# Geothermal Energy:

# An Outlook on the Possibility of Introduction into Canada

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The purpose of this paper is to examine the potential for geothermal development in Canada and the benefits and drawbacks of introducing this energy into the country. The paper examines the various uses of geothermal energy, available technology options, suitable locations for establishment of geothermal energy, environmental impacts, mitigation efforts for these impacts, economic significance, public perceptions and social licensing, as well as overall relative impact. Geothermal energy is a resource that is yet to be developed within Canada, however, based on the analysis of tectonic plate boundaries on a global scale along the "Ring of Fire," the western coast of Canada lies along an area where heat flow is at a maximum ("Plate Tectonics & Heat Flow", 2004). This energy originates in the core of the earth where the radioactive minerals are decaying, and is visibly displayed on the surface through natural geological occurrences such as volcanoes, hot springs, and geysers (Mburu, 2013; Dickson & Fanelli, 2003). To obtain this energy, heat from the core of the earth is conducted to surrounding rocks and then transferred to underground water reservoirs by convection (Mburu, 2013). Through the application of various technologies, the resulting steam and water that is heated by the geothermal energy process can then be captured and employed for various uses.

Geothermal energy has been used for centuries, as evident in the popularization of the Roman Baths in the 16$^{th}$ century (Gallois, 2006). Since the introduction of this energy into society, it has been adapted for many different uses. Applications of geothermal energy vary widely due to its versatility and abundance. The most common association of geothermal energy is with the production of electricity, however there are many other ways in which geothermal energy has proven to be beneficial. Direct use involves using hot water from geothermal resources directly, which allows for applications such as food preparation, tourism, aquaculture, heating, crop and lumber drying, and industrial processes. Geothermal heat pumps are another way in which geothermal energy is being used (Mburu, 2013). The application of geothermal fluid is determined by the enthalpy, as high-temperature resources are utilized for electricity production whereas low to medium resources are preferred for direct application. (Mburu, 2013). According to studies, over the period 1995-2010, the energy utilization across multiple categories of direct use world-wide in TJ/year has increased from 112,441 to 438,071, which means globally the utilization increased by roughly 290 per cent (Lund, Freeston & Boyd, 2010). The variability of the usage of geothermal allows for an increase in overall revenue for each output of energy.

Due to the attention and increased usage of geothermal energy over the past few decades, many advancements have been made concerning the technological options for harnessing this energy. Deep geothermal extraction/EGS occurs through creating a fracture system below the surface, then water is added to the system via injection wells. The added water is heated when it encounters the rock and is returned to the surface through production wells where it will be converted into electric energy at a power plant (Mburu, 2013). There are multiple technologies that can be integrated into power plants to extract geothermal energy, these include the atmospheric exhaust conventional steam turbine, condensing exhaust conventional steam turbine, binary plant, and the biphase rotary separator turbo-alternator (Dickson & Fanelli, 2003). The atmospheric exhaust conventional steam turbine involves separating the steam from the geothermal discharge before it enters a conventional axial flow steam turbine that exhausts into the atmosphere. This is the simplest system, has the lowest capital cost of all geothermal cycles, and can be started without an external energy supply, although it consumes twice the amount of steam per kilowatt of output as condensing plants. Regardless, this application is still used in pilot plants and for generating electricity using the discharge from test wells during field development (Dickson & Fanelli, 2003). The condensing exhaust conventional steam turbine is similar to the atmospheric exhaust system; however, the steam is discharged into a condensing chamber with a low absolute pressure which results in the generation of approximately twice as much power as the other system at typical inlet conditions. This type of plant is the most commonly used for geothermal power generation even though the additional equipment increases the total cost of the plant and requires a power consumption totalling approximately 4.6 per cent of the gross energy being generated (Dickson & Fanelli, 2003). Binary plant technology utilizes smaller module units, which increases cost-effectiveness due to shorter manufacturing and installation times. This plant type was created to generate electricity using low-medium temperature resources and increases its efficiency by recovering waste heat. Geothermal fluid transfers heat to the binary cycle through heat exchangers, and a secondary working fluid, usually n-pentane, then goes through a heating and vaporization stage before being expanded through a turbine to a lower pressure or temperature (Dickson & Fanelli, 2003). The biphase rotary separator turbo-alternator is a complex system that utilizes a two-phase steam/water mixture to extract power. It involves passing the mixture through a nozzle, which expands the gas, due to changing pressures, to increase the kinetic energy of the mixture. During the second phase of the process the mixture encounters the separator, which uses centrifugal acceleration forces to separate the liquid from the steam. While the steam exits the system, the liquid passes through transfer holes to the liquid turbine where flow direction is reversed by 180 degrees, causing a force on the element and a torque on the turbine rotor before the liquid is passed to the transfer rotor. The transfer rotor operates using the kinetic energy remaining in the liquid, which is approximately 4 per cent, to transport the liquid towards the stationary diffuser where it diverges at a 3 to 1 expansion ratio, converting the last portion of energy into pressure allowing the system to reach re-injection requirements. When paired with a conventional turbine, the steam released as discharge by the separator can also be utilized for energy production (Dickson & Fanelli, 2003). These four different systems are the typical plant options used for geothermal power production.

