Policy Brief

Facilitating Geothermal Power in British Columbia: Lessons from California's Energy Policies

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Executive Summary

British Columbia (BC) is currently facing an energy deficit. The BC Energy Plan's goals to maintain a 93% clean energy standard and produce energy self-sufficiency in the province require ambitious planning. Among a list of alternative solutions is geothermal energy. The energy technology can provide a large capacity of clean energy and long term generation. Certain geothermal locations also cost less than other alternative energy sources. Despite a number of preliminary projects, there has not been any generation of the energy in BC. The high uncertainty and cost of the first stages for implementing geothermal plants reduces the incentive for independent power producers to take on the challenge. BC does not currently have the legislation nor strategies that addresses this issue of economic uncertainty. In contrast, California has a long history of successful geothermal implementation while using similar geothermal reserves on the Ring of Fire. The state is examined to determine its successful methods of subsidization to surpass the geothermal barriers of economic uncertainty.

Due to the unpredictable cost of most locations in BC, they will remain unfeasible until development in drilling technology and geothermal reserve mapping and research is furthered. Only a small fraction of the locations are economically feasible to access and implement generation. However, implementing geothermal plants for even the most economically feasible locations in the province will require some subsidization to further minimize the drilling and exploration risk. Using data collected from existing surveys on the province's reserves, the government can subsidize these select few locations to begin generating geothermal energy. Following California's model, the BC government should re-invest the long term profits from generating in these select locations into a subsidy pool for further geothermal research and mapping of the province's reserves. This process will create a compound effect that will allow for the province to eventually tap into its vast potential geothermal energy.

Introduction

BC is currently facing an uncertain future in energy. The province's history of producing energy surplus and export is no longer the case. The last few years saw BC facing an energy deficit, where the province purchased and imported external energy on an annual basis. This was a necessary step as BC could not provide enough total energy on its own. The province currently generates the vast majority of its energy from hydro power. To eliminate the need for energy import, the ambitious 2007 BC Energy plan was formulated, where BC would implement the goal of becoming energy self-sufficient by 2016. Moreover, the Energy Plan also aims to include extra "insurance" energy added onto the self-sufficient levels.

These goals must be accomplished under a policy that maintains 93% clean energy output in the province.[1] Based on these guidelines, one of the proposed solutions was to develop geothermal energy production as a potential energy alternative. British Columbia is widely estimated to have one of the largest natural geothermal reserves in Canada. There is enough

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[1] Legislative Assembly of British Columbia, "BC Clean Energy Act," http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_10022_01.

theoretical geothermal reserve to generate sufficient energy to meet the goals of the 2007 Energy Plan. Since there has not been any implementation of geothermal energy to date, one must examine the political and economic barriers that geothermal energy faces in BC. These barriers currently exist at the legislative and policy level in the province. Unlike California (CA), BC does not provide sufficient subsidies to reduce the initial uncertainty of exploration and drilling costs. CA is a comparable region for geothermal energy, and the state has already implemented numerous operating geothermal plants. California's geothermal legislation will be assessed to determine its relevancy as a case study for geothermal energy in BC, and whether it provides solutions to existing barriers in the Canadian province.

1.0 Geothermal Reserves in BC

Figure 1

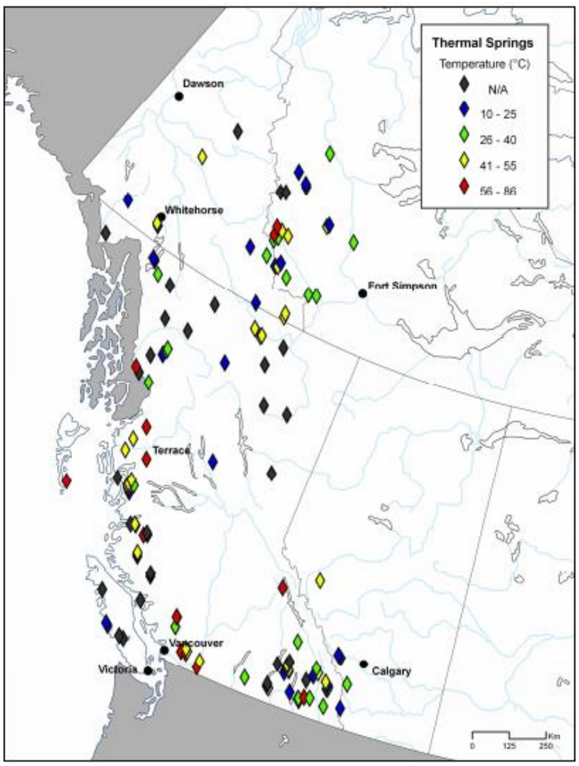
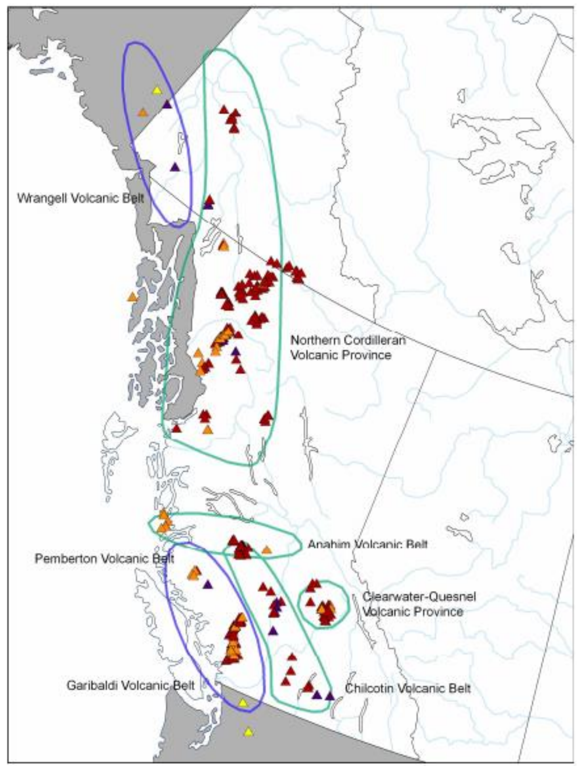


Figure 2



Source: Grasby et al. "Geothermal Energy Resource Potential of Canada." Natural Resources Canada.[2]

Grasby et al conducted a large study on geothermal potential in BC. Figure 1 shows a number of thermal springs that can be tapped into for energy. Their level of heat is categorized into different colours based on the legend. Figure 2 demonstrates the location and age of a large number of volcanoes that can be utilized for geothermal generation. The volcanic belts are shown with green (basaltic type) and blue (stratovolcano type) outlines. Based on one estimate from a Cangea sediment survey, there is a 33,877 MW total indicated generating capacity of geothermal

[2] S.E. Grasby et al. "Geothermal Energy Resource Potential of Canada." Natural Resources Canada. (2012): 27, 29. http://publications.gc.ca/collections/collection_2013/rncan-nrcan/M183-2-6914-eng.pdf

energy in BC.[3] This "indicated" capacity refers to geothermal sources that exist through direct measurements, and indicate recoverable thermal energy with a reasonable level of confidence. There is also an "inferred" capacity of 5,688 MW on top of this value that refers to geothermal sources identified with insufficient data to confidently interpret them.

However, based on the Grasby et al assessments, a number of volcanoes and hot springs are located at distant locations from BC's urban centers. A few projects however, are located close to urban centers. Table 1 demonstrates that BC Hydro estimated there is a potential for 780 MW of installed capacity based on 16 project locations with economically viable locations. The multiple assessments state that the indicated capacity of geothermal power is clear; there are abundant reserves of the energy in the province. It is important to note that certain project locations demonstrate a more predictable cost than others. Therefore, certain locations may be more economically feasible than others. However, none of these locations have had any exploration yet. The next section discusses the other energy technologies that the province has already implemented instead.

