Canadian Geothermal Energy Poised for Takeoff

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ABSTRACT

Canada's high temperature geothermal resource areas are predominantly in the western part of the country, principally in British Columbia and Yukon, on the tectonically active Pacific margin. Canada, however, has lagged behind other Pacific Rim countries in the development of high temperature geothermal power. This inertia is attributed to a combination of factors including traditionally low energy prices, especially cheap hydro and natural gas in the west - but the mood has been changing since the turn of the Millennium. Increasing energy prices and commitment to greenhouse gas reduction has given considerable momentum to the Canadian geothermal power industry.

New MT survey and core drilling in the South Meager Creek area has led to the discovery of both heat and permeability on the slopes of Mt Pylon. Deep rotary drilling and reservoir evaluation will be completed in late 2004 and early 2005. The first phase of commercial production of 100 MWe is planned to be online by mid-2007. Another advanced high temperature prospect in the Pebble Creek area (North side of the Meager Creek complex) is expected to follow the same route and bring an additional 200 to 300 MWe geothermal power online before the end of the decade.

Low and medium-temperature geothermal resources are present throughout Canada and growing interest in these opportunities holds promise for a bright future. Geothermal heat pumps are now in use in all Canadian Provinces, most notably in Manitoba and Ontario, where a creative financing environment has helped investors pay-back the up-front capital expenditures from substantial savings in operating costs. The geothermal heat pump market has been growing in Canada at the rate of 10 to 15% per annum since the turn of the Millennium. With about 600 million kWh of energy savings, Canadian geothermal heat pump users presently contribute about 200,000 tonnes to the reduction in greenhouse gas emissions per year. Direct use applications (limited to hot-spring resorts) are estimated at about 100 million kWh of geothermal heat per year.

1. INTRODUCTION

Geothermal energy is abundant in Canada from coast to coast. High-enthalpy hydrothermal resources are, however, specific to British Columbia and Yukon. Including hot dry rock resources, geothermal power can also be produced in the Atlantic Provinces (Jessop et al., 1991, Alan et al., 2000). Medium-temperature resources are present in British Columbia, Yukon, Alberta, and Northwest Territories (NWT), where more than150 hot-springs with temperatures up to 80°C have been reported (Ghomshei and Sadlier-Brown 1996). The western Canadian sedimentary basin stretching from the Rockies in the west to the Canadian Shield, is also a gigantic resource of deep-circulating lukewarm to warm waters that reach 50°C in some areas (Vigrass and Jessop, 1984). It is estimated that the energy value of the extractable geothermal energy from the waters in the western Canadian sedimentary basin is more than that of the total Canadian oil and gas reserves (Jessop et al., 1991).

As well, low-grade geothermal heat pump technology is usable from coast to coast and is considered as the fastest-growing "green energy" alternative in Canada. Direct use application of medium- and low-grade geothermal resources can play an important role in Canadian commitment to reducing greenhouse gas emissions. One of the proposed direct use applications of the lukewarm waters in the sedimentary basin is related to possible use of low-grade heat for bitumen extraction from oil sand.

Commercially developable high-temperature geothermal resources in British Columbia are estimated to be at least 1,500 MWe. In the populated south-west British Columbia, these resources are mostly associated with the Garibaldi Volcanic belt, the northern extension of the Cascade Range volcanoes of the western U.S.

Interest in the west-coast high-grade geothermal resources started shortly after the 1973 oil crisis. Exploration activities led to delineating potential mountain ranges in British Columbia (Jessop et al., 1991; Ghomshei et al., 1992). Detailed fieldwork (including geophysics and gradient drilling) was confined however, to potential areas in the south-west part of the province where presence of an energy market and power-line infrastructure made the prospects commercially attractive. Exploration in the Garibaldi and Pemberton Ranges led to discovery of several interesting anomalies including Mt. Meager and Mt. Caley. The Mt. Meager complex became the focus of exploration activities by the provincial and federal governments of the time. Two hydrothermal reservoirs were believed to be present under the Meager Creek Complex, the South Reservoir (known as South Meager) and the North Reservoir (known as Pebble Creek). Extensive core drilling in both prospects and deep exploratory drilling in the South, were successful in identifying high enthalpy reservoirs. Unfortunately, work stopped in 1985 due to financial constraints of B.C. Hydro. Low energy prices and lack of government incentives frustrated several attempts to revive the geothermal industry in the 1990s. The mood changed at the turn of the Millennium due to rising energy prices and growing interest in reducing greenhouse gas emissions. The South Meager Project was revived in 2000 with extensive MT exploration

(Frontier Geosciences 2001) and core drilling at higher elevations. The lease in the South Meager area (Ghomshei et al. 2004; Fairbank, 2002) was extended to cover the more interesting higher elevation prospects. Geothermal permits were also awarded to other prospectors in the North Meager area, Mt Caley, and Canoe Reach areas.

