Comparative validation of a novel commercial simulation tool for retrofit analysis of a GSHP system with solar PVT collectors

Summary

This study presents a comparative validation of OptCore, a commercial simulation tool for building energy systems, against TRNSYS for the retrofit analysis of a Swedish single-family house with a long-term operated ground source heat pump (GSHP) system. The case includes a baseline GSHP installed in 2011, a heat pump replacement in 2026, and the addition of a south-facing PVT array. Preliminary results show that the baseline system gradually loses performance due to borehole cooling. Replacing the heat pump improves seasonal performance but increases borehole loading, while adding PVT collectors improves seasonal performance and raises minimum brine temperatures through borehole regeneration. These preliminary results will be further assessed through comparison with a TRNSYS model under the same boundary conditions.

Keywords: photovoltaic-thermal, ground source heat pump, borehole regeneration, retrofit analysis

Field of application for the findings: solar heating and cooling systems for buildings

Addressed audience: researchers, practitioners, developers, building owners

1. Introduction

Buildings account for a large share of global final energy use and electricity consumption, which makes heating electrification a central part of building decarbonization strategies (IEA, 2022). In Sweden, heat pumps are particularly relevant because they can replace fuel-based heating with a technology compatible with a largely low-carbon electricity mix (Johansson, 2021). Ground source heat pumps (GSHPs) generally provide high efficiency, but in heating-dominated climates their long-term performance can deteriorate when annual heat extraction exceeds natural ground replenishment, leading to thermal imbalance and declining source temperatures (Karim et al., 2026).

Photovoltaic-thermal (PVT) collectors are a promising way to address this challenge because they can simultaneously generate electricity and recover low-temperature heat that can be used to support heat pump operation and regenerate the borehole field (Liravi et al., 2024; Sommerfeldt & Madani, 2019). Previous studies have shown that PVT-assisted GSHP systems can reduce long-term ground temperature degradation, improve seasonal performance, and lower borehole requirements, which is especially relevant in buildings where drilling area is constrained (Lee & Song, 2025; Liravi et al., 2024; Sommerfeldt & Madani, 2019).

However, the design of these systems depends heavily on simulation tools. TRNSYS offers high flexibility for modeling complex GSHP and PVT systems, but its use in early-stage decision making is limited by model complexity and setup time, while more user-friendly commercial tools remain less documented and less validated in the literature (Olausson & Wernius, 2021; Persson et al., 2016). This study addresses that gap by evaluating a new commercial tool, OptCore, for a long-term GSHP retrofit case, comparing its results with the same model built in TRNSYS.

2. Methods

The analysis is based on a single-family house model adapted from previous TRNSYS studies and representative of Swedish residential buildings (Castañeda Rodas, 2025). The case study corresponds to a single-family house in Stockholm with a heated floor area of 140 m², an annual space heating demand of

16,100 kWh, an annual domestic hot water demand of about 2,900 kWh, and a vertical borehole system.

The study follows a realistic long-term retrofit approach. The initial system consists of a GSHP installed in 2011 and sized to cover 65% of the peak heating demand, reflecting common historical design practices. After 15 years of operation, the heat pump is replaced in 2026 with a new unit sized to cover 75% of the peak demand. In the final configuration, a rooftop PVT array is integrated into the system alongside the new heat pump. Three incremental PVT array sizes are considered: 5, 10 and 15 collectors.

The systems are simulated over a long-term horizon using OptCore, considering building demand, heat pump performance, and borehole thermal behavior. Key performance indicators include seasonal performance factor (SPF), auxiliary heating demand, borehole temperature evolution. The complete study includes a comparative validation against TRNSYS, analyzing both system-level performance and component-level modeling differences, particularly in the representation of borehole heat transfer. However, only OptCore results are presented in this extended abstract.

3. Preliminary results

Tab. 1, Fig. 2 and Fig. 2, show a clear shift in system behavior after the 15-year retrofit. In the baseline case, the borehole is gradually depleted by long-term heat extraction, which is reflected in a slowly declining inlet brine temperature and persistently high purchased electricity. Replacing the old heat pump with a larger modern unit improves the 2035 SPF from 3.17 to 3.83, but it also intensifies the thermal load on the ground, reducing the minimum brine temperature to −2.6 °C.