As mentioned above, the western portion of Canada's land mass is situated along the "Ring of Fire", which means that high enthalpy zones suitable for electricity production exist within Canadian boundaries ("Plate Tectonics & Heat Flow", 2004). Although high enthalpy zones are preferable for electricity production, it is still possible to produce electricity from low-medium enthalpy sources granted that cost efficiency and production efficiency may be reduced. The energy consumption in Canada is extremely high per capita at approximately 200 kWh/person/day, with 40% of the consumption used for heating purposes. Currently, the high temperature geothermal resources are concentrated mainly in southern regions of the Northwest Territories, northeastern British Columbia, and northern Alberta, however the composition of rock is not suitable for the common geothermal extraction approaches. EGS will need to be used to extract the energy contained in these regions, however is has not been proven on a commercial scale (Barrington-Leigh & Ouliaris, 2017; Mburu, 2013). Based on the analysis of the proposed areas for high temperature geothermal development potential within Canada, I propose that a pilot project in the northeastern region of British Columbia would be an appropriate location to introduce this energy into Canada. This is due to the higher potential that there will be a suitable basin of existing groundwater and permeable rock to extract using the EGS method when compared to Alberta and the Northwest Territories (Barrington-Leigh & Ouliaris, 2017). Based on the priority geothermal exploration areas map, the potential for geothermal in British Columbia is sufficient to meet the entire province's energy demand. Although, significant improvements need to occur in the extraction technology before the theoretical power generation potential for sediments only estimated in the report can be reached (Thompson et al., 2014).

The main environmental impacts associated with geothermal extraction are noise pollution, disposal of drilling fluids, possible ground subsidence, induced seismicity, and impacts of air quality. Noise pollution exists during the exploratory drilling, construction and production phases, with the loudest being during air drilling at 120 dBA. Mitigation efforts for noise pollution include muffling and silencers, which can reduce the noise caused by air drilling to around 85 dBA, well testing noise to 70 t0 110 dBA, and well bleeding noise to 65 dBA (Dickson & Fanelli, 2003). Geothermal water contains many contaminants that need to be properly disposed of either through designated hazardous-waste disposal sites, or disposed in the local area through a deep re-injection. The proper disposal of these contaminants protects the surface water and groundwater of that location from toxic contaminants such as arsenic and mercury (Dickson & Fanelli, 2003). The possibility of ground subsidence could negatively affect pipelines, drains, well castings, local watersheds and nearby buildings. Although mitigating ground subsidence is challenging, proper monitoring and assessments throughout the development and usage of the field needs to be completed to reduce the effects of subsidence on the surroundings (Dickson & Fanelli, 2003). Induced seismicity is another concern associated with geothermal extraction. There are naturally occurring earthquakes that are unrelated to extraction due to the location of geothermal fields in areas of high seismic activity. Increased seismicity has been acknowledged as occurring in areas where fluids are injected into deep formations. In a study of induced seismicity at a geothermal field in New Zealand, re-injection of water at saturated water vapour pressures rather than at high well-head pressures produced no seismic activity (Dickson & Fanelli, 2003). Contaminants that are released into the air through geothermal power generation are carbon dioxide, hydrogen sulfide, ammonia, mercury, boric acid, and other hydrocarbons. Depending on the field and plant size and processes, the amount of each contaminant released into the environment vary greatly. Proper monitoring and assessments of each field is important to trace the amounts being released, and how they are affecting the environment, as well as if they are within the air quality guidelines for that area (Dickson & Fanelli, 2003). Furthermore, to properly mitigate these environmental impacts, the various possible effects need to be identified before or during the first stage of site development to ensure proper procedures are in place before the impacts progress beyond mitigation.

