Unlocking the Potential of

GEOTHERMAL TECHNOLOGY

Opportunities & Barriers

CRIN

Clean Resource Innovation Network

EXECUTIVE SUMMARY

Geothermal energy development in Alberta, Canada, has significant potential, underpinned by the province's skilled workforce, resource extraction expertise, and existing infrastructure. Yet innovators and the industry face considerable political, financial, technical, and regulatory challenges that must be addressed to fully harness this potential for Canada and aid its energy transformation.

Early in 2024, CRIN hosted a workshop series to explore geothermal development in Canada. Participants included developers, service providers, industry leaders, Indigenous groups, academics, and funders. The workshops targeted identifying challenges and benefits of geothermal energy in Canada, such as energy security, decarbonization, food security, job creation, and supply chain opportunities.

Barriers and Challenges

Political instability and inconsistent policies create uncertainty, deterring investors and complicating access to funding. Clear financial frameworks, including short-term subsidies and support programs like Investment Tax Credits (ITCs) or carbon contracts, are essential to attract risk-averse funders and stimulate growth.

Technically, geothermal projects face scalability and operational hurdles. Direct-use heat applications are the most viable near-term solution. Alberta's initiatives, such as the Cascade Institute and Alberta Drilling Accelerator (ADA), are advancing geothermal research by testing innovative drilling techniques and refining processes to overcome barriers.

Regulatory ambiguity introduces further complexities to development. Current frameworks do not fully address geothermal rights, creating additional risks for developers. Adjustments, like explicitly including geothermal in existing resource regulations, could streamline processes and build investor confidence.

To realize its geothermal potential, Alberta must address political, financial, technical, and regulatory obstacles. By building on its existing strengths and fostering collaborative efforts, Canada can lead the way in geothermal energy development, contributing to a sustainable and resilient energy future.

Opportunities

Canada's legacy in responsible hydrocarbon resource development offers a strong foundation for geothermal development, with experienced personnel, established infrastructure, regulatory and risk management expertise. Leveraging this foundation allows geothermal developers to reduce startup costs and operational challenges. By viewing geothermal as complementary to traditional energy sectors, Canada can integrate this resource into its energy mix while optimizing economic and environmental benefits for Canadians.

ABOUT GEOTHERMAL ENERGY

In Canada, residential and commercial buildings are responsible for 57% of urban greenhouse gas (GHG) emissions, 74% of these emissions are attributed to heating requirements. Alberta's extensive hydrocarbon exploration history has provided a well-characterized geological profile, making it an ideal region for leveraging geothermal resources. Furthermore, the province's infrastructure, extensive subsurface data, and expertise in resource extraction and asset management position it to effectively use geothermal energy. This renewable resource has the potential to help address Canada's growing energy demands for space and water heating while contributing to GHG emission reductions.

Geothermal energy is a renewable and low-emission resource that holds significant potential for meeting global energy demands sustainably. It leverages the Earth's natural heat to provide reliable and versatile solutions for heating, cooling, and power generation. The diverse range of geothermal technologies highlights its adaptability across various applications and geological settings, making it a critical contributor to the global energy transformation.

Geothermal Technologies

Ground source heat pumps, also known as GeoExchange systems, are a widely used geothermal technology for heating and cooling buildings. These systems transfer heat between the ground and a structure, providing an energy-efficient solution for temperature regulation. Similarly, Aquifer Thermal Energy Storage systems store thermal energy in underground aquifers, enabling the seasonal management of heat and cooling demand. Both technologies are particularly effective in urban environments and contribute significantly to reducing carbon emissions in residential and commercial buildings.

