A Holistic Approach To The Energy Transition And Sustainability: Geothermal Energy For Power And A Variety Of Industrial Uses In Alberta, Canada

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ABSTRACT

Edmonton-based Terrapin Geothermics has been working in the Alberta marketplace for several years, engaging communities to investigate the geothermal potential beneath their feet; the Municipal District of Greenview (MDGV) is one of them. Despite being one of the most economically advantaged municipalities in Alberta (with continued strong hydrocarbon plays in tight shale formations), MDGV saw the importance of developing their economy beyond hydrocarbons. Taking the "green view," they are a strong supporter of Terrapin's Alberta No. 1 (ABNo1) project, the first conventional geothermal electricity and heat project in Alberta that has been under development since 2017. The project is building connections with other companies to support creation of two sustainable, holistically oriented "resource parks" powered by green electricity and heated by green thermal energy. Projects under discussion include supplying thermal energy to a nearby forestry production facility creating oriented strand board, an industrial composting facility using earthworms, and other agricultural and aquaculture endeavors likely to be located at the Grovedale Light industrial Park. Thirty km farther south, adjacent to the Grovedale Industrial Gateway (GIG), a heavy industry park, ABNo1 is supporting Alberta's Oil & Gas industry in CO_2 sequestration and other elements of the energy transition. As a conventional hydrothermal geothermal project, as opposed to emerging technology or enhanced geothermal project, which necessitates the production of large quantities of deep geothermal brines, ABNo1 is investigating the potential to separate the co-produced hydrocarbons and determine the feasibility of extracting minerals, including Lithium and rare earth elements. Although unlikely to be commercial on its own, geothermal may make Li mineral recovery economically feasible.

1. Introduction

In the past five years, the development of a geothermal energy industry in Alberta has become an increasingly significant focus in order to support the energy transition. The focus of this discussion has been how geothermal energy can become a significant source of baseload electrical energy for the Province. This has not led to a significant number of developing geothermal projects or significant Alberta investment into the sector. The greatest hurdle to building a robust geothermal industry in Alberta with baseload electrical energy as its sole value proposition is the de-regulated low cost of power (average pool price for electricity in Alberta in the last 12 months is $52.19/MWh) and the low cost of Natural Gas (NG) (produced locally) that is the major input fuel source for electrical generation and the primary fuel for space heating (2020 average price of NG was $1.90/GJ). In the Alberta marketplace, due to these low energy prices, commercial viability of conventional geothermal projects relies on the utilization of at least three income sources; power generation, heat off-take sales and carbon credits (Hickson and Colombina 2021). Alberta No. 1 (ABNo1), Alberta's first conventional geothermal power and heat project (Hickson et al. 2020), has been seeking alternative development hypothesis to enhance the value proposition even further for geothermal power and heat production in Alberta .and drive investment into the conventional geothermal energy space. ABNo1 is investigating three locations for its geothermal projects south of Grande Prairie in the Municipal District of Greenview #16 (Figure 1), all of which have opportunities to generate revenue from the three previously identified sources but also may have the opportunity to derive revenue from previously undiscussed sources in the geothermal value chain.

