The Feasibility of Repurposing Oil and Gas Wells for Geothermal Applications

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ABSTRACT

Approximately 450, 000 hydrocarbon wells have been drilled in Alberta since exploration began in the early 20th century (Energy 2022a). Many of these wells produce high water cuts with reported high bottomhole temperatures, making them suitable to assess for geothermal potential. Further, wells that are suspended or orphaned have high liability and reclamation costs, and repurposing of wells and associated infrastructure has been suggested to offset a portion of these costs. However, there are significant differences between hydrocarbon and geothermal energy exploration, therefore existing wells must be thoroughly screened for the ability to produce geothermal energy. Here we propose a two-phase multidisciplinary study to assess existing wells for geothermal potential. The objective is to create a shortlist of wells for community-owned geothermal repurposing projects. The assessment will first screen candidates for geologic and engineering requirements such as downhole well problems, fluid production, and downhole temperature. Candidates that pass will then be screened for geographic and regulatory requirements and assessed for their potential geothermal uses. Candidates that meet the requirements of both phases will be proposed to local communities; those interested may begin the next stage which involves re-entering and testing the wells. Associated infrastructure may also be repurposed and data from unsuitable wells may be useful for future geothermal projects. If this feasibility assessment is granted funding, the study could result in some of the first geothermal energy projects in Canada while simultaneously offsetting reclamation costs and utilizing existing infrastructure.

1. INTRODUCTION

Hydrocarbon extraction has been occurring in the Western Canada Sedimentary Basin (WCSB) since the beginning of the 20^{th} Century. In Alberta alone there have been over 450,000 hydrocarbon wells drilled (Energy 2022a; Figure 1). At present there are approximately 333,000 hydrocarbon wells that have yet to be reclamation certified (Energy 2022a). These wells are in various statuses of operation, including operating, orphaned, suspended, and abandoned. The current estimated liability of all non-reclamation certified wells in Alberta is $100 billion dollars (McNeill 2018). In recent years, there has been increasing interest in the potential for repurposing oil and gas wells in Alberta for geothermal applications. If even a small percentage of these wells can be reused or repurposed, significant liability and reclamation costs could be offset. As well, synergies between these energy sources and industrial operations could be a win-win for geothermal development and oil and gas operations, especially where grid electrification is unavailable. Through the co-production of geothermal energy and hydrocarbons, well operators may be able to extent the economic life of their hydrocarbon pools. This would allow for increased recovery of hydrocarbons, while transitioning to renewable geothermal energy generation.

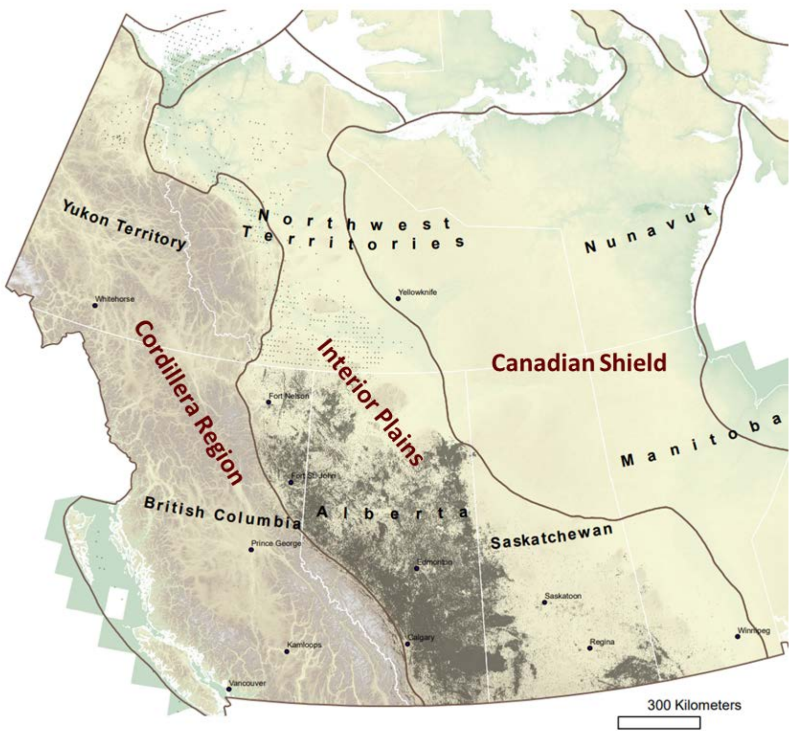

Figure 1: Map of Western Canada showing all oil and gas wells drilled (gray points). Image courtesy of GEOSEIS.

