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Geothermal Industry Development in Canada- Country Update

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ABSTRACT

Geothermal energy in Canada is currently only utilized for space conditioning through the use of ground source heat pumps; and for bathing and swimming in naturally occurring hot springs and geothermal natatoriums. Geothermal heat pumps have been deployed across the country and have seen significant growth over the last decade. More than 150 thermal springs are known to exist in Western Canada but only 48 have sufficient data for characterization. 12 have been developed into commercial hot spring resorts and spas that account for the only direct use in Canada with an installed capacity of roughly 8.8 MWt.

Geothermal power generation has been explored for several years but policy limitations and the lack of adequate provincial and federal support has stifled any substantial progress towards a viable industry. It is estimated that over 5,000 MWe is available from shallow geothermal resources, including hot sedimentary aquifers, using current technology with an additional 10,000 MWe or more available in deep geothermal resources for future exploitation using enhanced geothermal systems. There are currently 5 active power generation projects developing in Canada but none have moved past the feasibility phase. One power generation project and two direct use projects were also recently discontinued for non-technical reasons. It is difficult to establish the economics of projects in Canada due to the absence of operating plants.

Current industry initiatives include the development of the National Geothermal Innovation Roadmap (GIR), the Canadian National Geothermal Database, provincial/territorial geothermal favourability maps, and various lobbying efforts on the part of the Canadian Geothermal Industry Association to build provincial and federal policy support for the geothermal industry.

It is noteworthy that the Toronto Stock Exchange, TSX, and the Toronto Venture Exchange, TSX-V have been used extensively for financing global geothermal projects, and to a lesser extent, Canadian projects.

1. INTRODUCTION

The geothermal industry in Canada has remained nascent despite continuous efforts to spur growth since the 2010 World Geothermal Congress. It is estimated that there is as much as 5,000 MWe of economically feasible geothermal potential in Western Canada using currently available technology although none has been realized yet for power generation (Ghomshei, 2010). High-temperature hydrothermal resources exist in the province of British Columbia and the Yukon Territories in addition to hot sedimentary basins in Alberta, Saskatchewan, and Northwest Territories. However, there has yet to be a geothermal power project that has moved past the feasibility phase although there are five projects in preliminary phases in Western Canada.

Geothermal energy utilization in Canada has been limited to bathing and swimming in commercial hot springs and space heating and cooling utilizing geothermal heat pumps (GHPs). Naturally occurring hot springs are found in all Western Canadian provinces and territories and 157 have been identified thus far. Of the 157 identified naturally occurring hot springs, 12 sites have been developed as hot spring destinations and are used by the general public for bathing, swimming, and balneological purposes. These sites, in addition to a spa and resort in Saskatchewan that is fed from a hot sedimentary aquifer, represent a total installed capacity of 8.8 MWt. Geothermal heating and cooling using GHPs is present throughout the country with total installed capacity estimated to be 1,680 MWt (Raymond et al., in press).

Market factors such as low fuel prices and limited policy support from federal and provincial governments have resulted in a slow – growth geothermal industry in Canada with many, world-class geothermal sites waiting to be developed. The geothermal industry has not yet been able to build substantial political support to create or re-word policies to provide the appropriate legislative framework for industry development.

The Canadian Geothermal Energy Association (CanGEA) was founded and incorporated in 2007 and earned the right to continue its mandate in 2014 under the new *Canadian Not for Profit Corporations Act*. CanGEA is distinct from previous geothermal industry efforts in the 1980's-mid 2000's in that CanGEA's main activity is political advocacy with a truly pan-Canada effort on the direct use of geothermal heat and geothermal power production. CanGEA complements the activities of the Canadian Geo-Exchange Coalition (CGC), which represents the ground source heat pump industry, and the Canadian Geothermal Research Council (CanGRC), which serves the academic and research community.

2. GEOLOGY BACKGROUND

Geothermal energy is an accessible resource all across Canada. However, for the purpose of electrical generation, high-temperature geothermal resources are restricted to a corridor in western Canada that has been influenced by Mesozoic/Cenozoic tectonic and orogenic events.

2.1 Volcanic Geology

Along the western margin of British Columbia and Yukon Territory, in the Canadian Cordillera, two distinct volcanic regions with Quaternary eruptive episodes constitute the areas of greatest interest to geothermal power production.

2.1.1 Garibaldi Volcanic Belt

The Garibaldi volcanic belt in southwestern BC is the product of an active subductive margin between the Juan de Fuca and Pacific plates. The result is a belt of stratovolcanoes that trend parallel to this tectonic boundary. Within this belt lie several prominent stratovolcanoes, amongst them Mount Meager, Mount Cayley and Mount Silverthrone, which have been uniquely identified as areas of interest for geothermal power (Jessop et al., 1991).

