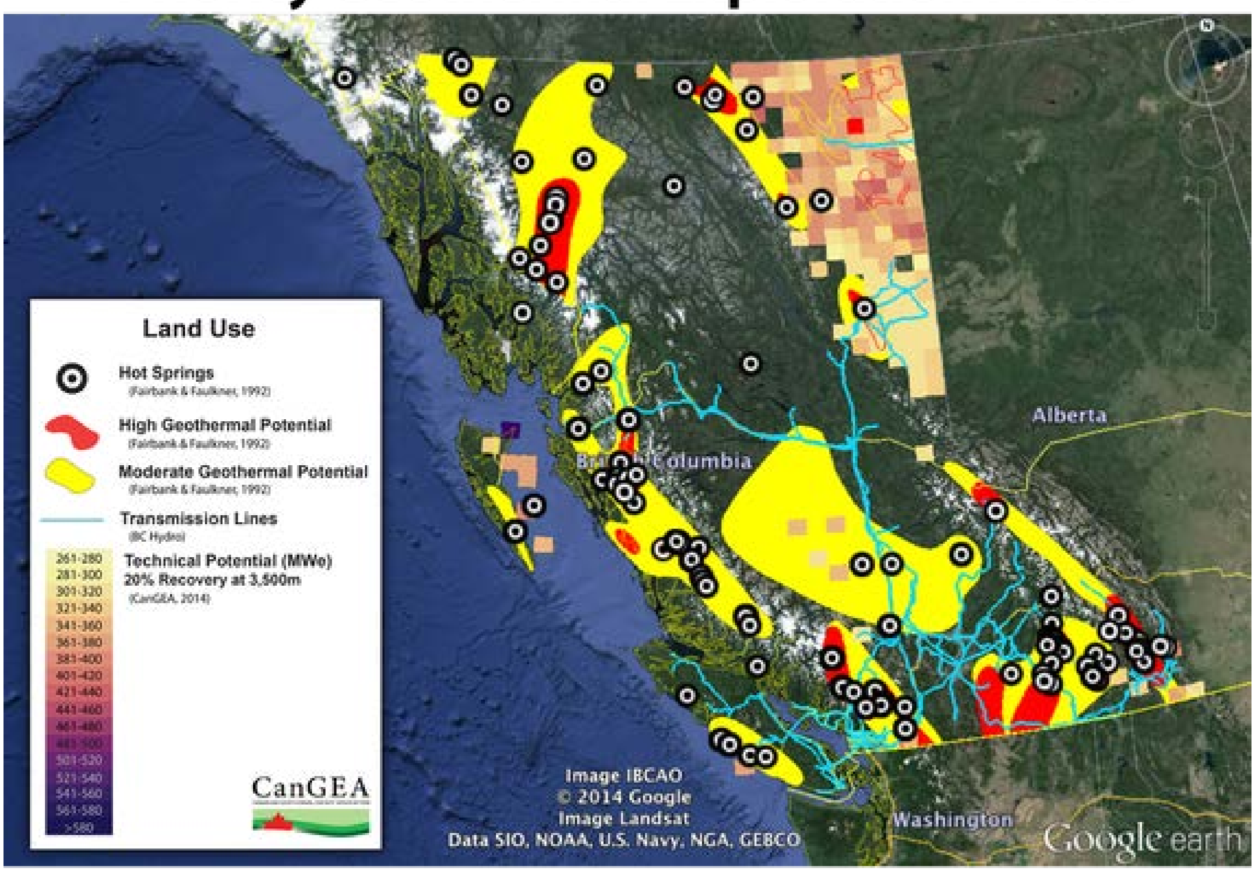
CanGEA
CANADIAN GEOTHERMAL ENERGY ASSOCIATION

Submission to the British Columbia Utilities Commission Inquiry Respecting Site C

August 30, 2017

Priority Geothermal Exploration Areas



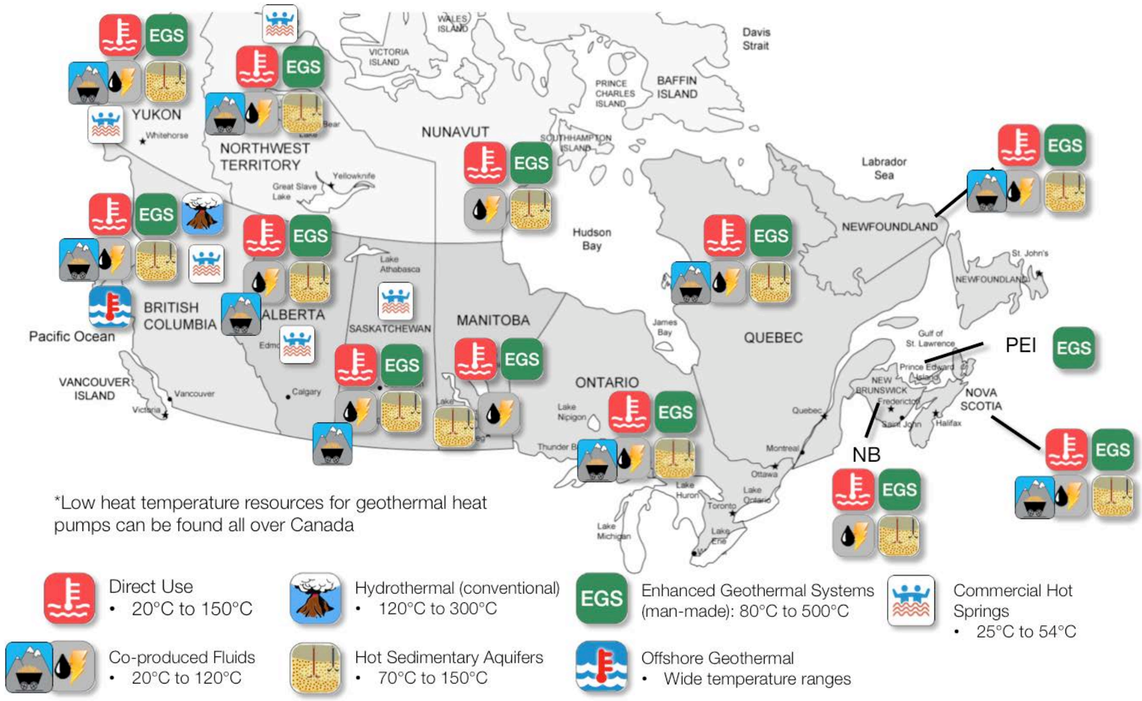
Canadian Geothermal Energy Association (CanGEA)

CanGEA is the collective voice of Canada's geothermal energy industry, and provides a forum to promote geothermal energy development in Canada and abroad. As a non-profit industry association, CanGEA represents the interests of its member companies, with the primary goal of unlocking the country's tremendous geothermal energy potential.

