Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Geothermal energy from retrofitted abandoned oil and gas wells in Alberta (Canada) for heating and electricity generation applications

Mohammad Zolfagharroshan[1], Jade Boutot[2], Kim Leong Liaw[1], Bianca Lamarche[2], Muhammad S. K. Tareen[1], Mary Kang[2], Agus P. Sasmito[1*]

Mining Engineering Dept., McGill University[1]*, Civil Engineering Dept., McGill University (Montreal, Canada)[2]

Corresponding author: agus.sasmito@mcgill.ca

Keywords: Abandoned oil and gas wells; methane mitigation; closed-loop geothermal systems; power generation.

1 INTRODUCTION

Alberta accounts for roughly 85% of Canada's oil and gas production and hosts a large inventory of abandoned oil and gas wells (AOGWs) (Canada Energy Regulator, 2024). These inactive wells pose significant environmental risks, particularly through methane leakage to the atmosphere and hydrocarbon migration into shallow groundwater systems (Kang et al., 2023), as shown in Figure 1(a). Converting AOGWs into geothermal wells presents a practical solution to mitigate emissions, reduce drilling costs, and eliminate the non-revenue burden associated with conventional plugging and abandonment (P&A). Drilling fresh geothermal wells typically costs about 4–6 million USD, which represents 40% to 90% of total project expenditures (Santos et al., 2022). Moreover, P&A operations for onshore wells can cost up to $150,000 per well with no revenue return (Jello and Baser, 2023). In line with Canada's commitment to the Global Methane Pledge (GMP), geothermal energy recovery from retrofitted AOGWs offers a compelling pathway that has recently attracted growing interest from researchers, government agencies, and industry stakeholders.

Several field demonstrations in the United States, China, and Europe have showcased the potential for power generation from repurposed AOGWs (Jello and Baser, 2023). Most of these projects have employed open-loop geothermal systems (OLGSs), where heat extraction and co-production of oil and thermal brine occur through direct contact between the working fluid and the reservoir. Although OLGSs provide relatively high heat extraction rates, mineral scaling and deposition have frequently been reported as long-term operational challenges (Zolfagharroshan and Khamehchi, 2024). Closed-loop geothermal systems (CLGSs) overcome these issues by eliminating direct fluid–rock interaction, allowing better control over flow rates, and addressing environmental concerns associated with hydraulic fracturing (Zolfagharroshan et al., 2024a). Among CLGS designs, U-tube and coaxial configurations are the two most common types discussed in geothermal research (Liu and Taleghani, 2026). The only known pilot-scale application of a CLGS in a repurposed AOGW was conducted in Hungary, where approximately 0.5 MW of thermal energy was produced. This amount of heat was sufficient to provide space heating for a floor area of 20,000 to 30,000 square meters (ThinkGeoEnergy, 2021). In the Canadian context, a recent study identified significant potential for reusing AOGWs in Alberta for geothermal heat extraction. Statistical analysis indicated that roughly 80% of wells in the province could feasibly operate as coaxial CLGSs (Zolfagharroshan et al., 2024b). However, while previous research has demonstrated the technical feasibility of heat extraction, no strategic study has yet examined the selection of operational parameters based on resource potential and end-use application, or provided a comprehensive assessment of Alberta's AOGW database.

The present study evaluates the geothermal potential of AOGWs in Alberta, Canada through a comprehensive database analysis and the selection of realistic operational parameters that reflect the true potential of each well. A validated multiphysics model of a CLGS with a coaxial configuration is employed to simulate 10,000 representative AOGWs across the province. A curve-fitting approach is then used to develop a mathematical correlation that expresses the outlet fluid temperature as a function of well and ground characteristics. The developed correlation, which demonstrates high predictive accuracy, is then applied to the broader inventory of approximately 350,000 AOGWs in Alberta. The characteristics of wells suitable for heating and electricity generation are further discussed.

