Our Deep Geothermal Energy Potential: A Case Study in Saskatchewan with Application Throughout the Western Canadian Sedimentary Basin

Introduction

Deep geothermal energy relates to the heat-energy stored in the earth's crust. With greater depth, the earth becomes progressively hotter, and depending upon the location, the sedimentary rocks in the crust may contain aquifers filled with water. Under the appropriate conditions, this water can be pumped to the surface where the heat is extracted and used in direct heating applications. The amount of heat that can be supplied by a single geothermal plant can be very large, therefore, this energy source lends itself very well to district heating systems and to some larger industrial applications.

Recent investigations have attempted to quantify the geothermal energy available from the deepest aquifer in southern Saskatchewan and to develop the business case for its exploitation (Brunskill and Vigrass, 2009). This work may be useful in the evaluation of many other aquifers present throughout the Western Canada Sedimentary Basin.

Background

The southern two-thirds of Saskatchewan is situated within the Western Canada Sedimentary Basin (WCSB). In simple terms, the Basin in Saskatchewan can be regarded as a wedge of sub-horizontal sedimentary strata sitting on top of the older Precambrian crystalline rocks. In Saskatchewan the wedge has a maximum thickness of about 3500 m at the International Boundary south of Weyburn. In southeastern Saskatchewan the wedge is influenced further by the structural geometry of the Williston Basin. In the southern part of Saskatchewan the sedimentary column can be divided into three gross subdivisions: the Upper Clastic Unit, the Middle Carbonate-Evaporite Unit and the Basal Clastic Unit.

The *Basal Clastic Unit* lies unconformably on eroded and weathered Precambrian crystalline rocks. The unit consists of the Deadwood Formation (mostly Cambrian in age) and the overlying Winnipeg Formation of Ordovician age. These two formations, occurring at the base of the sedimentary sequence, are the most deeply buried and consequently they have the highest ambient temperature. In general they also have good fluid flow properties with the result that, at any given location, they likely have the best potential for development of the deep geothermal resource. The water present in the unit is relatively stagnant. Flow in the aquifer is created when the water is pumped to the surface to be used as a geothermal energy source then re-injected back into the aquifer.

In 1978, the University of Regina undertook a deep geothermal project with the goal of supplying the space and hot water needs of a large sports complex to be built on the campus. One well was drilled and completed in the Winnipeg/ Deadwood aquifer section at a depth of about 2200 m (Vigrass *et al*., 2007). Although the project was not completed the geothermal energy potential of the Regina area was established. Related studies have shown that the geothermal resource within a large area of southern Saskatchewan to be immense.

The Geothermal Loop Concept

To utilize a deep geothermal heat source, two wells (a *doublet)* must be drilled from surface and completed in the source aquifer, creating a geothermal-water loop. A production or *source well* pumps hot water to the surface where it passes through a heat exchanger, transferring useful heat to a fresh water circuit. The fresh water circuit carries hot water to the buildings or other heating load. The cooled geothermal water from the exchanger is pumped back to the aquifer via the *disposal well*. The amount of heat that can be extracted from each doublet is finite. In a geothermal loop, the cooled water that is re-injected into the aquifer will pick up heat from the rock matrix as it migrates slowly back toward the source well. Eventually this cooling effect will reach the source well and *thermal breakthrough* will occur, reducing the productive capacity of this doublet. Figure 1 illustrates a simple geothermal loop as located near Regina.