Although there is great potential for repurposing oil and gas wells for geothermal purposes, doing so will require thorough assessment due to fundamental differences in the two energy sources. One of the major challenges when assessing the feasibility to repurpose oil and gas wells to geothermal uses is the differences in well design. To produce power at the temperatures expected in the WCSB, geothermal wells will require flow rates of around 300 L/s which is significantly more than flow rates of a hydrocarbon well (although heat can be extracted for direct use at much lower flow rates) (Butler and Sanyal 2010). To allow for such high flow rates, production casings of geothermal wells typically range from 9 5/8” to 13 3/8”, compared to 4 1/2" for typical hydrocarbon wells. As well, hydrocarbon wells in the WCSB are typically drilled to a depth less than 2 km, while geothermal wells are estimated to be drilled to depths greater that 3 km to produce power.

2. WORKFLOW

Repurposing can refer to a variety of activities with respect to oil and gas well sites. The surface rights, facilities, equipment, and subsurface exploitation rights all have potential to be repurposed (Cameron and Morrison 2020). Here we focus on the potential for oil and gas wells or pools (referred to as candidates) to be converted to geothermal energy extraction. Many factors must be considered to create a robust screening and ranking system for the candidates.

Phase 1 will use a multidisciplinary approach using publicly available downhole and production information to evaluate the candidates. This first pass will remove wells with known downhole problems (corrosion, casing damage, vent flows, etc.) from further consideration. Orphan wells will be included in the initial filtering, but because most are in poor states of repair due to lack of ownership, we expect that very few will meet the requirements for repurposing. However, the surface infrastructure may be repurposed, and these wells can provide important data about subsurface conditions.

Following the initial screening for downhole problems, the candidates will then be evaluated for fluid production and downhole temperature. To be viable for geothermal heat generation, the candidates need to produce fluids at high flow rates (>10 L/s) and temperatures of at least 40 °C (Butler and Sanyal 2010). A list of potential screening criteria is shown in Table 1.

Only candidates that meet the screening criteria and can be re-entered at a low cost will be considered for Phase 2 of the study. This phase will create a prioritized list of candidates using a multidisciplinary geospatial approach. Candidates will be targeted for a variety of potential uses such as co-production, wellbore re-entry, and direct heat production (Figure 2). They also must be near communities or industrial centers to ensure a market for the geothermal energy generated. Rural, remote, and Indigenous communities stand to benefit most from geothermal energy use. Direct use projects such as greenhouses, drying facilities, aquaculture, and community heating have many potential socio-economic benefits for these communities (Figure 2; Hoicka and MacArthur 2018). Community and industry engagement will be key to ensuring successful repurposing of oil and gas infrastructure.

Once a short-list of candidates has been established, each will need to be tested to verify their geothermal potential. This will involve casing and cement inspection, bottom hole temperature measurements, cased hole logging, and produced fluid analysis. These analyses will require the cooperation of the wellbore operator and the Alberta Energy Regulator. Because the wells in Alberta were drilled and completed for oil and gas extraction purposes, existing public data may not capture their geothermal potential. Therefore, it is crucial to test each well prior to determining options for geothermal use.

Table 1: A list of potential screening criteria an oil or gas well to be repurposed for geothermal energy use.

Category	Criteria	Requirements
Engineering	Well Depth	> 2 km
Engineering	Historical Production Rates	Fluid rate (all fluids) > 864 m^3/day (10 L/s)
Engineering	Well Age	Younger is better
Engineering	Casing Integrity	Good cement bond, no scaling, no corrosion, no casing breaks
Engineering	Produced Fluids	Oil/water > gas
Engineering	Well Orientation	Horizontal > vertical
Engineering	Casing Diameter	Larger > smaller
Geographic	Well Location	Community proximity, infrastructure proximity, environmental considerations
Geographic	Surface Facilities	Utilities tie in, road access, pad size, existing facilities
Geologic	Bottom Hole Temperature	> 70 □C (but temperatures as low as 40 □C may be useful)
Geologic	Potential Reservoir Formation	Fractured limestone > Limestone > Sandstone > Shale
Geologic	Completed Formation	High porosity and permeability
Regulatory	Well Status	Well is not abandoned, well has been inactive < 12 months, well is not suspended
Regulatory	Well Owner	Interested in green energy transition
Regulatory	Environmental	No past leaks/spills (liability issues)