We are asking the Commission to allow our application for intervener status, so that we can participate in the inquiry proceedings and make application for a cost award in accordance with the Commission's Rules of Practice and Procedure.

CanGEA meets the criteria for standing to participate as an intervener in this proceeding. CanGEA's interests, and the interests of its members, who are existing or potential developers of geothermal electricity in BC, will be directly affected by the Commission's findings on Section 3(b)(iv) of the Inquiry's Terms of Reference, pertaining to what, if any, other portfolio of commercially feasible generating projects could provide similar benefits to ratepayers at similar or lower unit energy cost as the Site C Project. CanGEA qualifies both as an interested party (as per Section 3(d) of the Inquiry's Terms of Reference) and a source of expert advice (as per Section 3(f) of the Inquiry's Terms of Reference) that the Commission must and may consult, respectively. CanGEA therefore respectfully makes this submission and requests the Commission grant CanGEA intervener status and the ability to apply for a cost award.

Our members are the visible embodiment of our commitment to the development and production of clean, renewable and sustainable geothermal energy. It is through our collective desire and dedication that we continue to achieve progress in this industry towards making geothermal energy a reality in Canada.



Possible Geothermal Energy Applications in Canada

The map above displays the geographical distribution of possible geothermal electricity and heat applications in Canada.

Executive Summary

Geothermal energy is delivering clean, base load, and low-cost electricity in 25 countries, as well as commercial heating in over 70 countries. In British Columbia, despite its potential to provide low cost, clean, continuous base load electricity, geothermal electricity has remained underdeveloped compared to other renewable energies. In addition, the lack of a functioning geothermal industry in Canada has resulted in a lack of knowledge pertaining to the proper value assessment of these resources.

CanGEA is concerned there may be some inaccuracy in the costs of geothermal electricity, and its suitability for procurement, as derived in the BC Hydro and Geoscience BC analyses of Site C conducted over the past 4 years. Therefore, CanGEA supports the BCUC review of the Site C Hydroelectric dam project as it allows for the consideration of the geothermal alternative.

In the event that Site C is delayed or canceled, CanGEA has found there to be the following advantages to including geothermal electricity projects in a portfolio of viable renewable options:

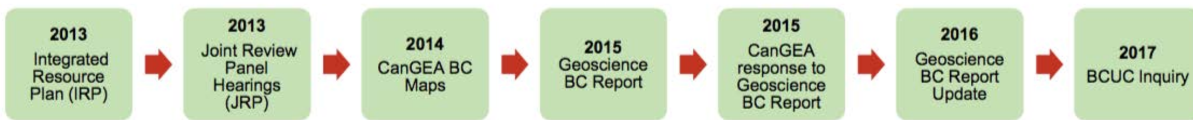
1. **Geothermal projects have the advantage of greater consent and cooperation of First Nations.**
2. **Feasibility Studies reveal the high potential of geothermal sites to provide cost-effective and reliable base load electricity.**
3. **Review of past studies by Geoscience BC and BC Hydro reveals drilling and development costs of geothermal projects have been overestimated. Geothermal is more cost-effective than previously thought.**
4. **A series of smaller geothermal projects is less likely to suffer from cost overruns than a single large-scale project.**
5. **Costly BC Hydro system transmission upgrades and line losses are avoided or minimized.**
6. **Geothermal strengthens the electricity grid through ancillary services, including base load and dispatchable capacity.**
7. **Geothermal belongs at the centre of a portfolio of renewable energy sources, due to its reliability and cost-effectiveness.**

These are reasons why geothermal electricity would provide more benefits than promised by the Site C Project alone. There are even more key advantages to geothermal electricity, described in detail in past reports by CanGEA[1], but the advantages listed above are the most directly relevant to the terms of reference of the BCUC Site C Inquiry.

Studies of the feasibility of the Site C Project by CanGEA have been ongoing as far back as 2013. We have participated since then in response to the results of Site C studies that, in our

[1] *CanGEA, "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C*", (2014): 1-45.

opinion, may have been based on inaccurate numbers or flawed assumptions.



The graphic above shows the timeline of CanGEA's involvement with the Site C Project.

An Integrated Resource Plan was developed in 2013. Subsequently, during the Joint Review Panel hearings in 2013, BC Hydro based their cost estimates pertaining to geothermal projects on their Resource Options Data (RODAT)[2]. RODAT was, in part, derived from an extra-jurisdictional literature review. Accordingly, the RODAT geothermal cost estimates were not based on British Columbia data, nor were they the subject to verification by BC geothermal developers. CanGEA participated in the public hearings as an interested party.

CanGEA released its British Columbia Geothermal Resource Estimate Maps Project in September 2014. This included over 50 maps, tables, graphs and databases. CanGEA continued to work with the raw data, and released a resource estimate update in November 2014 to accompany the Unit Energy Cost (UEC) provided in CanGEA's 2014 Site C Report.[3] The CanGEA UECs are believed to be the first BC data-derived cost estimates shared broadly with the public. UECs can be assumed to be interchangeable with Levelized Costs of Electricity (LCOEs).

Next, in 2015 Geoscience BC and BC Hydro released a report titled: "An Assessment of the Economic Viability of Selected Geothermal Resources in British Columbia", the contents of which were troubling to CanGEA for several reasons. Of primary concern was the use of the Geothermal Electricity Technology Evaluation Model, or GETEM, to derive an LCOE for the 9 favourable sites chosen in the report. The U.S. Department of Energy (DOE) authors of this model, themselves, have indicated that it is inappropriate for use in estimating absolute versus differential costs.

Furthermore, in the 2015 Geoscience BC report, only 2 of the 18 chosen sites to study were Hot Sedimentary Aquifers (HSA) projects, representing only a fraction of the potential for geothermal energy from HSA geological settings. HSA development is believed to be the lowest cost and lowest risk form of geothermal electricity generation in BC.[4]

CanGEA released a comprehensive critique of the 2015 Geoscience BC report later that same year, detailing our concerns described above as well as many others. In response, in October 2016 Geoscience BC released a technical update attempting to correct the flaws in its 2015 report, but this update exacerbated some of the existing problems.

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[2] BC Hydro, *"Integrated Resource Plan: 2013 Resource Options Report Update" BC Hydro*, Appendix 3A-4, (2013): 311-340

[3] *CanGEA, "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C*", (2014): 1-45.

[4] CanGEA, *"CanGEA Critique: An Assessment of the Economic Viability of Selected Geothermal Resources in British Columbia-Geoscience BC*", (2015): 2-3.

For this Inquiry, CanGEA and CanGEA BC developer members have assembled new data, with assistance from an Oregon-based geothermal developer and 2 additional global geothermal experts, that shows discrepancies between Geoscience BC's estimates of the exploration and drilling costs, and the Energy Sector Management Assistance Program (ESMAP) international standard. This new data suggests the cost per MWe of developing geothermal projects is lower than Geoscience BC and BC Hydro concluded.