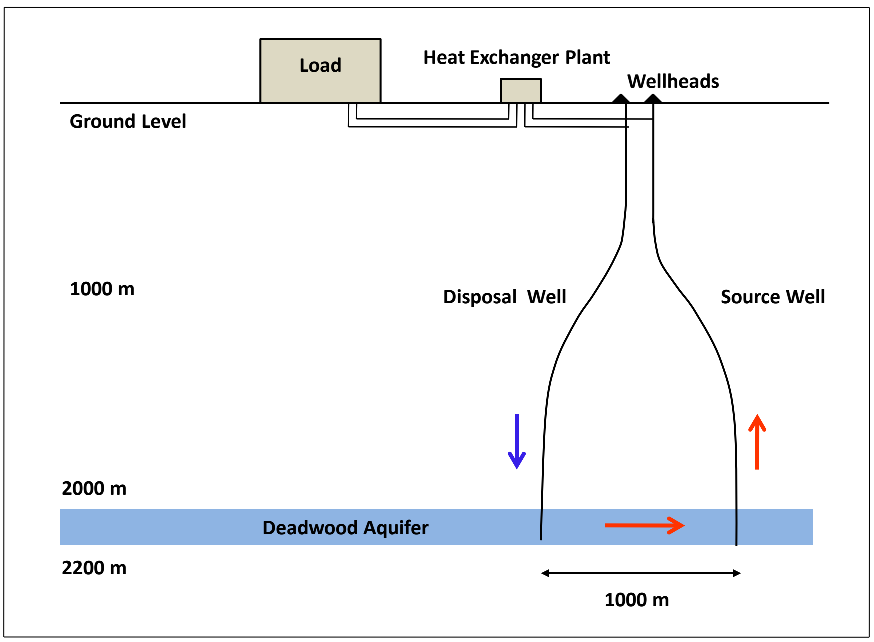

Figure 1 – Illustration of a model geothermal heating doublet near Regina. The source and disposal wellheads are located close together at surface and the wells have approximately 1000 m separation in the aquifer. The water in the aquifer is relatively stagnant so movement is created by the pumping and injection of the water; arrows show direction of water flow.

Modelling completed for the University of Regina project suggests that if the two wells at the aquifer level were spaced approximately 1000 m apart, thermal breakthrough would occur after about 35 years operating at full capacity. Since the system would be operational seasonally this heating source would be available for about 70 years.

Geothermal water will be piped from the wellheads to the *heat exchanger plant.* Heat exchangers are used to transfer the heat from the geothermal water to fresh water. Heated fresh water is pumped to residential, commercial and industrial buildings to provide space heating and domestic hot water. The source pump operates at a variable rate, adjusting to both daily and seasonal heating requirements. Figure 2 provides an illustration of a district heating system using the geothermal heating source.

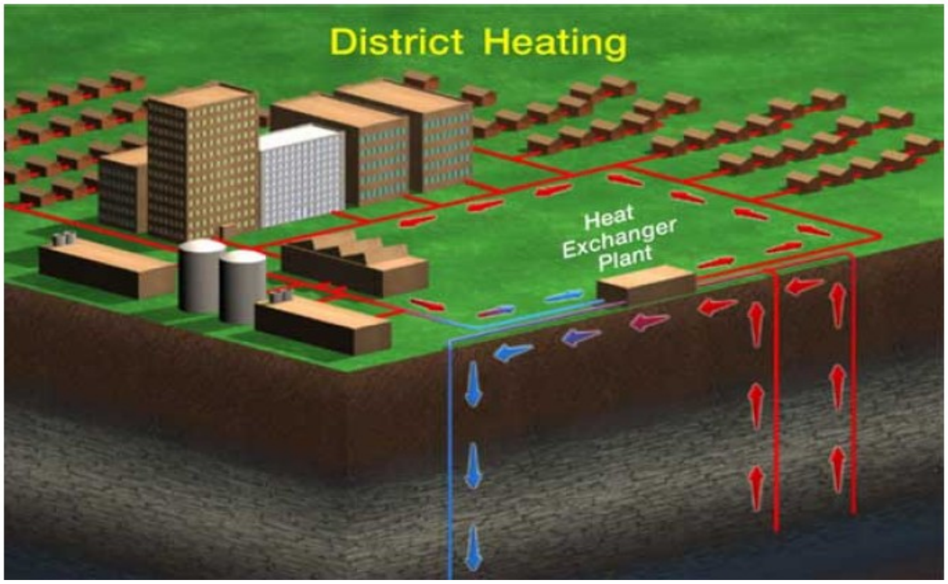

Figure 2 – Model of a District Heating System Triplet Using Geothermal Energy. Figure courtesy the US Geothermal Education Office.