The introduction of geothermal energy into Canada could prove to be very beneficial for the economy in terms of the economic cost of power generation. Geothermal energy generation costs are mainly a fixed cost, which means that the cost per unit of geothermal power decreases as the capacity factor increases. This relationship is significant because maximum operation in turn yields maximum return. There is also the possibility of co-production of silica and other products from geothermal brines. Co-production can improve the efficiency and overall usage of the site, while being sold on the market for approximately US$1 to $10 per kilogram with an estimated market value of US$84 million a year. The removal of silica also allows for downstream extraction of other minerals such as zinc, manganese, and lithium which also all have moderately high market values. A plan in the Salton Sea geothermal area which recovers zinc from geothermal brine produces 30,000 metric tonnes of zinc with a value of approximately US$50 million per year (Dickson & Fanelli, 2003). Applications of direct use through heat pumps within Canada has proven to be beneficial for the economy as well. Federal and local subsidies have allowed for consumers to gain access to this technology for a lower financial cost. The usage of heat pumps in abandoned mines has reduced energy costs, as the City of Yellowknife saved C$13 million per year in district heating by installing a pump in an unused gold mine (Lund et al., 2010). The increasing popularity of geothermal is important because as oil and gas supplies decrease and prices of these resources increase, geothermal energy will prove to be an economically feasible alternative energy source (Lund et al., 2010).

The public perceptions regarding geothermal energy use vary by country. In Canada, the introduction of renewable energy can be problematic due to the reliance on oil and gas as a main energy sector throughout Canada, specifically in Alberta. One may argue that the country was built upon oil and gas, though it would be naïve to believe that building an energy sector solely on a non-renewable resource would be sustainable. The main problem with public perception is the lack of knowledge regarding geothermal energy. Many people associate geothermal exchange with geothermal energy, however they are two different applications. Even though direct use application has been around for centuries, the public knowledge concerning geothermal for energy production is minimal. As with any new project, the introduction of geothermal energy may be hindered by the refusal to receive a social license from the public. If Canada is truly going to begin a shift from an oil and gas driven energy sector to a renewable energy sector, the acquisition of a social license will allow for the process of shifting to flow quickly and efficiently. With the wide variety of renewable energies available, the attainment of the publics acceptance will pave the way for other emerging technologies to be introduced into Canada. With proper mitigation procedures and increased public awareness and acceptance, geothermal energy can be introduced to Canada in the foreseeable future.

The use of renewable energy allows for each region to have a diverse array of energy sources. Depending on limitations, the relative abundance of each energy would vary from region to region. With current geothermal technology, countries with low-temperature geothermal resources are now able to harness geothermal energy for different uses. When compared to other renewable energy sources, geothermal is one of the most economically feasible options concerning US¢/kWh. Geothermal and hydro are both currently costing 2-10 US¢/kWh, biomass costs 5-15 US¢/kWh, wind costs 5-13 US¢/kWh, solar photo voltaic costs 25-125 US¢/kWh, and tidal costs 8-15 US¢/kWh. The potential future energy costs of these renewables are also calculated with geothermal dropping to 1-8 US¢/kWh and hydro becoming 2-8 US¢/kWh (Fridleifsson, 2001). When comparing both renewable energies and conventional energies, geothermal has the highest capacity factor at approximately 90-95%, nuclear follows at approximately 85-90%, and coal is between 80-85%. The renewable energy closest to matching the capacity factor for geothermal is biomass at 78-83% (Hales, 2014). From this data, one can argue that based on capacity factor alone geothermal is the most productive renewable energy, and when compared to conventional energy geothermal remains as the top energy choice. The remaining renewable energy options have capacity factors between approximately 15-50% (Hales, 2014). Despite geothermal being more environmentally invasive than other renewable energies and having location limitations for energy production, further development of the technology will allow for these restrictions to be overcome or mitigated. When compared with other renewable energies, geothermal has a higher number of available co-products and usage options. A larger amount of the total resource, meaning all physical and chemical properties, can be captured for different uses.

Overall, geothermal is a renewable resource that should be considered for production in Canada as a viable future energy source. With proper mitigation, assessments, procedures, and prevention, the environmental effects of geothermal energy production can be properly maintained and addressed. As a country, we can take our knowledge from mistakes made in our current energy sector concerning environmental impacts and apply it to the emerging renewable energy sector. If our country plans to uphold current climate change agreements and goals, renewable energy is the road that needs to be followed, and geothermal energy can be a beneficial and efficient resource that will allow us to continue the implementation of renewable energy use across Canada.

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