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Heat Seeking

Alberta's geothermal industry potential and barriers

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December 2017

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Executive summary

Alberta has significant geothermal resources that may be developed to provide a renewable source of heat and power. Geothermal energy has been receiving increasing attention here, in large part because the province's oil and gas (O&G) history potentially makes geothermal energy development a logical fit for the province.

However, Alberta currently has no installed geothermal capacity, with the exception of two commercial hot springs. This raises the question of whether Alberta really is strongly positioned to develop geothermal energy and, if it is, why a substantial industry has failed to form.

This report identifies six similarities between geothermal energy and O&G that demonstrate Alberta is indeed strongly positioned to develop geothermal energy:

1. Geothermal and O&G technologies use similar technical and non-technical skills.
2. Both collect and use sub-surface data such as that regarding temperature and depth.
3. They use wells drilled into the sub-surface to extract fluids.
4. They involve similar regulatory processes and approvals.
5. Both are subject to high financial risk.
6. Benefitting from oilsands demand for steam by providing incremental heat for bitumen processing through innovative enhanced geothermal systems technologies, recovery of injected heat, or other opportunities.

A nascent geothermal industry is forming in Alberta by taking advantage of these similarities. Yet some key innovation processes must take place for a geothermal industry to successfully develop. This report outlines the broad policy actions required to facilitate these missing innovation processes. Specifically, to support the development of a geothermal industry in Alberta, government should develop and implement:

1. A comprehensive regulatory framework for geothermal energy to reduce uncertainty for entrepreneurs and investors.
2. Policies to reduce exploration risk during early project stages.
3. Policies to improve return on investment, including a guaranteed long-term price for geothermal electricity.

1. Introduction

Geothermal energy is heat beneath the earth's surface that originates from the outward flow of heat from the earth's core and the decay of radioactive elements in the earth's crust. It is typically harnessed by extracting heated water, referred to as geothermal fluid, from a sub-surface geothermal reservoir.[1] Geothermal energy has been harnessed by people for hundreds of years and is currently used in more than 80 countries.[2]

Uses of geothermal energy

Geothermal energy can be used to provide heat or electricity[3] (Figure 1). High-temperature resources (>150°C) can directly generate electricity, with steam from the hot fluid used to spin a turbine. Medium-temperature resources (~80°C-150°C) can also generate power but require a heat exchanger to transfer the heat to a lower boiling point working fluid that vapourizes and spins a turbine in a binary cycle power plant. Low-temperature resources (<80°C) can be used to provide heat for buildings, greenhouses, industrial processes, and other applications, referred to as the "direct use" of geothermal energy.

[1] Geoexchange, often referred to as geothermal heating and cooling, is a different technology commonly used for home heating that uses a heat pump to "upgrade" shallow low temperature heat.

[2] J. Lund and T. Boyd, "Direct Utilization of Geothermal Energy 2015 Worldwide Review," in *World Geothermal Congress*, *Melbourne, Australia, 19-25 April 2015,* 1. https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2015/01000.pdf

[3] S.E. Grasby, et al., *Geothermal energy resource potential of Canada* (Geological Survey of Canada, 2012), 15. http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=291488

