

Accelerating Geothermal Development in Canada with Advanced Geothermal System (AGS) Technology

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Summary

Canada has committed to reach net zero emissions by 2050 and cut emissions by at least 40-45% below 2005 levels by 2030. The country has abundant geothermal potential with high-temperature geothermal resources in the western area along the Garibaldi, Northern Cordillera. Recent electricity generation projects have been along the Garibaldi Volcanic Range and in Alberta, Saskatchewan, and British Columbia areas, but much more geothermal energy is needed to reach net zero emissions. Until now, geothermal projects have been risky because conventional geothermal technology requires encountering commercial permeability, temperature, and benign fluids. Also, geothermal projects are capital-intensive, and many exploration drilling projects experience low success rates. GreenFire Energy Inc. (GreenFire) has been developing its versatile Closed-Loop Geothermal (CLG) technology called GreenLoop (GreenLoop), an Advanced Geothermal System (AGS), that addresses the shortcomings of conventional geothermal technology and has the unique capability to leverage idle and unproductive wells and de-risk any drilling activity. GreenFire's GreenLoop™ consists of a downbore tube-in-tube (co-axial) heat exchanger that circulates large volumes of a working fluid. The working fluid returns at elevated temperatures to the surface through a vacuum-insulated tubing (VIT) and can be flashed to produce power in an existing steam condensing power plant or an Organic Rankine Cycle (ORC) power-generating system. Aside from power generation, the hot working fluid can be directly used for space heating/cooling and other industrial applications. GreenLoop only extracts heat and conserves mass and pressure in the reservoir, thus ensuring the long-term sustainability of the geothermal resource. GreenLoop has the potential to dramatically expand power production from geothermal resources where conventional geothermal technology is challenged and from idle and unproductive wells.

Introduction

In Canada, geothermal energy is currently utilized mainly for direct use applications like space heating (via ground source heat pumps) and for bathing and swimming (Thompson et al., 2021). However, Canada has abundant geothermal potential with high-temperature geothermal resources in two main regions, namely, (1) the Garibaldi volcanic belt in southwestern BC, an active subduction margin between the Juan de Fuca and Pacific Plates, and (2) Northern

Cordilleran Volcanic Province, in northwestern BC and encompassing most of the Yukon Territory that is a product of continental rifting from within the North American plate (Thompson et al., 2021). Aside from these two volcanic regions, the Western Canada Sedimentary Basin (WCSB) is a deep, vast sedimentary basin hosting moderate temperatures.

Recently, the 21 MW South Swan Hills Hybrid Power Project in Alberta, consisting of an Organic Rankine Cycle (ORC) turbine, which captures geothermal heat from the production fluid, and a Natural Gas Turbine (NGT), commenced operations in September 2022 for the NGT while the ORC unit began operations in January 2023 ([Co-produced geothermal power project in Swan Hills, Canada starts operations \(thinkgeoenergy.com\)](#)). Thompson et al. (2021) reported that other high-temperature prospects being explored now are Canoe Ranch, Lakelse Lake and Pebble Creek in BC, Fort Liard in the Northwest territories, Ross River in Yukon Territory, Estevan in Saskatchewan and Condor and Greenview County in Alberta.

The GreenLoop Closed-Loop Geothermal Technology

Since 2014, GreenFire has been developing its AGS closed-loop geothermal technology. GreenFire's GreenLoop™ (GreenLoop) is a novel downbore heat exchanger (or DBHX) technology that typically requires a single well and no injection well to dispose of any effluent. The GreenLoop system circulates a selected working fluid through the DBHX to absorb and transport heat from the geothermal fluids entering the wellbore (Higgins et al, 2019). As the technology extracts thermal energy only, reservoir mass and pressure are conserved thus ensuring long-term sustainability of the resource. GreenLoop is designed to deliver targeted pressures, temperatures and flow rates for both conventional steam-flash turbines and ORC binary power plants. GreenFire's patented GreenLoop designs promote near-wellbore convection and leverages convective heat transfer for sustainable heat extraction.