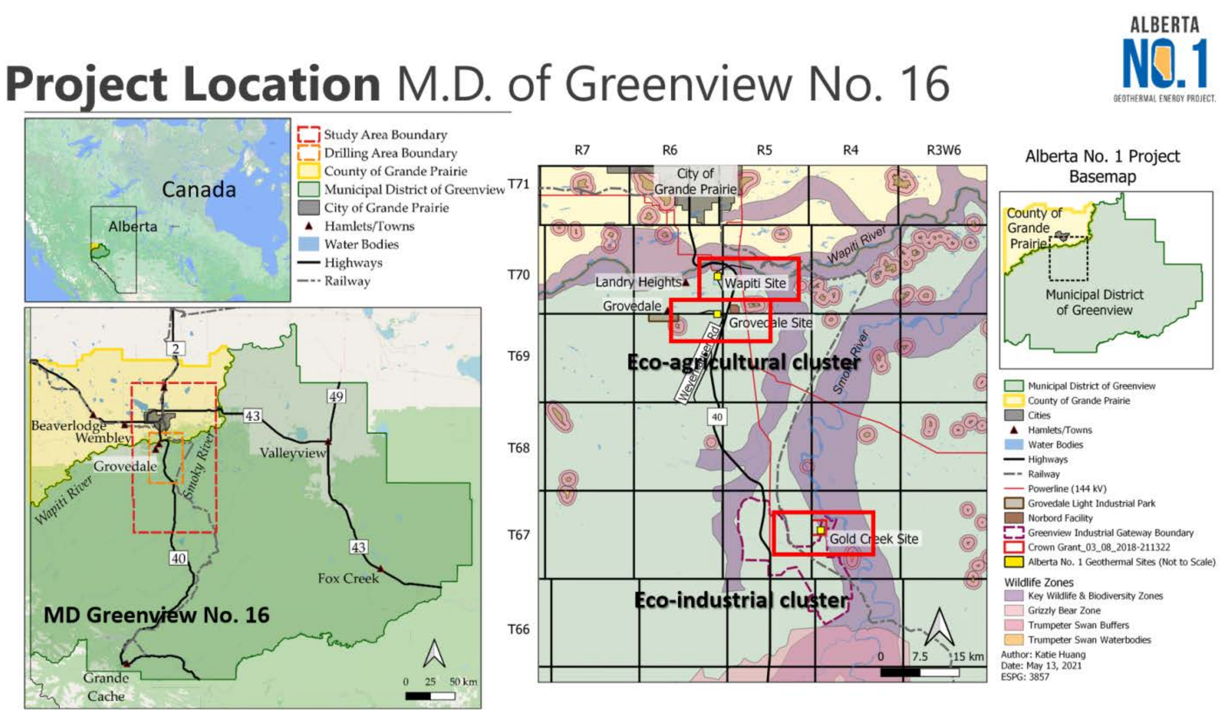

Figure 1: Alberta No. 1 is in north central Alberta and has sites associated with future eco-industrial and agricultural opportunities.

2. Geothermal's Holistic Value Chain

ABNo1 as a conventional geothermal project will be processing brines from the deep subsurface of the Western Canada Sedimentary Basin (WCSB) (Hickson et al., 2020). Knowledge of these deep formations is sparse due to the shallower depths of most of the hydrocarbon resources in the WCSB. However, it is this deep subsurface resource that holds the most promise for electrical generation in the WCSB where temperatures are anticipated to be at or above 110°C (Champollion et al., 2021; Huang et al. 2021). Geothermal electrical generation projects must target these deeper formations to obtain brines of sufficient temperatures (>110°C) (Huang et al., 2021) to efficiently produce electricity using most commercial Organic Rankine Cycle (ORC) units.

Accessing these brines provides a unique opportunity for conventional geothermal projects; conceptualized as the "holistic value chain" presented in Figure 2. Purpose drilled geothermal wells require significant capital expenditures which, due to the lower value of heat and electricity (in comparison with hydrocarbons), proves to be an early project financial hurdle. This value chain optimizes the geothermal project, further justifying the drilling of wide diameter, geothermal injection and production wells (Figure 3) into the deep strata of the WCSB. If the project can produce additional commodities, or if costs are shared between other commodity producers, for example metallic and industrial minerals (MIM), petroleum and natural gas (PNG), then geothermal developers would potentially see a much higher rate of return. Additionally, with the growing realization that carbon sequestration is going to be a key element for economies to reach net zero by mid-century, maximizing injection capacity to accommodate CO_2 sequestration will be a key element to assist in the energy transition – making geothermal projects not just zero emitters, but carbon negative. Focusing on this expanded value proposition is a key messaging focus for ABNo1 in conversations with both regulators and investors. Each aspect of the value chain is discussed in the following sections.

