What Ever Happened to Geothermal Energy?
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There are severe challenges ahead for Canada in terms of the supply, quality and reliability of conventional forms of energy, such as coal, natural gas and petroleum. These issues could significantly affect our environment and standard of living. Consequently, Canada needs to develop sustainable, affordable and environmentally-sound energy alternatives. One such alternative is geothermal energy which is classified as a renewable-clean resource, along with solar, wind and biomass. The ultimate source of energy for geothermal systems is the tremendous heat stored within and flowing through the earth. This is estimated at 40 million megawatts worldwide by Rybach, although the ultimate potential for development is highly variable. The energy that is actually accessible is still massive and is contained in a whole spectrum of grades. Some of this energy is stored in high-grade systems (> 150 ^{o}C), but the vast majority of energy is stored in low temperature (low-grade; < 150 ^{o}C) environs. Geothermal resources are exploited worldwide for electric generation by withdrawing fluid from deep reservoirs and specific geologic features, and extracting the heat content. There are many examples where this has been carried out in an environmentally sound and sustainable manner. In a classic high-temperature hydrothermal system (> 175 ^{o}C), hot water and/or steam is used to drive turbines, which, in turn generate electricity. In mid-range temperatures (typically 100-175 ^{o}C) there are plant designs called "binary cycle-power" which allow for electric generation in much cooler geologic environs, and for example in 2006, a binary cycle plant in Chena Hot Springs, Alaska, started generating electricity from a record low fluid temperature of 74°C . Many examples of binary cycle geothermal plants can be found and these are responsible for about 682 MW worldwide. According to the Geothermal Energy Association, "geothermal power makes up a total of 3 gigawatts (GW) of installed capacity in the United States, its largest producer, and more than 10 GW worldwide. And those numbers are growing in spite of the recession, with the association calling 2009 a take-off year for a new era of geothermal growth."

Although the aforementioned conventional-hydrothermal resources are used world-wide in an effective manner they are somewhat limited in their locations and ultimate generating capacity. In addition to these resources there are enhanced geothermal systems (EGS), and these have an enormous potential for electric generation using a new generation of technologies. These are geothermal systems in which hydraulic fracturing is used to enhance the in-situ permeability of the rock enough to allow for reasonable fluid circulation. These system open up the possibilities of wide-spread electric generation from the vast horizon of moderate grade resources.

In Canada, the focus has been on relatively low-temperature sources; those of the shallow subsurface at much less than 100 ^{o}C. The method of extraction is typically in the form of a heat pump and these are often referred to as geoexchange systems. Heat pumps are important examples of how one can utilize the vast, ubiquitous low-grade energy supply stored in the shallow earth from about 2 to 200 m. They can lead to substantial energy savings, even up to 75% in electrical energy consumption. The use of this technology has seen considerable expansion. As of 2005, there were 1.1 million of these world-wide. Manitoba is the Canadian leader in the installation of new systems; 5,000 in 2005 with an increase of 920 in one year alone. In Winnipeg, nearly 100 systems are in place that directly use groundwater for thermal applications (open-loop), in addition to numerous ground-source (closed-looped) systems.

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Canadian Geothermal Assessments

Various estimates have been made for Canada's high-grade geothermal resources. These are primarily located in Western Canada. CanGEA, the Canadian Geothermal Energy Association, a high-temperature industry lobby group, estimates (based on work by Ghomshei) the Province of B.C.'s high-grade conventional- geothermal resources at 3,000-5,000 megawatts (compare these figures with BC Hydro's combined total generating capacity at present at 11,000 MW). In comparison, the Yukon has an estimated potential of 500-1,500 MW and the province of Alberta, 500-1,000 MW. These numbers for Canada are speculative, but we know that currently there is 3,150 MW actually produced in the United States and it is thought that resources for BC should be at least comparable. Note that the bulk of the U.S. geothermal capacity is concentrated in California with 2,555 MW operating. Agencies such as the USGS estimate the high-grade geothermal resources in the US at 30,000 MW, about 10 times today's current production.

Recently, two well known and respected Canadian geoscientists, Majorowicz and Grasby, did an assessment of the quantity of energy present at relatively shallow 3-4 km depths that might be suitable for enhanced geothermal (EGS) systems, for all of Canada. They estimate 1.4×10^{24} Joules (J), and conclude "the potential for geothermal energy to provide a significant renewable energy supply for Canada is significant". If only 2% of this resource was available for use and thus equal to a reserve then we have 2.8×10^{22} J or 1×10^{17} horsepower. We can compare these figures to total petroleum (oil and gas) reserves for Canada. Factoring in the tar sands, Canada has 1.1×10^{21} J for oil and 6.3×10^{19} J for natural gas. Therefore, the geothermal resource of Canada is easily at least one order of magnitude greater than our oil and gas reserves with the important distinction that *it is renewable.*

Majorowicz and Grasby also noted that conversion of existing coal-fired thermal plants to geothermal could offer a significant reduction in CO_2 emissions. A coal-fired thermal plant typically generates about 1 tonne CO_2 per MWh. They note that Canadian and US EGS projects could possibly save 164 t/day of CO_2 and 88,000 m^3/day of natural gas. Therefore, replacement of antiquated thermal plants and/or turning to alternatives like EGS could form part of a comprehensive plan for emissions reductions in Canada.