Tab. 1: Values for 2035 for the baseline and retrofit configurations for seasonal performance factor and minimum brine temperature.

Indicators	Baseline	New HP	New HP + 5 PVT	New HP + 10 PVT	New HP + 15 PVT
Seasonal performance factor [-]	3.17	3.83	4.07	4.15	4.20
Minimum brine temperature [°C]	-1.3°C	-2.6	-1.7	-1.5°C	-1.2

Fig. 2 makes this trade-off particularly clear. After the retrofit year, the new-HP-only case drops below the baseline in inlet brine temperature, indicating higher heat extraction from the borehole. In contrast, all PVT-assisted cases reverse that trend. Moving from the 5-PVT to the 15-PVT configuration progressively raises the inlet brine temperature and keeps it well above the baseline, which is consistent with effective borehole regeneration and improved evaporator source conditions.

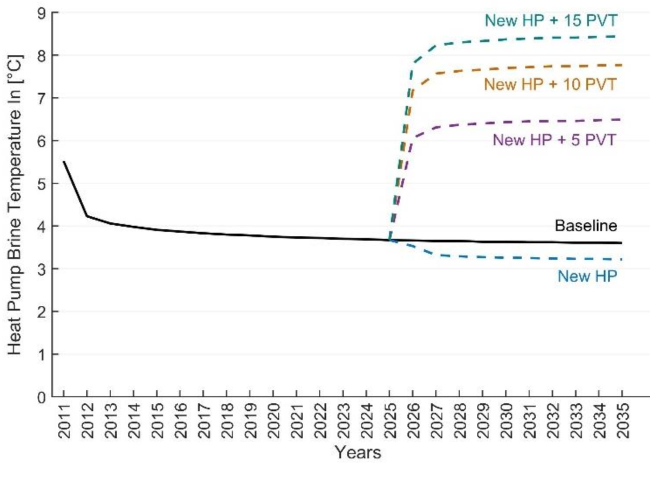

Fig. 1: Mean heat pump brine temperature evolution under baseline and retrofit scenarios

The lower graph shows the corresponding effect on purchased electricity. The new heat pump alone yields a modest reduction relative to the baseline, whereas adding PVT leads to a much larger drop in annual purchased electricity. The 15-PVT case gives the lowest demand, while the 10-PVT and 15-PVT cases are already relatively close to each other, suggesting diminishing marginal gains as collector coverage increases. This pattern is also reflected in the SPF values in Tab. 1 , which increase from 3.83 for the new heat pump alone to 4.20 in the 15-PVT case.

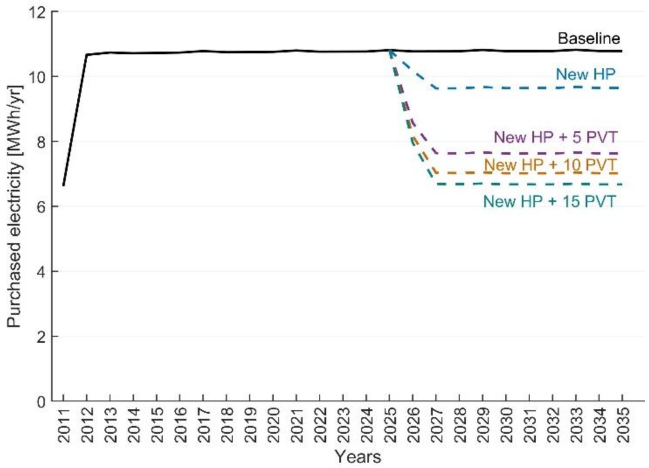

Fig. 2: Annual purchased electricity evolution under baseline and retrofit scenarios

Overall, the preliminary results indicate that OptCore captures the expected physical trends of stronger ground loading after heat pump upsizing and progressive recovery when PVT is added. The results also suggest diminishing marginal improvements at higher PVT coverage. In the full paper, these trends will be examined through comparison with an equivalent TRNSYS model under the same boundary conditions.

4. References

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