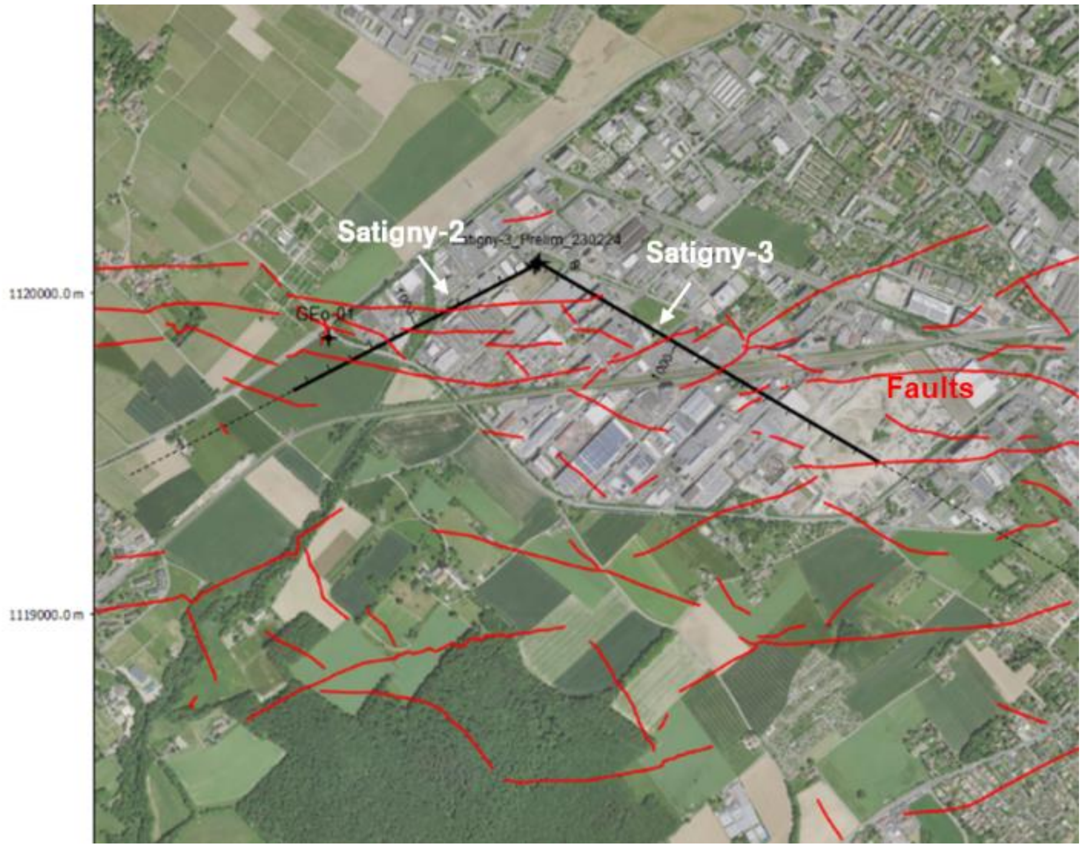

Figure 4: Projected trajectories of the wells Satigny-2 and Satigny-3 with interpreted faults in red

To ensure optimal performance and sustainable reservoir management, the system will use a doublet configuration with directional drilling. The production well (Satigny-2) and the injection well (Satigny-3) will reach total vertical depths (TVD) of approximately 1,200 meters and 1,320 meters, respectively. The two wells will be spaced horizontally by about 500 meters at the reservoir level, minimizing the risk of premature thermal breakthrough and ensuring long-term energy recovery (see Figure 4 and 5).

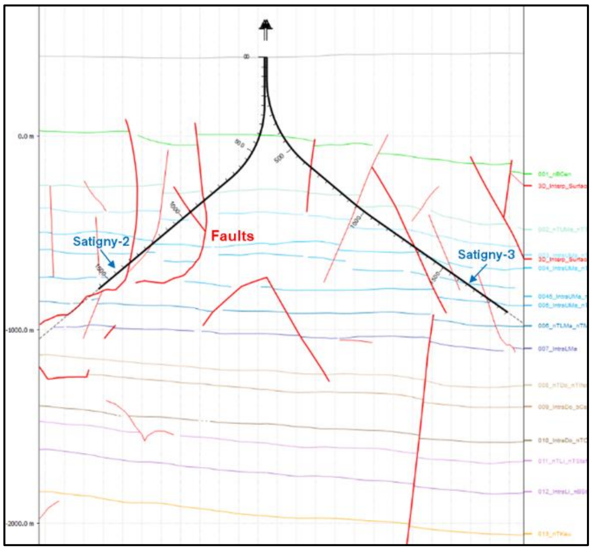

Figure 5: Cross section showing the planned trajectories for Satigny-2 and Satigny-3