The environmental impacts of high temperature systems are reasonably well understood. Waters that are taken from deep in the earth can contain a mixture of gases such as hydrogen sulfide (H_2S), methane (CH_4), ammonia (NH_3) and carbon dioxide (CO_2). Existing plants release an average of about 120 Kg/ MW-hr of electricity which is actually a very small fraction of the output of conventional fossil fuel plants. In addition to the gases as noted above, waters may contain trace amounts of toxic metals such as mercury, arsenic and so on. The practice of re-injecting cooled geothermal fluids back into the source rocks in many plant designs has the added benefit of reducing risks of metals contamination and air pollution at the surface.

The question of sustainability is also of interest and importance. To what extent would we "mine" energy from the subsurface and will temperatures recover under the stress of prolonged development? As energy is extracted from a rock mass, temperatures will drop over time. Studies have shown that the cooled part of a typical EGS rock reservoir will recover 90% of its maximum temperature drop in 3 times the time it took to get there. Hence, a total development area of only 3 to 5 times the size of the original reservoir area would be required to cycle the geothermal field through over a 100 years of operation.

Economics and Resources

The principle challenge that exists for all geothermal developments is the depth of the resource, because the costs of development are dominated by drilling. Costs are non-linear; i.e. the cost per meter of drilling follows an exponential curve. Aquifer or rock hydraulic characteristics are also important in that satisfactory flow rates involving injection and withdrawal wells are essential to generate electricity at economic levels.

Defining areas for geothermal development requires information on deep geological and thermal conditions. These include heat flow values, sub-surface temperatures, geologic and hydrogeologic information, and thermal properties. Drill holes with high-precision temperature logs with depth and bottom hole temperatures are of key importance. These data are principally used to predict temperatures at much greater depths, say 5-10 km where temperatures of 100-200 ^{o}C for electric generation are needed.

Small communities with high heat flow (Watson Lake, Fort Simpson, etc.) may have populations that are too small to support costs associated with enhanced geothermal; however, they may very well have better economies associated with binary geothermal at lower temperatures (90 – 100 C). These targets can be reached at depths as low as 2.5 km. Any developments may also receive a benefit from a direct use of warm waters from deep aquifers (e.g. greenhouses, street warming, geoexchange).

The details of heat flow in Canada are severely limited because there are large regions with either no, or sparse data. High-density definitions and good resolutions are found throughout the Western Canada Sedimentary Basin, Mackenzie corridor and the Beaufort Basin. This density derives as a result of an exceptionally large dataset of heat flow determinations made from oil and gas wells. However, in the Yukon, however, recent assessments by Majorowicz and Grasby show only about ten points for heat flow determinations in this territory. This is far too low a number to make accurate resource assessments. The heat flow determinations that do exist were collected by the now defunct federal Geothermal Energy Program . While this program made huge strides in characterizing geothermal energy potential in Canada, and was just starting geothermal demonstration projects, it was canceled abruptly in 1985. Since that time very little government research has been done.

What is needed?

The use of the low-grade, shallow energy particularly in the form of commercial and residential ground-sourced heat pump systems, is increasing at an astonishing rate. Increasing geoechange development will require a greater degree of understanding of heat flow and groundwater flow in the subsurface. Energy experts agree that in a few years time all large-sized building environmental controls will revolve around heat pump technology. However, greater effort will be required in the design of individual systems and associated hydrogeological investigations to ensure that they are, in fact, environmentally sound and sustainable. Since the use of geoexchange systems is viewed rightly or wrongly as an energy efficiency measure and not a earth-energy supply, one could argue that sufficient incentives are already in place for their promotion.

There are a number of issues that, to date, have prevented moderate to high temperature development in Canada. These issues include the locations of the sources being far from existing the communities that may benefit from them, lack of transmission corridors for getting the energy to market and high initial costs. Geothermal exploration, like its counterparts in oil, gas and mining rely, in the main, on exploratory drilling. For this reason, especially in areas where very little subsurface data is available, geothermal exploration is inherently risky.

Government policies and actions are needed to support development. For example, in the 2010 Federal budget there is an extension for two years of a mining tax credit. This will cost $65 M. In comparison, there are power production incentives for renewable energy but these are expected to be fully subscribed. There are also funds set aside in the federal budget for clean techniques but these focus almost exclusively on carbon capture and storage, costing $800 M. So, in spite of intense lobbying and while there are federal and provincial programs to develop technologies to deal with greenhouse gas emissions, there is nothing to support exploration for green resources. Most American states have incentives such as premiums paid for renewable power, and federal tax credits, loans and grants for exploration. Grants and subsidies for geothermal are also common in Europe. Australia recently announced a commitment of 1.1 $B in the form of tax credits and rebates . This program will enable geothermal developers in Australia to write-off the large initial exploration costs of geothermal development.

Finally, it is interesting to note other items in our federal budget. There is 300 $M allocated to AECL for operation costs, 35 $M to Natural Resources Canada (NRCan) for R&D in isotopes and 60 $M for the budget for the Geologic Survey of Canada. NRCan's total budget is estimated at 700 $M but they have only one geoscientist partially dedicated to geothermal studies. For the same cost as the new sound system in the New Orleans Superdome, or mere 1% of NRCan's entire budget (7 $M) we could offer at least some support to the geothermal industry in producing better maps of fundamental thermal data. An even better effort would be redirect activities within NRCan to geothermal and away from more traditional geologic work. Without fundamental geoscience knowledge and government incentives we cannot expect industry to risk exploration dollars in Canada.