Building decarbonization applications from the subsurface: Calgary building developers are leaning into geothermal technologies

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Introduction

While many geoscientists are familiar with the importance of their practice in the exploitation of conventional geothermal resources, the spectrum of geothermal technologies that include geoexchange is rarely given serious thought by subsurface professionals. Various practitioners in Alberta have sought to emphasize the importance of geoscientific study for the efficient exploitation of low enthalpy energy resources, including commissioned works by the Alberta Geological Survey (Grobe et al., 2009). In collaboration with a major real estate developer in Alberta – Telsec – the Energi Simulation Centre for Geothermal Systems Research (GeoS) at the University of Calgary is extending this work by conducting a multidisciplinary demonstration project to prove the efficacy of closed loop geoexchange systems for multi-family and mixed-use communities while developing a system to provide thermal energy balance in the shallow reservoir.

GeoS consists of practitioners, researchers, students, and industry market makers. The goal of GeoS is to realize “geothermal anywhere” and expand the applicability of geothermal to cold climates and warm sedimentary basins away from plate margins. Geoexchange in the form of closed loop vertical systems (BHEX) is one method of implementation that could offer significant decarbonization opportunities for developers and building portfolio managers, while enhancing economic conditions by leveraging local resources. At scale, these resources can serve Thermal Energy Networks (TEN) – often called district heating and cooling – across entire neighborhoods, in rural and urban centers, reducing the combustion of fossil fuels for space heating and domestic hot water (DHW) needs across the province.

Motivation

In cold climates like Alberta, where there is a significantly longer heating season than the cooling season, borehole arrays serving many structures will tend towards imbalance over time. Annual building load imbalances can cause long-term ground temperature changes from heat accumulation or depletion in the ground, leading to significant reduction in system efficiency and eventually premature system failure (Fine et al., 2018). To overcome this imbalance and improve BHEX sustainability, the energy system or the building envelopes can be modified. Building envelopes are most appropriate for modification at the outset of a design effort. After construction, and often during design, it may be found more economically feasible to create bivalent energy systems. Bivalent energy systems are hybrids. In such systems, much of the thermal load can be met by one source/sink combination – such as geoexchange – while the remainder is met by another – such as solar thermal (PVT). Additionally, excess energy from one system may be dumped into the other for seasonal storage. In this work, working with a local property developer, the potential of using a low enthalpy solar thermal PVT system to improve the long-term performance of a vertical borehole geoexchange system is being considered.

Method / Workflow

Telsec, in cooperation with GeoS, is testing univalent and bivalent borehole thermal energy systems using a field scale experimental set up and numerical modelling approaches. The univalent designs will be standard 1.25" u-tube high-density polyethylene (HDPE) pipe to a depth of 500 ft or 150 m, inside 6" or 152 mm boreholes. Bivalent systems will include low temperature solar thermal collectors and a conventional u-tube inside of 7" or 178 mm boreholes to the same depth, coupling with the building heating, ventilation, and air-conditioning (HVAC) equipment. Bentonite grout with an expected thermal conductivity, λ, of 1.5 W/m.K will couple formation materials to the HDPE.

For the experimental test platform, the energy load comes from a 10' by 45' trailer. The resulting load is met by a 3-ton heat pump coupled to BHEX. The ground temperature distribution in the BHEX region would be monitored using thermocouples positioned at different distances and depths. The fluid temperature entering and leaving the BHEX as well as the flow rate would be monitored using temperature sensors and flow meters connected to a data acquisition system.

The building energy models are developed in OpenStudio, using EnergyPlus for the trailer to be used in the experimental tests. Figure 1 shows the profile of the hourly building energy heating load requirement of the trailer. A heat pump coupled with a geoexchange system will be used to supply the building heating required by the trailer for thermal comfort.

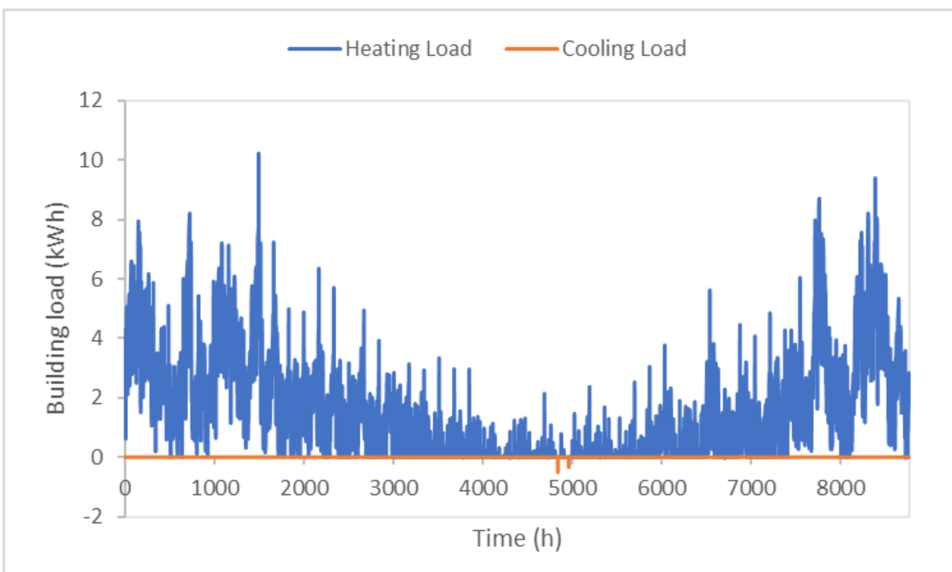

Figure 1 Hourly load profile of test site building, given insulation properties and a typical meteorological year in Alberta.

Using the building energy profile, we estimate the capacity of the water source heat pump to be 3 tons. Besides, it is evident that this is a heating dominant load with the heating load representing more than 90% of the total load in preliminary simulation. To mitigate thermal saturation in the ground, we will inject heat from a solar thermal system at the rate required to seasonally balance the BHEX. Proper control systems for a PVT solar thermal collector and a low-cost thermal storage device are intended to meet this objective. Preliminary analysis of a PVT collector for the system indicates the need for 20 m^2 of surface area at a tilt of 45°, south-facing provides the necessary thermal load to ensure a balanced system.

Ongoing Work

A field-scale test platform is being designed for installation and eventual system monitoring at a site in southeast Calgary. Experimental results from the data acquisition system will be used to validate a numerical model to determine long-term performance and characterization of the system. Moreover, the result from this field-scale test platform may be extended to the design of a broader system for a suburban community. This project is intended to culminate in distributed TENs serving structures from multiple borehole arrays. GeoS will use the results to begin mapping efforts for system feasibility throughout Alberta, identifying energy system design techniques for given subsurface conditions.

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