2.1 Hydrocarbon Separation

There are existing hydrocarbon fields already documented to flow fluids at 100°C or above in AB and they are being investigated for geothermal energy production. Most advanced of these projects is Futera Power's Swan Hills project.

Futera Power has just announced plans to build a power plant of 21 MWe, of which 3MWe is geothermal. Futera is a wholly owned subsidiary of Razor Energy which holds the Petroleum and Natural Gas (PNG) rights to much of the South Swan Hills Unit Reef complex. The synergistic project uses Razor's existing production, injection wells and 100's of km of pipelines to provide NG and geothermal fluid to its generation facility. They are also planning to capture an additional 23,000 tons of CO_2 using existing injection wells.

Just as Futera is showing it can achieve commercial success piggy backing off existing infrastructure for co-production of commodities (hydrocarbons and heat), Terrapin, as heat to value experts, are pointing out that the reverse is also true. If a hydrocarbon resource is found within the target strata of the geothermal development, it can be separated, and its commodity value realized as another link in the value chain (Figure 2).

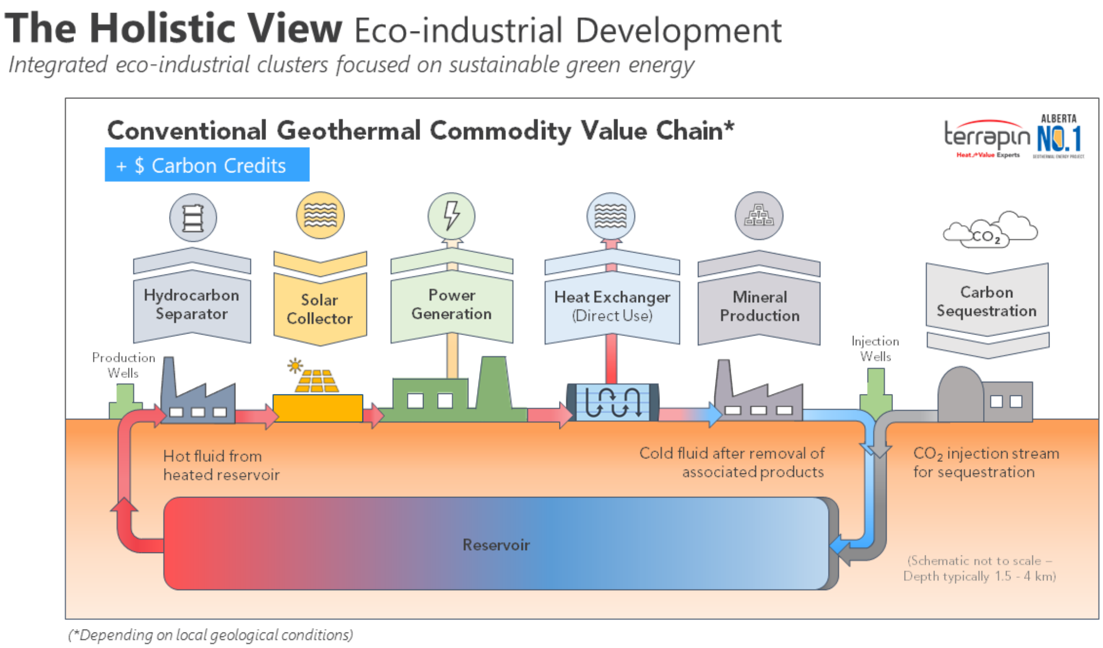

Figure 2: A view of geothermal development potential expanded beyond just heat and power to build a robust industry, supportive of O&G and Alberta's energy transition.

2.2 Solar Additions

As the cost of solar installations continues to be reduced, many new geothermal projects, as a matter of course, install solar collection. Many existing installations are also adding solar such as Cyrq Energy's Soda Lake plant. Although the northern latitudes make solar less attractive than more southerly locations, the low cost of adding generation (either thermal or electrical) to an already existing, or to be built, power facility, make it an attractive "add on" to the facility with minimal additional capital costs.

