Techno-Economic Modelling for Enhanced Geothermal System Projects in Canada: Challenges and Future Prospects

Megan Eyre, Peter Massie
Cascade Institute

Summary

Geothermal energy has long been recognized as a promising source of renewable baseload power. However, in Canada, geothermal development remains at a nascent stage, facing economic and technical challenges. This study presents a techno-economic analysis (TEA) of geothermal projects in British Columbia, Alberta, Saskatchewan, and the Northwest Territories (NWT) using the Geothermal Electricity Technology Evaluation Model. The current state-of-the-art is evaluated in terms of levelized cost of energy (LCOE), well and surface infrastructure costs, and operational parameters. Furthermore, future technology advancements—such as reduced drilling costs, enhanced reservoir stimulation, and learning-curve effects—are incorporated to assess the potential for geothermal energy to achieve cost competitiveness. Results indicate that geothermal project costs vary significantly depending on depth, temperature, location, and reservoir conditions. While economic challenges remain for Enhanced Geothermal Systems (EGS), future innovations have the potential to significantly improve geothermal energy's economic feasibility, justifying investment in continued research and development.

Method

Modelling geothermal power projects requires assumptions about many variables, which often interact with each other. This makes geothermal projects significantly more complex to model than other energy technologies. Key variables include:

- The optimal ratio of production and injection wells
- Injectivity and productivity indices
- Pump type and size based on flow rates and inter-well connectivity
- Geological uncertainty and subsurface variability
- Real-world well performance data to refine cost assumptions

The TEA utilizes GETEM (DOE, 2016) within the System Advisor Model (SAM) to estimate the LCOE of geothermal power for enhanced geothermal systems within different geological settings across Canada. Site-specific thermal gradients and well depths were used to determine production temperatures, with binary plants selected for temperatures below 200°C and flash plants for temperatures above this threshold. Model inputs were defined based on current industry estimates and projected advancements:

- **Drilling Efficiency**: Reduced drilling time and cost per well in the future scenario
- **Reservoir Productivity**: Higher achievable flow rates based on improved reservoir stimulation techniques

- **Well Configuration**: Optimization of production-to-injection well ratio and pump requirements
- **Learning Curve Effects**: Reduction in capital expenditures due to experience gained from prior projects (n^{th}-of-a-kind developments)

For each site, models were run under present-day and future-innovation scenarios (Table 1), highlighting the impact of technological progress on cost reduction.

Table 1: Key Model Input Parameters for Present-Day and Future Innovation Scenarios

Parameter	Present-Day Case	Future Innovation Case
Plant Size	50 MW	500 MW
Injectivity Index	3,000 lb/hr-psi	7,645 lb/hr-psi
Productivity Index	2,500 lb/hr-psi	6,370 lb/hr-psi
Flow Rate per Production Well	75 kg/s (binary) 60 kg/s (flash)	110 kg/s (binary) 80 kg/s (flash)
No. of Exploration Wells	3	2
Ratio of Injection Wells to Production Wells	1	1
Well Type	Deviated Liner	Deviated Liner
Well Size	Larger Diameter	Larger Diameter
Well Drilling Cost Curve	Baseline * 0.78	Ideal
Drilling Success Rate	80%	95%
Reservoir Stimulation Success Rate	85 %	95%
Opex	150 US$/kW	99 US$/kW

Results, Observations, Conclusions

The current LCOE results indicate that economic challenges persist in certain scenarios due to well costs and reservoir performance uncertainties. However, future scenario simulations incorporating technological improvements indicate a significant decrease in LCOE, demonstrating that geothermal energy could achieve cost parity with other renewables and fossil fuel-based power generation. The LCOE calculated for EGS projects at 5,000 m depth, based on present-day and future innovation scenarios, is shown in Figure 1.