CanGEA urges the government to adopt the following recommendations:

1. **In the event of delay or cancelation of the Site C Project, meet BC's future electricity needs with a comprehensive portfolio of renewable sources, with geothermal at the centre.** CanGEA believes that BC Hydro ratepayers, BC taxpayers, First Nations, the economy and the environment all stand to gain from a strong government commitment to geothermal and other renewable energy sources in BC.
2. **Invest directly in already-federally-supported geothermal projects in BC.** Gain leverage that the federal government has supplied, and support projects from CanGEA members.
3. **Offer additional permits to geothermal developers** so that more geothermal energy projects can go forward.
4. **Undertake a full Spectral Spatial Analysis (SPAN) of all of British Columbia, followed by an independent analysis to compare with previous volumetric (MW) reports by CanGEA, Geoscience BC, BC Hydro and their consultants.** Although a SPAN would take several months, it would make clearer the full extent of BC's capacity for geothermal electricity generation above and beyond the individual sites highlighted here and in previous reports.
5. **Establish a public education program** on geothermal energy production in BC.
6. **Form an industry-government taskforce to make recommendations on the policy and regulatory changes required** to support cost-effective and efficient development of a geothermal industry in BC by 2020.

We also support the release of BC Hydro's models, contracts and reports, as requested by the Clean Energy Association of BC (CEBC).

By following these recommendations, British Columbia will be well positioned into the future to provide its citizens with clean, reliable, cost-effective electricity.

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First Nations Support

TAKEAWAY: Geothermal projects have the advantage of greater consent and cooperation of First Nations.

In our opinion, Geothermal development is less controversial with First Nations groups compared to the Site C Project. Two geothermal projects described in this submission are both proceeding with the consent and cooperation of the nearby First Nations. The Lakelse Lake project near Terrace, being developed by one of our members, is in fact a joint venture with the Kitselas First Nation.

The Canoe Reach project has received vocal public support from the Simpcw First Nation. In 2016 the Simpcw issued a public statement in support of the Canoe Reach geothermal project.[5] Additionally, in the summer of 2017, the Simpcw First Nation sent a letter of support for the project to the Ministry of Energy, Mines and Petroleum Resources.

In the event Site C is delayed or canceled, an alternative portfolio of renewable energy sources would be more respectful of the rights of local First Nations. It would bring greater opportunity to engage with First Nations groups and the many advantages their participation brings. It would also better fulfill the obligations of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).

BC Feasibility Studies of Geothermal Electricity Projects

TAKEAWAY: Feasibility Studies reveal the high potential of geothermal sites to provide cost-effective and reliable base load electricity.

Recent (Spring 2017) analyses by independent consultants demonstrate the capacity of 2 of the favourable BC Hydro sites to provide reliable electricity at a comparable or lower cost to Site C. Note: a CanGEA member company plans to provide the following 2 publicly as a press release in September 2017 in accordance with the Canadian Geothermal Code for Public Reporting.

The Canoe Reach geothermal project near Valemount, previously mentioned in this submission, is one such example. Independent assessment of the site by Dewhurst Group LLC, using standard heat-in-place stochastic methods, reveals the Canoe Reach reservoir may generate (at P90, or 90% probability to be the minimum electricity generated) 58MWe of continual (gross) electricity (flash or binary plant) over a 30-year span. Guidelines of the World Bank Energy Sector Management Assistance Program (ESMAP) suggest that the project is likely to have an average development cost of USD$240M.

Lakelse Lake, located near the town of Terrace, BC, is another example with significant potential for electricity generation. Independent assessment of the reservoir by Dewhurst Group

[5] https://www.youtube.com/watch?v=z-OsBVAaD2Q retrieved August 28, 2017. Courtesy: Borealis Geothermal.

LLC, again using standard heat-in-place stochastic methods, expects the reservoir to be able to achieve a P90 figure of 23MWe of continual (gross) electricity over a 30-year span. This at an approximate average development cost according to ESMAP guidelines, of USD$96M.

The following summarizes the findings of these assessments:

The Site C dam, at a cost of CAD$8.8B for 1,100MW, has an installed capital of approximately CAD$8.0M/MW for a 53% capacity factor.

Canoe Reach, at a cost of CAD$300M[6] for 58MW, has an installed capital of approximately CAD$5.1M/MW for a 95% capacity factor.

Lakelse Lake, at a cost of CAD$120M[7] for 23MW, has an installed capital of approximately CAD$5.2M/MW for a 95% capacity factor.

For illustrative purposes only, CanGEA has chosen a 30 year notional project life for each of the Site C and the Canoe Reach geothermal projects. Next, the gross MWh delivered is calculated, taking into consideration the capacity factors of each project. This leads to 153,212,400 MWh for Site C and 14,480,280 MWh for Canoe Reach

These values are then divided by capital cost to calculate the ratio of capital cost per MWH produced. **At a capital cost of CAD$8.8B, Site C has an approximate capital cost to generation ratio of CAD$57.4/MWh. At a capital cost of CAD$300M, Canoe Reach has an approximate capital cost to generation ratio of CAD$20.7/MWh. This yields a $36.7/MWh advantage to the geothermal project.**

These assessments demonstrate the considerable capacity of individual geothermal sites to generate consistent electricity. Investment in and development of strategically-located sites throughout British Columbia is expected to be capable of generating electricity with a greater capacity factor and lower installed cost intensity than Site C.

Industry-Realized Drilling Costs and Expected Development Costs

TAKEAWAY: Review of past studies by Geoscience BC and BC Hydro reveals drilling and development costs of geothermal projects have been overestimated. Geothermal is more cost-effective than previously thought.

Since 2013, CanGEA has participated in discussions of the Site C Project. In 2014 we published our report titled "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C" which contained numerous detailed examples of geothermal's ability to produce reliable, base load electricity at a reasonable price.[8] We also published a detailed response to the 2015 report by Geoscience BC and BC Hydro "An Assessment of the Economic Viability of Selected

[6] Based on 1.25 USD-CAD conversion rate, current as of August 28, 2017.
[7] Based on 1.25 USD-CAD conversion rate, current as of August 28, 2017.
[8] *CanGEA, "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C*", (2014): 1-45

Geothermal Resources in British Columbia" in which we described the many instances in which the assumptions upon which Geothermal BC and BC Hydro based their conclusions resulted in inaccurate pricing models for potential geothermal opportunities.