2.1.2 Northern Cordilleran Volcanic Province

In northwestern BC and encompassing most of the Yukon Territory lies the northern Cordilleran volcanic province (Edwards & Russell, 2000), a product of continental rifting from within the North American plate. Resulting is a series of basaltic shield volcanoes, which currently constitute the most active volcanic region of Canada (Geological Survey of Canada, 2008). Mount Edziza and Hoodoo Mountain are particularly regarded as areas of geothermal potential in this volcanic region (Jessop et al., 1991).

2.2 Sedimentary Geology

The Western Canada Sedimentary Basin (WCSB) is a vast sedimentary basin, which consists of a maximum of 6 km of stratigraphy in its western margin, thinning to 0 m at the eastern basin edge (Wright et al., 1994). The depositional history is protracted, and the diversity of sedimentary units reflects this history. Where the sediments are deepest, a moderate temperature geothermal resource is found. Conservatively assuming that 1% of the water in the WCSB could be considered a geothermal resource, then the geothermal reserves in the WCSB would be 4-5 times higher than the thermal equivalent of the remaining oil reserves (Jessop et al., 1991).

3. GEOTHERMAL RESOURCES, POTENTIAL, AND UTILIZATION

Canada boasts a substantial geothermal resource with some level of geothermal development possible throughout the country. A recent report by the Geological Survey of Canada concluded that Canada "has enormous geothermal energy resources that could supply the country with a renewable and clean source of power" but that sufficient data to quantify the geothermal resource existed for only 40% of the Canadian landmass (Grasby et al., 2012). This is likely a result of a 30-year hiatus in federal government funding of geothermal science. As such, both high-temperature power production opportunities as well as low-temperature direct use and geo-exchange opportunities exist throughout the country but there has been very limited development of the Canadian geothermal resource to date.

3.1 High-Temperature Hydrothermal Resources: Power Production

Canada is often cited as the only country along the Pacific Ring of Fire that has yet to develop any geothermal power capacity, even though its southern neighbour, the United States, ranks 1st in total installed capacity. The United States has almost exclusively developed its 3 GWe of generation capacity in the west and Figure 1 suggests that any future developments in Canada will likely also occur in Western Canada.

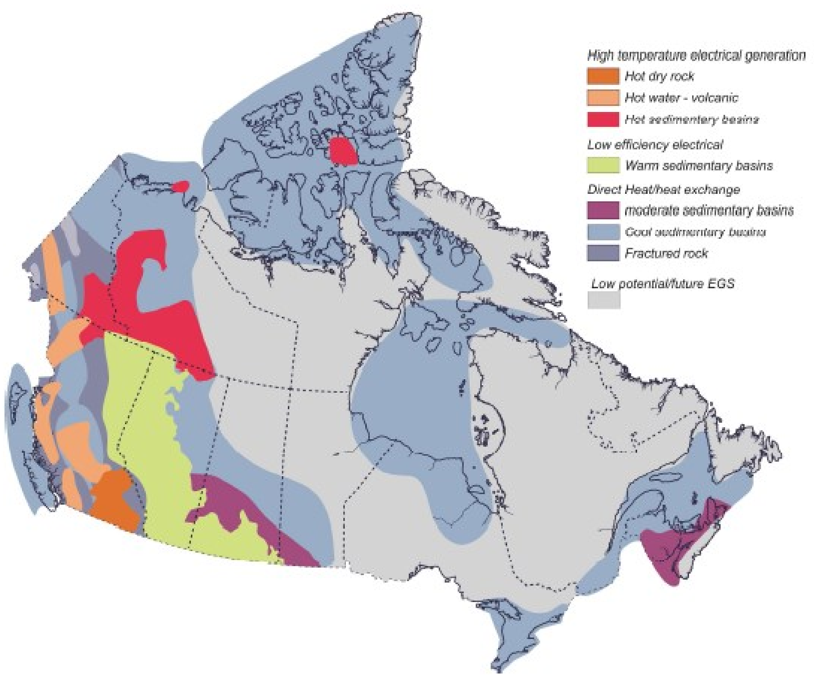

Figure 1: Canadian geothermal resource potential (Grasby et al., 2012)