GreenLoop can have different architectures, and the most common configuration used is the tube-in tube coaxial heat exchanger as described in this paper (Figure 2). The coaxial GreenLoop configuration consists of a typical liner with a plug at its bottom and a VIT inside. As previously mentioned, a working fluid is circulated inside the coaxial configuration by injecting it cold and producing it hot after extracting the heat energy from the geothermal fluids entering the wellbore. The geothermal resource is allowed to flow around the liner and may be co-produced to the surface especially if its high enthalpy steam. The VIT prevents significant thermal degradation of the heated working fluid as it ascends the well.

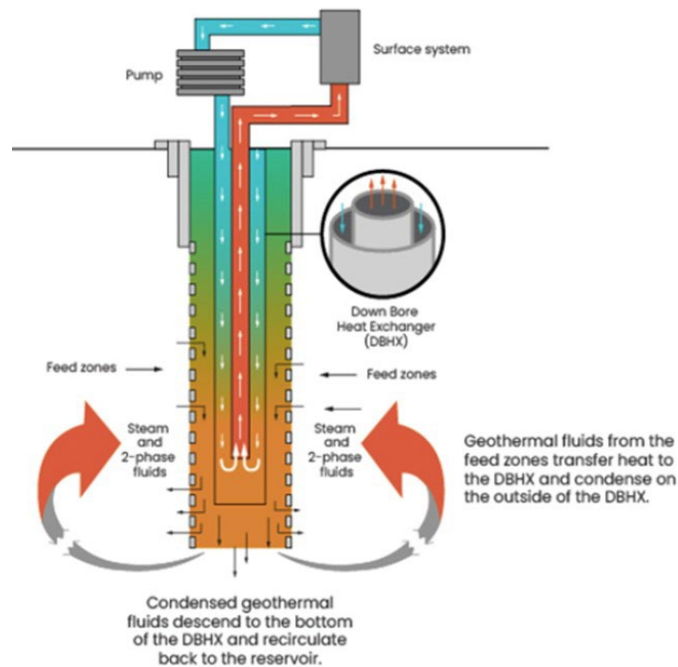


Figure 2. Schematic diagram of a single-well GreenLoop for steam- and two-phase-dominated geothermal systems. Although not depicted, the GreenLoop system hung from the wellhead. Cold and hot fluids flow in the annular region and the center vacuum insulated tube, respectively. Steam from the reservoir condenses and flows downwards in the well as depicted by the arrows below the DBHX. The condensed fluid is allowed to recycle back into the reservoir to gain heat and supply the DBHX or other wells in the resource.

The GreenLoop working fluid can either be water, organic hydrocarbons, refrigerants or supercritical carbon dioxide (sCO₂). Chandrasekar et al. (2023) reported the pros and cons of using water, sCO₂ and organic hydrocarbons as GreenLoop working fluid - each working fluid has advantages (and disadvantages) with regards to power generation and capital cost. Lastly, GreenLoop can be operated either in forward or reverse flow (Figure 3). In forward flow, the cold GreenLoop working fluid is injected into the VIT and it is harvested hot through the annulus of the VIT and the plugged liner. For reverse flow, the cold GreenLoop working fluid is injected in the annulus and harvested hot from the VIT. The reverse flow is typical when the working fluid is water as it allows better control on the required discharge pressure of the GreenLoop working fluid. Conversely, the forward flow is better suited when the working fluid is either organic hydrocarbons or sCO₂.

