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Evaluating the Potential for Geothermal Energy Extraction from Depleted Gas Wells in British Columbia

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INTRODUCTION

As global energy demand rises and jurisdictions move to reduce fossil-fuel use, new low-carbon energy sources are essential. Geothermal energy is a renewable, abundant resource with low environmental impact (Qiao et al., 2024). Intermediate-depth systems (1–3 km) are particularly attractive for space heating of community buildings and agricultural facilities in cold regions, even where surface geothermal gradients are modest. Deep oil and gas wells often intersect warmer subsurface temperature gradients, making them promising candidates for geothermal heat extraction for direct heating or, where temperatures allow, electricity generation (Qi et al., 2024). End-of-life wells may be converted into wellbore heat exchangers for geothermal energy extraction. There are millions of inactive (suspended, abandoned, and orphaned) oil and gas wells in Canada and the United States that are placing a burden on the environment, climate, society, and the economy (Kang et al., 2023). Repurposing these wells can both generate revenue for operators and defer or reduce costly plug-and-abandonment (P&A) liabilities (Boutot and Kang, 2025).

The extent of geothermal energy production varies depending on well depth and geothermal gradient of the area. Low-temperature geothermal systems may only provide energy for space and water heating (Weijermars et al., 2018), whereas high-temperature systems may be used for electricity production (Michaelides, 2016). The temperature of the heating fluid (i.e., the working fluid exiting the borehole) depends on several parameters such as geothermal gradient, well depth, rate of circulation, and the temperature of the fluid entering the borehole. Therefore, the feasibility of repurposing oil and gas wells must be determined on a case-by-case basis. The wealth of subsurface data from previous drilling, including geophysical, lithological, and thermal information, can provide a valuable foundation for preliminary energy performance estimations. This approach minimizes exploration risks and enables a more accurate cost-benefit analysis (Jello and Baser, 2023).

The objectives of this study are to map the locations of most inactive wells across British Columbia, Canada and assess the potential for geothermal energy production at well sites.

1 Geothermal energy extraction approaches and study area

For the extraction of geothermal energy from deep wells, there are two general methods, open-loop and closed-loop systems. In an open-loop system (Figure 1a), the production and circulation of hydrothermal fluids pose risks such as corrosion, scaling, and damage to casing and instrumentation, as well as environmental concerns including fluid dispersion, subsidence, and induced seismicity (Chen et al., 2020).

Closed-loop systems avoid groundwater use, instead circulating a chosen thermal fluid through a ground heat exchanger. This fluid exchanges heat with the surrounding rock primarily by conduction before releasing it at the surface (Brown and Falcone, 2023). The advantage of closed-loop systems is their flexibility; they can be installed in any terrain, unlike open-loop systems that require a reliable water source (Chen et al., 2020). Therefore, closed-loop systems can be considered as a better option due to their lower environmental impact and less scaling concerns, compared to open-loop systems.

Closed-loop geothermal extraction systems, typically implemented with two techniques: U-tube or double-pipe (twin-pipe) heat exchangers, provide a practical path to convert wells into heat sources. In U-tube installations, a U-shaped tube is placed in the wellbore and the space between the U-tube and the well is filled with a material chosen for its thermal conductivity to improve heat transfer (Figure 1b). In the double-pipe approach, the existing casing becomes the outer pipe and the tubing the inner conduit; a working fluid is circulated down the annulus and returns through the tubing, extracting heat from the formation (Figure 1c). Design options (insulation,

material conductivity, working fluid selection) govern thermal performance and application (direct heating versus conversion to electricity).