2.3 Power Generation

A conventional, low enthalpy facility requires significant quantities of fluids to generate power. ABNo1 calculates that to generate 8MWe gross, will require 300 l/s of mass flow at 120^{o}C. By drilling wide diameter wells with high-capacity pumps, individual wells are designed to flow over 100 l/s of fluid and be strata limited (rather than well bore limited). These wide diameter wells are costly, but routine in low enthalpy geothermal production (Figure 3).

The volumes of brine required for power generation also provide some context for why suspended O&G wells are poor candidates for repurposing into geothermal power producing wells, an idea often discussed in Alberta as a way to mitigate a portion of the existing legacy hydrocarbon environmental liabilities In Alberta there are more than 2,500 wells classified as "orphan wells". These wells run the gamut of suspended wells to fully plugged and abandoned wells, but where site reclamation has yet to be completed. Critical for an "orphan well" or "orphan site" is that the liability for reclamation of the site has passed to Government. It is possible that some of these wells could be useful for direct-use applications, monitoring or injection wells. However, oil field brines in the WCSB often have high salinity, are frequently sour and well bore integrity may be an issue over time (Hickson et al. 2020). Re-entering the well is also often costly with unexpected, time and money consuming results.

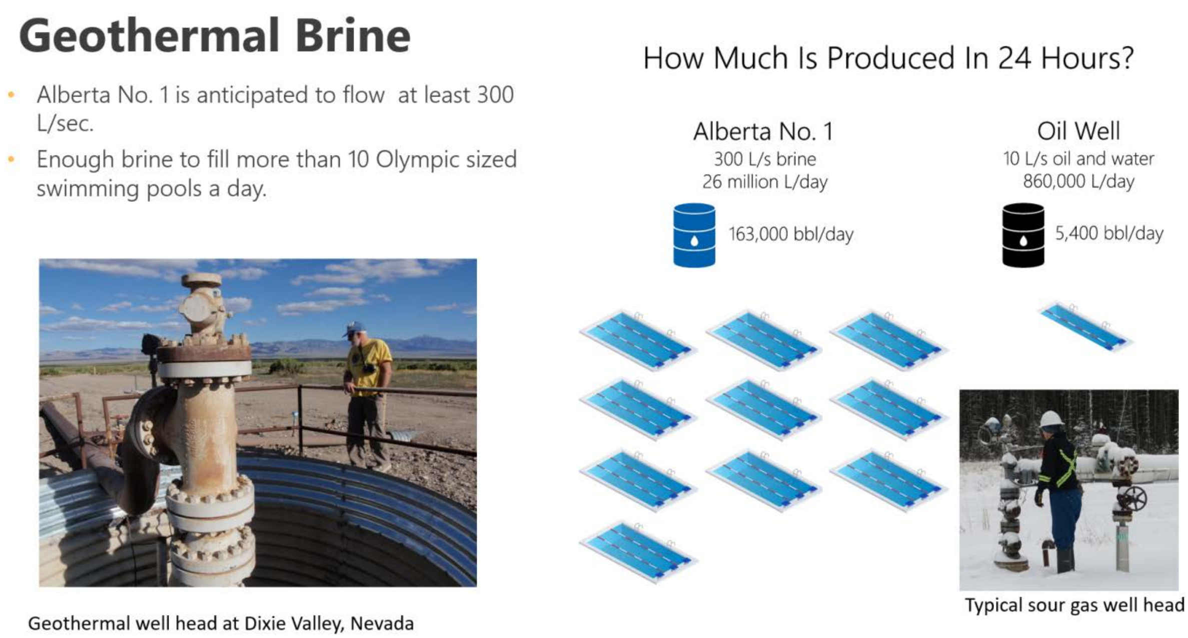

Figure 3: Typical geothermal well head compared to a gas well. Also shown are the volumes pumped. For the 300 l/sec mass flow, it is anticipated that 3 wide bore wells will be required.