2. REVIVAL OF THE MEAGER CREEK PROJECT

The Meager Creek geothermal project at Mt. Meager, a Quaternary volcano about 160 km north of Vancouver, is the best known exploration site in the Garibaldi belt and has been the subject of advanced Canadian exploration efforts. B.C. Hydro (the government-owned principal provincial electric utility), worked this prospect during the '70s and early '80s. Detailed geology, geophysics and core drilling on the south and north sides of the Meager Creek complex were conducted. This work culminated with the drilling of three deep rotary test holes to a depth of 3500m in the South Meager region (Adams and Moor, 1985, 1987; Ghomshei et al., 1989). Unfortunately, this work was unable to provide convincing evidence for the presence of a commercially viable reservoir. Government activities halted in 1985. Private developers drilled one additional deep exploratory well in 1995 which also did not encounter any significant permeability. After several years of sporadic activity, exploration work resumed in 2000, this time aimed at extending the exploration towards the north where permeability was believed present around volcanic vents.

The advanced exploration activity in the South Meager area resumed with detailed deep MT surveys followed by drilling of three deep core-holes in 2001 and 2002. Temperatures up to 224°C were encountered at depths below 600 m. Several highly altered and fractured zones further evidenced the presence of significant permeability. Water chemistry and extrapolation of temperature data were indicative of presence of a reservoir with temperatures over 250°C, at depths less than 2500m.

2.1 Deep confirmatory drilling and production

Based on the volumetric heat content of accessible portions of the upflow zone, the geothermal power reserve within the South Meager Creek lease boundaries is estimated at approximately 250 MW based on a probabilistic model using Monte Carlo simulation which accounts for reasonable assumptions on (i) the percentage of heat expected to be recovered at surface, and (ii) efficiency factors related to converting that heat to electrical energy (GeothermEx, 2004, Ghomshei et al, 2004). This value is similar to an earlier assessment (Ghomshei and Stauder, 1989) which had suggested 200 to 300 MWe for a period of at least 30 years. The most secure part of this resource is expected to provide 110 MWe. Based on this estimate, the first phase of development for 100 MWe (net) is planned to come online in mid-2007. Full development of the South Meager Creek resource depends on three conditions: (i) commercial well productivity to be demonstrated by drilling and testing of confirmation wells; (ii) an adequate number of drilling sites to be identified in the rugged terrain of this field; and (iii) availability of a long-term power sales contract at a price of at least C$50/MW-hr (GeothermEx, 2004). At present two deep rotary holes are being drilled to 2500m. The wells are planned to be completed and tested by early 2005.

3. OTHER HIGH-TEMPERATURE PROSPECTS

The North Meager reservoir (also known as the Pebble Creek geothermal prospect) has been the subject of a feasibility study and review of previous drill-hole data (Nevin, 1992). Potential for a high-capacity commercial development of 300 to 500 MWe has been established based on the borehole data, as well as geophysics, geology and geochemistry evaluations. Plans for deep confirmatory drilling have been proposed for this prospect (Ghomshei, 2004). Incremental development up to 300 MWe is viewed be feasible before the end of the decade.

Other high and medium-temperature prospects within the Garibaldi Volcanic Terrain in southern B.C. have also been the subjected of recent exploration. Geophysical, geochemical, and geological surveys and a limited amount of test drilling have been carried out west of Mt. Cayley, a prominent Quaternary Volcano north of the town of Squamish. Reconnaissance exploration for low temperature resources has also been carried out on the east flank of the volcanic terrain in the region near the Whistler ski resort.