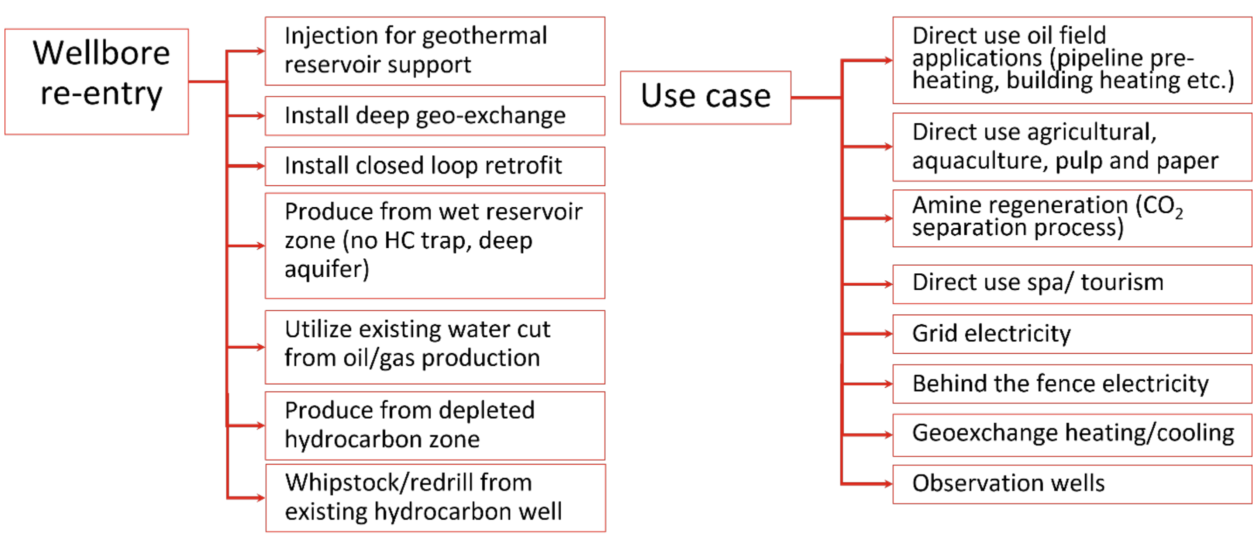

Figure 2: Repurposing options for existing oil and gas wells and potential uses for the captured geothermal energy.

Work to repurpose existing oil and gas wells is already underway worldwide (Figure 3; Duggal et al. 2022). The Huabei Field in China has been operating a pilot power plant on the co-production of oil and geothermal since 2011. It produces 400 kW gross power co-production, 310 kW of which is geothermal (Xin et al. 2012). Recently, the DOE announced funding for a project in Nevada, U.S.A., which is a partnership between Transitional Energy and Grant Canyon Oil & Gas (Energy 2022b). In this repurposing project, the operator maintains the well liability of the existing oil wells and the pool is repurposed for co-production, and eventually transitioned to renewable geothermal power (Energy 2022c). In Alberta, Canada, FutEra Power is developing a natural gas/geothermal co-production power plant using existing natural gas wells to generate 21 MW of electricity, 30% of which will come from geothermal energy (FutEraPower 2022).