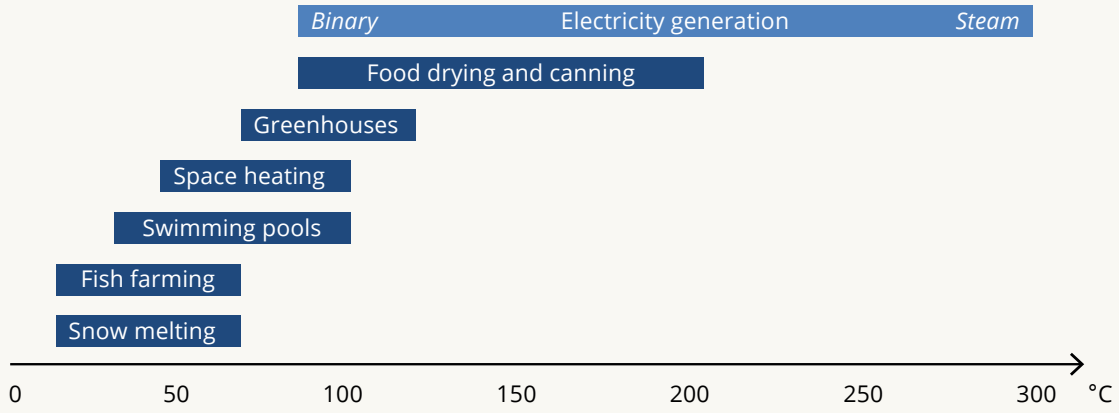

Figure 1. Potential uses of geothermal energy

Source: Adapted from the World Bank[4]

Alberta is estimated to have as much as 389 gigawatts (GW) of geothermal energy capacity that could be developed.[5] That is 24 times more than the province's current electricity generation capacity.[6] Geothermal energy has been portrayed as a logical fit for Alberta, particularly in the popular media, because of the province's history of oil and gas (O&G) development.[7] Despite this potential, Alberta has no installed geothermal capacity with the exception of two commercially developed hot springs.[8]

To better understand Alberta's geothermal opportunity, we identify potential synergies between the O&G sector and a geothermal industry that strongly position Alberta to develop geothermal energy. We then draw on innovation theories to identify current barriers to the development of a geothermal industry and broad policy responses that could address those barriers.

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[4] World Bank, *Geothermal Handbook: Planning and Financing Power Generation* (Energy Sector Management Assistance Program, 2012), 37. https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf

[5] Estimate of Alberta's technical geothermal potential based on 14% recovery. See: CanGEA, *Alberta Favourability Maps: Summary Report* (2013), Table 3. http://www.cangea.ca/ alberta-geothermal-favourability-maps.html

[6] Alberta Energy, "Electricity Statistics: Electricity Supply," *About Electricity*, December 2015. http://www.energy.alberta.ca/Electricity/682.asp

[7] See for example: K. Bakx, "Geothermal pitched as Alberta's next big energy source," *CBC News,* July 1, 2015.

[8] A. Thompson, F., Bakhteyar, G. Van Hal, "Geothermal Industry Development in Canada - Country Update," in *World Geothermal Congress. Melbourne, Australia, 19-25 April 2015,* 7. https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2015/01037.pdf

Geothermal geology in Alberta

Alberta's geothermal resources are found in the Western Canada Sedimentary Basin, the same geologic formation containing the province's O&G resources.[9] Areas where the porous rock of the basin is filled with geothermal fluid are referred to as "hot sedimentary aquifers."[10] The fluid in these aquifers is of medium and low temperatures, at depths of at least 2500 m.[11] This differs from the resources used for most geothermal energy generation, which lie in regions close to tectonic plate boundaries where the geothermal fluid is hot and located close to the earth's surface. Hot sedimentary aquifers therefore face challenges posed by the resource depth and temperature compared to "conventional" geothermal energy generation. However, they have recently been exploited for geothermal energy, particularly in Europe. Germany, for example, developed 44 megawatts (MW) of geothermal power between 2006 and 2016 and has an additional 337 MW of installed heat capacity.[12,13]

While the identified synergies between O&G and geothermal suggest that geothermal energy may be a strategic technology for Alberta, it was beyond the scope of this report to systematically compare geothermal energy to other economic development opportunities in the province. Furthermore, while the report identifies broad policy responses that could encourage geothermal development in Alberta, detailed policy design is left to subsequent work.

[9] *Geothermal energy resource potential of Canada*, 35.

[10] J. Crewson, *International Geothermal Policy Mechanisms Best Practices* (CanGEA, 2015), 7. http://www.cangea.ca/store/p91/International_Geothermal_Policy_Mechanisms_Best_Practices%3A_Identifying_the_Canadian_Gap.html

[11] R. Dipippo, "Geology of Geothermal Regions," in *Geothermal Power Plants* (London: Elsevier, 2016), section 1.5.4.