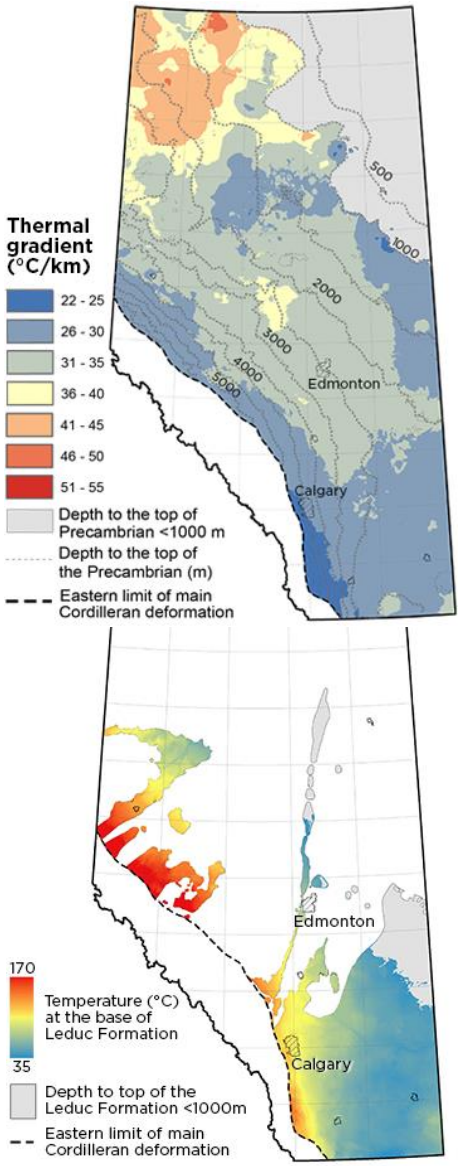


Image source: Alberta Geologic Survey: ***Assessing Our Geothermal Potential*** *(ags.aer.ca/research-initiatives/geothermal-projects)*

The Alberta Energy Regulator database contains date for over 500,000 wells.

Alberta Geologic Survey and the AER are developing tools like the Geologic Framework of Alberta GIS Map Layers, and the Alberta Geothermal Atlas.