A key technological innovation of the project is the planned use of Managed Pressure Drilling (MPD). MPD enables real-time control of wellbore pressure, which is particularly advantageous in karstic formations like the Malm. It helps prevent common drilling issues such as wellbore instability and fluid loss into highly permeable zones. The use of MPD with water-based, underbalanced drilling fluids allows for better reservoir protection, reducing the risk of contamination and facilitating in-situ productivity testing. These real-time measurements will be critical for assessing well performance and optimizing the final completion strategy.

Overall, the drilling strategy is designed to balance efficiency, reservoir integrity, and long-term sustainability, while generating valuable data to guide future geothermal developments in the region.

4. RESERVOIR PROPERTIES AND HYDROGEOLOGY

Based on current geological and hydrogeological knowledge, the Satigny 2&3 geothermal doublet is expected to operate under artesian conditions within the Malm formation, with anticipated flow rates exceeding 50 liters per second (l/s) and fluid temperatures around 51°C.

The Malm formation, consisting of fractured and karstified limestones and dolomites, presents favourable permeability and hydraulic conductivity. These features are essential for sustaining high flow rates over extended operational periods while maintaining reservoir pressure through reinjection.

In parallel, a secondary reservoir has been identified in the Cretaceous carbonates. Although this formation is expected to yield lower temperatures (approximately 33°C), it could offer comparable or even superior flow performance. It is therefore being considered as a backup resource, potentially adding redundancy and operational flexibility to the geothermal system.

To better characterize reservoir behaviour and optimize system performance, a series of pumping and tracer tests will be conducted following well completion. These tests will provide critical data on parameters such as reservoir transmissivity, fracture connectivity, natural recharge rates, and thermal recovery potential. The outcomes will inform the long-term operational strategy of the doublet, including reinjection management and sustainable production planning.

In addition to assessing baseline performance, the testing phase will also evaluate the potential for seasonal thermal storage. Initial thermo-hydraulic and chemical modeling suggests that the Satigny 2&3 system could be adapted to store excess renewable heat produced in summer — such as waste heat from the incineration plant — by reversing the flow direction and injecting warm fluid into the reservoir. Over time, this could raise production temperatures in winter and enhance thermal output.

Altogether, the integration of real-time reservoir testing and dynamic thermal modeling will be instrumental in validating assumptions, refining plant operation, and determining the long-term geothermal potential of the site.

5. INTEGRATION INTO REGIONAL HEAT STRATEGY

The Satigny 2&3 geothermal doublet is designed to play a pivotal role in the GeniTerre district heating network, which currently supplies approximately 500 GWh/year of heat to the Geneva region. Today, this network relies on a combination of heat recovery from waste incineration (50%) and centralized natural gas boilers (50%). The Canton of Geneva has committed to expanding the network as part of its efforts to achieve carbon neutrality by 2050. This expansion is outlined in the Cantonal Energy Master Plan, with a key objective to increase the network's heat output to 1,000 GWh/year by 2030, reduce return temperatures to 40°C, and achieve an 80% renewable energy mix (see Figure 6).

The Satigny geothermal plant is the first large-scale geothermal heating facility developed under this strategy and is expected to play a central role in meeting the region’s renewable energy targets. Once operational, it will be integrated into the GeniTerre district heating network, providing a total thermal capacity of 7 MW (see Figure 7). This includes 2 MW of direct geothermal heat extracted from the fluid through a primary heat exchanger, and an additional 5 MW generated by a heat pump connected to a secondary exchanger. The heat pump will lower the reinjection temperature from 40°C to 20°C, thereby enhancing system efficiency and maximizing heat recovery.

