Geothermal options for remote Canadian communities: example of the town of Golden, British Columbia

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Abstract: As a typical remote Canadian community, Golden is a growing town with a high demand for heating energy and electricity As replacement to wood, propane and heating oil are being used for heating all new buildings These fuels are expensive and involve significant carbon emission. Geothermal is a green alternative to fossil fuels and stand-alone electricity, with significantly lower operating costs . Viability of geothermal options is investigated for Golden, as a typical remote Canadian community with cold and long winters and no access to natural gas. Semi-distributed systems (consisting of several medium-scale open-loop resource developments for different sections of the town), with geothermal surge tanks, and distributed heat pumps can provide heat to the entire town. Installation of such systems can lead to more than 60% savings in energy costs and 90% to 100% reduction in carbon emissions. It would also eliminate local air pollution problems associated with wood burning. Capital costs for a geothermal district heating system producing 10,000 GJ/y (for 60 homes, as the first step) is estimated at $725,000, with a payback period of about 5 years. The proposed geothermal model once implemented in Golden, cab be applied to many other remote Canadian towns, suffering from high heating costs and air pollution.

Keywords: *Low temperature geothermal energy, remote communities, geothermal heat pump, district heating application*

1. Introduction

1.1. Golden's characteristics

Golden is a town with a population close to 4600 [1]. It is located in southeastern British Columbia, 260 kilometers (163 miles) west of Calgary, Alberta and 720 kilometers east of Vancouver, British Columbia. Golden is situated in the Rocky Mountain Trench, at the confluence of two rivers (Columbia and Kicking Horse). It is a Valley surrounded by three different mountain ranges and five National Parks: Yoho National Park, Banff National Park, Jasper National Park, Glacier National Park, and Kootenay National Park. The town of Golden is located on the Trans-Canada Highway and at the end point of Highway 95, which is connected to the United States, passing through the rest of the East Kootenay region and some major cities (such as Cranbrook). Golden has a relatively cold climate with considerable heat demand in all seasons, especially in winter, when the temperature can drop below 45°C.
Table 1 and Fig. 1 provide a summary of record and average high and low weather temperatures in Golden. Fig. 2 shows the geographic situation of the Town of Golden.

Table 1. Weather temperatures in Golden

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	8.3	12.2	19.5	28.9	35.6	37.2	40	37.8	33.9	25.6	17.2	10	40
Record low °C	-46.1	-39.4	-31.7	-19.4	-9.4	-6.7	-2.2	-2.8	-9.4	-18.3	-32.8	-43.9	-46.1
Ave. High °C	-5.6	-0.3	6.3	13.1	18.3	21.6	24.4	24	18.1	10.1	0.8	-5.1	10.5
Ave. low °C	-13.7	-10.2	-5.6	-0.8	3.8	7.8	9.7	9	4.4	-0.4	-5.7	-11.7	-1.1

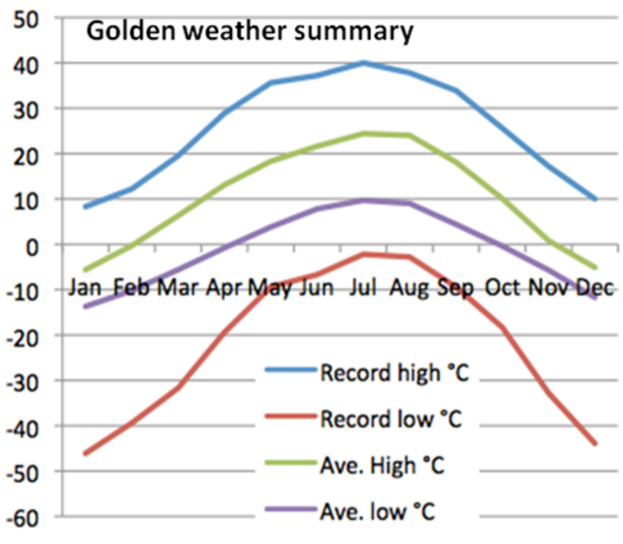

Fig. 1. Temperature statistics of Golden

1.2. Energy demand

Being a growing city, Golden is in need of energy in all its forms for its survival. Golden is; however located at the end point of the Power line (Fig. 2) and therefore suffers from frequent electricity blackouts or brownouts. The city also needs heat especially during the cold season when the average low temperature is below freezing. The heat demand of the city is presently met by fossil fuels (mostly heating oil and propane) and wood. While wood is considered as carbon neutral (condition to burned wood being replaced by new plantation), it produces significant amounts of air pollution such as carbon monoxide and air-born particles and for this reason it has been banned in all new buildings and retrofits[1]