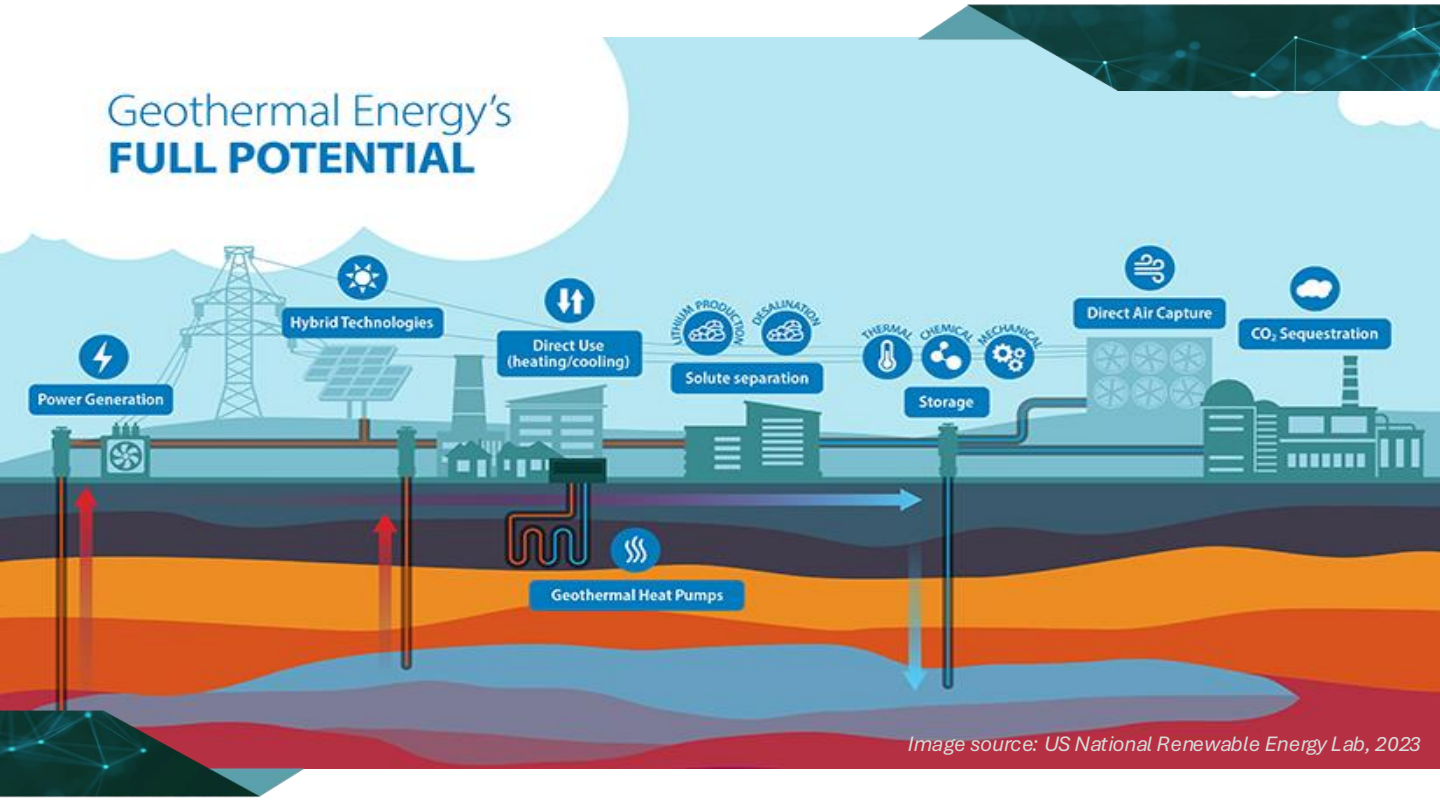


Image source: US National Renewable Energy Lab, 2023

Conventional doublet systems, which utilize a producer well to extract hot water and an injector well to return cooled water, are a staple in geothermal power and direct-use projects. Co-production methods, where hydrocarbons and geothermal fluids are simultaneously extracted, present a unique opportunity to integrate geothermal energy with existing oil and gas operations, making energy extraction more efficient. Microgeneration systems, which involve small-scale geothermal power production, allow for localized and independent energy solutions, often suitable for remote or rural areas.

Innovative advancements like Enhanced or Engineered Geothermal Systems (EGS) and CO2 plume geothermal push the boundaries of geothermal energy use. EGS involves artificially enhancing the permeability of deep rock formations to access geothermal heat, while CO2 plume geothermal utilizes carbon dioxide instead of water as the working fluid, enhancing heat transfer efficiency. Closed-loop systems, which circulate a heat-exchange fluid through sealed pipes, and deep borehole heat exchangers, which tap into geothermal heat at significant depths, provide further options for efficient energy extraction while minimizing environmental disturbance. Together, these technologies underscore geothermal energy's vast potential to reduce fossil fuel reliance, enhance energy security, and support the global shift toward sustainable and resilient energy systems.

WORKSHOPS

In the first half of 2024, CRIN hosted a workshop series to better understand the status of geothermal development in Canada. Workshop attendees were curated for diversity of participation from the five CRIN sector groups.

Workshop #1 – Identifying challenges & benefits

Gord Brasnett, Energy Advisor – Carbon Management and Geothermal Groups, joined us on behalf of Sproule, kicked off the first event with a broad overview of geothermal systems. Brasnett guided the group of around 35 participants through the nuances of various geothermal energy solutions. He covered topics ranging from GeoExchange systems, which use near-surface underground layers as seasonal heat batteries, to co-production methods that leverage conventional well pairs (doublets) to deliver high-quality heat. Additionally, he discussed Deep Enhanced Geothermal Systems, which replicate practices from deep oil and gas development—such as hydraulic fracturing—within hot, saline aquifers to generate both heat and electricity. The recording of the presentation is viewable on CRIN's YouTube Channel.