The chart below, taken from CanGEA's 2014 report, shows the geothermal potential in British Columbia and how it is sufficient to put geothermal electricity at the centre of any portfolio of renewables for the province's future electricity needs, including the 1,100 MW of capacity and 5,100 gigawatt hours per year (GWh/yr) of energy that would come from the Site C Dam project.[9]

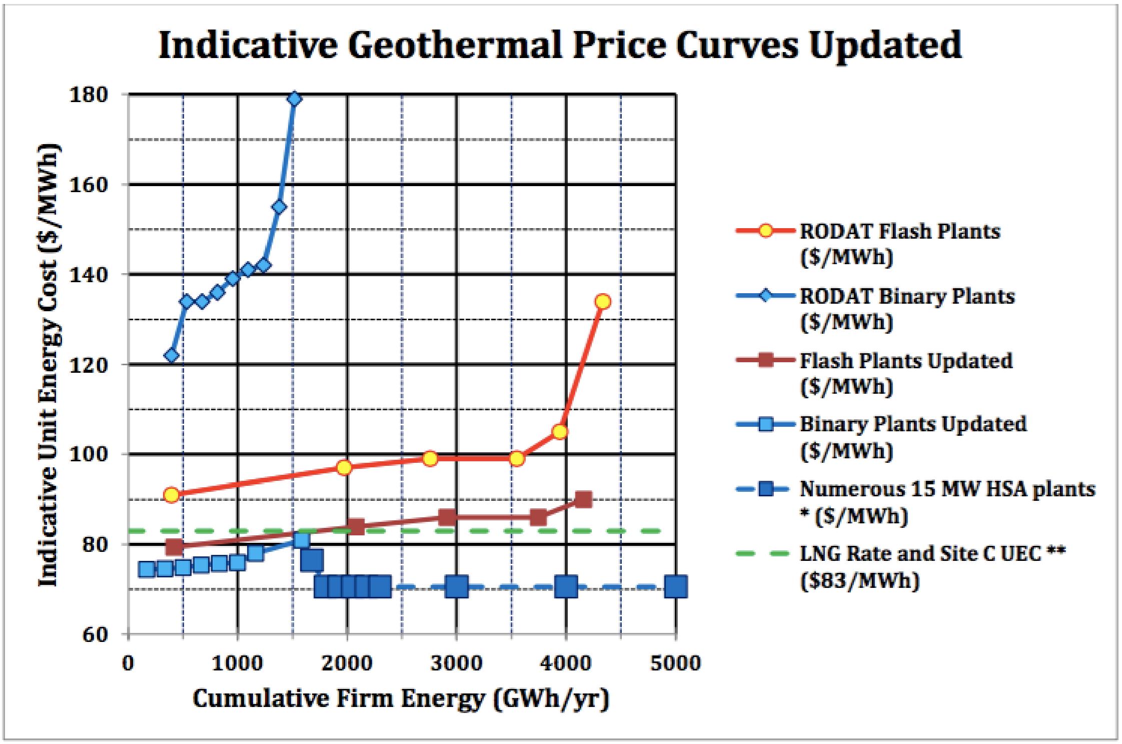

Figure 1: Indicative Geothermal Price Curves Updated

For this Inquiry, with the help of external consultants, CanGEA has assembled more recent data to demonstrate the possible costs of the exploration and drilling of geothermal resources in BC.

A crucial aspect of any geothermal energy project is the exploration & drilling program and thus the costs related to drilling fundamentally affect the overall economic model. We agree with Geoscience BC in that "the cost of drilling wells during the various phases of a geothermal project has a significant impact on the LCOE" (Levelized cost of Energy)."[10]

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[9] *CanGEA, "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C"*, (2014): 8.
[10] GeoScience BC. http://www.geosciencebc.com/s/Report2015-11.asp

With actual data provided from a geothermal energy developer working in Oregon (similar geology to BC), CanGEA has confirmed that the data presented by BC Hydro and Geoscience BC regarding modern day exploration and drilling costs for geothermal energy development may have been grossly overstated by Geoscience BC and BC Hydro, potentially by a factor of 2-4.

It is important to note that these CanGEA cost estimates assume efficient buildout, i.e. elimination of project development delays that are currently experienced in the province.

One key source of relevant data is from the ESMAP Geothermal Handbook: Planning and Financing Power Generation. The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. This document was produced in June 2012 and compiled from actual cost data related to global geothermal project development.[11]

One of the key findings of this document is "technological risks involved are relatively low; geothermal power generation from hydrothermal resources—underground sources of extractible hot fluids or steam—is a mature technology. For medium sized plants (around 50 MW), levelized costs of generation are typically between US $0.04 and 0.10 per kWh ($40-100/MWh), offering the potential for an economically attractive power operation."

However, Geoscience BC's calculations for $/MWh are greater than $170/MWh for 10 of the 11 projects analyzed. For example, a 'flash' facility at the Canoe Reach geothermal project was estimated at $268/MWh. One reason for the discrepancy between CanGEA's and Geoscience BC's and BC Hydro's values is the use of BC and region-specific exploration and drilling costs.

Geoscience BC's report calculated 'exploration, confirmation and development costs' as part of the breakdown of overall project costs and levelized costs of capital installed (see Table 6-3).

[11] Geothermal Handbook: Planning and Financing Power Generation.
https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf

Table 6-3: Estimated Capital Costs for Favourable Sites

Geothermal Prospect Area/Site	Transmission-Line Costs (incl. Substations) (million CAD$ 2015)	Road-Building Costs (million CAD$ 2015)	Permitting & Leasing Costs† (million CAD$ 2015)	Resource Exploration Costs** (million CAD$ 2015)	Resource Confirmation Costs†† (million CAD$ 2015)	Resource Development Costs*** (million CAD$ 2015)	Power Plant Costs (million CAD$ 2015)	Total Capital Costs (million CAD$ 2015)	Total Cost per Gross kW Installed (CAD$ 2015)
Canoe Creek – Valemount	$16.4	-	$0.5	$13.0	$45.2	$50.7	$43.8	$169.6	$11,900
Clarke Lake	$14.4	-	$0.5	$15.9	$52.6	$54.0	$67.3	$204.7	$11,100
Clarke Lake (5 MW scenario)	$1.5	-	$0.5	$5.3	$16.5	$19.6	$19.3	$62.8	$12,600
Jedney Area	$34.5	-	$0.5	$10.6	$36.3	$42.1	$45.3	$169.3	$13,900
Kootenay	$10.2	-	$0.5	$10.6	$33.1	$45.7	$72.7	$172.8	$8,700
Lakelse Lake	$12.2	-	$0.5	$10.6	$33.1	$44.5	$72.1	$173.0	$8,800
Lower Arrow Lake	$13.7	-	$0.5	$10.6	$33.1	$44.9	$71.6	$174.4	$8,900
Meager Creek	$13.2	$1.0	$0.5	$30.0	$85.9	$262.9	$172.5	$566.0	$5,700
Mt. Cayley	$30.6	-	$0.5	$10.6	$33.1	$79.8	$110.0	$264.7	$6,500
Pebble Creek	$6.8	$0.5	$0.5	$28.0	$85.9	$262.9	172.5	557.1	$5,600
Okanagan	$12.3	-	$0.5	$10.6	$33.1	$41.5	$67.0	$165.1	$9,000
Sloquet Creek	$2.1	-	$0.5	$7.0	$22.9	$21.0	$28.6	$82.1	$8,200

* Also includes the Jedney Area, and Clarke Lake at 5 MW
† Permitting and leasing costs are for entire project life, including environmental studies.
** Resource Exploration Costs comprise primarily slim-hole drilling costs, as well as costs for geological, geochemical, and geophysical studies.
†† Resource Confirmation Costs include confirmation drilling and well testing costs.
*** Resource Development Costs comprise wells drilled between resource confirmation and plant start-up, as well as production and injection pipelines in the wellfield.