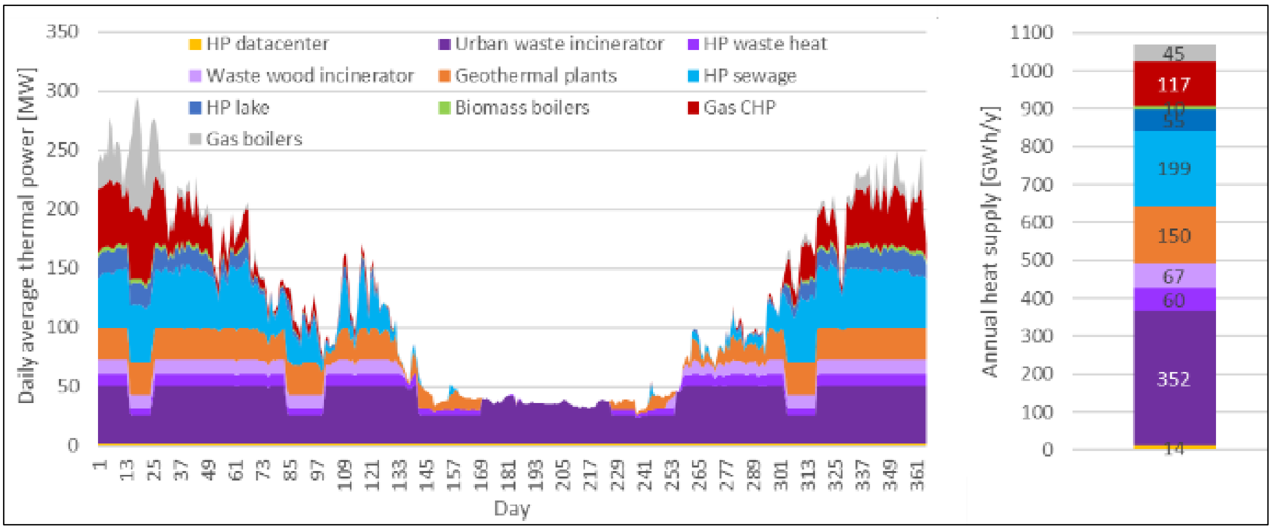

Figure 6: Daily (left) and annual (right) district heating supply projected for 2030, with 3 geothermal plants.