The Canadian Cordillera stretches north from British Columbia to the Yukon and offers the greatest potential for high temperature geothermal resources (>150°C) in Canada. There are several volcanic structures present but those older than roughly 10 million years have likely lost most of their residual heat. Tertiary volcanism is restricted to the Garibaldi Belt, which is the continuation of the Cascade Volcanic Belt, the Anaheim Belt, and the Stikine Belt. The tertiary intrusive rocks present have high geothermal gradients as a result of radiogenic elements within the rocks. There are also over 157 identified hot springs in the Canadian Cordillera and hot sedimentary basins, which provide a good indicator of the presence of a geothermal resource. In fact it was the presence of a hot spring at Mt Meager in the Garibaldi Belt that led to the discovery of a major geothermal resource at Meager Mountain that has been investigated for geothermal power development. Several hot sedimentary basins can also be deemed geothermal resources of interest. The WCSB that stretches from British Columbia into Alberta and Saskatchewan as well as others in the western portions of the Northwest Territories, eastern Yukon, and in localized areas of the Mackenzie corridor, the Sverdrup Basin, and the Foreland basins.

It is estimated that over 5,000 MWe is available from shallow geothermal resources, including hot sedimentary aquifers, using current technology with an additional 10,000 MWe or more available in deep geothermal resources for future exploitation using enhanced geothermal systems (Ghomshei, 2010). Due to a lack of sufficient policy support and the resulting financing climate, no power projects have been commissioned yet. There are currently 9 power generation projects developing in Canada at various levels of progress (Figure 2).

Project	Developer	Province/Territory	Regulatory Status
Canoe Reach	Borealis GeoPower	British Columbia	Permit
Lillooet	Alterra Power	British Columbia	Permit
South Meager	Ram Power	British Columbia	Lease
Ft. Liard	Borealis GeoPower	Northwest Territories	Permit
Rafferty	Deep Earth Energy Production Corp.	Saskatchewan	Permit
Pebble Creek	Tecto Energy	British Columbia	Permit
Lakelse	Borealis GeoPower, Enbridge, Kitselas First Nations	British Columbia	Permit
Ross River	Kaska First Nations	Yukon Territory	n/a
Swan Hills	Devon, Borealis GeoPower	Alberta	n/a

Figure 2: Geothermal power projects in Canada

3.2 Low Temperature Resources: Direct Use Applications and Geothermal Heat Pumps

By virtue of their characteristics, there are substantially more opportunities with low-temperature resources in Canada, particularly direct use applications and the use of geothermal heat pumps. Direct utilization of geothermal heat is currently limited to commercial hot springs. As mentioned earlier, 157 hot springs have been identified in British Columbia, Alberta, Yukon Territory, and the Northwest Territories. Sufficient data exists to characterize 48 hot springs, which have an estimated heat output of 250 MWt. It should be noted that hot springs tend to vary in heat flow annually based on a variety of factors and due to the lack of up-to-date data; there is a large margin of error in the estimated heat output.

Currently, 12 naturally occurring hot springs in Western Canada have been commercialized and developed into bathing, swimming, and balneological facilities and are listed in Table 1.

Table 1: Hot springs of Western Canada

Name	Province	Flow rate (L/s)	Springs temperature (°C)	Pool outlet temperature (°C)	Capacity (kW_t)
Banff Upper	AB	14.9	47	38	563
Miette	AB	15.3	54	37	1092
Ainsworth	BC	6.9	47	32	435
Fairmont	BC	20.9	46	44	176
Halycon	BC	3.5	54	32	323
Harrison	BC	26.1	40	28	1,315
Liard	BC	30.0	52	30*	2,772
Nakusp	BC	1.2	57	30	136
Mount Layton (Lakelse)	BC	9.9	41	30	457
Radium	BC	28	40	32	941
Skookumchuck (St. Agnes)	BC	3.2	35	30	67
Takhini	YT	5.7	40	35	120
Temple Gardens Mineral Spa	SK	5.7	46	30	383
				Total capacity (kW_t)	8,780

Abbreviations: AB, Alberta; BC, British Columbia; SK, Saskatchewan; YT, Yukon. *Assumed temperature as water flows in swamps.

Cumulative installed capacity of the hot springs is estimated to be 8.8 MWt. Liard Hot Springs is located in a provincial park that has an entrance fee but the spring itself has been left in its natural state and thus an assumption was made about the outlet temperature. Temple Gardens Mineral Spa and Resort in Saskatchewan is not the site of a naturally occurring hot spring and is the truest example of a direct use operation in the sense that the facility required a well to supply groundwater at 46°C to the site. The main pool at Takhini Hot Springs is currently closed for renovations and will reopen to the public within a year.