Table 1

Transmission Region	Number of Projects	Installed Capacity (MW)	DGC (MW)	Annual Energy (GWh/yr)	Annual Firm Energy (GWh/yr)	UEC at POI Range ($2013/MWh)
Peace River	1	20	20	140	140	134
North Coast	3	270	270	2,111	2,111	97 - 136
Kelly Nicola	1	20	20	140	140	141
Revelstoke	1	20	20	140	140	142
Vancouver Island	2	70	70	534	534	134 - 573
Lower Mainland	5	320	320	2,505	2,505	91 - 139
Selkirk	3	60	60	420	420	134 - 179
Total	**16**	**780**	**780**	**5,992**	**5,992**	**91 - 573**

Source: BC Hydro, "2013 Resource Options Report Update."[4]
* UEC at POI is the Unit Energy Cost at the Point of Interconnection

1.1 Energy Comparison

The initial construction and implementation costs of geothermal power require a smaller overnight cost for a project initiated in 2014 (cost without interest incurred) to construct and implement an energy generating facility compared to other energy types as shown in table 2 below. However, it is important to note that the cost of implementing a geothermal plant can vary widely based on location. The table below provides an average cost for geothermal power, but only for

[3] Cangea, "British Columbia Geothermal Resource Estimate Maps," 2014. http://www.cangea.ca/bc-geothermal-resource-estimate-maps.html.
[4] BC Hydro, "2013 Resource Options Report Update," (2013):5-44. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/ror-update-report-20131115.pdf.

site-specific data assessing viable geothermal locations.[5] These locations are based on a U.S. study and do not reflect BC's lack of mapping, and potentially higher costs. The price for establishing a plant in BC can be higher based on their expertise and knowledge of the reserve locations. The lead time is the number years required to develop the energy system, and is similar when examining most energy types. Table 2 shows that geothermal energy would not take significantly longer to develop compared to other technologies. This is crucial, as the 2007 BC Energy Plan requires expedience for investing in new energy alternatives. Based on the current 2016 deadline, none of these new energies will meet the plan's self-sufficiency requirements on time. Therefore, lead time is not necessarily an issue. In terms of cost, geothermal energy is comparatively cheap to implement. The only technology type that has a smaller initial investment cost than geothermal is wind.

When examining wind, it is important to note that its overnight cost is not the only factor for price. The overnight cost is the measured cost to build the plant without interest incurred, as if the plant was constructed overnight.

Table 2

Technology Type	Size (MW)	Lead time (years)	Total Overnight Cost in 2014 (2013 $/kw)	Fixed Operations & Maintenance Cost (2013 $/kw/yr.)
Wind	100	3	1,980	39.53
Solar Thermal	100	3	4,502	67.23
Geothermal	50	4	2,448	112.85
Hydro	500	4	2,651	15.15
Scrubbed Coal New	1300	4	2,917	31.16
Biomass	50	4	3,659	105.58

Source: U.S. Energy Information Administration, "Cost and performance characteristics of new central station electricity generating technologies."[6]
* Overnight cost refers to cost without interest incurred
* Overnight capital cost provided is including contingency factors, excluding regional multipliers and learning effects. These represent costs of new projects initiated in 2014.

Table 3 shows that the estimated price for the cheapest geothermal locations is less than both wind varieties if onshore wind's integration cost is included for its intermittency.[7] The reliability rating for geothermal is far greater than wind. BC Hydro states that "reliability refers to energy that can be depended on to be available whenever required."[8] When intermittent, wind power has to be stored to avoid black-outs and power shortages. Storing wind energy in batteries at a utility scale would incur much higher costs that are not included in the cost for wind in table 3. Wind energy also posits a number of ecological issues, namely the wide consensus that birds, bats and other

[5] U.S. Energy Information Administration, "Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants," 3. http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
[6] U.S. Energy Information Administration, "Cost and performance characteristics of new central station electricity generating technologies," http://www.eia.gov/forecasts/aeo/assumptions/pdf/table_8.2.pdf.
[7] BC Hydro, "2013 Resource Options Report," 3-45.
[8] Ministry of Energy, Mines and Petroleum Resources, "BC Energy Plan," (2007): 22. http://www.energyplan.gov.bc.ca/PDF/BC_Energy_Plan.pdf

flying creatures face higher mortality rates, and their migration patterns are dispersed. Onshore would require the construction of a large number of turbines, and this would further magnify the ecological issues. In comparison, geothermal energy has a low impact on ecology and wildlife with comparatively little controversy.

Table 3

Technology Type	Number of Projects	Installed Capacity (MW)	UEC at POI Range ($2013/MWh)	Reliability
Onshore Wind	121	16,425	115 - 365	Intermittent
Offshore Wind	43	14,688	166 - 605	Intermittent
Geothermal	16	780	91 - 573	Firm

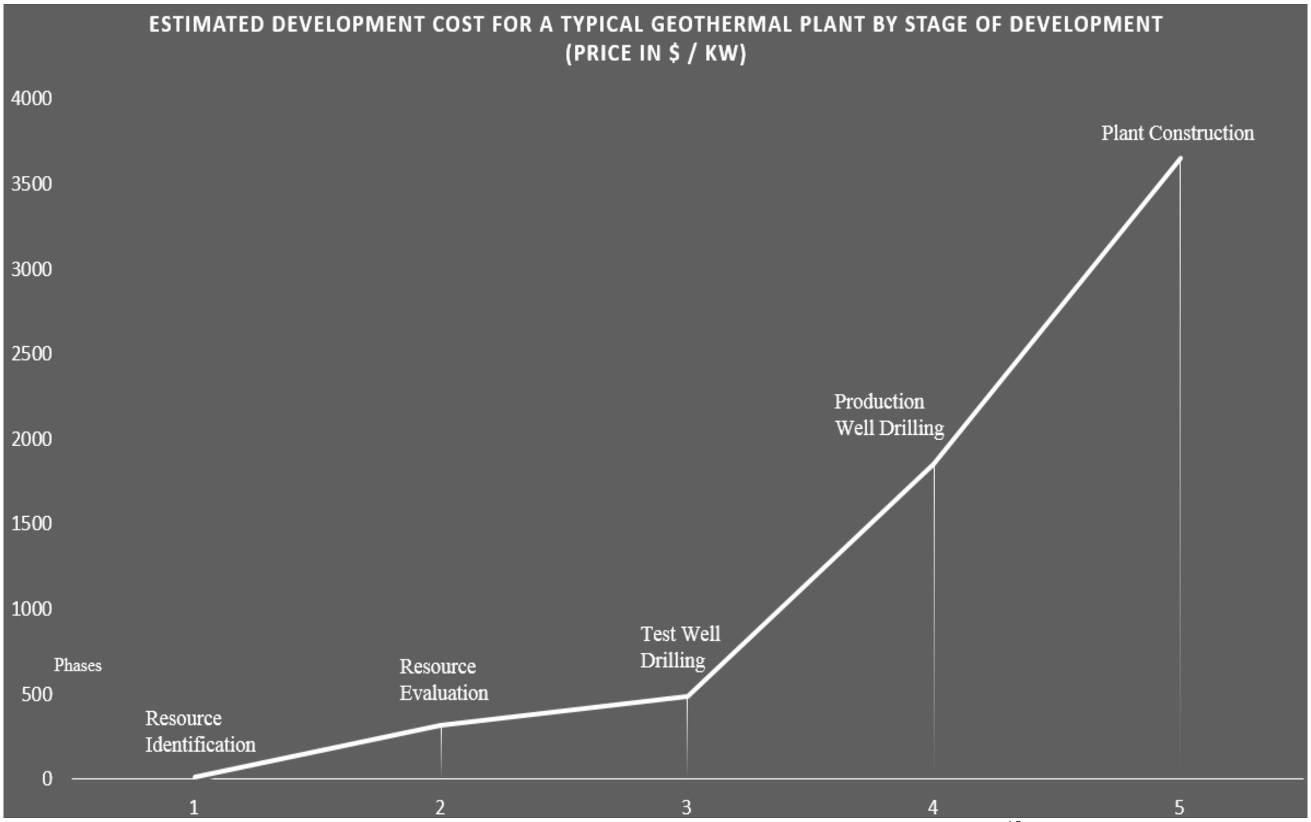
Source: BC Hydro, "2013 Resource Options Report Update."[9]
*The base unit energy costs (UECs) for each resource option at the point of interconnection (POI) reflect:
- Overall costs to the point of interconnect for total energy, i.e., both firm and non-firm energy;
- Costs within plant gate;
- Access road costs; and
- Transmission interconnection costs

1.2 Geothermal Implementation Costs

Figure 3 demonstrates the significantly rising costs of implementing a geothermal plant as it progresses through its developmental phases. The initial three stages including test well drilling are currently the greatest barriers that potential geothermal independent power producers (IPP) face in BC. By the time they reach the test well drilling phase, an average geothermal company is already paying a cumulative total cost of $483/KW. This average cost is incurred without the company being certain of how much test drilling it must perform, as this can vary greatly based on location. Therefore, the economic risk in the initial stages of implementation pose the highest risk for IPPs. Excluding the regional cost multipliers of constructing a plant, figure 4 shows that the three initial stages of geothermal implementation constitute approximately 13% of the total cost. Therefore, the figure shows that an IPP on average will risk 13% of their total implementation cost without knowing with certainty that they can proceed to production well drilling. As this value is averaged, it may be higher and constitute even more of the total cost.

