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Unlocking Dual Potential: Is Co-Production of Lithium and Geothermal Energy Feasible for Devonian Brine in Alberta?

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INTRODUCTION

Thanks to advances in direct lithium extraction (DLE) technologies, lithium (Li)-bearing Devonian brines in the Alberta basin (Figure 1) have emerged as promising resources to support Canada's energy transition. However, for low- to moderate-grade brines ([Li] = 38–140 mg/L), DLE alone does not guarantee a low-carbon supply, because brine production on the order of 10^7 m^3/year must be achieved by lifting from depths of up to several thousand meters, and reinjecting underground after processing (Peng et al., 2026). At the same time, these reservoirs can reach formation temperatures (T_{FM}) up to 133 °C, implying substantial geothermal energy could be wasted, particularly where T_{FM} exceeds the optimal surface temperature window for DLE process (50–80 °C). Co-producing geothermal energy with Li extraction could, in principle, improve both the environmental and economic performance of standalone DLE projects. Yet, despite growing interest, no commercial-scale DLE project has been realized in such settings, and key uncertainties remain regarding required resource conditions, market constraints, economic outcomes, sustainability gains, and appropriate geothermal utilization strategies.

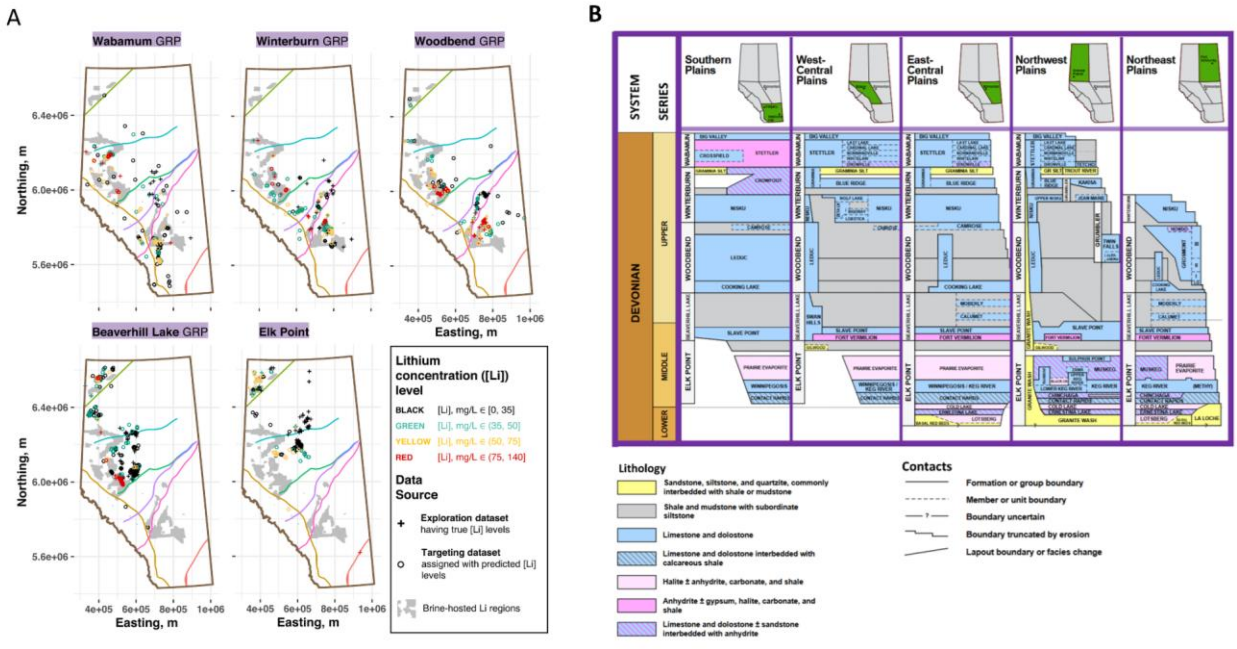


Figure 1. Overview of Devonian lithium-bearing brines in Alberta. (A) Observed and predicted lithium concentration ranges and spatial distributions across five Devonian formation groups (modified from Peng et al. (2025)). (B) Stratigraphic framework of Devonian units (modified from Alberta Geology Survey (2019)).

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METHODS & RESULTS

Data and methods

We first compiled [Li] and T_{FM} datasets for Devonian brines in Alberta from recent sources (Brinsky et al., 2022; Lyster et al., 2022; Reimert et al., 2023; Peng et al., 2025). The T_{FM} dataset was then joined to the [Li] dataset using the unique well identifier (UWI), providing estimated T_{FM}, true vertical depth (TVD_m), and the elevation of kelly bushing (KB_el_m28, meters above sea level) for each well. Missing values for TVD_m, KB_el_m28, field name, and pool name in this merged dataset were subsequently filled using the GSC in-house database wherever sufficient information was available.