2 METHODS & RESULTS

Figure 1(b) illustrates the proposed CLGS configuration used for retrofitting the individual wells analyzed in the present study. The model consists of two main computational domains: the surrounding ground and the

wellbore. The three-dimensional energy equation governing heat transfer in the ground, expressed in cylindrical (radial) coordinates, is given as:

$$\rho c_p \frac{\partial T}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(kr\,\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial \phi}\left(k\,\frac{\partial T}{\partial \phi}\right) + \frac{\partial}{\partial z}\left(k\,\frac{\partial T}{\partial z}\right) \quad (1)$$

where T is temperature, t is time, and ρ, c_p, and k represent the rock density, specific heat capacity, and thermal conductivity, respectively. By assuming homogeneous and isotropic rock properties, the three-dimensional energy equation can be reduced to a one-dimensional form that yields equivalent results while significantly decreasing computational time. The boundary conditions for the ground domain include a constant temperature at a radial distance of 50 m from the wellbore axis and a convective boundary at the interface between the ground and the wellbore wall. The analytical solution of the heat conduction equation, derived using Green's function, is employed to solve the energy equation, while the temperature of the circulating fluid inside the well is updated through Newton's law of cooling. A marching algorithm is implemented to vertically sweep the entire well–ground contact interface, forming a reduced-order model (ROM). The detailed governing equations, model features, and validation and verification procedures are provided in our previous work (Zolfagharroshan et al., 2024b).

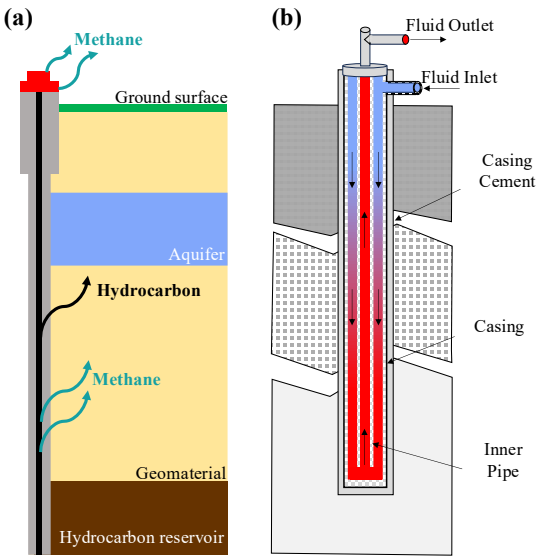


Figure 1. (a) The environmental risks posed by an AOGW and (b) the proposed retrofit configuration for geothermal energy extraction (Zolfagharroshan et al., 2024b).

To model an individual well, five key input parameters are considered: the rock's thermophysical properties including density (ρ), specific heat capacity (c_p), and thermal conductivity (k), along with the well depth (Z), and the geothermal gradient (g_g). To develop a mathematical expression with fast computational performance, it is necessary to conduct a statistical analysis using the developed ROM. In this regard, the pipe diameters are kept constant, while 10,000 combinations of the five key input parameters mentioned above are generated using the distribution of well depth data in Alberta and a normal distribution for the remaining parameters to cover all possible variations. These Monte-Carlo samples serve as inputs to the ROM. Each well configuration is simulated over a 20-year operational period to evaluate the geothermal heat extraction potential. The operational parameters are defined as a water circulation rate of 1.66 kg/s and an injection temperature determined as a function of the bottom-hole temperature (BHT). The BHT values are estimated using regional geothermal gradients derived from Canada's geothermal maps (Majorowicz and Grasby, 2010), assuming a linear temperature–depth relationship. Accordingly, the injection temperature is set to 20 °C for wells with BHT below 60 °C, 40 °C for BHT between 60 and 90 °C, and 70 °C for BHT above 90 °C. The rationale behind this approach is to align the injection temperature with the bottom-hole temperature and the intended application of the produced heat.

The simulation results indicate that approximately 39% of the wells demonstrate positive potential for geothermal energy extraction. Based on these findings, a mathematical expression was developed using a curve-fitting technique and published in our recent study (Zolfagharroshan et al., 2025). Considering that Alberta contains an inventory of approximately 349,432 wells, direct simulation of all wells would require substantial computational time. To address this limitation, the developed mathematical correlation, which predicts the outlet water temperature of wells after 20 years of heat extraction, was applied. Figure 2 presents the distribution

of well depths and bottom-hole temperatures in the AOGW database in Alberta. Approximately 91% of the wells are shallower than 3 km, which makes them easier to operate compared with deeper formations, as shown in Figure 2(a). Deep formations that are often suitable for electricity generation, due to their higher BHT, are typically located at depths greater than 4.5 km and account for about 1% of the total wells. As illustrated in Figure 2(b), only 0.6% of the wells have bottom-hole temperatures above 150 °C, which are generally suitable for electricity generation, while the majority, about 90%, have temperatures below 77 °C and are expected to be more suitable for heating applications.