[9] BC Hydro, "2013 Resource Options Report Update," (2013): 3-72, 5-31 - 5-44. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/ror-update-report-20131115.pdf.

Figure 3



Source: National Renewable Energy Laboratory, "Guidebook to Geothermal Power Finance."[10]

British Columbia currently allows for IPPs to bid for geothermal contracts and generate private energy. Based on this system, there have not been any geothermal plants that fully and successfully implemented energy generation. A number of geothermal projects were attempted such as Meager Creek, Mount Cayley and Pebble Creek, but none have generated energy to date. Since 2002, the province awarded geothermal permits to 12 different locations, and only one active geothermal lease has been issued that was for the Meager Creek location.[11] The greatest uncertainty for geothermal energy in BC arises from the risks involved to confirm the potential development of geothermal resources.[12] More specifically, IPP's must drill "three to ten slim-holes" that "may cost from $0.5 million to $5 million, with no guarantee of identifying a viable geothermal resource."[13] This cost would translate into a cost estimate ranging from $91 - $573 in $2013/MWh at the point of interconnection. Further, some BC geothermal resources are in remote

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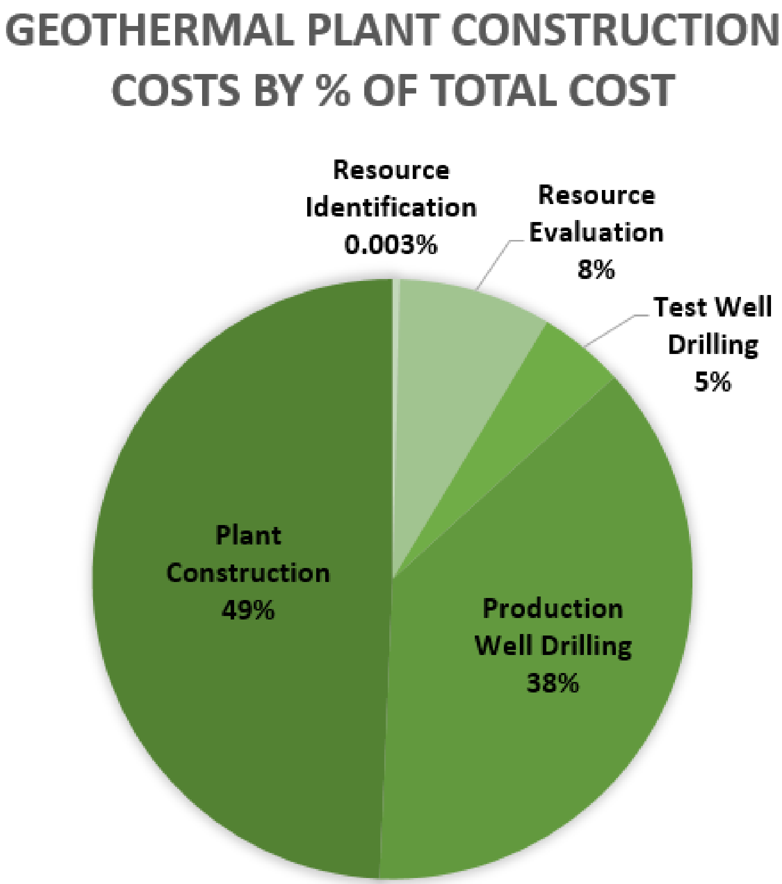
[10] Salmon et al, "Guidebook to Geothermal Power Finance," National Renewable Energy Laboratory, 5. http://www.nrel.gov/docs/fy11osti/49391.pdf.

[11] BC Hydro, "2013 Resources Options Report Update," 5-46. https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/ror-update-report-20131115.pdf.
[12] Ibid.
[13] Ibid.

areas that may incur large infrastructure and transmission costs.[14] Therefore, the uncertainty of geothermal projects in BC largely relies on the initial cost of investment.

Figure 4



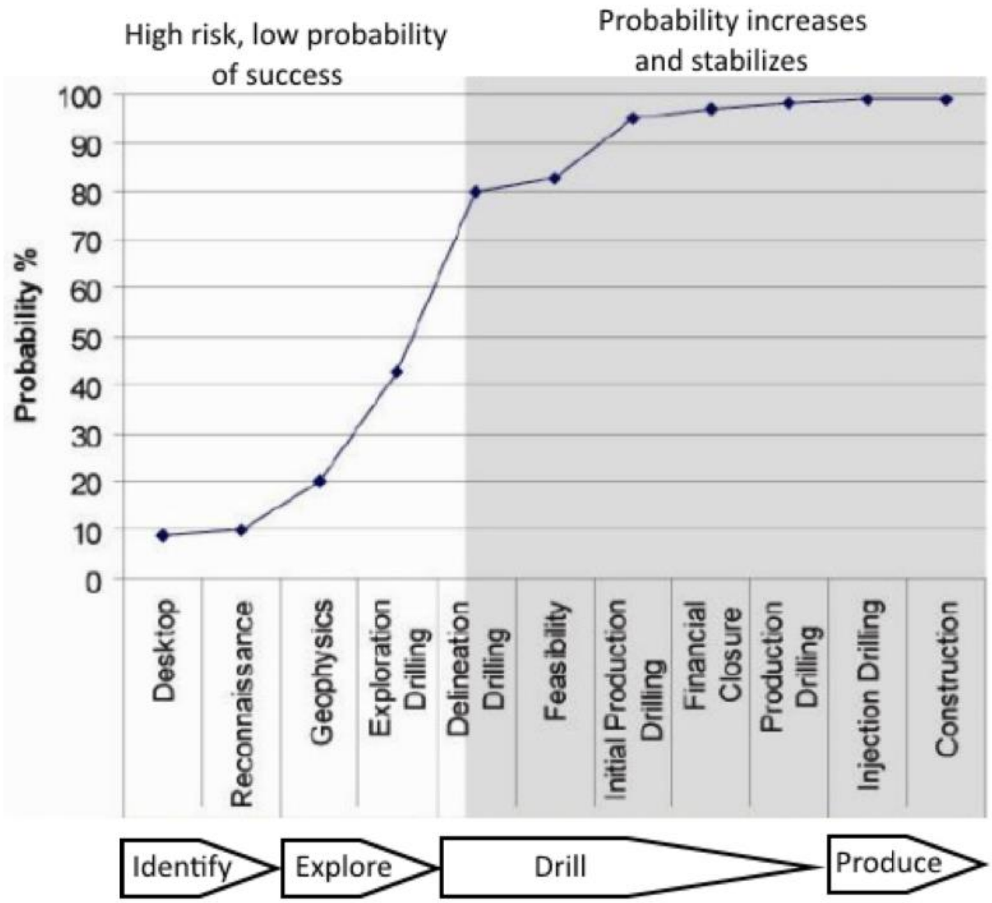
Source: National Renewable Energy Laboratory, "Guidebook to Geothermal Power Finance."[15]

Figure 5 demonstrates this uncertainty through the probability of success in each stage for implementing a 50 MW plant. The total probability of successful implementation is very low in the identification and exploration stages. When the IPP initially begins exploration of geothermal reserves, their total probability of successful implementation is only 10%. Even if the IPP locates a potential site and begins test well drilling to measure its viability, their probability to eventually succeed is still less than 50%. However, once the company locates a reliable source of geothermal energy, their probability of success significantly jumps to approximately 90%. The critical stages to overcome are the initial stages that pose the greatest risk. Once these initial stages are passed, the company can confidently finish implementation. Both the uncertainty of initial success and the potential to incur large costs hinder the economic incentive for development. There is a lack

[14] Ibid., 5-47.
[15] National Renewable Energy Laboratory. "Guidebook to Geothermal Power Finance" 5. http://www.nrel.gov/docs/fy11osti/49391.pdf

of BC policy that can specifically address this issue, as the government expects the IPPs to fund the process themselves. The province's approach to geothermal funding is largely unseen as they focus on other energies such as a new large hydro dam and bioenergy.