The Energy Available from a Geothermal Source

At Regina, for example, the geothermal source water temperature is approximately 61°C. This heat source can generate approximately 23,800,000 Btu/h or 6,960 kW of thermal power which can provide enough base-load heating for about 1.5 million ft^2 of commercial space **(equivalent to an area the same as roughly 16 CFL football fields)** or for about 510 houses (each being 2,000 ft^2 in size). Electricity is required to operate the pumps. The Coefficient of Performance (COP), or the ratio of energy produced compared to the energy required for operations, is about 18. For comparison, near Estevan, where the same aquifer is present at a depth of approximately 3260 m the water temperature is about 105°C. A geothermal system operating there could potentially generate about 49,800,000 Btu/h, satisfying the base-load heating needs of over 1,100 houses.

The Economic Value of Utilizing a Geothermal Energy System

Many buildings are heated by air or water that has been heated by burning natural gas. For these buildings, the economic value of the geothermal source can be considered to be equivalent to the amount of natural gas *not purchased* to provide the same amount of heating. This value is used to calculate the cost avoided (or *revenue*) of a geothermal system. For our assessment in Saskatchewan, we used $7.49/GJ, which was the current SaskEnergy five year delivered contract price for natural gas (SaskEnergy, *pers. com*.).

Capital and construction costs are significant, and must all be paid in advance of energy production. All costs up to and including the heat exchanger plant are included. Additional capital costs to develop the on-surface water distribution network to the load have not been included. Economic forecasts were used in the development of the business case in. Net Present Value (NPV) calculations are based upon a 6% discount rate determined over the first 20 year period. All expenses and the price of natural gas have been inflated annually at the rate of 2%.

At Regina, for example, the total capital cost is estimated to be approximately $5.8 million. The NPV is about $3.5 million with a 12.6% Internal Rate of Return (IRR) and 7-8 year payout. Near Estevan, the total capital cost is estimated to be approximately $8.1 million. The NPV is about $13.7 million with a 22.4% IRR and 4-5 year payout.

The Environmental Value of Utilizing a Geothermal Energy System

Carbon dioxide (CO_2) is released directly into the atmosphere during the combustion of natural gas used for heating. The "environmental value" of using a deep geothermal heat source is based upon the replacement of natural gas to provide the equivalent amount of heating, and the associated CO_2 *emissions avoided*. These CO_2 emissions avoided are measurable. Using deep geothermal energy does not directly produce a significant volume of CO_2, however, there may be emissions from the combustion of coal and other sources to generate electricity to operate the pumps. These emissions must be considered when calculating the *net* or actual emissions avoided.

At Regina, for example, the utilization a geothermal heating source could potentially result in the avoided emission of approximately 6,290 tonnes of CO_2 per year. This value is reduced to about 5,050 tonnes per year when the emissions generated by SaskPower to generate the electricity to operate the pumps are considered. Near Estevan, the annual CO_2 emissions avoided are about 13,200 tonnes per year or about 11,600 net tonnes per year.

Since July, 2007, the Alberta Climate Change and Emissions Management Fund has allowed Alberta companies to pay $15 into the fund for every tonne of CO_2 produced over their predetermined reduction target. Using the Regina and Estevan scenarios from above, the value of these emissions avoided could potentially be worth $75, 750 and $173,850 per year, respectively.

There are no capital expenditures required to receive this benefit. These emissions avoided could be used to offset emissions from other sources or credits in future trading schemes.

Where Deep Geothermal Energy Can Be Utilized

In southern Saskatchewan where some of the aquifers are at least 2-3 km in depth, the temperature of the water ranges from approximately 60 – 105°C. Sedimentary rocks up to 5 km or more in depth are present in the WCSB and many of these sections contain deep aquifers with enormous geothermal heating potential. Figure 3 shows the partial extent of the WCSB and thickness of the sedimentary rocks.