[12] T. Agemar, J. Weber, R. Schulz, "Deep Geothermal Energy Production in Germany," *Energies*, 7 (2014), Figure 7. doi:10.3390/en7074397

[13] J. Weber, B. Ganz, B. Sanner, I. Moeck, "Geothermal energy use, country update for Germany," in *European Geothermal Congress, Strasbourg, France, 19-24 September 2016*, 5. http://ubeg.de/Lit/GERMANY%20country%20update%20EGC%202016.pdf

2. Alberta's geothermal opportunity

Economic development and diversification studies have established new industries can emerge in a region by drawing on existing resources from similar industries.[14] This chapter outlines similarities between Alberta's O&G sector and a geothermal energy industry that create the potential for Alberta to develop a geothermal industry by harnessing O&G resources. It also notes that some O&G resources may not be directly applicable to geothermal energy, highlighting the need for experimentation and knowledge development to explore Alberta's geothermal opportunity.

Skills

O&G and geothermal projects use many of the same technical and non-technical skills. Exploration and drilling techniques from conventional O&G are highly transferable to geothermal, and oilsands engineers are already familiar with sub-surface thermodynamics and heat transfer. From a market perspective, oilsands companies have experience generating and selling electricity to the grid through cogeneration. Alberta's O&G sector also holds relevant expertise related to permitting, environmental assessment, site safety, and project management. This creates the potential for oil field service companies, O&G producers, and O&G workers to apply their skills to geothermal energy.

Sub-surface data

O&G and geothermal projects both collect and use sub-surface information like depth and temperature, which enables the location and size of geothermal resources to be estimated from O&G data rather than by conducting expensive field exploration.[15] With close to 600,000 drilled wells in Alberta,[16] relevant data exists for much of the province.

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[14] This idea is discussed in academic literature on economic geography. See for example: R. Boschma, K. Frenken, "Technological relatedness and regional branching," in *Dynamic Geographies of Knowledge Creation, Diffusion and Innovation* (London: Routledge, 2012).

[15] M. Richards, D. Blackwell, "Low-Temperature Sedimentary Geothermal Exploration," in *38th New Zealand Geothermal Workshop, Auckland, New Zealand, 23-25 November 2016*. https://www.geothermal-energy.org/pdf/IGAstandard/NZGW/2016/Keynote_Richards.pdf

[16] R. Milley, "Whose O&G Wells Have Geothermal Potential?" *Fuzeium Innovations Inc.*, 27 July 2017. https://fuzeium.com/ whose-og-wells-have-geothermal-potential/

However, O&G data collected in Alberta is often from closer to the surface than geothermal resources, requiring assumptions to extrapolate the shallow O&G data to deeper depths.[17]

Sub-surface wells

Geothermal and conventional O&G projects both involve drilling wells to extract fluids, meaning that existing O&G wells could be used by the geothermal industry either by repurposing inactive wells[18] or through co-production, where the hot water generated during active O&G extraction is used to produce heat or power.[19] Using existing O&G wells significantly reduces the cost of geothermal development because drilling accounts for 30–40% of project costs.[20,21] In addition, repurposing inactive O&G wells converts a liability into a productive geothermal asset.

The Canadian Geothermal Energy Association (CanGEA) estimates that 60,935 of Alberta's inactive and active wells may be suitable for geothermal energy production based on the temperature at the bottom of the well (Figure 2).

[17] J. Banks, *Deep-Dive Analysis of the Best Geothermal Reservoirs for Commercial Development in Alberta: Final Report* (University of Alberta, 2016), 15. http://www.ai-ees.ca/wp-content/uploads/2017/04/Deep-Dive-Analysis-of-Best-Geothermal-Reservoirs-for-Commercial-Dev....pdf

[18] Ibid, 56-57.

[19] *Geothermal energy resource potential of Canada*, 38.