As a comparison, the ESMAP document completed a similar analysis.

TABLE 1.6
Indicative Costs for Geothermal Development (50 MW ex generator capacity), in US$ Millions

PHASE / ACTIVITY		LOW ESTIMATE	MEDIUM ESTIMATE	HIGH ESTIMATE
1	Preliminary Survey, Permits, Market Analysis[16]	1	2	5
2	Exploration[17]	2	3	4
3	Test Drillings, Well Testing, Reservoir Evaluation[18]	11	18	30
4	Feasibility Study, Project Planning, Funding, Contracts, Insurances, etc.[19]	5	7	10
5	Drillings (20 boreholes)[20]	45	70	100
6	Construction (power plant, cooling, infrastructure, etc.)[21]	65	75	95
	Steam Gathering System and Substation, Connection to Grid (transmission)[22]	10	16	22
7	Start-up and Commissioning[23]	3	5	8
	TOTAL	**142**	**196**	**274**
	In US$ Million per MW Installed	2.8	3.9	5.5

Source | Authors.

To accommodate the slight variations in project categories, CanGEA calculated the total cost for the key exploration and drilling program stages (See Column "Total Exploration & Drilling" in the following chart) and then referenced this to capital intensity, stated in $/MWe terms. This allowed us to calculate a comparison between the Geoscience BC report as an estimated ratio to the ESMAP estimate (Box in Red).

The following chart demonstrates how the $/MWe estimates in the Geoscience BC report exceed the estimate provided by the international ESMAP standard. Note the red and blue rounded rectangles highlighting the relevant columns. For instance, the Geoscience BC Canoe Creek geothermal project estimate of $7.26/MWe is 3.4 times the ESMAP estimate.

Units in $MM	Resource Exploration Costs	Resource Confirmation Costs	Resource Development Costs	Total Exploration & Drilling	Total Capital Cost	Project MWe Total	$/MWe Exploration	Ratio to ESMAP Estimate
Canoe Creek	$13.00	$45.20	$50.70	$108.90	$169.60	15.0	**$7.26**	3.4
Clarke Lake	$15.90	$52.60	$54.00	$122.50	$204.70	20.0	**$6.13**	2.9
Clarke Lake 5MW	$5.30	$16.50	$19.60	$41.40	$62.80	5.0	**$8.28**	3.9
Jedney Area	$10.60	$36.30	$42.10	$89.00	$169.30	15.0	**$5.93**	2.8
Kootney	$10.60	$33.10	$45.70	$89.40	$172.80	20.0	**$4.47**	2.1
Lakelse Lake	$10.60	$33.10	$44.50	$88.20	$173.00	20.0	**$4.41**	2.1
Lower Arrow Lake	$10.60	$33.10	$44.90	$88.60	$174.40	20.0	**$4.43**	2.1
Meager Creek	$30.00	$85.90	$262.90	$378.80	$566.00	100.0	**$3.79**	1.8
Mt. Cayley	$10.60	$33.10	$79.80	$123.50	$264.70	40.0	**$3.09**	1.4
Pebble Creek	$28.00	$85.90	$262.90	$376.80	$557.10	100.0	**$3.77**	1.8
Okanagan	$10.60	$33.10	$41.50	$85.20	$165.10	20.0	**$4.26**	2.0
Sloquet Creek	$7.00	$22.90	$21.00	$50.90	$82.10	10.0	**$5.09**	2.4
ESMAP Medium Estimate MM	**$3.00**	**$18.00**	**$86.00**	**$107.00**	**$196.00**	**50.0**	**$2.14**	**1.0**

ESMAP calculated an average of $3M for exploration, $18M for well testing and reservoir evaluation, $70M for production/injection drilling, and $16M for surface piping and transmission infrastructure (the latter does align with calculation from the GeoScience BC report) for a total of $107 million for a 50MWe project. As the project sizes (MWe output) vary for each project, it is helpful to compare the $/MWe calculation. The ESMAP handbook calculation works out to ~$2.14/MWe for the exploration, reservoir confirmation and production/injection drilling phase of a project, as the chart above shows in its bottom row.

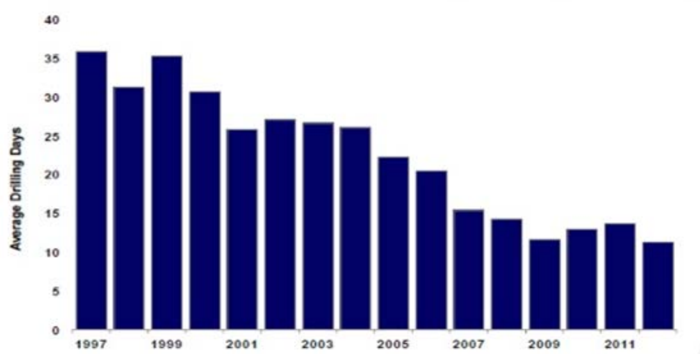
The model used by GeoScience BC is also a US-based model with cost calculations in $USD and requires local estimated well cost. We have confirmed with global geothermal drilling experts that drilling costs are approximately 30-50% lower than in 2012. In order to verify that actual North American cost analyses did not vary significantly from global ESMAP examples, CanGEA was able to acquire actual project drilling costs from an Oregon geothermal company for a drilling program run in 2007 (the same year Geoscience BC's calculations were based on).

By way of comparison, the cost estimate for a single confirmation or production well with the Geoscience BC data set was a minimum of $5.0M, to as much as $11.9M. The actual data set from drilling programs in 2007/2008 from the Oregon geothermal developer (drilling hard basalt rock formations) ranged from $1.9M to $5.1M for full size production and injection wells. As geothermal drilling programs may have significant variability associated with depth of drilling (and therefore overall drilling costs), it is helpful to calculate drilling costs on a $/meter analysis.

Based on drilling costs for the depth of wells, the Geoscience BC report estimated ~$4,000/m. The Oregon project developer's actual data was $2,200 to $2,400/m.