For all the reasons noted above, a small percentage of the thousands of suspended wells held in inventory by operating companies and the Orphan Well Association might be useful for repurposing as direct use, monitoring or injection wells. ABNo1 is investigating wells near its sites (Figure 1) for repurposing and where possible, using existing infrastructure (pads, roads, pipeline right of ways, etc.), to reduce new land disturbance and utilize existing surface infrastructure.

2.4 Direct Use Heat Exchange and Industrial Clusters

The fourth pillar in the holistic value chain is direct use applications. As most geothermal operators know, extracting every Joule of energy out of pumped brine makes economic sense. This is the concept behind HS Orca's Svartsengi Resource Park, masterminded by Alberta Albertson (Albertsson and Jonsson 2010).

In the case of low enthalpy systems, the exit temperatures from most ORC units are not high enough for additional electrical generation. Several companies are working on low temperature units that may make economic sense in the range of 70 to 110°C. These may be economical in certain circumstance where outlet temperatures are high enough and fluid flow sufficient to generate commercial quantities of electricity. However, temperatures above 40°C can be usefully used for direct-use applications of various types (i.e. resource parks, low temperature industrial process heating, space heating).

Europe has paved the way for large district heating networks and industrial applications using low enthalpy resources, but it is China that this leading the pack in terms of MWt (Lund and Toth 2021). According to Lund and Toth (2021), "[global 2020] thermal energy used is 1,020,887 TJ/yr (283,580 GWh/yr.), a 72.3% increase over 2015, growing at a compound rate of 11.5% annually".

The hurdle for Canada for direct use is the low-density of population and vast distances between population and industrial centers. However, constructing purpose built industrial clusters like the Svartsengi model (Albertsson and Jonsson 2010), but using a lower temperature resource, is a way to attract business to co-locate where the resource is favourable. Albertsson and Jonsson (2010) outline the philosophy behind a resource park. They state:

1. Integrated usages of a variety of subjective and objective resources of different nature.
2. The Resource Park has to equally accentuate ecological balance, economic prosperity and social progress and by doing so it fully supports the sustainable development of the society as defined by the Brundtland commission
3. The Resource Park is to bridge different technical and social cultures
4. The inherent time scale of the Resource Park activities is centuries.

In the MDGV, an already zoned light industrial area near Grovedale (Figure 1) is being targeted for eco-agricultural "resource park" development. The concept is to provide and agricultural oriented industrial cluster (greenhouses, aquaculture, food processing fascilities, etc.) with green power and heat. Already ABNo1 has signed an MOU with an industrial vermicomposting company and is looking forward to working with the MDGV to attract more complimentary business to the location.

To the south, near the Gold Creek geothermal site, plans are in the works to develop a heavy eco-industrial park, dubbed the Greenview Industrial Gateway (GIG) (Figure 1), focused on natural gas processing. Here the need will be for green power and carbon sequestration, with more limited direct use applications. However, these large industrial complexes will need space heating and drying rooms for gear used during rainy and snowy days.

2.5 Metallic and Industrial Mineral Extraction

Moving on in the value chain the next commodity is metallic and industrial minerals (MIM). Based on data available, the deep strata of the WCSB is likely to be of high salinity and may contain extractable quantities of Lithium or other metals, such as Rare Earth Elements (Bachu et al., 1995). Lithium extraction from oil field brines is being pursued by several companies in Alberta and elsewhere. Extraction in the context of an operating oil and gas field is conceptualized to be carried out after hydrocarbon separation by direct extraction technologies under development (c.f., Hickson and Coolbaugh 2018; Kumar et al., 2019; Ying et al., 2021). After extraction, the spent brines are re-injected into the subsurface. Companies are working with oil field operators to build a business case based on the operators sunk costs to install the infrastructure to pump the brines (wells, piping and pumps).

In the case of Alberta, where the Lithium concentrations are low (<150 mg/l) (Bachu et al., 1995), it is speculative that a standalone Lithium development investing in the drilling of deep, high volume wells will be economic. Even piggy backing off of existing O&G infrastructure may not provide sufficient volumes for economic extraction (Figure 3). What is likely to be economically attractive is a partnership with a geothermal development already investing in deep, wide diameter drilling to extract the heat from the brines, leaving the metallic and industrial minerals intact and available for extraction.