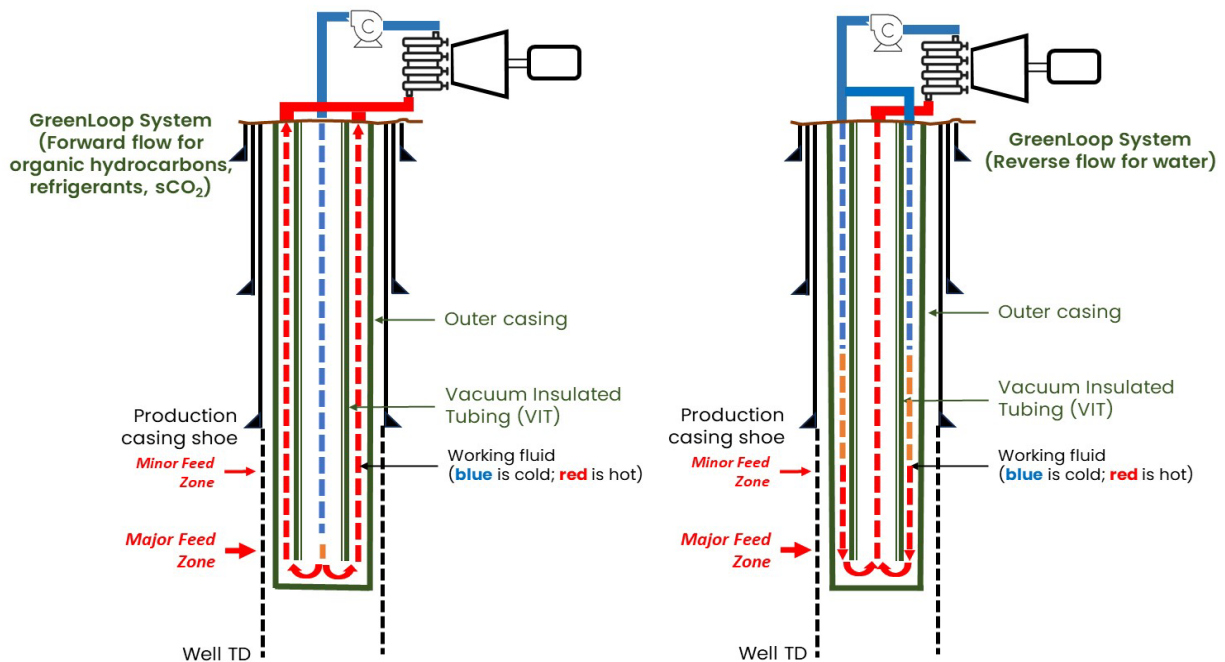


Figure 3. Schematic diagram of forward (left) and reverse (right) flow modes in the GreenLoop system. Each flow configuration is suitable for certain GreenLoop working fluid.

Observations and Conclusions

GreenFire successfully field-tested its GreenLoop technology at the Coso geothermal field in California, U.S.A. in 2019 under the auspices of the California Energy Commission (CEC). Another field test in a hot dry rock system was successfully conducted in 2021 with a private Japanese company. GreenFire's projects have resulted in the following conclusions:

- Conduction-only systems require vast surface area for commercial power generation.
- GreenLoop designs that induce convective heat flow boost power generation and reduce the need for surface area (which is the target for conductive heat extraction AGS), and that near-wellbore and interzonal communication mechanisms (crossflow, downflow, etc.) are critical to promote convection.
- Greenloop systems can operate in a much wider range of resource temperature, pressure, and permeability than conventional hydrothermal projects. Applications can range from relatively low-temperature to hot dry rock systems.
- Mature geothermal fields that have experienced significant reservoir pressure and resource mass decline contain many unproductive and/or idle wells and stranded infrastructure. GreenLoop can still extract heat from these wells (including played out oil and gas wells that are relatively hot) and reuse existing facilities.

- As all geothermal drilling activity (e.g., exploration, appraisal, development, production make-up, expansion/step-out, etc.) have inherent risks and uncertainties, GreenLoop can be used to de-risk drilling wells. If wells do not encounter commercial permeability, installing GreenLoop can still make the well profitable. With GreenFire’s specialized modeling techniques, the net power from GreenLoop can be predicted accurately.

Additive Information

CLG technologies are in their early commercialization stages. Applications accessing permeable layer geothermal resources can incorporate down-hole heat exchangers (DHX), apply different concentric pipe-in-pipe architectures, or use single or multi-lateral wellbore configurations to connect inlet and outlet wells in sealed U-Loop systems. CLG energy systems can also access the vast, untapped heat in deeper and hotter rocks, greatly expanding available worldwide geothermal resources. In addition to electric power generation from both new and retrofit geothermal and oil and gas wells, promising applications of CLG systems can provide direct heat and cooling, enhance hydrogen production, improve lithium extraction from geothermal brines, and desalinate water, all while significantly reducing global GHG emissions.

CLG systems can make significant contributions toward satisfying global energy and environmental needs. Overall:

- Advanced technologies are essential to supply clean energy and reduce greenhouse gases.
- Electricity is the world’s most versatile form of energy.
- Reliable, renewable, climate-resilient, and environmentally preferred geothermal energy provides clean, continuous heat and electric power.
- Innovative, closed-loop geothermal systems can access previously unavailable, abundant high energy resources and deliver secure, sustainable carbon-free energy at competitive costs.

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