The optimal operating temperature for DLE is assumed to be 70 °C. To retain only records with sufficient geothermal headroom after heat losses, records with T_{FM} <75 °C were excluded, as they cannot deliver usable geothermal energy for co-production. Records missing latitude–longitude coordinates, geological unit, field name, [Li], potassium or sodium concentrations, or T_{FM} were also removed. The resulting cleaned dataset is referred to as DF_Dev.

Within DF_Dev, wells belonging to the same field and geological unit, and exhibiting similar TVDSS_m (referenced to sea level) and consistent geochemical characteristics, were treated as representing a single hydrogeological system. For each system, corresponding reservoir realizations from our prior Monte Carlo simulations (Peng et al., 2026), parameterized by [Li], T_{FM}, and TVD, were selected to evaluate lithium–geothermal co-production at a constant brine circulation rate of 5.66×10^7 m³/year (reflecting the industrially relevant flow range).

Two geothermal utilization pathways within the DLE project framework were assessed from technological, environmental, and economic perspectives: geothermal heat recovery (GHR) and binary-cycle based geothermal power generation (GPG). Their utilization feasibility was then evaluated in relation to three regional demand indicators: population density, electricity-demanding facilities, and the number of farms (as a proxy for agricultural heat use). In the end, the integrated results were provided for assessing where DLE–geothermal co-development is feasible and sustainable.

Results

The DF_Dev dataset consists of 113 records from 94 distinct wells, which collectively delineate 17 prospective lithium-bearing brine locations extending from Northwest to Southeast across Alberta (Figure 2A). These wells exhibit substantial variability in resource quality (Figure 2B-D), with measured [Li] ranging from 30.5 to 140 mg/L, T_{FM} around 75 to 122 °C, and TVD_m between 1,777 and 3,860 m. The Leduc and Swan Hills formations dominate the sampled intervals, reflecting their regional geological prominence and historical fluid sampling density.

Of the 17 identified locations, 12 possess corresponding subsurface realizations within our prior Monte Carlo simulation framework (Peng et al., 2026), enabling quantitative evaluation of Li–geothermal co-production potential. Using the baseline engineering parameters in Peng et al. (2026), these realizations yield diverse production profiles. Geothermal power generation is highly site-dependent, with simulated outputs spanning 0 to 18.5 MW (refer to Figure 2E), while recoverable geothermal heat ranges from 9.76×10^5 to 8.06×10^6 GJ/year (Figure 2F). Modeled lithium carbonate equivalent (LCE) output ranges from 1.33×10^4 to 3.79×10^4 t/year (Figure 2G), reflecting the combined influence of feed brine [Li], extraction efficiency assumptions, and volumetric throughput.

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The thermal characteristics of the reservoirs dictate utilization pathways: locations 5, 6, 7, 8, 9, 10, and 13 possess sufficient fluid temperature gradients to support both GHR and GPG, whereas locations 3, 4, 11, 16, and 17 are restricted to direct heat utilization due to their lower enthalpy conditions.