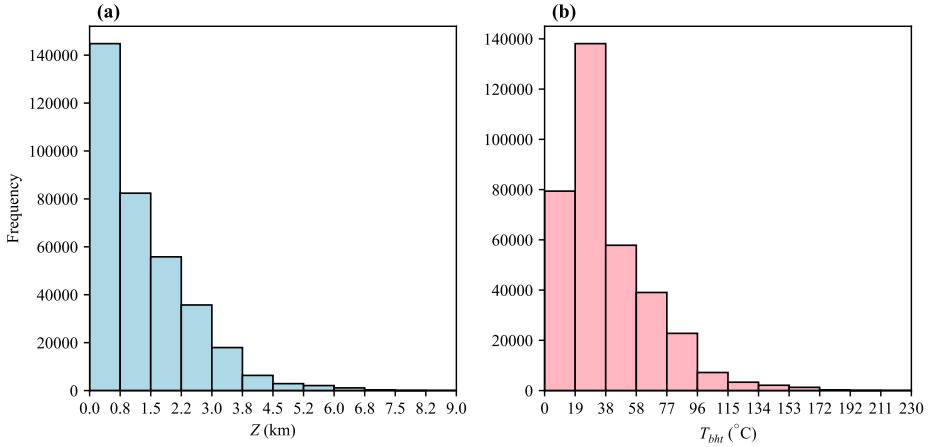


Figure 2. Distribution of (a) well depth and (b) bottom-hole temperature in the database of abandoned oil and gas wells (AOGWs) in Alberta, Canada.

Applying the developed correlation to the AOGW database indicates that 35% of the wells have positive geothermal potential, meaning that the outlet water temperature is higher than the inlet temperature. This subset, comprising 124,788 wells, is classified according to outlet temperature values, as shown in Figure 3(a), and their corresponding heat transfer rates, as presented in Figure 3(b). The ORC group, where ORC stands for Organic Rankine Cycle and refers to wells suitable for electricity generation, includes 788 wells. Approximately 24,400 wells belong to the medium-grade heating (M-H) group, while about 99,600 wells fall within the low-grade heating (L-H) group. In Figure 3 (a), the ORC group exhibits the highest median outlet temperature of approximately 96 °C, reflecting the need for elevated working-fluid temperatures to achieve efficient power generation. In comparison, the medium-grade heating group has a median temperature of about 78.7 °C, which is suitable for district or industrial heating applications where moderate thermal levels are sufficient. The low-grade heating systems operate at lower temperatures, with a median of 24 °C, aligning with low-temperature end uses such as ground-coupled heat pumps and space heating. A similar pattern emerges in thermal power produced in Figure 3(b) with the ORC category again demonstrates the highest median heat transfer rate (≈180 kW). The media for medium and low-grade heating are 60 and 20 kW respectively.

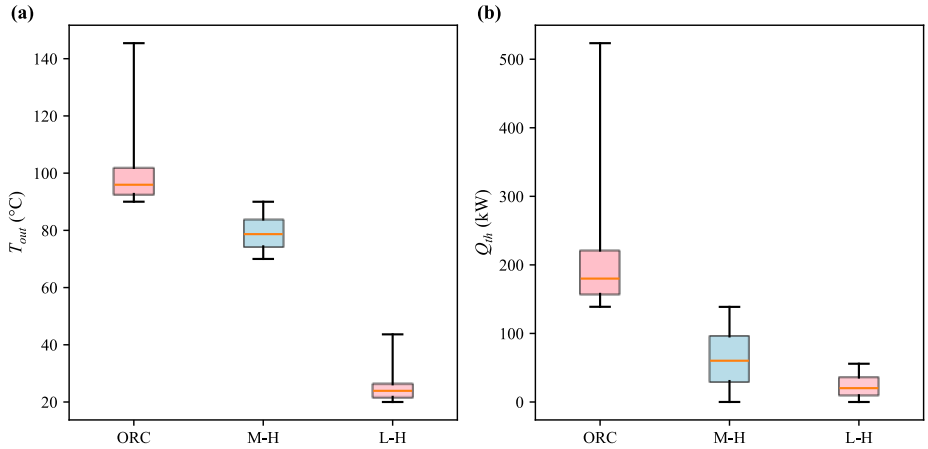


Figure 3. Boxplots of (a) outlet water temperature and (b) heat transfer rate, categorized by the intended application of the produced geothermal energy.