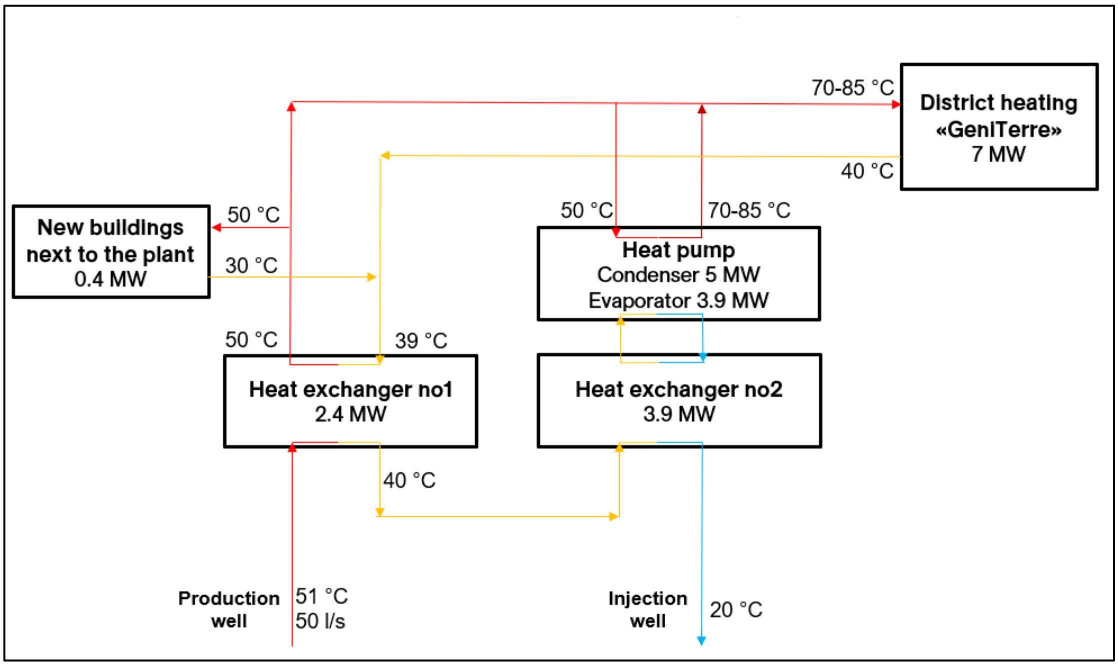

Figure 7: Simplified operating diagram of the future geothermal heating plant

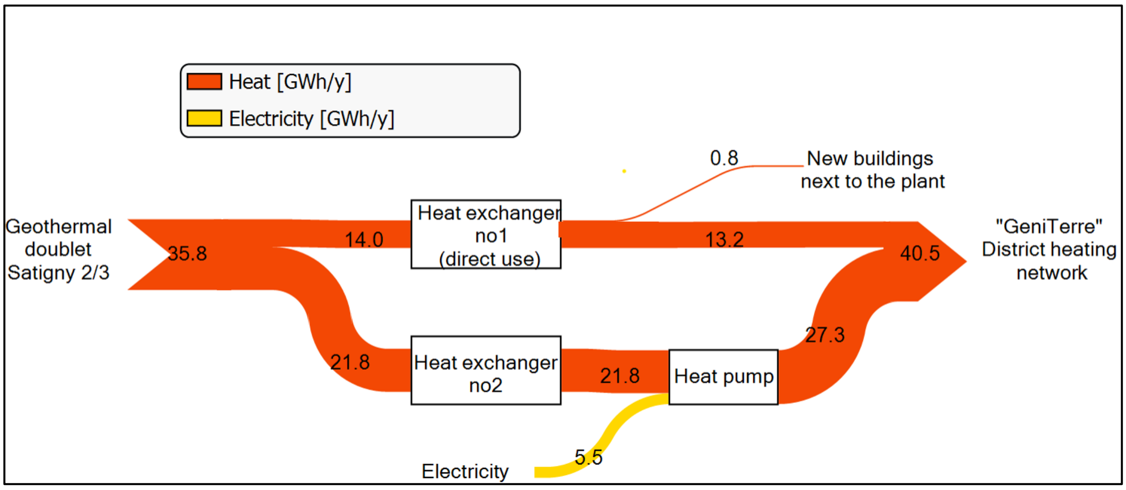

Figure 8: Energy flow chart of the future geothermal heating plant

Contribution to Carbon Emission Reduction

By replacing traditional natural gas-based heating systems, the geothermal plant will help avoid the emission of approximately 8,000 tons of CO2 per year. This reduction is a critical step toward meeting Geneva's ambitious decarbonization goals, and it supports the overall strategy to reduce reliance on fossil fuels for heating and increase the share of renewable energy in the district heating mix.

Seasonal Thermal Storage Potential

A further key aspect of the Satigny 2&3 geothermal project is the potential for seasonal thermal storage. The GeniTerre network currently faces challenges with underutilized waste heat during the summer months, particularly excess heat from the waste incineration plant. The Satigny geothermal doublet is designed with flexibility in mind, enabling it to reverse the direction of pumping and injection during the summer. Initial modeling suggests that by injecting excess thermal energy into the geothermal reservoir at temperatures around 69°C, the system could store this heat for use during the colder months, effectively raising the production temperature by approximately 10°C. This would result in an additional 2 MW of thermal output during the winter months, enhancing the system's efficiency and supporting its contribution to meeting seasonal heating demands.

6. FUTURE PROSPECTS AND REPLICABILITY

The Satigny 2&3 geothermal project marks a significant step in the development of geothermal energy in Geneva and serves as a model for similar projects across Switzerland and beyond. As the first large-scale industrial geothermal doublet targeting medium-depth aquifers in the region, it offers valuable insights into drilling techniques, reservoir management, and integration with district heating systems.

The lessons learned will directly support the deployment of additional geothermal plants in Geneva, with plans for at least two more by 2030, adding over 100 GWh/year to the region's capacity. This expansion will strengthen local energy security and grid flexibility.

The success of the Satigny project could also serve as a blueprint for other Swiss cantons and similar regions worldwide, demonstrating the feasibility of geothermal energy as a scalable and reliable solution for renewable heating systems. With its combination of innovative drilling, seasonal thermal storage, and urban integration, the project could pave the way for more cost-effective, efficient geothermal developments globally, contributing to the transition to a sustainable, low-carbon energy future.

7. CONCLUSIONS

The Satigny 2&3 geothermal development marks an important step toward expanding the role of geothermal energy in Geneva’s energy transition. While the project remains in the development phase, its design incorporates advanced drilling techniques, reservoir management strategies, and integration with urban energy systems — offering a solid foundation for future geothermal projects.

If confirmed by forthcoming drilling results and operational testing, Satigny 2&3 could significantly contribute to regional decarbonization goals and provide a replicable model for similar urban-industrial settings. The upcoming project phases will be crucial in validating the current geological and technical assumptions and in demonstrating the long-term feasibility of medium-depth geothermal energy in Switzerland.