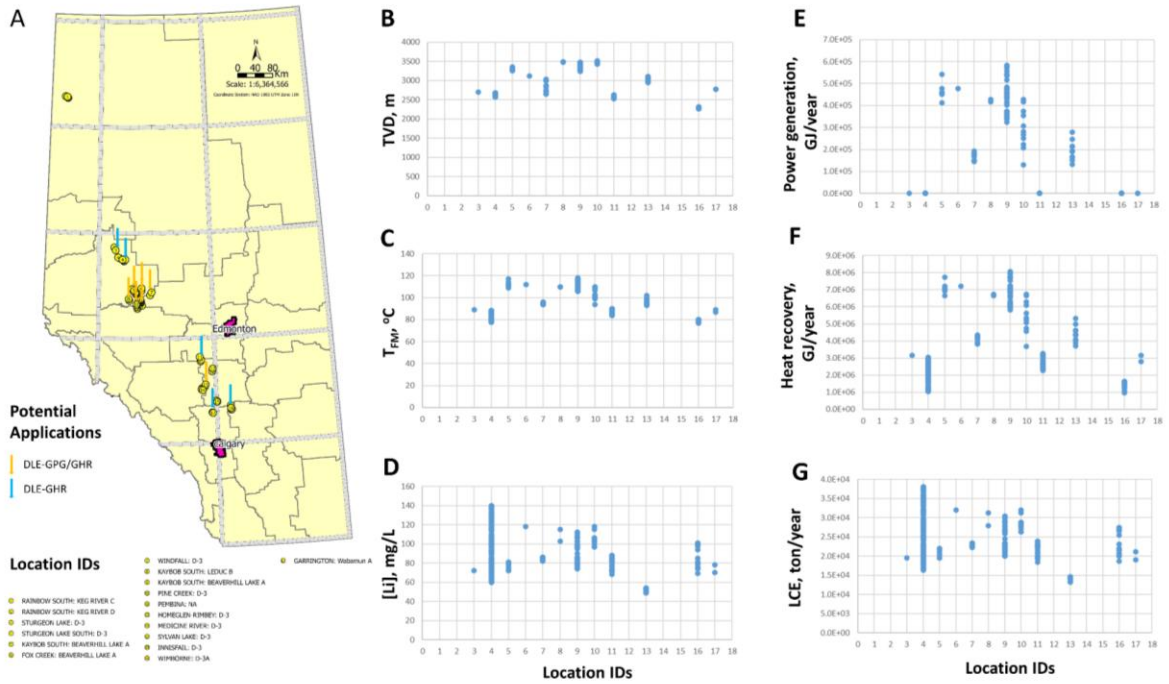


Figure 2. Integrated assessment of lithium brine potential and geothermal co-development pathways in Alberta's Devonian strata. (A) Geographic distribution of candidate resources and associated dual-resource developing options (DLE for direct lithium extraction; GPG for geothermal power generation; GHR for geothermal heat recovery). (B–G) Subsurface parameter distributions and project outcomes for viable DLE scenarios derived from Monte Carlo simulations (Peng et al., 2026). Simulations are conditioned on site-specific ranges for: (B) true vertical depth (TVD); (C) formation temperature (T_{FM}); (D) lithium concentration ([Li]). Modeled results include: (E) annual power generation; (F) annual heat recovery; and (G) annual lithium carbonate equivalent (LCE) production.

Environmental performance exhibits strong dependence on geothermal integration. Standalone DLE operations produce 3.07×10^5 to 4.31×10^5 t CO_{2e}/year, corresponding to carbon intensities (CI) of 8.94 to 29.13 kg CO_{2e}/kg LCE. Integrating GHR with DLE substantially reduces emissions, yielding CI values from –47.10 to 6.64 kg CO_{2e}/kg LCE. In contrast, coupling DLE with GPG yields only modest reductions, with CI values clustered between 9.48 and 26.01 kg CO_{2e}/kg LCE, reflecting the limited power output achievable at the prevailing reservoir temperatures.

Economic performance follows similar patterns. Under current market assumptions, which are 2 USD/GJ for heat, 23 USD/GJ for electricity, 14,000 USD/t for LCE, and a carbon price of 59 USD/t CO_2, the standalone DLE cases generated 119–377 million USD/year in gross revenues. Incorporating GHR increases revenue potential to 168–409 million USD/year, owing to the substantial quantity of recoverable heat available across several locations. By comparison, integration with GPG yields only moderate revenue gains, with total annual revenue ranging from 124 to 328 million USD/year.

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DISCUSSION & CONCLUSION

It is important to note that the techno-economic-environmental assessment presented here relates to processes only up to the wellhead, meaning that downstream distribution, transmission, and end-use infrastructure requirements are not included. As a result, costs associated with transporting geothermal heat or electricity to end users remain outside the present system boundaries.

Typically, direct-use geothermal heat deployment requires the development of both supply and demand within a confined local area, necessitating the construction of new distribution pipelines and customer-side interconnection infrastructure (Robins et al., 2021). In contrast, geothermal electricity generation can often leverage pre-existing electrical transmission networks, allowing generated power to be absorbed by broader regional demand with substantially fewer distribution-system investments (Sneum et al., 2025). Consequently, although the modeled results indicate that DLE integrated with GHR performs more favorably than DLE–GPG in terms of wellhead economics, this advantage may diminish once full downstream infrastructure is considered.