[20] A. Kagel, *A Handbook on the Externalities, Employment, and Economics of Geothermal Energy* (Geothermal Energy Association, 2006), 25. http://geo-energy.org/reports/Socioeconomics%20Guide.pdf

[21] International Finance Corporation, *Success of Geothermal Wells: A Global Study* (2013), 4. http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_gpn_geothermal-wells

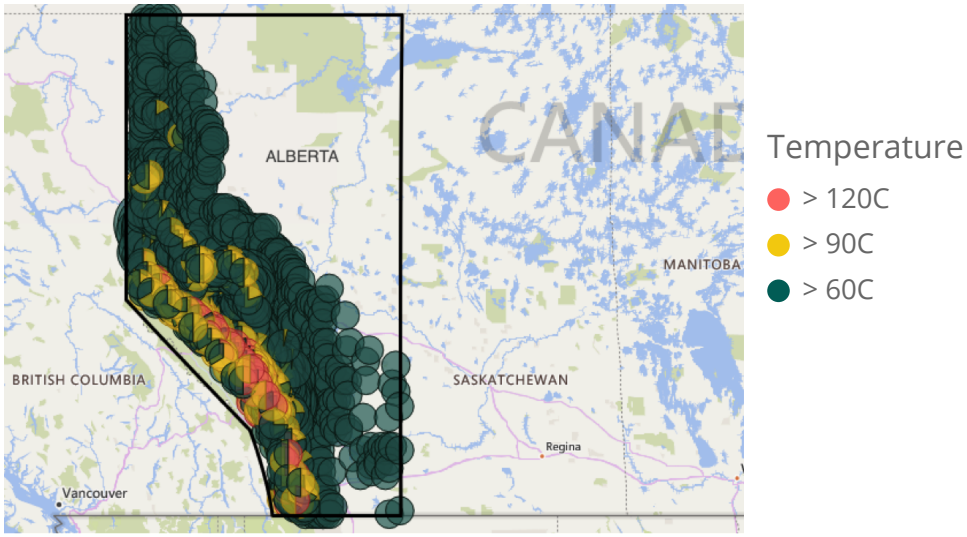

Figure 2. Inactive O&G wells potentially suitable for geothermal energy production

Source: Fuzeium Innovations Inc.[22]

However, a number of other characteristics influence how many O&G wells will be suitable for geothermal energy production. For an inactive well to be repurposed, it must encounter a geothermal reservoir or be able to be drilled deeper to reach a reservoir. The well must also be in good condition and wide enough to achieve the necessary flow rate of geothermal fluid. However, the status of many of Alberta's inactive wells is unknown, and O&G wells are generally much narrower than geothermal wells. In order to co-produce geothermal energy, a sufficient volume of heated water must be produced by the O&G operation. The number of O&G operations producing sufficient quantities of heated water is currently unknown.

Furthermore, using O&G wells for geothermal energy generation is fairly uncommon. The authors are aware of no operational projects that have repurposed inactive wells and only a small number of projects that have generated electricity through co-production.[23] Co-production for heat rather than electricity may be more common, however, because heat can be produced with cooler water or a lower flow rate.[24]

[22] Fuzeium Innovations Inc., "Which Oil & Gas Wells have Potential for Geothermal Power or Heat Applications?" *Dashboards - Public - Geothermal Co-Production*. https://fuzeium.com/dashboards/which-oil-gas-wells-have-potential-for-geothermal-power-or-heat-applications/

[23] "Low-Temperature Sedimentary Geothermal Exploration," section 5.1.

[24] For example, Calgary-based Vermilion energy has been co-producing geothermal heat from one of its O&G operations in France since 2008, heating 10 hectares of greenhouses. See: Vermilion Energy, "Vermilion Energy Inc. receives National Ecology Award in France," media release, December 4, 2013. http://www.vermilion energy.com/news/latestnewsrelease.cfm?newsReleaseAction=view&releaseId=76

Inactive O&G wells can also be used for geothermal exploration as opposed to the ongoing production of geothermal fluid for heat or power, which avoids costs associated with drilling wells to verify the presence of a geothermal reservoir.[25] Wells used for exploration do not need to meet the same standards regarding integrity and diameter.