British Columbia is the only jurisdiction in Canada where geothermal resources are regulated. The B.C. Ministry of Energy and Mines has the authority to administer geothermal rights, which are issued by public tender as 20-year renewable leases. The Ministry regulates exploration activities and collects revenues from these rights.

4. DIRECT USE APPLICATIONS

There are about 150 hot-springs in Canada of which 110 are located in British Columbia. The rest are in Yukon, North West Territories (NWT) and Alberta (Ghomshei and Sadlier Brown, 1996). Most hot-springs are undeveloped because of their remote location. Current use of a dozen developed Canadian hot-springs is limited to recreational facilities – hot-springs and spas although some hot-springs, such as Takhini in Whitehorse, Yukon, and Radium and Miette in the Rockies (Lund, 2003) use the geothermal heat from the hot-springs and wells to heat the resort facilities. At Radium and Miette some of the hot water is passed through heat exchangers for direct use in space heating and other direct applications such as laundry and domestic hot water supply

The flow rates at developed hot-spring resort sites are between 100 to 500 GPM. The total direct use geothermal energy applications in Canada (including pools and space heating) are estimated at 10 to 15 MWt.

Major hot-spring resorts in Canada are as follows:

1. Harrison Hotsprings - Spa Hotel; southwest B.C.
2. Fairmont Hotsprings - Spa Hotel; Kootenay area, B.C.
3. Ainsworth Hotsprings - Spa Hotel; Kootenay area, B.C.
4. Nakusp Hotsprings - Pool, Spa; Kootenay area, B.C.
5. Albert Canyon Hotspring - Pool, Spa; Revelstoke, B.C.
6. Halcyon, Hotsprings - Pool, Spa Hotel; Arrow Lake, B.C.
7. Radium Hotsprings - Pool, Spa, Kootenay Area, B.C.
8. Lakelse Hotsprings - Pool, Hotel, Terrace, B.C.
9. Takhini Hotsprings - Pool, Whitehorse, Yukon.
10. Banff Springs Sulphur Mountain - Pool, Spa; Banff, AB.
11. Banff Springs Cave and Basin - Pool, Spa; Banff, AB.
12. Miette Hotspring - Jasper Park, Alberta.

In addition to these developed resorts, there are probably over 90 wilderness springs many of which are partly developed such as at Meager Creek, Maquinna Park, Hot Spring Island and Lussier. Most of these remain in their natural state.

5. GEOTHERMAL HEAT PUMPS

The geothermal heat pump (GHP) industry is growing in Canada at an exponential growth rate. Over 30,000 heat pumps had been installed in Canadian residences and commercial/institutional outlets by the Year 2000. In 2004, over 3000 new systems were installed. Canadian government recently announced a plan to install GHP systems in many of its buildings across the country. This initiative is expected to double GHP use over the next two years (Canadian Association of Renewable Energies, 2004).

Presently about one third of all installed GHP systems in Canada are commercial/institutional or multiple residential applications. The payback for a GHP system in a single-family dwelling depends on: 1- type of system, 2- geographic location, and 3- seasonal demand requirements. In cities along the Pacific Coast (e.g. Vancouver) the cost of a GHP system per kW energy saving is generally higher than in other parts of Canada due to relatively warm winters and cooler summers. In the Prairies and Eastern Provinces (e.g., Manitoba, Ontario and Quebec), cold winters and hot summers generate demand for heating and cooling that significantly impact on cash flow.

5.1 Barriers and Incentives to GHPs

Geothermal heat pump systems generally have a higher first (capital) cost than alternative heating and cooling systems. The payback period for the capital cost can vary between 2 to 10 years (Ghomshei et al., 2001, Ghomshei and Meech, 2003). For open loop systems, payback can be as low as one year for medium and large-scale systems.

For close loop systems, the additional cost of a geothermal heat pump system is mainly due to investment in a ground loop for heat collection and rejection. This cost is usually proportional to the capacity of the system. For open loop systems, the main capital cost is related to drilling water wells, where cost per KWt capacity depends on well productivity. In many parts of Canada, where a single (30 to 50m deep) water well can produce between 1 to 10 L/s, the additional cost can be well justified for medium- to large-scale systems. Nevertheless, because of the complexity of tapping into ground water systems (seasonal supply variations and environmental concerns), most HVAC companies in Canada prefer the easier and simpler close loop systems regardless of the project scale.