Figure 5

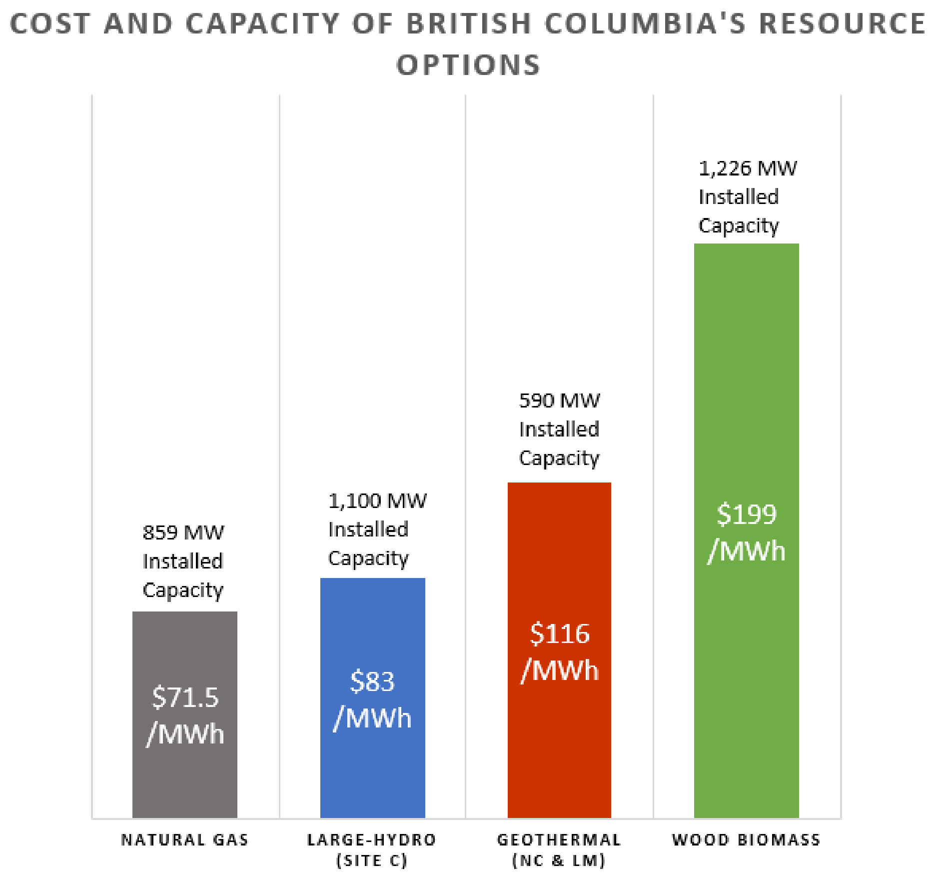


Source: Cross and Freeman, "2008 Geothermal Technologies Market Report"[16]

[16] Jonathan Cross and Jeremiah Freeman, "2008 Geothermal Technologies Market Report," 21. http://www1.eere.energy.gov/geothermal/pdfs/2008_market_report.pdf

1.3 Comparing Resources in BC

Figure 6



Source: BC Hydro, "2013 Resource Options Report Update."[17]
*Costs are averaged

Figure 6 shows the current energy technologies that BC has implemented with geothermal inserted for comparison. When selectively choosing the North Coast and Lower Mainland for geothermal development due to their estimated cheaper costs and higher capacity relative to other locations, the energy technology is still more expensive on average than the Site C large-hydro project and natural gas. However, Site C is a long term project that may span over 100 years, and may be susceptible to droughts and long term climate change. There are also no other large hydro projects planned by the BC government. Further, unlike natural gas, geothermal energy does not produce emissions and is a renewable resource. Therefore, the most significant advantage of geothermal energy is both its long term reliability as well as a long term return on investment. It is a clean energy that will not have unexpected carbon offsetting costs. By guaranteeing that the facilities on the North Coast and Lower Mainland operate long enough for a reasonable return on investment, IPPs will have greater incentives to invest in geothermal technology. Long term power purchase agreements (PPA) are required in order for an IPP to generate profit, and more importantly to return an investment for loans and subsidies. BC must implement legislation for minimum term PPA agreements on geothermal leases. Alternatively, BC Hydro must create

[17] National Energy Board of Canada, "Emerging Technologies in Electricity Generation," 28.

standardized contracts that guarantee a long term purchase agreement. Based on geothermal energy's ability to re-use its reserves, it can theoretically never deplete if properly re-injected.[18] Site C already demonstrates that both BC Hydro and the provincial government are looking towards long term energy investments that can provide continuous and stable energy. Hence, geothermal technology caters towards both long term contracts and the interests of the government.

2.0 Comparing British Columbia's Policy to California

BC's energy policy focuses on a wide scope of energy technologies. The 2009 "Report on Progress" for the BC Energy Plan states that to ensure their original commitment for 93% clean renewable energy in the province, they have begun a "review of Geothermal Resources Act and associated regulations to allow increased geothermal development."[19] The status of this review is currently in process. The review also states that "the [Innovative Clean Energy Fund] supports the development and commercialization of new, clean and renewable energy technologies, including bioenergy, solar and geothermal energy."[20] The government currently offers a grant program for alternative energy research and development. The Innovative Clean Energy Fund (ICEF) provides $25 million "to support the development of clean energy and energy efficient technologies in electricity, alternative energy, transportation and oil and gas sectors."[21] This subsidy was created within the BC Energy Plan. While the subsidy provides this funding, its scope is far too wide.

The Energy Fund targets too many energy technologies, and thus spreads it funding too thin. The program also includes biomass energy as a potential investment. This may hinder geothermal energy's ability to receive funding as biomass energy is already a focus of the government. The BC Bioenergy Plan already stated that the government would fund up to $10 million over three years for biodiesel energy production.[22] Moreover, they invested another $25 million for a BC Bioenergy network.[23] From 2009 - 2014, the average predicted biomass energy composed 9.3% of the total electricity supply in BC.[24] By 2020, the BC Bioenergy Plan aims "to meet 50 per cent or more of the province's renewable fuel requirements" through biomass energy alone, and establish 10 community biomass energy projects.[25] Despite the much larger cost of biomass compared to geothermal, the province continues to fund it. Lastly, BC Hydro has renewed its focus on LNG investment, with a number of new project plans for the future.[26] Thus, geothermal energy has not been the focus of government subsidies. BC's policies lack any direct subsidies

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[18] Canada National Energy Board, "Emerging Technologies in Electricity Generation," (2006): 28.
[19] Ministry of Energy, Mines and Petroleum Resources, "BC Energy Plan: Report on Progress," (2009): 6. http://www.energyplan.gov.bc.ca/report/BCEP_ReportOnProgress_web.pdf.
[20] Ibid., 8.
[21] Ministry of Energy, Mines and Petroleum Resources, "Backgrounder: Alternative Energy," 2007, http://www.energyplan.gov.bc.ca/PDF/2007EMPR0008_000178_Attachment2.pdf.
[22] Ministry of Energy, Mines and Petroleum Resources, "BC Bioenergy Strategy," (2008): 12. http://www.energyplan.gov.bc.ca/bioenergy/PDF/BioEnergy_Plan_005_0130_web0000.pdf.
[23] Ministry of Energy, Mines and Petroleum Resources, "BC Energy Plan: Report on Progress," (2009): 8. http://www.energyplan.gov.bc.ca/report/BCEP_ReportOnProgress_web.pdf.
[24] Ministry of Energy, Mines and Petroleum Resources, "Electric Generation and Supply," http://www.empr.gov.bc.ca/EPD/Electricity/supply/Pages/default.aspx.
[25] Ministry of Energy, Mines and Petroleum Resources, "BC Bioenergy Strategy," (2008): 4. http://www.energyplan.gov.bc.ca/bioenergy/PDF/BioEnergy_Plan_005_0130_web0000.pdf.
[26] BC Hydro, "Integrated Resource Plan," (2013): 1-13. https://news.gov.bc.ca/files/Newsroom/downloads/bc_hydro_integrated_resource_plan.pdf.