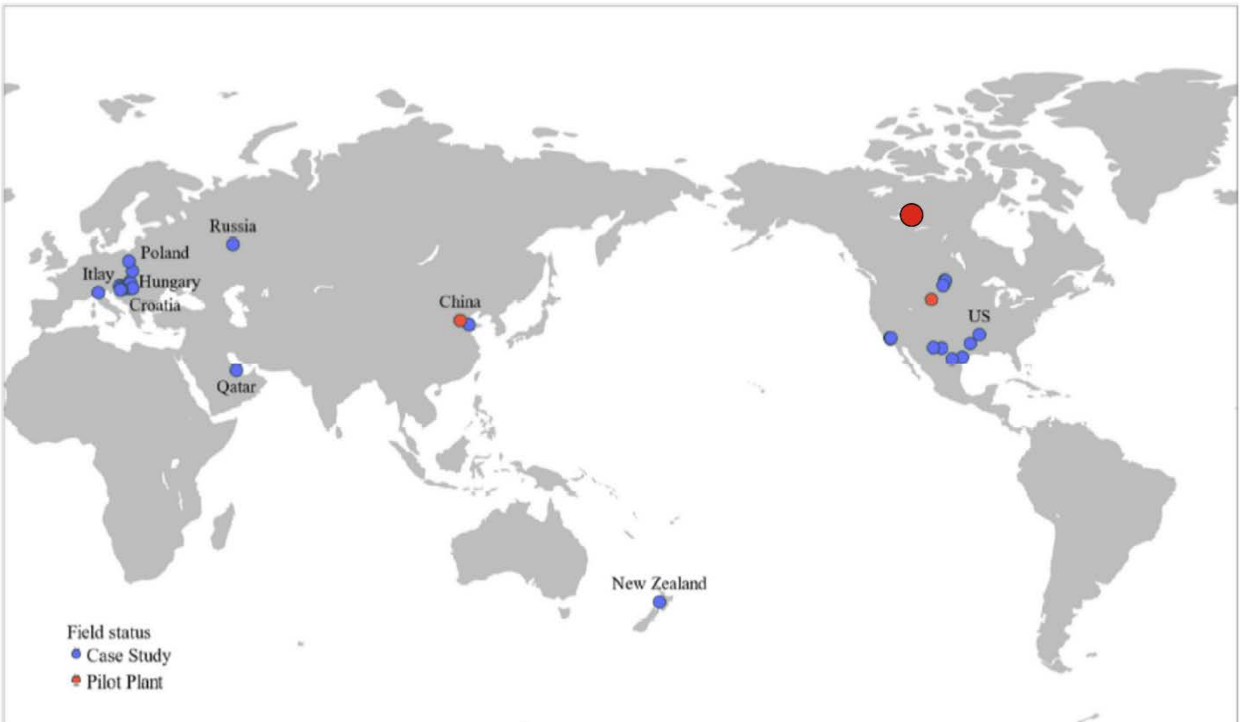

Figure 3: Map showing worldwide hydrocarbon fields that have been analyzed or piloted for geothermal operation. (Adapted from Duggal et al. 2022)

3. CONCLUSIONS

With the substantial number of oil and gas wells in Alberta, there are major benefits for evaluating the potential for repurposing to geothermal. The investigative process we propose will assess wells and well pools in two phases, the first which will screen candidates for downhole problems, flow rates, and temperature. The second phase will evaluate the screened candidates for potential geothermal uses and regulatory and geographic requirements. Suitable candidates will then need to be re-entered and tested. Even if the well cannot be repurposed, the information gained through the drilling and production of that well is valuable, as is the disturbed site and access route (including pipeline right aways) that the well sits on. By reusing these wells and disturbed sites, cost saving is possible, and the environmental footprint of the project is reduced, making repurposing projects amenable for targeted smaller communities.

ACKNOWLEDGEMENTS

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REFERENCES

Butler, S.J., and S.K. Sanyal. 2010. "Geothermal Power Capacity from Petroleum Wells – Some Case Histories of Assessment." Proceedings World Geothermal Congress, Bali.

Cameron, K., and L. Morrison. 2020. Bennett Jones Blog. In *Bennett Jones*.

Duggal, R., R. Rayudu, J. Hinkley, J. Burnell, C. Wieland, and M. Keim. 2022. "A comprehensive review of energy extraction from low-temperature." *Renewable and Sustainable Energy Reviews*.

Energy, Alberta. 2022a. "Oil and Gas Liabilities Management." Alberta Energy Regulator, accessed 2022/01/17. https://www.alberta.ca/oil-and-gas-liabilities-management.aspx.

Energy, Office of Energy Efficiency & Renewable. 2022b. DOE Awards $8.4 Million for Accessing Geothermal Potential from Abandoned Oil and Gas Wells. Energy.Gov.

Energy, Transitional. 2022c. "Transitional Energy Press Releases." Last Modified 2022/01/14. https://transitionalenergy.us/media.

FutEra Power. 2022. "FutEra Power." FutEra Power. https://www.futerapower.com/.

Hoicka, C.E., and J.L. MacArthur. 2018. "From tip to toes: Mapping community energy models in Canada and New Zealand." *Energy Policy*.

McNeill, Jodi. 2018. "Pembina Institute." Pembina Institute, accessed 2022/01/17. https://www.pembina.org/blog/alberta-government-has-transparency-problem-when-it-comes-oil-and-gas-liabilities.

Xin, S., H. Liang, B. Hu, Kewen, and K. Li. 2012. "ELECTRICAL POWER GENERATION FROM LOW TEMPERATURE CO-PRODUCED GEOTHERMAL RESOURCES AT HUABEI OILFIELD." PROCEEDINGS, Thirty-Seventh Workshop on Geothermal Reservoir Engineering, Stanford.