Factors important in improving market penetration include incentives such as rebates and or low interest loans offered by energy utility companies. Some Canadian electric utilities consider geothermal heat pumps as a way to improve load factors. In some provinces, utilities prefer to draw the ratepayers towards electricity rather than gas thus encouraging GHP, although heat pumps can be operated just as effectively on gas as well as electricity.

Manitoba is the lead province in promoting geothermal heat pumps. Manitoba Hydro offers an 8.5 per cent Residential Earth Power Loan of up to $15,000 to cover the additional cost to install a geothermal heat pump. The loan is paid-off through savings in the annual energy bill. In nearly all cases, a heat pump system can save more on a user's energy bill than the monthly loan payment (Ontario Hydro, 2004).

The total GHP energy saving in Canada is estimated at about 600 million KWh per year in terms of space heating and cooling (air conditioning) as well as other water heating applications. This translates into a reduction of 200,000 tonnes of GHG emissions (CO_2). The environmental benefits are higher if NOx and SOx are included (Geo-Exchange Coalition, 2004)

5.2 Usable Heat from Abandoned Mines

In most Canadian underground mines, all three elements of a low-grade geothermal system (heat source, water and permeability) are readily available (Ghomshei and Meech, 2003). Permeability is extensively present due to mine workings (in addition to fracture zones) while water is abundant below the water table (relatively near surface in most regions of Canada). As for heat, the rock temperature increases with depth. At Con Mine in Yellowknife, North West Territories, mine waters reach temperatures above 35°C at levels deeper than 1500m. Other heat sources are related to exothermic reactions triggered by exposure of minerals to oxygen (e.g. sulphide oxidation and slow-burning of coal). An underground mine can therefore be regarded as a significant heat deposit, where ground water does the mining.

5.3 First Canadian mine-water geothermal project (Springhill, Nova Scotia)

In Springhill (Jessop, 1998), water from a coalmine (abandoned after a mining disaster in 1958) is extracted to provide heat to commercial and residential users in the town. Water in the mine is at a temperature of 18 to 20°C within a few meters of surface. This is well above the normal shallow ground water temperatures of 6 to 10°C in the area. The heat flux from this mine is related to exothermic reactions at the exposed coal-faces and the circulation of waters and air from deeper parts of the mine. The first stage of developing this resource came onstream in 1989 to service an 8000-m^2 expansion of an existing industrial building. Water at 18°C is pumped from the mine, passed through a heat exchanger, and then returned to the mine at 12°C. The system is designed to provide cooling in the summer and is estimated to be 70% more efficient than conventional systems.

5.4 Britannia Mine

An example of a costly mine rehabilitation is the Britannia Mine located about 45 km north of Vancouver. Dubbed the worst Acid Rock Drainage (ARD) pollution problem in North America by Environment-Canada, this site is appropriate for an urgent, yet sustainable rehabilitation program. A plan to use the ARD waters to provide heat to the mine-site community is at the design stage and is expected to contribute up to 4 MWt by the year 2008. The savings in energy costs can significantly offset the operating costs to treat the water treatment.

Heat from the mine is brought to surface by the mine waters (ARD). This water is available for heat extraction since the effluent discharges from a single point. This effluent can be regarded as a geothermal resource that does not require drilling (as opposed to a conventional low-grade resource). The flow reduces the capital costs that would normally be required to drill which can amount to 300 to 600 thousand dollars assuming procurement of the same flow rate from wear wells. Acid resistant and easy-to-clean plate heat exchangers will be used to cope with the water chemistry.

6. CONCLUSION

Geothermal energy is abundant in Canada from coast to coast and can contribute significantly to the Canadian energy mix.

The geothermal heat pump industry is growing rapidly in all Canadian provinces and presently contributes to about 600 kWh of energy savings and about 200,000 tonnes of GHG reductions per year. Direct use applications are limited to hot-spring resorts and amount to about 100 kWh per year.

As for geothermal electrical power, development of the west coast high-enthalpy resources is taking on momentum. Current deep drilling at Meager Creek will bring the first 100 MWe of Canadian geothermal electric power online by the end of 2007. An additional 150 MW of reservoir capacity is estimated to be present in the South Meager area while 300 to 500 MW is believed present in the Pebble Creek (North Meager) prospect.

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