Geothermal heat pumps constitute almost the entirety of the geothermal industry with an estimated 120,000 installations constituting 1,458 MWt of installed capacity and annual geothermal energy usage of 11,338 TJ (Raymond et al., in press)

4. GEOTHERMAL POLICY DEVELOPMENT

Canada entirely lacks geothermal-specific policies, legislation, and generation targets at the federal level. While the geothermal resource is abundant in Western Canada, particularly in British Columbia, Yukon Territory, Northwest Territories, Alberta, and Saskatchewan, only British Columbia has a provincially administered legislative framework to govern geothermal development.

"Baby steps", this is the best way to describe geothermal policy development in Canada. Small incremental changes are being achieved, but major policy roadblocks need to be torn down. The two provinces with the most substantial geothermal resources are British Columbia and Alberta, but both face similar development obstacles. B.C. Hydro's 2013 Integrated Resource Plan, and previous government documents, specifically acknowledges existing deficiencies with the province's geothermal regulatory processes, but neither document offers solutions. In Alberta, there remains no avenue whatsoever to obtain a geothermal lease. Geothermal power was included under the now exhausted clean power incentive schemes, such as Alberta's *Small Research and Development Act* and the Federal ecoENERGY for renewable power program. The problem was that a developer cannot take advantage of incentive programs if the processes to obtain leases and permits are broken or absent.

There are also other federal and provincial funds that were available to most green energy developers that were historically not available to the geothermal industry and through CanGEA's efforts these oversights were successfully addressed. As a result, 5 projects related to the geothermal industry qualified for a maximum of almost $50 million. Unfortunately, much of this money went unused. This outcome cannot be disassociated from the deficiencies present in provincial regulatory regimes. However, promising signs of change are in the air.

On May 1st, 2014, a joint federal/provincial environmental assessment report completed for BC Hydro's proposed 1,100 MWe hydroelectric mega project concluded that "a failure to pursue research over the last 30 years into B.C.'s geothermal resources has left BC Hydro without information about a resource that BC Hydro thinks may offer up to 700 megawatts of firm, economic power with low environmental costs" and government investment in geothermal research was strongly recommended. This conclusion was fueled by facts furnished, earlier in the review process, by CanGEA. CanGEA's efforts are also making an impact in Alberta. CanGEA has met with numerous members of Alberta's Legislative Assembly and these decision makers have shown a strong willingness to identify and address the existing regulatory barriers faced by the province's potential geothermal developers. At present, it appears that this willingness will be reflected in the province's anticipated Alternative and Renewable Energy Framework.

From a federal perspective, small victories have also been achieved. For example, under Schedule II of Canada's Income Tax Act, if certain types of renewable energy and conservation equipment are included under Class 43.1, it then allows for a 30% accelerated capital cost allowance rate. Formerly, geothermal equipment was not included under Class 43.1, but now is. Further, on April 18th, 2014, the Obama administration again delayed its decision on the Keystone XL pipeline, and this delay will likely last until sometime after the U.S. mid-term elections in November. Many commenters attribute the delay to an unwillingness to upset America's green lobby. This scenario, combined with the Government of Canada's strong desire to have the pipeline approved, could conceivably inspire significant federal action on climate change in Canada. Such an outcome is far from certain, but could be essential in moving Canada's federal policy in a direction that will drive geothermal development beyond its current pace.

5. CURRENT INDUSTRY INITIATIVES

CanGEA's secondary priority to policy advocacy work is the Geothermal Innovation Roadmap project. Specifically, the GIR will entail a series of technology transfer workshops that will develop the geothermal industry roadmap with input from companies and subject matter experts. The project will also produce workshop material and reports that simultaneously lay the groundwork for the implementation plan portion of the GIR. The project kicked off in 2012.

Holistically the GIR will:

1) Include a series of workshops that will transfer the technology and expertise of companies in Mining, Oil & Gas, and Aerospace & Defense, etc. to the development of geothermal energy in Canada, with a focus on Western and Northern Canada;

    a. http://www.cangea.ca/workshops.html

    b. Completed in 2014: Project Developers' Technology Needs workshop, Mining Industry Technology Transfer workshop, and Aerospace & Defense Industry Technology Transfer workshop

    c. Begun in 2014: series of Direct Use Opportunities and Applications workshops

    d. Scheduled for 2015: Technology Transfer workshops from various industries (Oil & Gas, Carbon Capture & Storage, etc.)