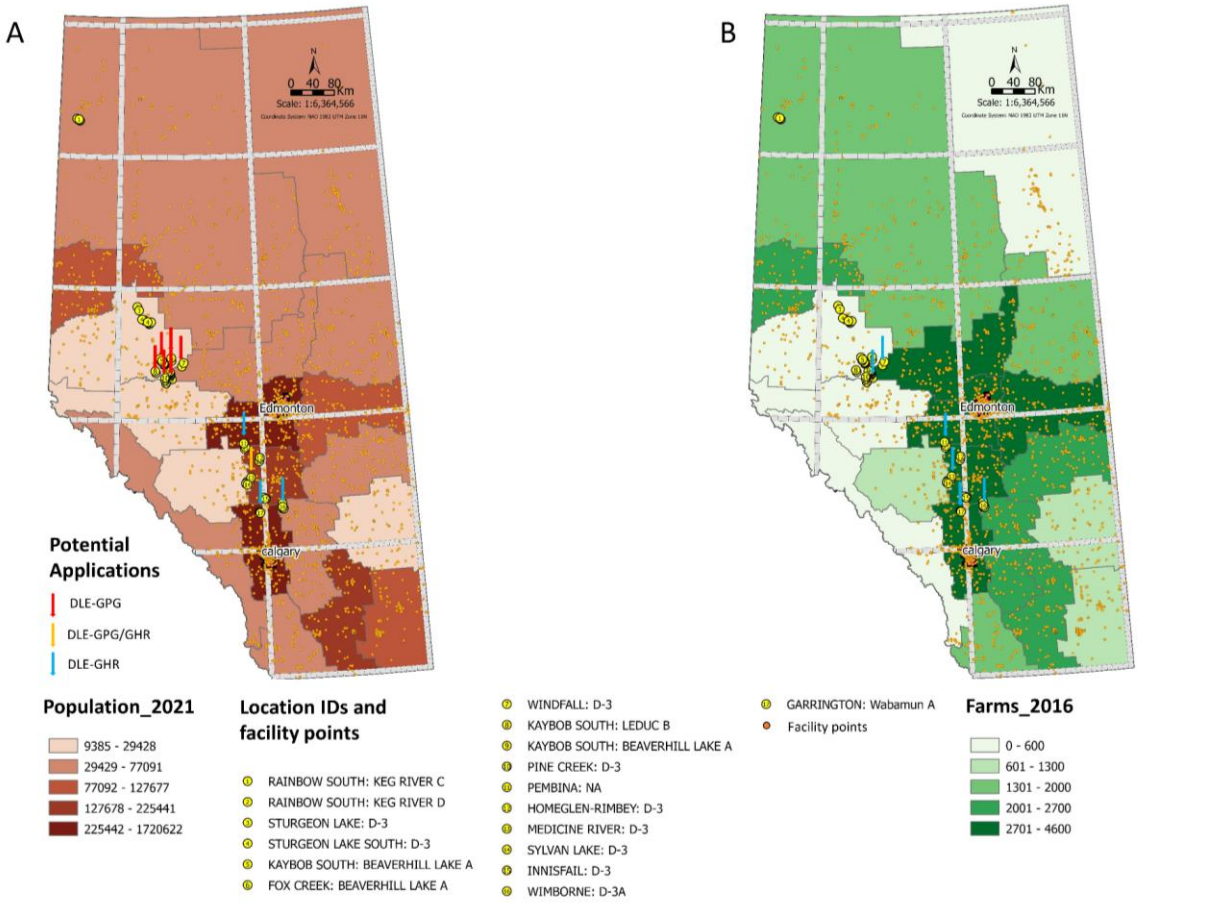


Figure 3. Dual potential for lithium extraction and geothermal energy utilization overlaid on regional demand indicators. (A) Population density from the 2021 census (Statistics Canada, 2021) and locations of electricity-demanding facilities. (B) Number of farms from the 2016 census (Statistics Canada, 2023), representing potential agricultural heat-use demand.

Opportunities for co-producing geothermal energy with DLE in Devonian brines are therefore strongly governed by reservoir conditions (T_{FM} and [Li]), market prices, and the spatial concordance between

thermal resources and local energy demand. The three regional demand indicators—population density, electricity-consuming facilities, and farm distribution (Figure 3)—further constrain feasible utilization pathways. Locations near population centers or agricultural districts provide immediate potential for GHR integration into district heating, greenhouse, and aquaculture cultivation, or municipal facilities, thereby reducing heat-transport distances and maximizing displacement of natural gas–based heating. Conversely, remote sites with limited nearby demand offer minimal practical benefit from heat co-production, even where T_{FM} is technically adequate.

As shown in Figure 3, locations 11, 16, and 17 (blue arrows) fall within high-demand corridors and are therefore potential candidates for direct-use heat applications. Location 13 (orange arrows) lies within a region of moderate population density but high densities of farms and facilities. With an average T_{FM} of 96.8 °C but [Li] of 52 mg/L, its economics remain dominated by LCE revenues, and additional GHR or GPG integration may reduce overall project value, indicating that site-specific assessment is required. By contrast, locations 7 and 9 (partially) show low population and facility densities but elevated agricultural presence, making them more suitable for DLE–GHR configurations. Meanwhile, locations 5, 6, 8, 9 (partially), and 10 are situated in very low-demand regions yet exhibit average T_{FM} values >100 °C and [Li] >95 mg/L, indicating that GPG may represent the more feasible integration strategy for these higher-enthalpy reservoirs.

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