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SOLAR-ASSISTED FOUNDATION BASED GEOTHERMAL ENERGY SYSTEM PERFORMANCE ASSESSMENT

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ABSTRACT

Unlike conventional geothermal systems, foundation-based energy systems integrate structural support and geothermal energy extraction into a single, unified design. It acts as a ground heat exchanger while also functioning as a structural element, such as a caisson or pile. These systems are embedded within the concrete foundation and contain pipes that are connected to a heat pump in the building that circulates a heat transfer fluid, typically a water-antifreeze mixture. Depending on the season, the fluid either absorbs heat from the ground (for heating) or releases heat into the ground (for cooling). This integration not only saves space but also reduces installation costs, making these systems both cost-effective and space-efficient. The thermal caisson (TC) is a newly developed geothermal energy system that relies on phase change material (PCM) within its foundation to enhance thermal performance. The inclusion of PCM as a backfill addresses challenges such as efficiency degradation. This work builds on previous research, which focused on the performance assessment of a PCM-integrated foundation-based geothermal energy system. It extends the analysis to include the integration of a solar collector for enhanced energy recovery and system efficiency.

This study models a hybrid solar-assisted foundation-based geothermal energy system that incorporates phase change materials (PCMs) as backfill using TRNSYS software. The system is evaluated for residential buildings ranging from 150 to 300 m^2 in size located in Ontario, Canada. Various scenarios are explored by adjusting the TC configuration (depth, spacing, and count) and other design parameters, such as collector area and PCM quantity. The study considers collector areas ranging from 2 to 60 m^2, TC counts from 1 to 12, and heat pump capacities between 6.7 and 40 kW. A sensitivity analysis and optimization framework are developed to enhance system efficiency. The goal is to identify the optimal configuration for maximizing energy savings, system efficiency, and cost-effectiveness.

Preliminary results indicate that the BIPV/T collector area substantially impacts the accumulated energy consumption over the system's lifetime, with a standardized sensitivity coefficient of -0.813. This negative influence indicates that increasing the collector area significantly reduces electricity consumption, which is logical because higher electricity generation leads to reduced grid dependency. The number of TC is the second most influential factor, with a standardized sensitivity coefficient of 0.384. This work provides a valuable picture for designing energy-efficient and cost-effective foundation-based geothermal energy systems, particularly in heating-dominated climates. It advances how renewable energy is incorporated into building applications.