Producers and consumers of heat

Crude oil is extracted from Alberta's oilsands by using hot water to separate the bitumen. Natural gas is currently used to heat the water, producing significant GHG emissions. However, it is possible to use geothermal energy to heat the water instead,[26] which creates the potential for the oilsands to act as a niche market for geothermal heat. Geothermal resources in northern Alberta likely need to be harnessed using enhanced geothermal systems (EGS),[27] which is a pre-commercial technology that involves hydraulic fracturing of hot rocks that would otherwise be too dry and impermeable to produce geothermal fluid.[28]

Regulatory structure

O&G and geothermal projects involve many of the same regulatory processes and approvals.[29] Alberta's O&G regulatory framework, in particular, is applicable to geothermal sub-surface tenure, exploration drilling, water use, and environmental assessment. Government could thus draw on its O&G regulatory experience to develop and implement a regulatory framework for geothermal energy. However, not all aspects of Alberta's O&G regulatory system are transferable. For example, it has been suggested that Alberta's royalty system for O&G resources is not well suited to geothermal

[25] *Deep-Dive Analysis of the Best Geothermal Reservoirs for Commercial Development in Alberta*, 55.

[26] Council of Canadian Academies, *Technological prospects for reducing the environmental footprint of Canadian oil sands* (2015), section 6.1.2. http://www.scienceadvice.ca/en/assessments/completed/oil-sands.aspx

[27] V. Pathak, T. Babadagli, J.A. Majorowicz, M.J. Unsworth, "Evaluation of Engineered Geothermal Systems as a Heat Source for Oil Sands Production in Northern Alberta," *Natural Resources Research*, 23 (2014), 248. doi:10.1007/s11053-013-9218-4

[28] *Geothermal energy resource potential of Canada*, 12.

[29] P. Holroyd, J. Dagg, *Building a regulatory framework for geothermal energy development in the NWT* (Pembina Institute, 2011), Chapter 4. https:// www.pembina.org/reports/building-a-regulatory-framework-for-geothermal-in-the-nwt.pdf

energy[30] and that geothermal resources should not be subject to royalties as a renewable energy resource.[31]

Investment risk

Geothermal projects are unique compared to many other renewable energy projects in that they involve high exploration risk due to the difficulty of determining the location and energy potential of a geothermal reservoir prior to drilling wells, combined with the high cost of drilling those wells.[32] Typically, each well requires an investment of US$1–7 million.[33] Conventional O&G projects also suffer from exploration risk, while oilsands projects face risks related to volatile oil prices, labour markets, and input prices that may vary substantially over the lifetime of a project. The Alberta government could thus draw on its experience managing risk for O&G projects to design and implement risk reduction policies for geothermal energy projects.

[30] G. Van Hal, *Legal Obstacles to the Development of Geothermal Energy in Alberta*, Occasional Paper #42 (Canadian Institute of Resource Law, 2013), 36. http://dspace.ucalgary.ca/jspui/retrieve/39528/GeothermalOP42w.pdf

[31] M. Colombina, *Geothermal Royalties in Alberta: An Industry Perspective* (Terrapin Geothermics, 2017), 3.

[32] *Geothermal Handbook: Planning and Financing Power Generation*, 5.

[33] *Success of Geothermal Wells: A Global Study*, 6.

3. Developing a geothermal industry in Alberta

Although similarities between Alberta's O&G sector and a geothermal energy industry create a strong opportunity for Alberta to develop geothermal energy, a geothermal industry has yet to substantially form. To understand the development of new technologies, innovation scholars have identified a set of interrelated processes that must take place in order for new industries to successfully develop. Tracking these processes helps identify the strengths and weaknesses of emerging industries and therefore provides a framework to understand why Alberta's geothermal potential has yet to be realized. The processes and their status in Alberta are highlighted in Table 1.