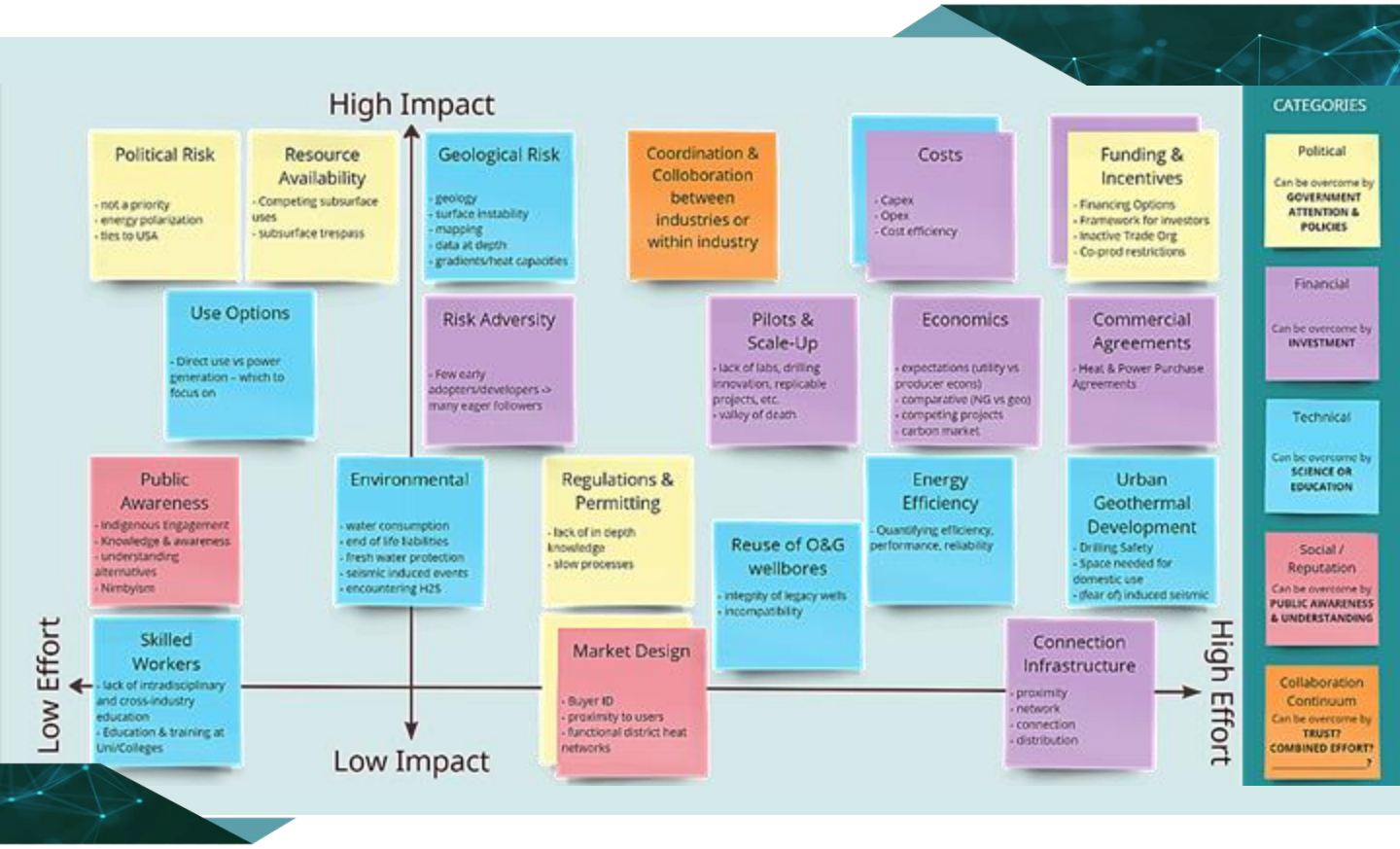
CRIN Sector Groups

- **Innovators**: geothermal developers and university researchers
- **Support services**: service providers including drilling and completion service companies, and technical and commercial advisors
- **Adopters**: oil and gas producers, utility providers, universities, airport authorities, and others from across various industries
- **Talent builders**: Indigenous Peoples representative organization, academic institutions, and skill transferability advisors
- **Funders**: provincial grant funders and members of industry

The group discussed the benefits of geothermal development in Canada and why it is important to continue to advance the technologies and break through the barriers to develop an economically viable heat and power system.

Canadian benefits discussed included:

- **Energy security and grid resilience:**
  - Net-zero baseload - Reliable and virtually endless supply of heat
  - Peak demand dispatchable
  - Low operating costs
- **Decarbonized heat and energy:** producing power and supplying heat "cleanly"
- **Food security:** supporting greenhouse agriculture – enabling year-round food production in northern and remote communities
- **Workforce:**
  - Skill transferability from oil and gas workers
  - Attracting younger and new workers to the energy sector
- **Supply chain:** local and community-based
- **Technology:** redeployment of oil and gas technologies



A facilitated discussion of the barriers to geothermal development led to the identification of five key categories – political, financial, technical, social, and collaborative barriers. As with other early-stage innovations, we must join efforts to overcome these obstacles before broad development and deployment of the needed technology. Collectively, the barriers illustrated in Figure 1 and listed in Table 1 were identified as requiring resolution.