One possible reason for this discrepancy is that Geoscience BC calculated the drilling costs in 2007-2008, when drilling services were at a premium due to Domestic Crude Oil Prices reaching >$90/Barrel. The recent downturn in oil commodity pricing has also significantly impacted the costs of drilling, with oilfield operators seeing a reduction of drilling costs of 20-40% as a result of many idle rigs in competition for fewer exploration/drilling programs. In the Western Canada oilfield industry, there have been many rounds of cost-cutting, layoffs, and pressure on oilfield service providers, resulting in significant cost savings for project developers.

Another relevant concept driving drilling costs are the recent advances in drilling time (Oil & Gas Sector), where increases in the ROP (rate of penetration), in terms of meters drilled/rig day have had significant impact in reducing the overall drilling cost.



Average drilling days per well in the Western Canadian Sedimentary Basin [WCSB]. All 3,000m horizontal wells from 1997 - 2012 (excluding Oil Sands).[12]

The above graph shows one example of the amount of time taken to drill oilfield wells to a 3km depth, which has been reduced to less than half the time over a 15-year period. This 15-year time span shows drilling days moving from 30-35 days in 1997 to less than 15 days in 2011. This reduction is due to the use of more technologically advanced directional drilling. Dialogue with leading-edge drilling companies in Western Canada state this number to be <12 days in 2017, and this is well aligned with drilling costs estimates from other global geothermal projects including recent drilling (Spring 2017) performed by the Oregon geothermal developer. Due to current oilfield market conditions and an abundance of idle rigs in Western Canada, there is currently an opportunity to use some of the best drilling companies and expertise in Canada, which may not have been available from 2008-2014 for the emerging BC geothermal industry.

As the above data shows, there are large discrepancies in the Geoscience BC exploration and drilling cost estimates compared to the ESMAP standard. An Oregon geothermal developer's experience suggests the former data may be overstated. The Geoscience BC calculation for exploration and drilling costs ranges from 1.4 - 3.9 times the estimates from ESMAP for geothermal energy projects.

[12] geoSCOUT, ARC Financial Research.

CanGEA asserts that the exploration and drilling costs for geothermal projects should not present a barrier to the inclusion of these projects into the BC Hydro system. Exploration risk can be jointly shared between the province and developers in order to position more projects ready for deployment, in the event the Site C Project is delayed or cancelled.

Reducing Cost Overruns of Large-Scale Projects

TAKEAWAY: A series of smaller geothermal projects is less likely to suffer from cost overruns than a single large-scale project.

Building costly, large-scale hydro stations that can take up to a decade to complete is a course of action that has been called into question, by such experts as London Economics International LLC. If BC needs additional power supply, technologies that have shorter lead times, with a planning framework that can be adjusted to actual demand, should be favoured. Additional geothermal electricity supply can be generated in smaller increments and closer to markets[13].

A useful byproduct of developing geothermal power plants is the fact that these plants will allow for build out in accordance with electricity demand. This will avoid risks of excess supply should expected future demand not materialize. A recent report produced for the Clean Energy Association of British Columbia (CEBC) by London Economics International (LEI), addressed these concerns at length[14].

CanGEA believes that geothermal energy's benefits are best realized through the distribution of projects throughout BC. This will help to ensure that the economic benefits of geothermal projects are felt by a broad array of BC's communities while keeping cost overruns in check.

Avoiding BC Hydro System Transmission Upgrades and Line Losses

TAKEAWAY: Geothermal projects can improve BC Hydro's existing transmission network, removing the need for expensive upgrades and reducing line losses.

Depending upon the location of geothermal projects, they can improve BC Hydro's existing transmission network. Moreover, they can help customers by improving local electricity service and reducing BC Hydro's costs in these areas. For instance, purchasing electricity from a base load project located at the end of a long radial transmission line, will improve the level of electricity service and reliability to local customers.

[13] Marc Eliesen, *An Evaluation of the Need for the Site C Project*, (August 2017): 18.
[14] London Economics International LLC, "Cost-effectiveness evaluation of clean energy projects in the context of Site C" Report Prepared for the Clean Energy Association of British Columbia, (Vancouver, BC: September 16, 2014): 1.

An example of this is the Canoe Reach geothermal project, currently in the drilling stage, located near Valemount, BC[15]. As a result of its location at the end of a 700 km long 138 kV radial transmission line, this region is known for frequent electricity outages. Placing base load capacity near Valemount will not only secure electrical service in the region, it will also negate the need for expensive upgrades to or expansion of the existing transmission line. This will help reduce some pressure for BC Hydro to increase electricity rates. It will also help to avoid regional economic damages caused by brown-outs and electrical instability. The inclusion of a base load project would also allow Valemount to grow its aggregate demand from incoming business projects such as the approved Valemount Glacial Destinations Ski Hill.

Similarly, the Lakelse Lake geothermal project near Terrace is not only poised to serve developing industrial loads, it also would reduce or eliminate line losses from Prince George through Terrace to Bob Quinn Lake. Additional geothermal resources in the province are located in 'end-of-line' scenarios as well.

As a third example, building geothermal projects near Fort Nelson would help electrify new industrial load. **This could likely save BC Hydro ratepayers hundreds of millions of dollars by avoiding or delaying the need to build a new North-East Transmission Line, the feasibility of which is still being studied by BC Hydro but the cost of which is estimated at $1 billion.**

Geothermal energy has the potential to save ratepayers and BC Hydro substantial sums, as it would delay, reduce, and/or eliminate the need to build or upgrade transmission lines.

Strengthened Electricity Grid Through Ancillary Services

TAKEAWAY: Geothermal strengthens the electricity grid through ancillary services, including base load and dispatchable capacity.

BC Hydro routinely penalizes renewable energy projects when they burden the grid, yet they do not credit a project when it improves the grid. It is in the ratepayers' interest that a credit should be granted for projects that strengthen the grid. If such a reward signal is not given, generators with helpful transmission characteristics will be less apt to move projects forward. **Geothermal is one of the few types of generators that can improve the local grid through firm electricity delivery and the ability to strategically enhance points of grid weakness.**

As these are technical issues, it is important to define exactly what is meant by the terms "ancillary services", "base load", and "dispatchable". With regards to ancillary services, the U.S. Federal Energy Regulatory Commission (FERC) defines them as "the services necessary to support the transmission of electricity from a supplier to a purchaser, given the obligations of a control area and that area's transmitting utilities to maintain reliable operations of the

[15] Think Geoenergy, Drilling for Canoe Reach Geothermal Project in British Columbia could start this year, (August 2017): http://www.thinkgeoenergy.com/drilling-for-canoe-reach-geothermal-project-in-british-columbia-could-start-this-year/

interconnected transmission system."[16] Neither wind, solar nor run of river hydro possesses both of these characteristics.

In contrast, geothermal electricity is both a base load source of energy, and is also dispatchable. Dispatchable energy sources are essentially those that can be ramped up and down by operators. While the Site C project is dispatchable to some degree, it is not able to do so as effectively as geothermal energy. Also, geothermal can accommodate energy delivery in the winter season with increased production, versus decreased in the case of large Hydro, from November to March.