2.6 Carbon Sequestration

It is recognized that hydrocarbons are critically important for Canada's and Alberta's economy (Hickson and Colombina 2021). In order to continue to produce hydrocarbons and associated products in Alberta, or any similar global jurisdiction, while meeting carbon reduction targets, carbon mitigation strategies are required. As geothermal projects have no emissions, the sale of electricity and thermal energy can offset the sale of electricity and heat from fossil fuel sources such as natural gas. In Alberta's emissions trading market, these offsets can generate carbon credits which are monetized, either through sale on the market or through satisfying compliance obligations, and provide an additional revenue stream to the project. Increases in carbon pricing and offset value further helps tip the equation steadily in favour of geothermal projects; even in markets with low power and heat costs.

This focus on offsetting fossil fuel generation has been the traditional view as to the extent of carbon mitigation value of geothermal activities in Alberta. However, the growing realization that (Carbon Sequestration (CCS)) will be critical, if Alberta, and the world, is to achieve net zero carbon by mid-century, brings to play an important contribution from geothermal projects. ABNo1 has recognized this as a potential opportunity and is beginning to focus on a relatively new concept: the co-injection of CO_2 into a geothermal reservoir. ABNo1 has partnered with academic and government research groups to investigate and answer questions surrounding CCS in conjunction with geothermal brine injections.

Adding CCS as one of the revenue streams has the potential to increase the economics of a geothermal project substantially. As noted earlier, the commercial aspects of geothermal projects are highly influenced by the price of electricity and cost of NG. In many jurisdictions in Canada, the cost of electrical power is very low compared with global markets. The levelized cost of geothermal power, according to research done by LAZARD is between US$59MW/hr and US$101MW/hr. There are few jurisdictions in Canada where Power Purchase Agreements (PPAs) can be negotiated to meet the high up front capital costs of geothermal power projects. Additionally, much of the Canadian geothermal resource is not suitable for power production due to the low temperatures. The addition of CCS to a geothermal project can provide revenue through a "fee for injection" business model. In addition to a fee for injection services, in areas with carbon taxation and crediting schemes, these projects would be able to garner additional carbon credits. As previously discussed, these carbon credits could be traded, depending on the jurisdiction, or used internally by the project owner to offset carbon in other parts of their business

The ability to carry out CCS is on the critical path for governments and corporations to reach carbon reduction goals in Canada and globally. This is especially true for Alberta and the government has requested $30B from the Federal government to assist in developing carbon capture and sequestration technologies. A geothermal facility with its large wells, has the potential to sequester large volumes of CO_2 through creative reservoir management (Buscheck et al 2016). In addition, the potential use of supercritical CO_2 as a working fluid brings possible efficiencies to a geothermal plant.

The GIG eco-industrial cluster is the perfect venue for co-location of a green power and energy facility with the added value of CCS. In fact, in today's commercial marketplace, new industrial projects such as "blue hydrogen" (hydrogen produced from Natural Gas) may not be able to attract capital unless they can show a path to CCS. Geothermal projects can help companies meet these goals in areas of Alberta that have not yet been investigated for CCS such as the GIG.

CCS can make geothermal project carbon negative, not just carbon zero. In addition to more positive economics, CCS can be considered a built-in well insurance policy for boreholes that under-perform for commercial geothermal heat and power operations. A drilled well could potentially have three outcomes: used as a producer, a fluid injector or for CO_2 sequestration.