Table 1: Barriers to Geothermal Development in Canada

Effort - Impact	Barrier	Challenging Narrative to Overcome
High – High	Funding & Incentives	• Limited investor knowledge • Inactive trade organization with respect to geothermal energy development • Uncertain investor framework • Co-production restrictions on renewable qualification.
High – High	Costs	• High capital costs • Wide range of operating costs • Cost efficiency vs. time
High – High	Commercial Agreements	Heat and power purchase agreements are not the norm in Alberta
High – High	Economics	• Expectations of utility ROI vs oil and gas producer ROI • Discrepancy in comparison of incumbent natural gas vs emerging/evolving geothermal • Competing projects internally with integrated energy developers or with investors • Carbon market uncertainty and applicability

Effort - Impact	Barrier	Challenging Narrative to Overcome
Medium – High	Collaboration	• Fragmented geothermal community • Adjacent industry lacking knowledge of geothermal
Medium – High	Geologic risk	• Geological uncertainty including variable gradients and heat capacities • Inadequate mapping data at effective geothermal depths • Surface instability
Med/High – Med/High	Pilots and scale-up	• Lack of labs, drilling innovation, replicable projects, etc. • Overcoming the innovation "valley of death" for a startup developer
High – Med/High	Urban geothermal development	• Drilling safety within communities • Space needed for domestic use • Lack of district heating models, infrastructure, norms, and operating procedures • Fear of induced seismicity • General public knowledge of geothermal opportunities within communities
Med/High – Med/High	Energy efficiency	Quantifying efficiency, performance, and reliability
High – Medium	Infrastructure	Proximity, connection, and distribution of geothermal source to grid or direct-use applications
Med/High – Medium	Reuse of oil and gas wellbores	• Uncertainty due to the depth and integrity of wellbores for additional long-term use (useable lifespan) • Incompatibility of dimensions, existing zone isolation, etc.
Medium – High	Resource availability	• Competing subsurface uses and users • Subsurface trespass potential
Low – High	Political risk	• Geothermal is not a priority within the government narrative • Energy polarization • Ties to the USA
Low – High	Use options	Direct use vs power generation
Low – High	Risk adversity	Few early adopters for geothermal and many eager followers
Medium – Medium	Environmental	• Water source/consumption • End-of-life liabilities • Freshwater aquifer protection concerns • Seismic-induced events (for enhanced geothermal applications) • Encountering H2S in target formation
Low – Med/High	Public awareness	• Lack of awareness by the public on opportunity and alternatives (no current "pull"/demand being vocalized by consumers) • Perceived or actual lack of Indigenous engagement both in awareness building and partnership building • "Not in my backyard" - Nimbyism
Low – Medium	Skilled workers	Lack of intradisciplinary and cross-industry education and education opportunities

Workshop #2 – Creating "Traction Plans" demonstrating the impacts of small actions

Workshop participants were separated into groups of up to six to discuss possible solutions to any previously identified barrier. Collectively each group selected one possible solution and created a "traction plan" as a starting point to advancing geothermal development. Traction plans developed are summarized in the following tables.

Barrier	Costs AND coordination and collaboration between industries
Traction opportunity	**Reduction of drilling and completion costs.**
What are the key items that need to be accomplished?	• Collaborative/consortium style test bed to advance drilling and completion technologies to reduce costs and increase tool/equipment efficiency/reliability • i.e. similar to Utah FORGE in the USA or AOSTRA in Alberta to advance the feasibility of oil sands technologies and development in 1970s to 1990s
Who is the target audience?	• Geothermal developers • Oil and gas developers
Who needs to be involved to make this happen?	• Geothermal developers • Oil and gas developers • Provincial government(s) • Industry associations
How might this be done?	• Government-endorsed consortium • Public and private funding partnerships/matching • Shared test facility that also allows parties to maintain IP
What has been done since this workshop	Eavor Partners with the Government of Alberta to Launch the Alberta Drilling Accelerator

Barrier	Commercial agreements
Traction opportunity	**Next-generation power purchase agreements plus heat purchase agreements**
What are the key items that need to be accomplished?	• Understand how to market geothermal as a decarbonization energy source with the option of heat or electricity
Who is the target audience?	• Utility generators and providers • Utility purchasers – general population and/or non-industrial businesses
Who needs to be involved to make this happen?	• Utility generators • Geothermal developers
How might this be done?	• Utility companies need to continue to become educated on the different geothermal technologies and applications and look to expand their service beyond electric generation/distribution. i.e. geothermal for heat • Look for different utility purchase models to provide a more competitive offering to different utility users