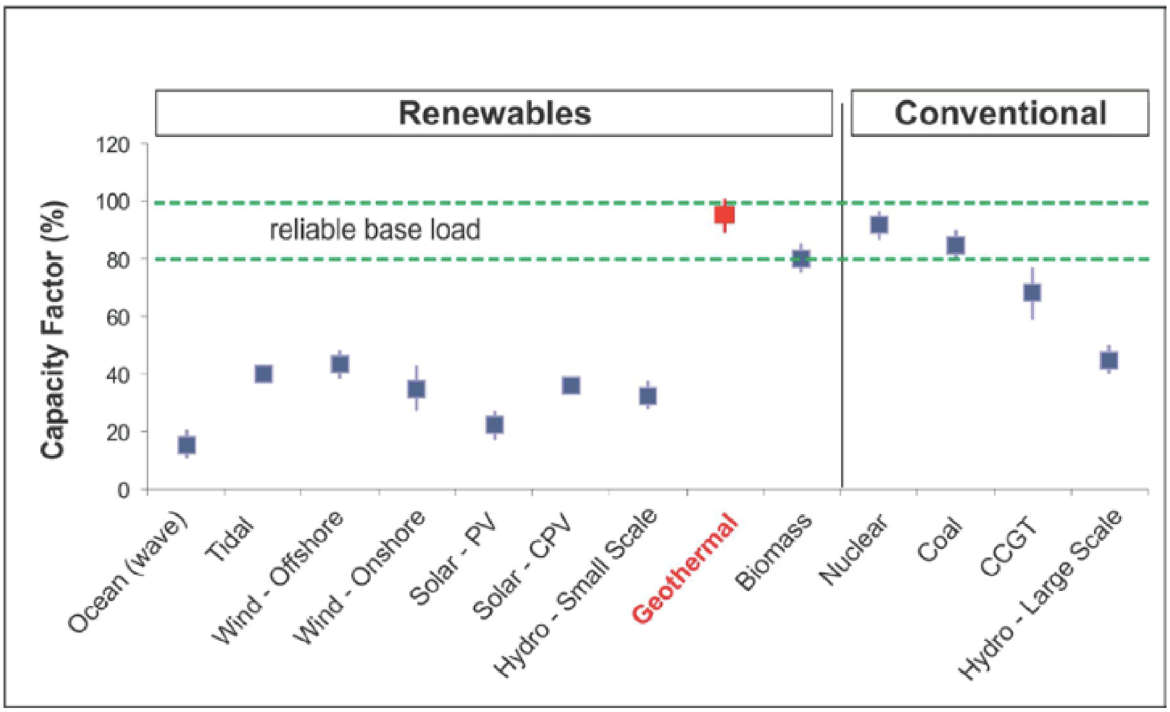


Figure 2: comparison of generation capacity factor for various electrical energy sources[17]

Geothermal power plants far exceed hydroelectric projects in terms of their capacity factor (also know as availability or uptime), especially when taking into consideration the challenges posed by climates with frigid winters. As a case in point, new geothermal power plants have average capacity factors in the 95% range[18]. Further, many modern geothermal power plants are able to ramp production up and down multiple times per day, from a minimum of 10% of nominal electricity, up to 100% of nominal electrical output[19]. This ability to be ramped up and down makes geothermal energy a dispatchable energy source, as it possesses the ability to be

[16] Benjamin Matek, "The Values of Geothermal Energy" Geothermal Energy Association, (Washington, D.C.: October, 2013): 4.
[17] *CanGEA, "Geothermal Energy: The Renewable and Cost Effective Alternative to Site C*", (2014): 29.
[18] Activated Logic, "Geothermal Energy in Australia" Australian Geothermal Energy Association (Adelaide, Australia: December, 2009): 9
[19] Matek, October 2013, 12.

controlled by a system operator, and “to be turned on and off” or ramped up and down[20].

By providing dependable capacity, geothermal electricity has the potential to shape, firm and help integrate intermittent and other renewable sources such as wind, solar and run of river hydro onto the grid, allowing BC’s existing network of hydroelectric dams to be used as a giant battery (a means for storing energy for when it is needed), and to use geothermal electricity as the first dispatched electricity in the merit order. This can then be used to maximize profits from electricity exports, **a policy objective of the Site C project.**

Geothermal at the Centre of a Renewable Portfolio

TAKEAWAY: Geothermal belongs at the centre of a portfolio of renewable energy sources, due to its reliability and cost-effectiveness.

It is part of the terms of reference of this Inquiry to consider other portfolios of commercially feasible generating projects capable of providing similar benefits as the Site C Project. Although a portfolio consisting entirely of geothermal projects is thought to be capable of providing these benefits, the dearth of geothermal developments currently underway in the province makes it imperative to explore the possibilities of a portfolio of generating projects that contains geothermal, and also contains other energy sources such as biomass, wind, solar, and run of river hydro. **In this case, geothermal energy must be given priority due to its superior reliability as a base load source of electricity, and resultant cost savings compared to variable renewable energies.**

A study provided to CanGEA for use in this BCUC submission, ahead of its October 2017 publication date, assessed the full costs of managing intermittent versus base load renewable electricity generation, scaling wind and solar production to a hypothetical 30MW demand for comparison with a 30MW geothermal project. The California grid, used in this study, is similarly as well as connected to the British Columbia grid and therefore offers a useful set of comparative data. Electricity generation data was downloaded from the California Independent System Operator’s (CAISO) Open Access Same-time Information System (OASIS) for the comparison. Based on the shape of solar and wind delivered throughout the California portion of the CAISO control area during 2015, a 30MW geothermal base load (262,800 MWh) is matched by name plate capacity installations of 106 MW and 101 MW, for solar and wind, respectively.[21]

Though large installed MWs of solar and wind provide a MWh equivalent to 30MW of base load geothermal, their intermittency results in many hours without adequate generation to meet the system demand. Geothermal has no such intermittency. The study factored in the use of gas turbine generation alongside wind and solar, to be used when they fell below the required

[20] Paul L. Joskow, “Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies” American Economic Review: Papers & Proceedings 100, no. 3, (2011): 238.

[21] Warren,Ian. "*Comparative Costs of Geothermal, Solar, and Wind Generation Based on California Independent System Operator on California Independent System Operator Electricity Market Data* ", GRC Transactions 41, (2017): 1.

30MW, and adjusted the cost accordingly to account for the gas turbine resources required to match the consistent, uninterrupted geothermal electricity generation.[22]

This is, of course, an incomplete account of the full costs to manage intermittent versus base load renewable electricity generation. But it provides a minimum basis determined from real data that should be considered when evaluating the complete per megawatt-hour costs of intermittent and base load resources.