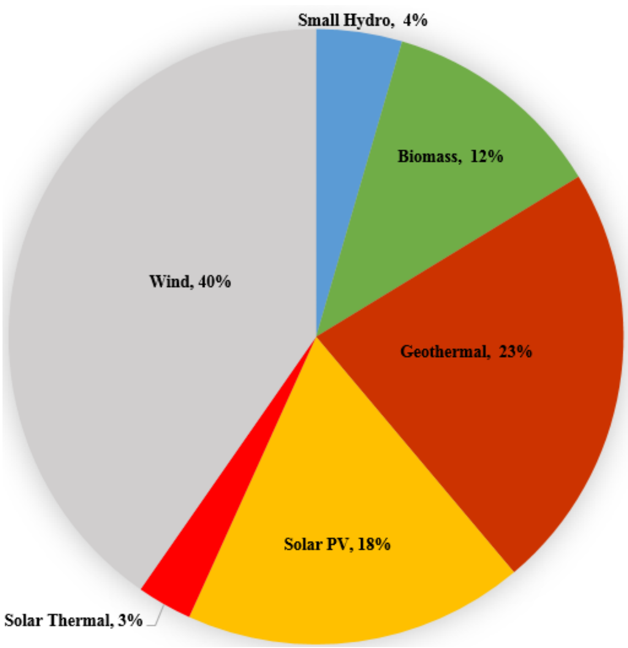
towards geothermal technology. Hence, California is examined to reflect on the direction BC should take to better cater to the technology's requirements. .

2.1 Energy Sectors

California presents similar geothermal potential with that of BC. The two areas share a coast on the Pacific Ring of Fire, along with comparable estimated geothermal sources. While BC has not yet implemented any geothermal generation, California has a long history of successful geothermal projects. It is important to examine the geothermal policies of California to better understand their successful implementation of geothermal plants. CA announced an overall clean energy goal similar to BC. California's governor Edmund G. Brown Jr. committed the state to target a 33% renewables portfolio standard by December 31, 2020.[27] Based on this goal, California has a number of systems that gradually implement various alternative clean energies including geothermal energy. Figure 7 shows that the American state has gradually expanded its alternative energy sector, and has a relatively diversified number of energy sources. This is a contrast to the hydro monopoly as shown in BC.

Figure 7

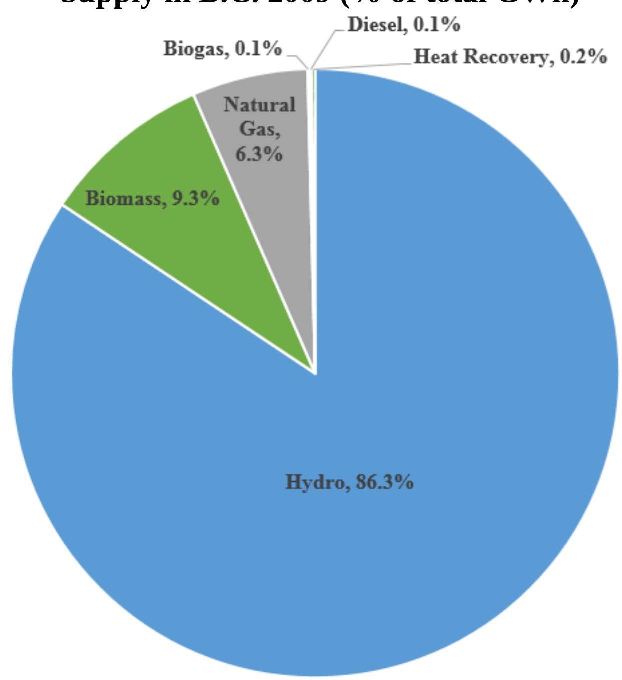
Estimated generation of California's Operating renewable facilities 2014 (% of total GWh)



Source: California Energy Commission, "California Generation and Supply"[28]

Figure 8

Estimated Five-year Average Electricity Supply in B.C. 2009 (% of total GWh)



Source: Ministry of Energy and Mines, "Electric Energy Commission Tracking Progress."[29]

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[27] Edmund G. Brown Jr, "Signing Message," https://www.gov.ca.gov/docs/SBX1_0002_Signing_Message.pdf.
[28] Ministry of Energy, Mines and Petroleum Resources, "Electric Generation and Supply," http://www.empr.gov.bc.ca/EPD/Electricity/supply/Pages/default.aspx.
[29] California Energy Commission, "Tracking Progress," 2. http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf

Figure 8 highlights the monopoly of hydro energy in the province with the resource providing 86.3% of the energy, while biomass energy is second with 9.3%. BC is still maintaining this trend since 2009, as Christy Clark announced a return to the development of the "Site C" dam project that that commences construction in summer 2015.[30] Natural gas is following closely in third, which dictates that the province is also interested in non-renewable energy. Figure 7 reveals that geothermal energy composes a significant portion of clean energies generated in California. Despite competition from a variety of sources, geothermal energy produces the second most in the state. California's success with geothermal technology is derived from their policy approach focusing on subsidization. BC must focus on similar subsidy strategies to enable geothermal implementation and diversification of its energy sector.

2.2 Geothermal Subsidies in California

Table 4

Subsidy Name	Type	Amount (Millions in USD)
GRDA	Development	Up to 5.8/project
PIER	Research/Development	62.5/year
EPIC	Electricty Innovation	162/year
EISG	Energy Innovation (small grant)	Up to 0.095/project Up to 0.050/research

Sources:
Public Utilities Commission of the State of California. "Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020."[31]
California Geothermal Energy Collaborative. "2005 California Geothermal Summit: PIER Consultant Report."[32]
California Energy Commission. "Geothermal Grant and Loan Program.[33]
California Energy Commission. "Program Opportunity Notice."[34]

As shown in table 4, CA offers four key economic incentives that facilitate geothermal energy projects:

1. The Geothermal Grant and Loan Program (GRDA)
2. The Public Interest Energy Research program (PIER)
3. Electric Program Investment Charge (EPIC)

[30] Office of the Premier, "Site C to provide more than 100 years of affordable, reliable clean power," https://news.gov.bc.ca/stories/site-c-to-provide-more-than-100-years-of-affordable-reliable-clean-power.
[31] Public Utilities Commission of the State of California, "Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020," 3. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/167664.pdf.
[32] California Geothermal Energy Collaborative, "2005 California Geothermal Summit: PIER Consultant Report," 2005. http://www.energy.ca.gov/2005publications/CEC-500-2005-176/CEC-500-2005-176.PDF.
[33] California Energy Commission, "Geothermal Grant and Loan Program," 2015. http://www.energy.ca.gov/geothermal/grda.html.
[34] California Energy Commission. "Program Opportunity Notice." 2014. 1-23. http://www.energy.ca.gov/contracts/PON-13-507/00_PON-13-507_GRDA.pdf

4. Energy Innovations Small Grants (EISG)

In combination, these four programs provide funding for new research and development in geothermal energy or alternative clean energies in general. The GRDA program is particularly useful. It specifically funds geothermal projects that win a competitive solicitation process for funding. As previously mentioned, BC Hydro estimated that the cost for drilling small holes to measure geothermal viability for future development can cost up to $5 million per project. The GRDA program provides up to $5.8 million per project, and in turn can cover the costs of initial drilling and surveying. This removes a large number of uncertainty in initial investment, where the IPP would otherwise be taking great economic risk.