Barrier	Public awareness
Traction opportunity #1	**Increase public knowledge of geothermal; create enough knowledge for "kitchen table" conversations**
What are the key items that need to be accomplished?	Awareness campaigns including opportunities and challenges alongside information on alternatives
Who is the target audience?	The general public
Who needs to be involved to make this happen?	• Subject matter experts • Geothermal developers • Government (municipal, provincial, federal)
How might this be done?	• Connect through story: at home, at work, in the community • Public forums • Conferences and tradeshows – cross-sectorial • Universities • Innovation hubs • Inclusive workshops • Success story sharing • Networks (EFL, CRIN, Quest, etc.) • Industry groups - Geothermal Canada, Cascade Institute, Canadian Geothermal Energy Association (CanGEA), SPE, others
What has been done since this workshop	SPE Canada Geothermal Workshop Planning Group (Workshop took place in Calgary in September 2024)
Traction opportunity #2:	**Build awareness and understanding with the public**
What are the key items that need to be accomplished?	Simplified messaging and tools with clear benefits and context on risks
Who is the target audience?	• Students of all ages • General public
Who needs to be involved to make this happen?	• Geothermal consortiums • Government • Educators • Community organizations • Public relations/communication professionals & Media
How might this be done?	• Clear messaging on the problems geothermal alternatives solve • Examples and case studies to aid in understanding • Tools to model technology solutions and enhance understanding

Barrier	Funding and incentives to support energy efficiency through pilots of new solutions and scale-up of proven ones
Traction Opportunity	**Collaboration across the value chain to evaluate cost-effective short-term opportunities and how to optimize them**
What are the key items that need to be accomplished?	• Provincial and federal geothermal-targeted funding support • Collaboration to access the non-diluted grant funding by members of the value chain
Who is the target audience?	Geothermal developers and technology adopters
Who needs to be involved to make this happen?	Provincial and federal government funders in consultation with technology adopters
How might this be done?	Coordinated discussion and planning on the needs of adopters an alignment to government's goals

Barrier	Urban geothermal development
Traction opportunity	**Successful conversion of a community to geothermal/GeoExchange**
What are the key items that need to be accomplished?	• Urban drilling regulations • Transfer of knowledge from other countries that have overcome this barrier • Decentralized utility • Proven benefits to consumers • Public education
Who is the target audience?	Communities
Who needs to be involved to make this happen?	• Municipal and provincial governments • Residential associations • Residential developers • Utility providers
How might this be done?	Implementing a demonstration project to: • Study and share economic viability • Allow the public to access/tour and understand the benefits and realities

Barrier	Geological risk
Traction opportunity	**Reducing geological risk**
What are the key items that need to be accomplished?	In-depth understanding of the area intended for drilling
Who is the target audience?	• Geothermal developers • Oil and gas developers
Who needs to be involved to make this happen?	• Financial support • Experts from industry (geoscientists)
How might this be done?	• Exploration in areas with high volumes of data – seismic, temperature logs, long-term wellhead temperature data, etc. • Bring area and technical experts together prior to selecting drilling locations • Consult other sources of expertise – international experts – to help with data interpretation and upskill Canadian geoscientists with geothermal interpretation skills, as required

Barrier	Environmental concerns AND coordination and collaboration between industries
Traction opportunity	**Leveraging oil and gas resource development regulations (e.g. upfront environmental security deposit) and applying this to other industries utilizing subsurface pore-space/heat**
What are the key items that need to be accomplished?	Cohesive voice to argue the case for commercialization
Who is the target audience?	• Geothermal developers • Regulators • Utility providers • Oil and gas developers • Other pore space utilization developers
Who needs to be involved to make this happen?	Education on policy vs. commercialization challenges
How might this be done?	Organized, collective industry group focusing on pore space utilization protocols
What has been done since this workshop	• CRIN Workshop #3: Geothermal Adoption in Canada: Next Steps • Recording available on CRIN website for members and summary below

During the first two workshops, some overarching ideas became evident:

- **There are big challenges to discuss.** While small actions help, there are large, planful actions that must be undertaken.
- **Collaboration is key in geothermal technology development.** There are currently few voices able to dedicate the time and resources to have the discussions needed to break down the barriers to geothermal resource development. It is critical that geothermal developers and advocacy groups align and coordinate their efforts and seek help from their advocates and supporters.
- **Geothermal developers have important information and knowledge to share.** Many key geothermal developers were missing from these discussions, and their knowledge and expertise would be beneficial to the community of practice.

Workshop #3 – Geothermal developers roundtable

Reflecting on the underlying outcomes of the first two workshops, the final workshop was designed to include all geothermal developers and geothermal advocacy groups in Western Canada an opportunity to contribute and was hosted in a closed circle format to allow for an informed and productive conversation. The participants were asked to address the following questions.