Although a solar or wind PPA contract price might appear to be USD $50/MWh (levelized), the extra costs to provide backup generation for when demand exceeds supply (extra costs not present for the more reliable geothermal generator) make the actual price upwards of $103.12/MWh for solar and $83.28/MWh for wind, based on an estimate of the fixed cost revenue requirements of existing gas turbine resources.[23]

Natural gas turbines are not allowed in BC as they are in California, but the point stands: extra generation sources are necessary with wind and solar power options, because wind and solar generation is intermittent. The added cost of these generators creates a "hidden cost" passed on to ratepayers above and beyond the low PPA contract price the wind and solar providers negotiate.

Intermittent renewable energy prices do not reflect their cumulative addition to grid management costs nor the real economic costs of gas turbine resources required to manage their integration into the real-time electricity demands of customers. Although wind and solar may seem the most economical on the surface, California stands as a test case where ratepayers bear the burden of "hidden costs" needed to keep demand met consistently.[24] Average EIA-reported retail prices exceeded USD $150/MWh in 2015 and USD $180/MWh at the beginning of 2017.[25] **The consistent output of geothermal eliminates the need for the added costs.**

From this study it can be seen how geothermal electricity generation is more reliable, and consequently more economical, than intermittent renewable electricity generation. **It is clear, therefore, that geothermal must be placed at the centre of any portfolio of generating projects in the event the Site C Project is delayed or canceled.**

[22] Warren,Ian. "*Comparative Costs of Geothermal, Solar, and Wind Generation Based on California Independent System Operator on California Independent System Operator Electricity Market Data* ", GRC Transactions 41, (2017): 1-2.
[23] Warren,Ian. "*Comparative Costs of Geothermal, Solar, and Wind Generation Based on California Independent System Operator on California Independent System Operator Electricity Market Data* ", GRC Transactions 41, (2017) : 2.
[24] Warren,Ian. "*Comparative Costs of Geothermal, Solar, and Wind Generation Based on California Independent System Operator on California Independent System Operator Electricity Market Data* ", GRC Transactions 41, (2017) : 7.
[25] U.S. Energy Information Administration, 2017, Electricity Data Browser: www.eia.gov

Conclusions and Recommended Next Steps

Renewable geothermal electricity generation has great potential in BC, as confirmed by our analysis. In particular, geothermal electricity generation is poised to provide similar benefits to ratepayers at similar or lower unit energy cost as the Site C project. Geothermal can provide firm energy at a lower cost, on a timetable and in a manner that benefits taxpayers, ratepayers, First Nations, and the economy, all with a lower carbon footprint.

There are discrepancies between the exploration and drilling cost estimates calculated by Geoscience BC and BC Hydro, and the ESMAP international standard, and Oregon developers' experience, resulting in the potential costs of developing geothermal projects in BC to appear higher than they actually are expected to be.

Site C will inevitably have a high transmission cost, while the strategic dispersion of geothermal projects throughout the province will be able to minimize transmission costs. Thus, there is every reason to believe that given the thoughtful and methodological development of BCs geothermal potential, geothermal electricity in combination with a portfolio of other renewable sources could provide all of BC's future electricity requirements at a reasonable cost to ratepayers.

HSA binary plants could be located in any of BC's sedimentary basins. In the northeast, they could be located adjacent to gas development and production, to facilitate direct electrification much more quickly than by the building of long and expensive transmission lines. In central or southeast BC, they could be located to provide clean, reliable, base load electricity and ancillary services directly to the BC electricity grid.

In addition, some of the most promising areas for geothermal development are located at the end of transmission lines. Such is the case with Valemount and Terrace. The Valemount area in particular experiences frequent electricity outages (brown-outs), and has restricted economic growth. This situation can be remedied through the strategic deployment of a geothermal electricity project.

CanGEA fully supports the need for independent verification of our findings.

In summary, geothermal development has the following advantages:

1. **Geothermal projects have the advantage of greater consent and cooperation of First Nations.**
2. **Feasibility Studies reveal the high potential of geothermal sites to provide cost-effective and reliable base load electricity.**
3. **Review of past studies by Geoscience BC and BC Hydro reveals drilling and development costs of geothermal projects have been overestimated. Geothermal is more cost-effective than previously thought.**

4. **A series of smaller geothermal projects is less likely to suffer from cost overruns than a single large-scale project.**
5. **Costly BC Hydro system transmission upgrades and line losses are avoided or minimized.**
6. **Geothermal strengthens the electricity grid through ancillary services, including base load and dispatchable capacity.**
7. **Geothermal belongs at the centre of a portfolio of renewable energy sources, due to its reliability, cost-effectiveness, and smallest carbon footprint.**

CanGEA urges the government to adopt a 6-point plan to become a Canadian and world leader in renewable energy:

1. **In the event of delay or cancelation of the Site C Project, meet BC's future electricity needs with a comprehensive portfolio of renewable sources, with geothermal at the centre.** CanGEA believes that BC Hydro ratepayers, BC taxpayers, First Nations, the economy and the environment all stand to gain from a strong government commitment to geothermal and other renewable energy sources in BC.
2. **Invest directly in already-federally-supported geothermal projects in BC.** Gain leverage that the federal government has supplied, and support projects from CanGEA members.
3. **Offer additional permits to geothermal developers** so that more geothermal energy projects can go forward.
4. **Undertake a full Spectral Spatial Analysis (SPAN) of all of British Columbia, followed by an independent analysis to compare with previous volumetric (MW) reports by CanGEA, Geoscience BC, BC Hydro and their consultants.** Although a SPAN would take several months, it would make clearer the full extent of BC's capacity for geothermal electricity generation above and beyond the individual sites highlighted here and in previous reports.
5. **Establish a public education program** on geothermal energy production in BC.
6. **Form an industry-government taskforce** to make recommendations on the policy and regulatory changes required to support cost-effective and efficient development of a geothermal industry in BC by 2020.

We also support the release of BC Hydro's models, contracts and reports, as requested by the Clean Energy Association of BC (CEBC). In order to have a truly open and transparent process, we recommend that the materials be made available to any interested party by September 20 through a secure site, so that interested parties can provide a comprehensive response to the BCUC preliminary Site C report.

In conclusion, we would like to reiterate our belief that a strong government commitment to geothermal development would strongly benefit BC Hydro ratepayers, BC taxpayers, First Nations, the economy, and the environment. Geothermal energy has numerous additional ancillary benefits above and beyond electricity that we are ready and eager to discuss further. A government that takes a strong stand in support of geothermal development is a government preparing to meet the needs of its people into the future.

Warm Regards,

Nathan Coles
BHum, JD
Senior Policy Manager

Paola Gongora
Policy Intern

On Behalf of CanGEA's Policy Team

www.cangea.ca

info@cangea.ca

www.powearthful.org