Table 1. Innovation processes

Process	Description	Status
Entrepreneurial experimentation	Individuals and organizations test variations of the technology in different applications, identifying successful combinations of technologies and markets	Moderate
Knowledge development and exchange	The development of scientific and technical knowledge as well as knowledge related to markets, logistics, and design, including the exchange of that knowledge amongst individuals and organizations	Strong
Influence on search activities	The regulatory, political, market, and economic conditions that influence the expectations that individuals and organizations hold for the new technology and therefore their motivation to engage with the technology	Weak
Market formation	The creation of protected markets in which the technology can be developed without directly competing with established technologies, often formed by public policies like favourable tax regimes and public purchasing quotas	Weak
Resource mobilization	The mobilization of financial, human, and physical resources necessary to develop the technology	Moderate
Creation of legitimacy	The creation of public support for the technology, which is necessary to overcome established interests that may resist technological change	Strong

Source: Adapted from Hekkert et al[34] and Bergek et al.[35]

This chapter outlines how well each of the innovation processes is taking place in Alberta's emerging geothermal industry. As will be demonstrated, some of the similarities with the O&G sector have been exploited to spur the early development of a geothermal industry but this has not been sufficient to adequately activate all of the innovation processes.

3.1 Strong processes

Knowledge development and exchange

Sub-surface O&G data has been used to develop knowledge of Alberta's geothermal resources, forming the basis of influential publications including the University of Alberta's Deep Dive study[36] and the Alberta Geothermal Favourability Map[37] as well as a number of academic studies. Most of the academic research has been prompted by the potential for geothermal heat to reduce oilsands emissions.

Creation of legitimacy

Geothermal energy has gained public support in Alberta as a potential way to employ oil field service companies and O&G workers, convert inactive O&G wells to a productive use, and reduce emissions from the oilsands. Further development of the geothermal industry could increase the legitimacy of geothermal energy by actually demonstrating these positive impacts.

3.2 Moderate processes

Entrepreneurial experimentation

Although no geothermal projects have been completed in Alberta, eight pilot projects have recently been proposed, all of which are being developed by O&G companies or

[34] M.P. Hekkert et al., "Functions of innovation systems: A new approach for analysing technological change," *Technological Forecasting and Social Change* 74 (2007). doi:10.1016/j.techfore.2006.03.002

[35] A. Bergek et al., "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis," *Research Policy* 37, no.3 (2008). doi:10.1016/ j.respol.2007.12.003

[36] *Deep-Dive Analysis of the Best Geothermal Reservoirs for Commercial Development in Alberta*, 13.

[37] *Alberta Favourability Maps: Summary Report*, 13.

new companies established by O&G workers. Four of the projects plan to use inactive O&G wells and two aim to co-produce geothermal energy from active O&G wells.

It is essential that some of the proposed projects proceed to completion to learn how to use O&G wells for geothermal energy, translate skills and experience from the O&G sector to the geothermal industry, implement successful business models, and develop EGS technologies, amongst other unknowns. However, stronger experimentation is constrained by the lack of a regulatory framework for geothermal energy in Alberta and the high risk and low return associated with geothermal projects (see "Guidance of the search" and "Market formation," below). These barriers discourage companies from pursuing geothermal projects, both directly and indirectly by deterring investment (see "Resource mobilization," below).

Resource mobilization

Oil field service companies have diversified to include geothermal energy in their portfolio, and O&G workers have formed or joined geothermal companies in Alberta as a way to apply their skills to a related industry. O&G producers have also engaged with geothermal energy in recognition of its potential to improve profitability through co-production or to address inactive well liabilities. Physical resources have been mobilized for the geothermal industry in the form of O&G wells. Financial resources for pilot projects are available through various public funding sources but obtaining private investment is challenging because of weak guidance of the search and market formation (see below).

3.3 Weak processes

Guidance of the search

Alberta does not have any geothermal legislation and therefore lacks a mechanism for companies to obtain regulatory approval to conduct geothermal projects.[38] This creates significant uncertainties related to issues such as the long-term ownership of geothermal resources and resource royalties, and thus increases the perceived risk of geothermal energy development and discourages companies and investors from pursuing projects.

[38] "Geothermal Industry Development in Canada - Country Update," 6.