1. Do geothermal developers agree with the barriers or categorization of the barriers as presented (in Figure 1)? What may need to change?
2. Which categories or barriers are geothermal developers currently finding most challenging? How could challenges be overcome to move the work forward?
3. What next steps can geothermal developers agree to? What activities may be best accomplished collaboratively?

Geothermal developers and advocates weighed in and agreed that the 20 barriers and five categories they fall into, as identified in the first workshop, reasonably reflect the challenges faced by geothermal development. They further agreed that there are many complexities, crossovers, and solutions or means to addressing the barriers, as was explored in the second workshop. A summary of the discussion and broad consensus from the third workshop, which focused on challenges and potential solutions, categorized as political and financial challenges, technical challenges, and collaboration challenges, follows.

Political and financial challenges

The development of geothermal technology in Alberta faces several political and financial challenges that hinder its progress, particularly in securing investment and regulatory support. Political shifts and major policy changes have disrupted access to funding, creating uncertainty in the investment market. While political changes can sometimes foster growth, the current environment has cooled investor confidence in geothermal commercialization. In Alberta, lenders and investors remain extremely risk-averse, and the lack of clarity around key financial tools like Investment Tax Credits (ITCs) and the applicability of public funding programs—such as carbon contracts for difference (CCfDs)—has made it difficult for developers to secure loans. Without greater certainty on these incentives, financing geothermal projects will continue to be a significant challenge.

Subsidies and incentives, while essential for launching new technologies, are not sustainable as long-term solutions. However, geothermal developers could benefit from a model similar to those used in the oil sands' early stages, where producers received a low royalty rate for an extended period, or the Quest CCUS project, which offers double GHG credits until capital investments are recovered. A similar short-term incentive structure could provide geothermal companies with the financial support needed to establish themselves and become competitive.

Alberta's regulatory framework would benefit from further clarity of language and incentives necessary to attract corporate investment. Currently, geothermal development falls into a gray area within the renewable energy sector: it is not intermittent like wind or solar but rather constant and dispatchable. Yet, the technology is categorized as a "non-exclusive right" in preliminary regulatory documentation, which raises red flags for potential funders who are unfamiliar with the complexity of application and approval processes for geothermal projects. This language introduces a perceived risk that makes it more difficult for developers to secure financial backing.

Another challenge lies in the co-production of multiple resources. Currently, geothermal licenses do not permit developers to retain even small amounts of oil or gas that may accompany the hot water they extract, whereas oil producers are free to use the heat from water they produce. This regulatory inconsistency limits the ability of geothermal projects to fully leverage the resources they encounter. Adjusting Alberta's resource production regulations to explicitly include geothermal—by simply adding the word "geothermal" to relevant acts—could streamline the process and reduce these cross-sector barriers.

Saskatchewan regulations offer both simplicity and clarity of process. The province treats geothermal development under its existing disposal well regulations, granting developers exclusive rights and establishing clear royalty frameworks. This approach offers a tested regulatory pathway, minimizing complexity and creating a more predictable environment for geothermal projects. Adopting similar regulatory simplicity in Alberta could help accelerate geothermal development by reducing uncertainty and attracting investment.

Technical challenges

The advancement of geothermal technology in Alberta faces several technical challenges but also promising solutions to overcome them. Currently, the optimal application for geothermal energy in Canada is through direct heat utilization projects, which offer the most immediate and practical benefits given the regional climate and existing infrastructure. Direct-use geothermal heat projects can provide reliable, sustainable heating, helping reduce reliance on traditional energy sources and move Alberta closer to its lower emissions energy goals.

Another key to unlocking geothermal's potential lies in building, testing, and iterating projects to gradually refine techniques and processes. The Cascade Institute, dedicated to solving deep geothermal power challenges as a global climate solution, is leading efforts to advance geothermal technology by seeking to establish a large-scale project similar to the Frontier Observatory for Research in Geothermal Energy (FORGE) in Utah, which would act as a model for Canada. The Institute is committed to investing resources to overcome barriers and accelerate geothermal development in Alberta. By fostering these breakthroughs, Cascade plans to share its findings globally, supporting worldwide geothermal advancement.