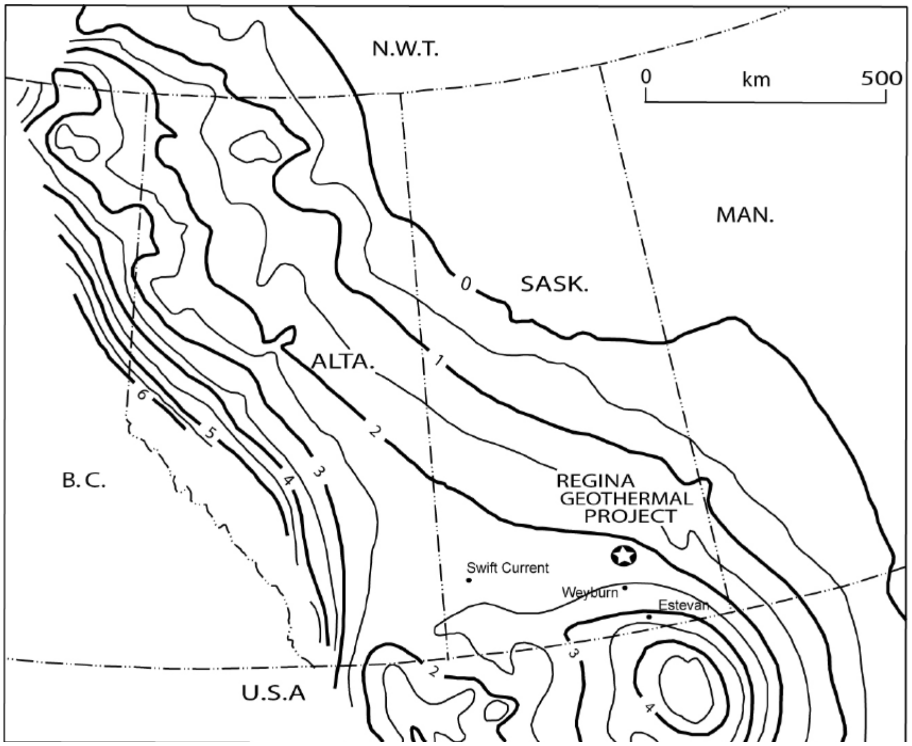

Figure 3 – Thickness in kilometers of the strata above the Precambrian Basement in the southern part of the Western Canada Sedimentary Basin (Vigrass, et al., 2007)

Benefits and Uses of Geothermal Energy

Depending upon the location, the primary benefits of using deep geothermal energy are that:

- A single plant can provide sustainable, base-load heating for up to 70 years or more
- The heating source is highly reliable and is available anytime without any storage requirements
- Energy production does not depend upon weather conditions
- The energy cost is stable, and is not subject to the future price of oil and gas
- Greenhouse gas emissions are very low
- Operational and maintenance costs are very low
- The technology is simple and widely understood
- The surface footprint of a geothermal plant is very small.

The main drawbacks to developing geothermal energy are:

- Lack of experience with its use
- High upfront capital cost of plant development.

There are many applications for geothermal energy use within the WCSB, however, project development is limited to the actual location where it is to be used. The amount of heat that is supplied by a single geothermal plant can be very large, therefore, this source lends itself very well to a distributed heating supply, providing the heating needs for several buildings. Some potential uses of geothermal energy include:

- Providing space heating and domestic hot water for residential, commercial and industrial buildings
- Providing heating for large-volumes of ventilation air in schools, hospitals, office buildings, apartment complexes, shopping malls and community centers
- Providing space and ventilation air heating in large manufacturing facilities and the pre-heating of industrial boiler or process water
- Providing heating for the drying of ethanol-plant distiller's grain and other agricultural products.

Using geothermal water to heat buildings in Europe and other places is common. In France, for example, geothermal energy provides heating for approximately 200,000 residential units and avoids the associated emission of about 650,000 tonnes of CO_2 per year.

Conclusions

There is utilization potential throughout large areas of the WCSB and the technology required to develop this enormous energy endowment is well understood and simple. Our oil and gas drilling industry has abundant experience in the drilling of deep wells and safely pumping oil and water to the surface, and our building heating industry is well experienced at distributing hot water to heat buildings.

A geothermal utility can be built and operated by an individual, a developer, a third-party joint venture partnership or by an existing utility operator. Communities could finance and independently develop and distribute the heat supply to community centers, homes, swimming pools and multiplex facilities. The geothermal system could provide a dependable heat supply and predictable return on investment for a generation or more.

To fully integrate deep geothermal energy into our energy supply mix we need full-cycle applied experience. Once the first plants are operational, this experience will provide confidence to engineers, architects, developers, builders, investors and consumers about this huge, nearly emissions-free energy resource.

We are all looking for ways to develop new energy sources ***and*** reduce our environmental footprint, and using deep geothermal energy will contribute significantly to both these goals.

References

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