2) Contribute to the development of reports and workshop/course materials that will form the basis of a CleanTech geothermal industry roadmap, which altogether will position Canadian companies to take advantage of the business growth opportunities that lie in the development of geothermal energy;

   a. (Relevant for the international geothermal industry) 2013 Geothermal Technology Roadmap: Global Best Practices Summary – Exploration through Generation http://www.cangea.ca/uploads/3/0/9/7/30973335/geothermal-technology-roadmap-global-best-practices-summary-exploration-through-generation.pdf

   b. Direct Use Opportunities and Applications Report (co-authored by Dr. John Lund) http://www.cangea.ca/geothermal-direct-use-applications-and-opportunities-report-and-workshops.html

   c. Scheduled for 2015: Remote, Northern Community and First Nations/Aboriginal Geothermal Opportunities

   d. In progress: Canadian Geothermal Technology Roadmap

3) Produce Favourability Maps of Canada's vast geothermal resources and a National Database. At first this work will be focused in Western and Northern Canada.

   a. Completed in 2013 and 2014: Alberta and British Columbia Resource Estimate Maps and National Database: http://www.cangea.ca/canadian-national-geothermal-database-and-resource-favourability-maps.html

   b. Proposed: Saskatchewan, Manitoba, Yukon Territory, Northwest Territories

CanGEA has also significantly contributed to investor confidence in the global industry via the adoption of the Canadian Geothermal Code for Public Reporting of Resources and Reserves (http://www.cangea.ca/uploads/3/0/9/7/30973335/canadiangeothermalcodeforpublicreporting.pdf) for those Canadian and foreign companies using the Toronto Stock Exchange (TSX) and Toronto Venture Exchange (TSX-V) or otherwise reporting to the investment community. This initiative followed closely on the heels of the Australian Geothermal Association's release of "the Code". CanGEA remains active in the global discussion about geothermal exploration results, resources and reserves through participation in the Resources and Reserves Committee of the International Geothermal Association.

CanGEA hosts an annual conference where the industry gathers to perform business development, hear policy updates and project case studies, and to learn about new technologies and trends. CanGEA has also hosted training sessions on the Reporting Code, presented community Outreach sessions, organized Investment Forums and led Policy Awareness sessions.

In 2014, CanGEA ran a direct-use of geothermal focused trade mission to Klamath Falls, Oregon in collaboration with the Geothermal Resource Council's Annual Meeting. The Canadian government's Department of Foreign Affairs, Trade, and Development provided funding support for the 15 attendees.

6. CONCLUSION

Geothermal energy in Canada continues to move forward but mostly through developments within the GHPs industry. Significant policy work will be required at both the federal and provincial levels to allow for an appropriate foundation for a power and direct use industry. Canada has a wealth of natural resources including geothermal resources and once the non-technical market factors are addressed, the country will host a viable and sustainable geothermal industry.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014	0		37500		77000		13500		7000		135000	
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020												

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

		Maximum Utilization						Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2] (kJ/kg)		Capacity[3]	Ave. Flow	Energy[4]	Capacity
Locality	Type[1]	(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor5)
Banff Upper	B	14.9	47	38			0.561			
Miette	B	15.3	54	37			1.088			
Ainsworth	B	6.9	47	32			0.433			
Fairmont	B	20.9	46	44			0.175			
Halycon	B	3.5	54	32			0.322			
Harrison	B	26.1	40	28			1.310			
Liard	B	30	52	30			2.761			
Nakusp	B	1.2	57	30			0.136			
Mount Layton (Lakelse	B	9.9	41	30			0.456			
Radium	B	28	40	32			0.937			
Skookumchuck (St. Agı	B	3.2	35	30			0.067			
Takhini	B	5.7	40	35			0.119			
Temple Gardens Mine	B	5.7	46	30			0.382			
TOTAL							8.747			

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

Use	Installed Capacity[1) (MWt)	Annual Energy Use[2) (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)
Individual Space Heating[4)			
District Heating [4)			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5)			
Industrial Process Heat[6)			
Snow Melting			
Bathing and Swimming[7)	8.78	277	
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	1,458	11,338	
TOTAL	1,688.78	13,177	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits a
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government (4) Paid Foreign Consultants
(2) Public Utilities (5) Contributed Through Foreign Aid Programs
(3) Universities (6) Private Industry

Year	Professional Person-Years of Effort -1	-2	-3	-4	-5	-6
2010	Unknown	Unknown	Unknown	Unknown	Unknown	10
2011	Unknown	Unknown	Unknown	Unknown	Unknown	11
2012	Unknown	Unknown	Unknown	Unknown	Unknown	12
2013	Unknown	Unknown	Unknown	Unknown	Unknown	13
2014	Unknown	Unknown	Unknown	Unknown	Unknown	14
Total	Unknown	Unknown	Unknown	Unknown	Unknown	60

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl. Surface Exploration & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	Unknown	Unknown	Unknown		Unknown	Unknown
2000-2004	Unknown	Unknown	Unknown		Unknown	Unknown
2005-2009	Unknown	Unknown	Unknown		Unknown	Unknown
2010-2014	2	0	0	2	25	75