3 DISCUSSION & CONCLUSION

The assessment of geothermal energy potential from abandoned oil and gas wells (AOGWs) in Alberta, Canada, reveals a significant opportunity given the large number of such wells in the province. Previous studies estimated that approximately 80% of AOGWs could be repurposed for geothermal use; however, those estimates were based on a fixed and low injection temperature of around 15 °C. The present study, which considers more realistic operational conditions, demonstrates that adjusting the injection temperature as a function of the bottom-hole temperature results in about 35% of the province's 350,000 wells exhibiting positive potential for heat extraction. Among this subset, approximately 0.6% are suitable for geothermal power generation, 19.5% for medium-grade heating applications, and the remaining 80% for low-temperature uses such as heat pump systems. Repurposing AOGWs not only mitigates methane emissions and contributes to climate change mitigation but also provides a sustainable energy source well-suited for Alberta's cold climate. The large-scale potential for geothermal heating from AOGWs offers a valuable pathway toward cleaner energy, improved energy security, and reduced dependence on fossil fuels, particularly for remote and rural communities located near existing petroleum infrastructure.

Acknowledgements

MZ, KL, MT thank McGill Engineering Doctoral Award (MEDA) scholarship and Fonds de Recherche du Québec-Nature et technologies (FRQNT) doctoral award (FRQNT - DOI: https://doi.org/10.69777/346490). We thank the Natural Sciences and Engineering Research Council of Canada (NSERC) Alliance Grant (ALLRP 577160-2022). JB thanks the NSERC Canada Graduate Scholarships - Doctoral program (CGS-D) and the McGill Vadasz Scholars Program

REFERENCES

Canada Energy Regulator. (2024). Provincial and territorial energy profiles – Canada. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/

Jello, J., & Baser, T. (2023). Utilization of existing hydrocarbon wells for geothermal system development: A review. Applied Energy, 348, 121456.

Kang, M., Boutot, J., McVay, R. C., Roberts, K. A., Jasechko, S., Perrone, D., ... & Peltz, A. S. (2023). Environmental risks and opportunities of orphaned oil and gas wells in the United States. Environmental Research Letters, 18(7), 074012.

Liu, S., & Taleghani, A. D. (2026). Closed-loop geothermal systems: Critical review of technologies, performance enhancement, and emerging solutions. Renewable and Sustainable Energy Reviews, 225, 116177.

Majorowicz, J., & Grasby, S. E. (2010). Heat flow, depth–temperature variations and stored thermal energy for enhanced geothermal systems in Canada. Journal of Geophysics and Engineering, 7(3), 232-241.

Santos, L., Taleghani, A. D., & Elsworth, D. (2022). Repurposing abandoned wells for geothermal energy: Current status and future prospects. Renewable Energy, 194, 1288-1302.

ThinkGeoEnergy. (2021, April 4). First closed-cycle geothermal heat plant set up in Hungary. https://www.thinkgeoenergy.com/first-closed-cycle-geothermal-heat-plant-set-up-in-hungary/

Zolfagharroshan, M., & Khamehchi, E. (2024). Mineral scaling impact on petrophysical properties of reservoir rock in a geothermal field located in Northwestern Iran. SPE Journal, 29(02), 1029-1044.

Zolfagharroshan, M., Zueter, A. F., Tareen, M. S., Xu, M., & Sasmito, A. P. (2024a). Two-phase closed thermosyphons (TPCT) for geothermal energy extraction: A computationally efficient framework. Applied Thermal Engineering, 248, 123205.

Zolfagharroshan, M., Xu, M., Boutot, J., Zueter, A. F., Tareen, M. S., Kang, M., & Sasmito, A. P. (2024b). Assessment of geothermal energy potential from abandoned oil and gas wells in Alberta, Canada. Applied Energy, 375, 124103.

Zolfagharroshan, M., Lamarche, B., Liaw, K.L., Boutot, J., Tareen, M.S.K., Kang, M. and Sasmito, A.P. (2025) 'Assessment of abandoned oil and gas wells in British Columbia, Canada, for low-carbon geothermal energy production for remote and Indigenous communities', Proceedings of the 11th Applied Energy Symposium: Low Carbon Cities & Urban Energy Systems (CUE2025), Kitakyushu, Japan, 18–22 July 2025.