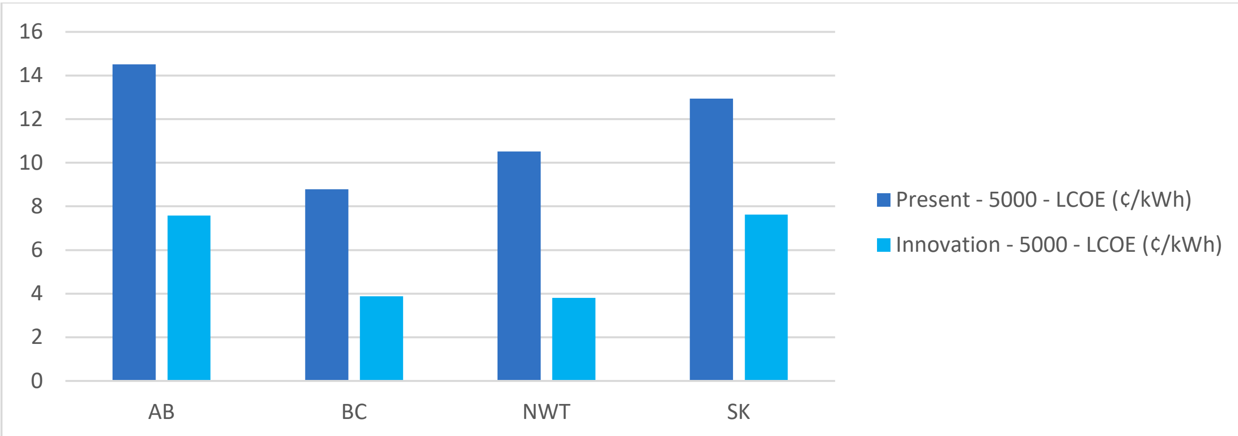

Figure 1: LCOE (¢/kWh) of 5,000 m deep EGS projects in Canada based on modelled present-day (dark blue) and future innovation (light blue) scenarios.

Despite challenges in GETEM modelling beyond 5,000m depth, the modelling did show that the economics of a project improved with greater temperature and thus greater depth (Figure 2). Therefore, the incremental cost of drilling deeper may be offset by lower LCOEs.

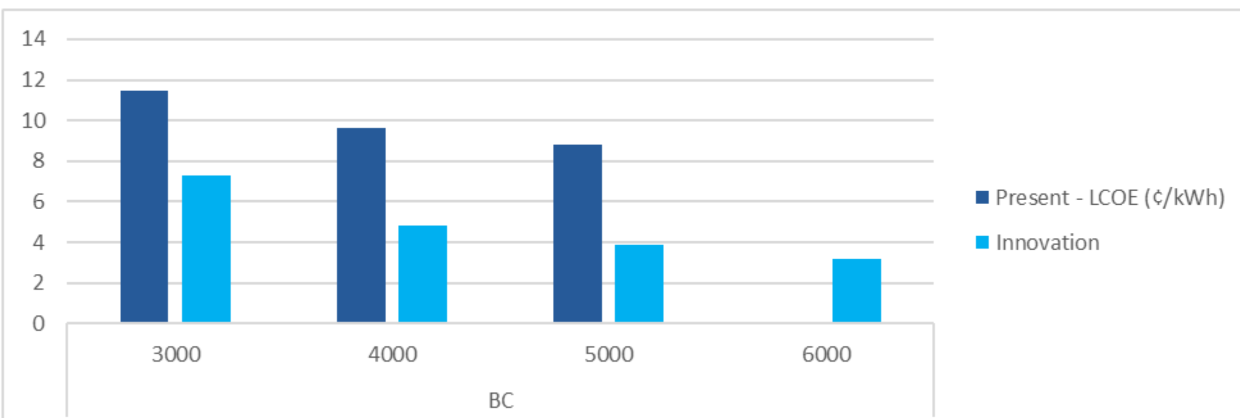

***Figure 2:* LCOE (¢/kWh) of an EGS project in BC, at different depths, based on modelled present-day (dark blue) and future innovation (light blue) scenarios.**

Overall, the findings emphasize the importance of continued innovation and investment in geothermal technology. By reducing drilling costs, improving reservoir stimulation techniques, and leveraging lessons from operational projects, geothermal power can emerge as a viable contributor to Canada's clean energy transition.

The results underscore that strategic investments in geothermal technology and policy support are necessary to unlock the full potential of this resource in Canada.

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