3. Conclusion

In Alberta, due to the existence of low-cost electrical energy and natural gas, along with a focus on potentially lower CAPEX emerging geothermal technology solutions, the value proposition for conventional geothermal developments as a source of baseload electrical energy requires re-tooling in order to attract the investment and support the deployment of multiple projects. As such, Alberta No. 1 has begun to focus on a "holistic view" of conventional geothermal energy development, a view that elucidates the potential benefits derived from producing deep geothermal brines to surface beyond heat to electricity conversions. The additional revenue streams (i.e. CCS, mineral extraction, hydrocarbon extraction et.) available to conventional geothermal projects as a result of this brine production, through partnerships and consortiums, is significant and can be the catalyst to drive investment to this space, creating a robust conventional geothermal industry that helps Alberta reduce GHG emissions and gain valuable Environmental, Societal and Governance credits (ESGs) during its energy system transition. Alberta No. 1 is proud to be on the rising wave and to be the first holistically envisioned conventional geothermal energy project in Alberta.

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REFERENCES

Albertson, A and J. Jonsson, 2010 "The Svartsengi Resource Park," *Proceeding World Geothermal Congress* 2010, Bali, Indonesia, April 25 – May 29, 2010.

Bachu, S., Yuan, L.P. and M. Brulotte, 1994 Resource Estimates for Industrial Minerals in Alberta Formation Waters, Alberta Research Council,1995-01-31, 65 pages.

Bachu, S., Brulotte, M., Grobe, M, and Stewart, S., 2000. Earth Sciences Report 2000-11: Suitability of the Alberta Subsurface for Carbon-Dioxide Sequestration in Geological Media. Alberta Energy and Utilities Board, Alberta Geological Survey https://ags.aer.ca/publication/esr-2000-11

Benson, S. M., Hingerl, F., Zuo, L., Pini, R., Krevor, S., Reynolds, C., and A. Niemi. 2015. "Relative permeability for multi-phase flow in CO2 storage reservoirs. Part II: resolving fundamental issues and filling data gaps".

Buscheck, T.A., Bielicki, J.M., Edmunds,T.A., Hao, Y., Sun, Y., Randolph, J.B., and Saar, M.O., 2016, Multifluid geo-energy systems: Using geologic CO2 storage for geothermal energy production and grid-scale energy storage in sedimentary basins: Geosphere, v. 12, no. 3, p. 1–19, doi:10.1130/GES01207.1.

Hickson, C.J. and M. Colombina, "Alberta No. 1 Launching Development in Oil and Gas Dominated Alberta, Canada" *Geothermal Rising, GRC Transaction 45, 2021*

Hickson, C.J., and Coolbaugh, M. 2018 "Do geothermal systems play a role in lithium brine enrichment in Nevada playas?" *Geothermal Resources Council, Transactions*, Vol. 41, pp. 1922-1937.

Hickson, C.J., Cotterill, D, Huang, K., and M. Kumataka, M. "Alberta No. 1: The province's first conventional deep geothermal power project" *Proceedings of the GeoConvention*, Calgary, Canada, September 21 – 23, 2020a

Hickson, C.J., Kumataka, M., Cotterill, D., and Huang, K. "Geothermal drilling and well completions in comparison to oil and gas practices in low temperature (<170°C) sedimentary basin reservoirs", *Proceedings of GeoConvention*, Calgary, Canada, September 21 – 23, 2020b

Huang, K., Hickson, C.J., Champollion, Y. "Preliminary Results of a Temperature Log Using a Deep Disposal Well in the Western Canadian Sedimentary Basin" *Geothermal Rising, GRC Transaction 45, 2021*.

Amit Kumar, Hiroki Fukuda, T. Alan Hatton, and John H. Lienhard, 2019, "Lithium Recovery from Oil and Gas Produced Water: A Need for a Growing Energy Industry", *ACS Energy Letters* 2019 4(6), 1471-1474.

Lund, J. and A.N. Toth, "Direct Utilization of Geothermal Energy 2020 Worldwide Review", *Proceeding World Geothermal Congress* 2020, Reykjavik, Iceland, April 26 – May 2 2020.

Ying Sun, Qi Wang, Yunhao Wang, Rongping Yun, and Xiang Xu 2021, "Recent advances in magnesium/lithium separation and lithium extraction technologies from salt lake brine, Separation and Purification Technology", *Elsevier* Volume 256, ISSN 1383-5866