In addition to Cascade's efforts, the Alberta Drilling Accelerator (ADA) is a collaborative initiative designed to expedite the testing and refinement of geothermal drilling methods. ADA brings together partners like the Province of Alberta, Eavor, the Canadian Geothermal

Energy Association (CanGEA), the Canadian Association of Energy Contractors (CAOEC), the Rural Municipalities Association, and Brazeau County. This partnership aims to create a dedicated geothermal test site where companies can trial innovative drilling techniques and off-site technology developments in a controlled environment. By providing a real-world testing ground, ADA helps developers address technical challenges specific to geothermal energy extraction, advancing both Alberta's and Canada's geothermal capabilities.

These collaborative and iterative projects represent a step-change for geothermal energy in Canada, making it possible to identify, tackle, and solve technical issues through direct application and experimentation. This hands-on approach to research and development is essential to advancing geothermal energy as a viable, reliable solution for the future.

Collaboration challenges

Geothermal technology projects in Alberta face several organizational and collaborative challenges that could be alleviated with a more unified and strategic approach. One critical step toward progress is establishing a cohesive, united voice among geothermal developers and advocates. By convening regularly and aligning on a few targeted, broadly beneficial goals, the geothermal industry can strengthen its advocacy and increase its impact. Taking cues from successful organizations like Geothermal Rising in the U.S., this united front can pursue initiatives that benefit the entire sector, ensuring a focused approach to policy requests and industry advancement.

Establishing a working group that brings together government representatives, regulators, and developers is another essential strategy. It is crucial to recognize that regulators enforce, rather than create, regulations, while developers work within these regulatory frameworks. A collaborative working group would not only improve the regulatory landscape but also help educate regulators on the unique aspects and challenges of geothermal development, enabling more responsive and relevant regulation. This alignment allows developers to provide direct insights into the technical and operational complexities of geothermal systems, helping to tailor regulations that promote safe and efficient project deployment.

Additionally, examining the successes of other emerging sectors, like hydrogen, helium, wind, and solar, can provide valuable insights into navigating Alberta's regulatory and operational landscape. These industries have faced and overcome similar challenges, offering geothermal developers an opportunity to adapt best practices and strategies. By learning from these sectors, geothermal projects in Alberta can leverage proven methods, streamline development, and accelerate growth in a competitive renewable energy market.

Though many challenges exist, Canada, and Alberta have many advantages in geothermal technology development and a strong need to pursue it. Canada's strong foundation in resource extraction, risk management, and regulatory excellence offers unique advantages that could support geothermal's rise.

Canadian Advantages

Canada, particularly Alberta, offers a unique and powerful foundation for geothermal technology development, leveraging its extensive expertise in oil and gas production. With a highly skilled workforce, Alberta is home to a vast pool of trained professionals who excel in resource extraction. This means that the rigs, equipment, and hands-on experience required for geothermal projects are already in place, providing a significant advantage. According to an industry participant, **"We have rigs; we have people; we know what hands-on iron looks like."** This existing infrastructure and workforce, seasoned by decades of experience, offers a seamless transition for geothermal development.

Canada's expertise in managing resource-related risks further strengthens its geothermal potential. Alberta, in particular, has spent decades mastering risk management in resource production, with industry professionals and regulators alike equipped to handle the inherent challenges responsibly. This experience builds confidence and reduces the perceived risks for new geothermal projects. As one participant emphasized, **"We know the risks inherent to resource development and production, and we take the responsibility for those big risks very seriously, with the whole of our province having decades of experience in managing risks responsibly."**

On the regulatory front, Alberta's strength lies in its regulatory expertise. The region's regulatory workforce is adept at managing the risks of resource production and developing the necessary standards, offering a ready-made framework to guide and regulate geothermal projects. One recommended approach is as simple as adding ', geothermal,' to existing resource production regulations. By making this small adjustment, geothermal energy can be readily integrated into Alberta's regulatory landscape, allowing for a smoother, more efficient pathway for development.

Canada's opportunity lies not in replacing oil and gas expertise but in enhancing it with geothermal capabilities. As an industry leader described, **"It's an AND conversation, and we win if we [acknowledge] how good we are at resource production."**

By building on Canada's legacy in resource extraction and harnessing existing skills and regulations, the country can position itself as a leader in geothermal energy, benefiting from both its past achievements and its future potential. ■

We wish to thank all who attended the workshops, contributed to, and supported this work towards clarifying the challenges and opportunities of geothermal development in Canada and in Alberta.