Market formation

Although the availability of O&G data and wells reduces the risk of geothermal projects in Alberta by increasing the likelihood of locating a suitable resource and decreasing the capital cost of the project, the extent to which O&G data will improve the probability of success and the exact cost and feasibility of repurposing O&G wells is currently unknown. As a result, the perceived exploration risk[39] of geothermal projects remains high in Alberta as in other jurisdictions.

High risk is often coupled with low return. In particular, the province's low and variable electricity price makes it difficult to achieve a reasonable payback period on high capital cost projects. Although Alberta recently initiated a reverse auction program for low-carbon electricity, geothermal electricity projects are unlikely to be able to compete with more mature wind and solar technologies.[40] Similarly, low natural gas prices create minimal incentive for oilsands companies to experiment with enhanced geothermal systems (EGS) for heating. Furthermore, the *Specified Gas Emitters Regulation* (SGER) enables oilsands companies to reduce emissions by purchasing offsets or paying the established fee rather than pursuing more expensive on-site reductions. Conversely, non-EGS geothermal heat projects may already be competitive in Alberta if O&G wells are used.[41]

The high risk and low return for many types of geothermal projects means that Alberta lacks a protected space in which entrepreneurs and investors can pursue those projects.

[39] Co-production projects do not have exploration risk as the water volume and temperature are known.

[40] *Deep-Dive Analysis of the Best Geothermal Reservoirs for Commercial Development in Alberta*, 66.

[41] Ibid, 67.

4. Policy recommendations

The innovation processes analyzed in the previous chapter are a useful tool to identify areas for strategic policy intervention. To promote the development of a geothermal industry in Alberta, policies should aim to strengthen the weak innovation processes — specifically, guidance of the search and market formation. This can be accomplished by developing and implementing:

1. A regulatory framework for geothermal energy
2. Policies to reduce exploration risk
3. Policies to improve return on investment

The policy recommendations presented in this chapter are high-level, identifying broad areas where support is needed and leaving detailed policy design to subsequent work. Furthermore, the three policy recommendations are based on the current state of Alberta's geothermal energy industry. Over time, the strength of each of the innovation processes and the necessary policy responses are likely to change, requiring ongoing monitoring and assessment of the industry's performance.

Regulatory framework

A comprehensive regulatory framework for geothermal energy would reduce uncertainty and guide companies and investors to pursue geothermal opportunities.[42] Regulatory similarities with O&G could be leveraged to develop this framework as previously noted. An important consideration when developing this framework is to ensure that it adequately addresses potential liability issues when inactive wells are converted to geothermal use.

Specifically, to encourage geothermal companies to repurpose inactive O&G wells, such companies should be able to take over the well lease, which is effectively prohibited by the current Licensee Liability Rating program. The industry needs balance in the management of who owns existing reclamation or environmental liability with any well lease transfer. There must be a framework for liability sharing between the geothermal company that repurposes and operates the well and the O&G company that originally drilled and operated the well.

[42] For a discussion of geothermal regulatory framework design see: *Building a regulatory framework for geothermal energy development in the NWT* and *Legal Obstacles to the Development of Geothermal Energy in Alberta*.

Risk reduction policies

Government policies to reduce exploration risk at the early stages of geothermal projects have been integral to the successful development of geothermal industries internationally by mobilizing financial capital.[43,44] Again, experience managing risk for O&G projects could be capitalized on to develop these policies. Various approaches have been employed in other countries that may be suitable for Alberta (Table 2).