The PIER and EPIC programs provide funding for alternative energy research and development. The two programs target a number of research initiatives for geothermal efficiency. An annual PIER report for 2014 indicates the program invested $3 million that year to investigate flexible generation capabilities at geysers in the state.[35] The goal of this investment was to increase electrical reliability from geothermal sources while also lowering costs.[36] This was one recent project for 2014, and the program has also funded a number of previous projects. Lastly, the EISG program provides numerous small grants to research various alternative energy initiatives. Geothermal energy development is specifically mentioned under this program.[37] By providing independent researchers with small grants, the program enables land surveying and formulating strategies for maximum geothermal efficiency. Through establishing a strong research base for geothermal power, the information gathered enables IPP's to make more educated decisions on where to drill and how to proceed with geothermal development in California. Similar subsidies and practices can occur in BC if mirroring legislation is established.

2.3 Obstacles to Geothermal Energy

Despite numerous legislative incentives, California faces a number of its own geothermal implementation problems. While learning from California's policy successes is valuable information, it is equally important to review their problems to predict similar issues in BC. According to an independent researcher, there are four main challenges to the development of using thermal power in California.

1. California faces weak demand for developing new projects compared to other energy types. Potential developers are able to purchase geothermal leases and tracks of land, but cannot proceed to early phases of development. This is because developers cannot find the required power purchase agreements to further their development.[38]
2. Transmission infrastructure is insufficient or available transmission does not cater to the location of geothermal resources. This mismatch for transmission viability accumulates cost for having to build new infrastructure.[39]

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[35] California Energy Commission, "Electric Program Investment Charge 2014 Annual report," (2015): 36-37. http://www.energy.ca.gov/2015publications/CEC-500-2015-013/CEC-500-2015-013-CMF.pdf.
[36] Ibid.
[37] California Energy Commission, "Energy Innovations Small Grants – Electricity Research Program," http://www.energy.ca.gov/research/innovations/electricity.html#500.
[38] Benjamin Matek, and Karl Gawell, "Report on the State of Geothermal Energy in California," 8. http://geo-energy.org/events/California%20Status%20Report%20February%202014%20Final.pdf.
[39] Ibid.

3. There are delays when giving permits, as it causes a development project to stagnate by adding extra time to an already long development timeline. This also increases the total cost of the project.[40]
4. The stakeholders do not sufficiently coordinate with each other. A strong example is when transmission planning efforts do not coordinate with utility power solicitations that require transmission.[41]

These four main problems are obstacles that BC must consider when the province determines its policy actions, as they are important obstacles beyond just the uncertainty of initial cost.

3.0 Policy Options and Recommendations

This section will determine whether BC can apply similar strategies that California demonstrates through its policies. First, the problems of the status quo in BC will be outlined. Next, the specific goals of the province are examined. Whether it is valuable to invest in geothermal energy in BC is determined, and if possible, what actions can be taken to implement them. Based on establishing this context, it will be possible to measure the feasibility of implementing geothermal power in BC.

3.1 Problems with the Status Quo

One of the highest priorities for BC is to maintain its 93% clean energy threshold. Simultaneously, the 2007 BC Energy Plan set forth the ambitious goal of province-wide energy self-sufficiency. The only solution is to expand generating and transmission capacity to meet these goals. The options for maintaining these energy output standards is to look towards other sources such as LNG, biomass, small and large hydro, wind or geothermal. The benefits of geothermal energy as the choice are that its cost is comparable to other sources, it does not produce emissions, and most importantly it can provide a reliable, continuous source of energy that may not deplete. Other clean alternatives such as wind and solar are not as economically desirable as geothermal. Based on their high costs of investment and intermittence of reliability, these sources of energy can create a number of complications. Determining how to account for their variability of power would further include costs of energy storage. Without storing the power, wind and solar could only target areas that already have sufficient energy to avoid blackouts. Therefore, these areas would provide unnecessary energy to already stable locations. Instead, looking towards California, it is plausible that geothermal energy has great potential for BC, particularly because of the similar geomorphological reserves between the two regions. BC Hydro estimated 16 potential locations in 2013, and they were assessed and selected by the company for geothermal development. These reserves can provide 780MW on a firm, continual and long term basis. However, only some of these locations present estimates with sufficiently low cost based on the information available. If BC can take the same steps that California has towards investing in research on the resource and subsidies towards implementation, then these and other more promising locations can be utilized.

[40] Ibid.
[41] Ibid.

Table 5

Technology Type		(2007$/MWh)	($2013/MWh) UEC at POI	($2015/MWh) Levelized Cost	Reliability
	Source	1	2	3	1,2
Wind (Offshore)			166-605	197	Intermittent
Wind (Onshore)		71-74	115-365	74	Intermittent
Solar PV		700-1700	266-746	125	Intermittent
Geothermal		44-60	91-573	48	Firm
Large Hydro		43-62	83 (Site C)	84	Firm
Coal		67-82	88	95	Firm
Wood Biomass		75-91	122-276	101	Firm
Natural Gas		48-100	71.5	75	Firm

Sources:

1. Ministry of Energy, Mines and Petroleum Resources. "BC Energy Plan."
2. BC Hydro, "2013 Resource Options Report Update."
3. U.S. Energy Information Administration, "Estimated Levelized Cost of Electricity for New Generation Resources, 2020."[42]

Table 5 indicates that geothermal can be one of the most cost-effective resources depending on the location and technology available. A cost estimate by the U.S. Energy Information Administration (EIA) established in 2015 indicates that geothermal has the lowest levelized cost of all the resource types. This is crucial, as a levelized cost determines what the cost will be over the lifetime of the project. This levelized cost indicates that geothermal energy can provide the greatest return on investment through its minimal cost over an average project lifespan. However, if BC does not change its current legislation on geothermal energy, then implementation will be unlikely. While the EIA estimated that the average cost for geothermal energy is $48/MWh, America has already established a number of subsidies for research and implementation to lower their costs. BC currently lacks funding for research, and in turn its selection of locations is limited to higher costing sites. From BC's unpredictable range of cost for geothermal, the two best locations shown in table 1 are the Lower Mainland (320 MW) and the North Coast (270 MW). These two regions each containing 8 locations provide the greatest generating capacity for the lowest comparative cost out of the 16 potential geothermal locations located in the province. Although the average cost of the 8 project locations in these two regions is $116/MWh, the province should only focus on the locations closer to the cheaper end of the price estimate. Both of these two regions are located in the Southern end of the province closer to transmission lines. As a result, this lowers their cost and implementation difficulty.

[42] U.S. Energy Information Administration, "Estimated Levelized Cost of Electricity for New Generation Resources, 2020," 2015. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

3.2 Factors Affecting Geothermal Consideration

A number of factors will determine whether geothermal power can overcome the barriers of implementation:

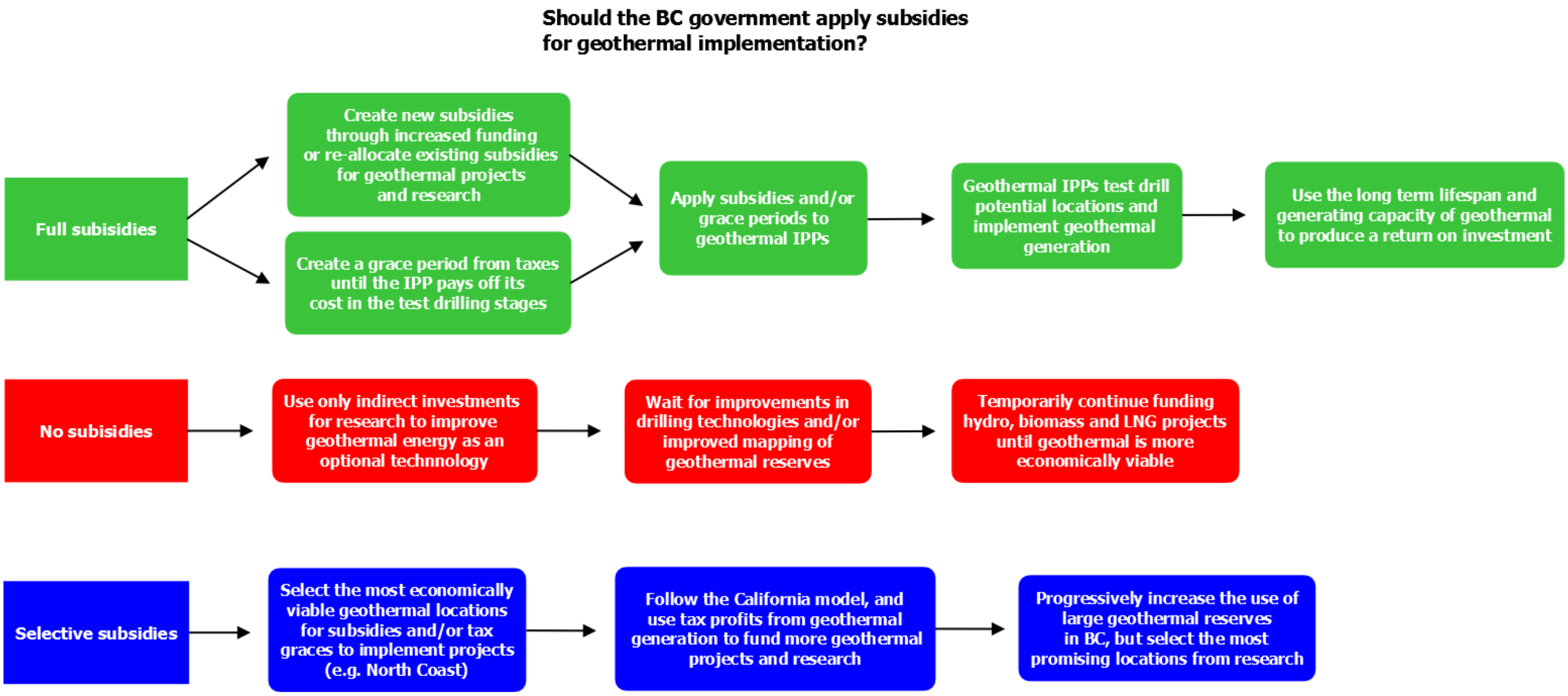
1. Government policy towards subsidizing IPPs for promising geothermal projects
2. Government policy towards subsidizing research on geothermal reserves and drilling technology
3. The economic feasibility of a geothermal site

As California has demonstrated, the high risk and uncertainty of investing in geothermal energy can be mitigated through subsidies. The greatest strength of CA's geothermal legislation is the ability to reduce the initial economic uncertainty through direct subsidies, but also to research reserves for greater reliability. The state uses a solicitation process to find the most promising geothermal projects and fund their implementation. CA receives a large portion of its subsidy funding from existing taxes on energy production in the state. The GRDA program specifically receives its funding from taxes on already existing geothermal generation.[43] This method creates an internal subsidization system where profit from geothermal energy encourages further geothermal development. CA enables a large amount of geothermal energy through its grants that target research on mapping the most promising reserves. Once research provides mapping for reserves and cost estimate reliability is increased, then more geothermal plants can generate energy at new locations, and the state receives long term tax returns from the projects invested into by its subsidies. In contrast, BC's approach allows IPPs to bid for contracts, but these power producers fund their own endeavors. Therefore, it is critical for BC to develop their own subsidies. The province has already developed a number of subsidies for biomass energy and hydrogen fuel. New subsidies must be considered to provide the economic incentive missing for geothermal energy.

[43] California Energy Commission, "Geothermal Grant and Loan Program," http://www.energy.ca.gov/geothermal/grda.html

3.3 Policy Options and Recommendations

Figure 9



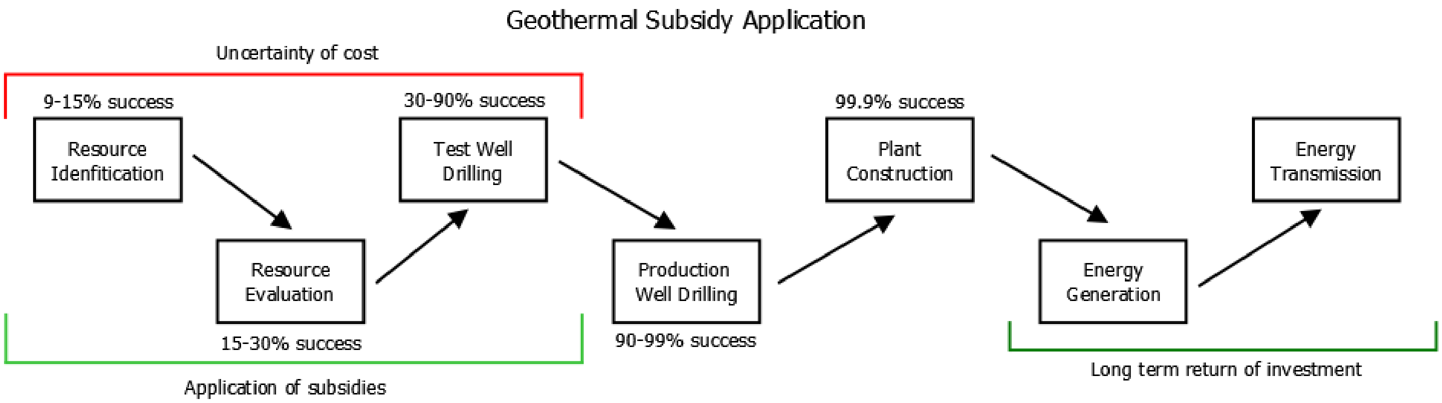
The most realistic option to pursue is the use of selective subsidies. If the province were to re-allocate the majority of its alternative energy subsidies towards geothermal alone, then previous investments for other technologies would be lost. Since the government has already invested large funds towards biomass, hydro and hydrogen projects, there is already room to develop those energy technologies further. However, based on the comparably low cost of geothermal energy depending on the location of the site, certain geothermal projects are more desirable. If the combined subsidy sources of the three levels of government were to create a dedicated geothermal fund for selective subsidies, then progress on the most economically feasible project locations could commence.

Learning from California, geothermal subsidies must be applied in two ways for British Columbia:

1. Direct subsidization for the cheapest geothermal locations available to initiate an internal geothermal subsidy pool from their taxation
2. Subsidizing research for mapping geothermal reserves and increasing drilling technology

Figure 10 shows that after the test well drilling phase, the probability of successfully implementing geothermal generation dramatically rises to 90% or higher. However, in the uncertainty of cost phase, the greatest expenses can unexpectedly occur. BC's widely varying cost estimate of $91-573/MWh is a result of this dependency on luck. Depending on how costly the initial implementation is, a geothermal plant may not produce the return of investment that an IPP desires. BC Hydro's estimated $0.5 - $5 million cost range for drilling has to be reduced either through increases in drilling technology, mapping and research, or implementing direct subsidies. Otherwise, an IPP may face high initial costs and a low lifespan for their reserve, which in turn would either provide a low return on investment or no return at all. The chance for a return on investment can be increased by selecting the most promising locations—the Lower Mainland and North Coast. If direct subsidies are applied to these locations to mitigate the drilling cost uncertainty, then development for these select locations may begin. Other locations that fall into the higher end of the cost estimate cannot be developed at this time. Those locations require subsidies for research and mapping that may decrease their estimated costs at a later date.