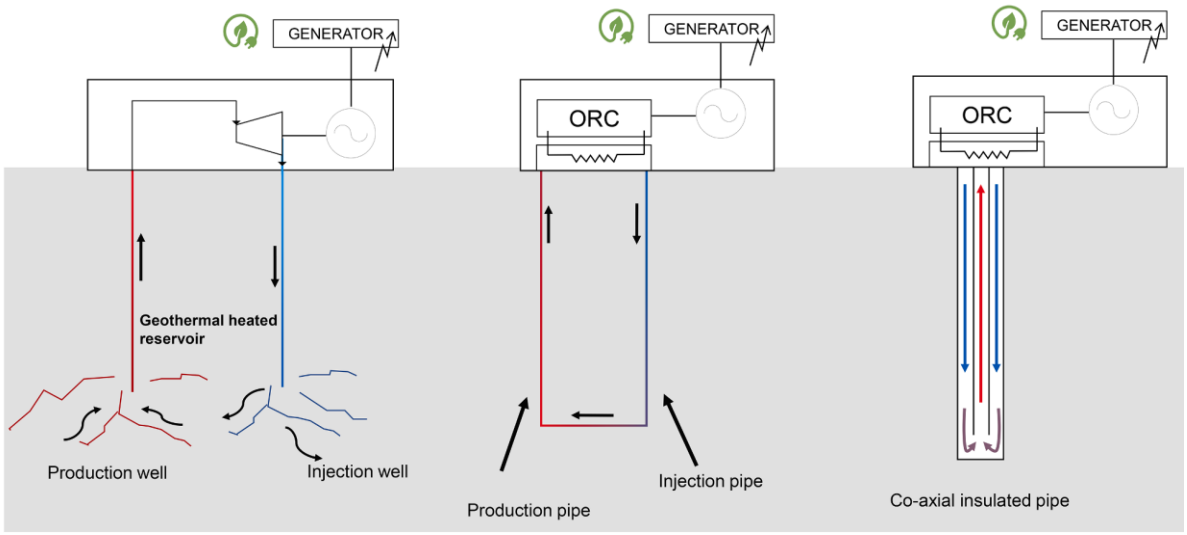


Figure 1. (a) Open-loop geothermal system; (b) U-tube closed-loop geothermal system with a closed path for the fluid; (c) Double-pipe closed-loop geothermal system, with the inflow in the external annulus and the upward flow in the inner pipe (Facci et al., 2024).

This study focuses on energy challenges in British Columbia (BC), where the past 2 decades have nearly exclusively developed horizontal unconventional gas wells. The Western Canada Sedimentary Basin in Northeast British Columbia (NEBC) includes two of the largest shale gas formations in Canada, the Montney and Horn River Basin shales (Ferguson and Grasby, 2018). There are ~30,000 wells in NEBC, with ~10,000 drilled in the period 2005-2019. Repurposing of wells in this region has not only economic considerations, but also social and cultural impact. Communities are remote, comprising agricultural and Indigenous: geothermal energy is one route to advancing energy independence. Blueberry River First Nation traditional territories cover much of the NEBC Montney developments (Figure 2). These wells typically show a short high-production period followed by long low-production tails, leaving many wells suspended or near retirement. Current BC data suggest on the order of 5,000 suspended wells that could be repurposed for geothermal use with modest surface construction. The prevalence of pad drilling in NEBC, meaning 5–30 wells from a single surface pad, reduces surface infrastructure needs and improves the economics of geothermal retrofits by concentrating wells and simplifying operations.

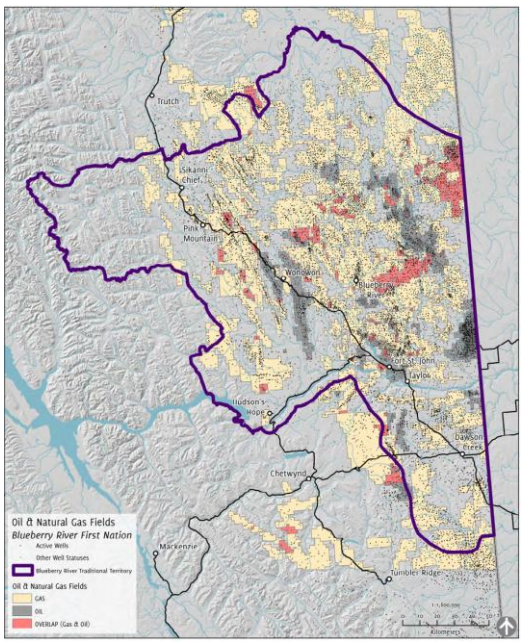


Figure 2. Oil and natural gas in Blueberry River First Nation Traditional territories, NEBC (Macdonald, 2016).

2 Operational strategies, mapping, and implications

To maximize long-term performance, we recently assessed both continuous and intermittent extraction strategies (Perser and Frigaard, 2022). Intermittent operation, alternating production with recovery periods (e.g., six months off), allows heat to diffuse back into the borehole wall and surrounding rock, sustaining higher extraction rates and higher borehole wall temperatures than continuous operation over multi-decadal horizons. Modeling results over a 30-year horizon showed that intermittent modes maintain better thermal recovery and that the performance gap between intermittent and continuous extraction increases with time. With pad-drilled wells there are evidently options for alternating wells in operation and those in thermal recovery.

Currently, we produce a geothermal map for BC using well temperature profiles and analyze a representative set of pad-drilled wells in NEBC with mathematical models focused on the closed-loop systems, both double-pipe and U-tube extraction methods. Both continuous and intermittent scenarios are evaluated to quantify long-term heat yields and recovery. Converting suspended and inactive oil and gas wells into closed-loop geothermal systems offers dual benefits: deferring P&A costs and liabilities while enabling local renewable heating (and potentially power) solutions. This pathway supports risk-informed reuse of subsurface assets and advances BC's role in the clean energy transition.

CONCLUSION

This study highlights the significant potential for repurposing inactive oil and gas wells in British Columbia as geothermal heat sources through closed-loop systems. By leveraging existing well infrastructure and extensive subsurface data, the approach minimizes exploration risks, environmental impacts, and P&A liabilities. Closed-loop designs such as U-tube and double-pipe systems provide flexible and sustainable options for community and agricultural heating in cold regions, even under moderate geothermal gradients. Mapping and modeling results indicate that strategic use of intermittent operation can enhance long-term performance and thermal recovery. Overall, converting inactive wells into geothermal systems presents an economically and environmentally viable opportunity to advance BC's clean energy transition while supporting local development and the adoption of sustainable energy.

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