Table 2. Approaches to geothermal risk reduction

Approach	Description
Government as project developer	Government develops the project from start to finish or contracts an independent power producer for construction and operation only
Government-led exploration	Government conducts geothermal exploration, after which the private sector bids to develop the risk-reduced project
Cost-shared drilling	Government covers some of the cost of exploration drilling conducted by the private sector
Drilling insurance	Geothermal project developer receives an insurance payment or is excused from repaying all or part of a government grant if the wells drilled are not as productive as anticipated
General fiscal incentives	Various approaches to reduce the cost of exploration, such as tax and import duty exemptions

Source: World Bank.[45]

Depending on the policy approach, government may leverage a relatively small amount of funds to achieve significant private sector investment in geothermal energy. For example, the French government has a drilling insurance program that reduces investment risk for private developers but relatively few claims are made because the

[43] World Bank, *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation* (Energy Sector Management Assistance Program, 2016), iv. http://documents.worldbank.org/curated/en/621131468180534369/ pdf/105172-ESM-P144569-PUBLIC-FINAL-ESMAP-GeoRiskMitigation-KS024-16-web.pdf

[44] The importance of risk reduction policies is also discussed in: B. Speer et al., *Geothermal Exploration Policy Mechanisms: Lessons for the United States from International Applications* (National Renewable Energy Laboratory, 2014). https://www.osti.gov/scitech/servlets/purl/1134132

[45] *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation*.

availability of O&G data has contributed to a 95% drilling success rate in the Paris Basin,[46] compared to an average of 50% globally.[47]

Return on investment

A guaranteed long-term price for geothermal electricity would incentivize investment in high capital cost geothermal electricity projects. Germany, for example, has a feed-in tariff for geothermal electricity that has encouraged the extraction of its deep, low-temperature resources.[48] A logical approach in Alberta may be to design the Renewable Electricity Program or the Capacity Market to enable geothermal electricity to successfully compete for government support. The contracts-for-difference program in the U.K., for example, was designed with separate competitions between groups of more and less established technologies.[49] Such policy designs are often aimed at promoting a variety of renewable energies or technologies of strategic importance to a jurisdiction. Over time, government support can be reduced as the technology becomes more competitive.

Longer-term experimentation and investment in innovative EGS technologies in Alberta for renewable heat could be encouraged by changes to the SGER that place more emphasis on achieving on-site emissions reductions.

[46] M. Antics, P. Ungemach, "Quantifying Risk in Geothermal Development–High Enthalpy and Low Enthalpy Cases," in *World Geothermal Congress, Bali, Indonesia, 25-29 April 2010*, 5. https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/0413.pdf

[47] *Success of Geothermal Wells: A Global Study,* 18.

[48] *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation*, 19.

[49] European Centre of Technology, "Major Changes for the Renewable Electricity Market: A Focus on UK Contracts for Difference (CFD)." https://theect.org/press-releases-and-news/major-changes-renewable-electricity-market-focus-uk-contracts-difference-cfd/ (accessed August 27, 2017).

5. Conclusions

Similarities between Alberta's O&G sector and the province's emerging geothermal energy industry make Alberta strongly positioned to develop geothermal energy. The province can capitalize on tangible and intangible resources associated with the O&G sector, including relevant skills, data, physical assets, markets, and regulatory experience, to facilitate the development of a geothermal energy industry. In some cases, the full extent of these similarities is currently unknown, requiring more learning about the potential for a geothermal industry to draw on O&G resources.

Spurred by this potential, innovation in geothermal energy has begun in Alberta, as seen by the innovation processes that are already taking place. However, the province's O&G resources do not make it inevitable that a geothermal industry will successfully develop. We identified two key innovation processes that are inadequately activated in Alberta, constraining further development of the geothermal industry.

To exploit Alberta's geothermal opportunity, government should take strategic policy action to address these weaknesses by developing and implementing a regulatory framework for geothermal energy, policies to reduce exploration risk for geothermal projects, and policies to improve return on investment. As the industry develops, the strength of the innovation processes and the necessary policy responses may change.

Alberta has a strong history of successfully developing its natural resources. Just as government support was required to successfully develop the province's oilsands,[50] strategic policy intervention is necessary to successfully exploit Alberta's geothermal opportunity created by the province's O&G history.

[50] For an overview of public support for oilsands development see: United Nations, *A sub-national public-private strategic alliance for innovation and export development: the case of the Canadian province of Alberta's oil sands* (Economic Commission for Latin America and the Caribbean, 2010). http://repositorio.cepal.org/handle/11362/3760