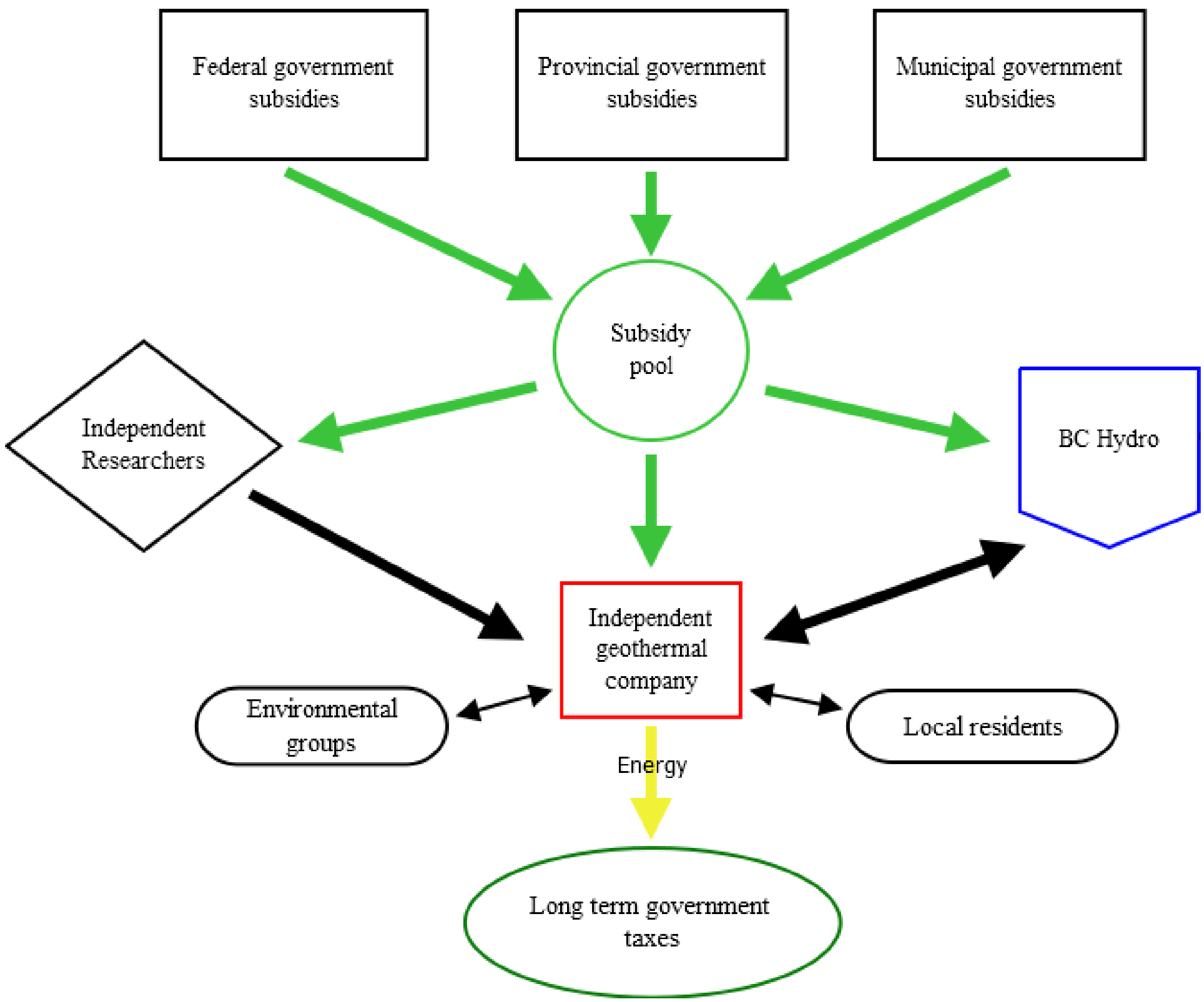
Figure 10



By initially focusing on locations that are on the lower end of the cost spectrum, geothermal plants could become economically feasible through a comparable cost to other resources. The proposed regions of the North Coast and Lower Mainland have 8 project locations that can potentially cost less than all the alternative resources. The project locations in the two regions with the cheapest estimated cost can provide a greater and more importantly quicker guarantee for a return on investment through future taxation. Geothermal energy's greatest economic benefits stem from its long term period of stable and consistent economic return. By focusing on the cheaper locations, the government can implement initial plants that generate taxes, and then as per the California model, they can re-invest these tax profits into more subsidies for a greater number of geothermal projects. By continuing research and development in the technology, BC can eventually see the same levelized costs that American states enjoy. Rather than developing project locations that cost \$91/MWh as is required today, BC can eventually lower their cost to the EIA estimate of \$48/MWh. This price would be lower than all of geothermal's alternative solutions, and the energy technology would be the clear choice for the greatest economic incentive.

3.4 Stakeholders

Figure 11



The stakeholders involved largely focus on the subsidy chain for geothermal projects. The provincial government is the main source of funding for projects and legislation as they govern the energy sector of a province. However, all three levels of government can generate a subsidy pool that can aid the IPP in initializing the process and surpassing hurdles of economic uncertainty. For example, there are a number of initiatives that the federal government can fund. Sustainable Development Technology Canada recently funded just over $8 million to an independent researcher for research on improved test well drilling for geothermal projects. They estimate that the new technology alone will enable 310 MW of cumulative generation capacity in Canada.[44] By continuing research projects that minimize drilling risk, BC can gradually tap into more potential geothermal reserves with lowered costs. Until then, the reserves with highest economic risk may not see any development. The municipal government can also largely involve itself depending on the location of the project, and whether contracts are made to provide transmission to the municipality. The governments have also engaged in a few large scale preliminary initiatives to generate knowledge of geothermal reserves in BC. One of the largest of these initiatives was "The Geological Survey of Canada" in 2011 that summarized geothermal data from 48 years of research by the National Geothermal Energy Program.[45] BC Hydro receives funding from the government, and as shown in table 1, they create valuable information from their own independent assessments of these surveys. This information is then publicized for IPPs who can make educated decisions on project locations. If grants are increased towards drilling technology, and funding is provided for the mapping of reserves as demonstrated by these initiatives, then costs for future geothermal projects can be lowered even more-so, and a greater expansion of viable geothermal project locations will occur.

It is important to note that locations in the South of the province can interfere with local residents if in proximity to urban centers. Establishing plant locations in the Southern portion allows for the use of existing transmission infrastructure, but the potential to upset local residents increases as the regional population density is higher. However, based on the current provincial legislation, these tracts of land would not be shared with residents as they belong to public government property. Geothermal plants do not emit emissions, and pose little environmental risk. One important factor to note is that a number of geothermal plants in various countries sparked localized earthquakes. Hence, it is important to ensure plants are constructed in locations away from other buildings or infrastructure that may be damaged in this scenario.

Conclusion

BC requires more power capacity to be energy self-sufficient. The province is backed into a corner where it must decide which resource options to pursue. BC has already committed to develop the Site C project that will significantly increase the province's generating capacity. Nonetheless, based on increasing population and growing electricity demand, more energy will be needed. BC must look towards other sources of energy beyond its large hydro project. The current investments for small hydro, biomass energy, and LNG are already producing a significant portion of the province's energy. These resources remain as the main options for electricity generation in the province. However, geothermal energy currently poses as a plausible alternative in certain circumstances.

The vast majority of the 33,877 MW total indicated generating capacity in BC will remain unusable for the time being. Most project locations are too far away from urban centers or lack insufficient mapping data for a predictable cost estimate. In turn, IPPs will not invest in these high

[44] Sustainable Development Technology Canada, "Optimized Geothermal Exploration," 2012. https://www.sdtc.ca/en/portfolio/projects/optimized-geothermal-exploration
[45] BC Hydro, "Resource Options Report," 5-41.

risk projects. Even the locations with the cheapest cost estimate still face a degree of economic uncertainty. Therefore, it will not be feasible for IPPs to pursue these locations without government subsidies. Based on the unpredictable lifespan of a geothermal reserve, an IPP may not see the return on investment it desires if the initial cost of drilling is too high. Consequently, this uncertainty must be reduced through subsidies for an IPP to gain economic incentive. Through subsidies to cover the cost of drilling, long term power purchase agreements with BC hydro established prior to drilling, and potential tax graces, IPPs may invest in the most promising locations. Together, the North Coast and Lower Mainland can produce up to 590 MW of energy depending on the estimated cost of the cheapest locations. By implementing geothermal in these locations, the government can establish an internal revenue stream for geothermal research and development. This will create an internal geothermal subsidy pool that can further more research for reserves, and unlock more geothermal energy in BC for use. Eventually, the province may also utilize the low levelized costs that more established American states like California often see.

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