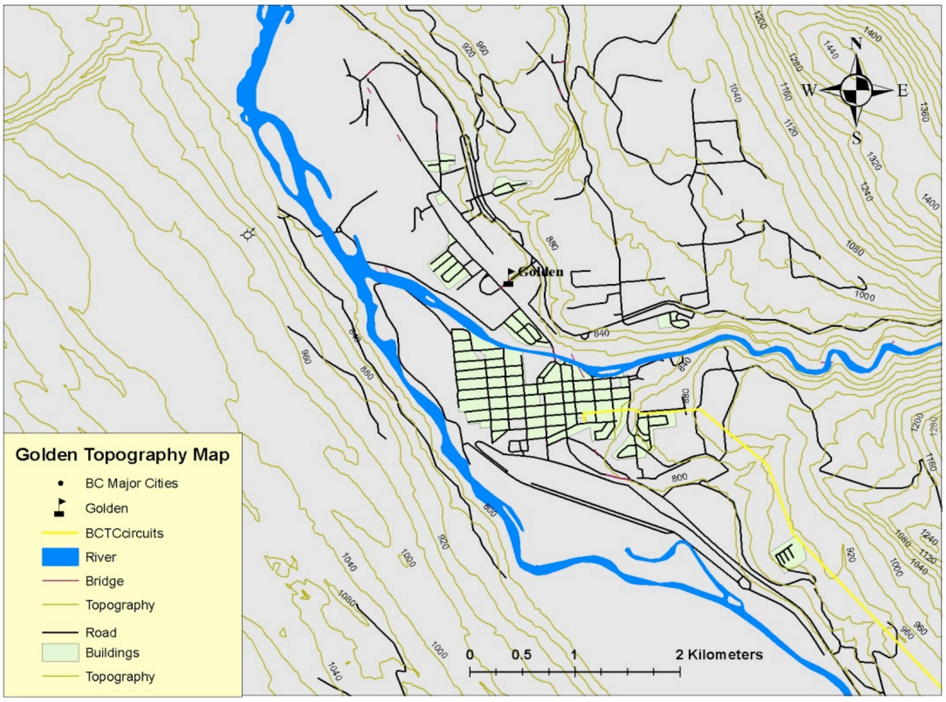

Fig. 2. Town of Golden: topography, roads, rivers and power line

A typical home (not using wood) in Golden spends about $3000/year on heating (based on inquiries from local home owners and the Municipality in August 2010). Due to both economical and environmental reasons, the City has been recently trying to investigate the viability of its renewable energy resources such as hydro and geothermal. While hydro and high-grade geothermal resources can potentially respond to the power demand, the medium-grade and low-grade geothermal resources can contribute to the much-needed heat energy.
Present price of propane in Golden is 53 cents per liter (including taxes) delivered to customers. Considering its heat value of 6100 kcal/l, the cost of propane energy amounts to $21 per GJ (Giga Joule), which is three times the price of natural gas (almost equal to the cost of electricity, when used for heating). Because of the high price of propane, this fuel is mostly used for cooking. Other cheaper fuels such as wood have been traditionally used in Golden for heating. The present price of heating oil (oil #2) is similar to propane per unit of energy delivery (at about 90 cents per liter and heat value of 9300 kcal/l).
Considering the weather temperature statistics (Table 1, Fig. 1), the heating energy demand of the City is estimated at about 150 GJ per year for an average home. In that environment close to 40 GJ a year is needed to heat a 40-gallon hot water tank for a family of three to four. About 10 to 15 GJ would be needed for household applications such as laundry, etc, and the rest will be needed for space heating.

2. Applications and discussions

2.1. Geothermal heating options for Golden

The Town of Golden, being in the valley between two rivers (Fig. 2 and Fig. 3), is blessed with secure groundwater at a relatively shallow depth (at less or around 100m below ground). The existing water wells in town are all very productive. Assuming that each well could produce at least 50 to 100 gallons per minute (GPM), each geothermal resource centre can potentially produce 150 to 300 GPM of ground water, which can be sufficient for producing up to 200 to 400 kW of heat (at 45°C to 50°C) steadily. Such a system can supply heat to 40 to 50 dwellings (with a total population of 150 to 200 people). Including a geothermal surge tank in the system, to store the well water for peak demand (Fig. 4) the same resource can provide heat for up to 60 to 70 dwellings (with a total annual heat delivery capacity of about 10000 GJ).
The downtown Golden (Fig. 3) can be divided into several geothermal "heating blocks" and a separate system can be developed for each "block". These separate systems can be managed by the same geothermal utility administration.

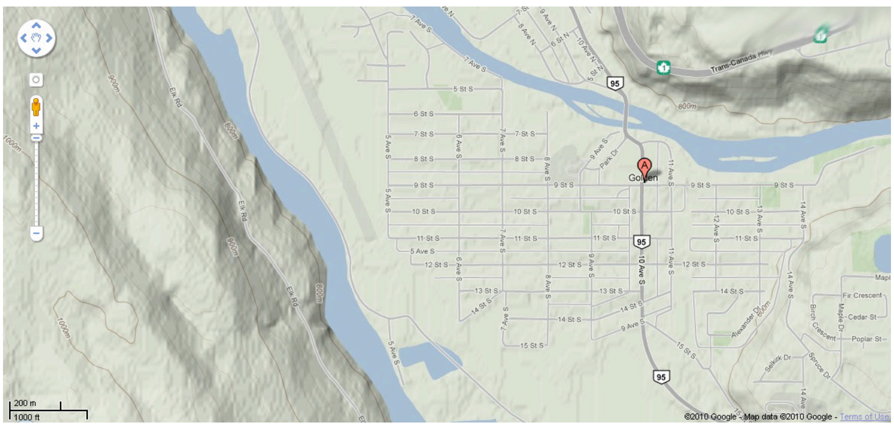

Fig. 3. Downtown of Golden (south of the Kicking Horse River) is flat and contains abundant groundwater for open loop geothermal. The core of downtown can be divided in several smaller geothermal heating blocks each using a semi-distributed open loop.

Cost of a semi-distributed open loop system is estimated at about $725,000 for 60 homes (Table 2). The total geothermal heat energy delivery of such a system can be as high as 10000 GJ/year (assuming a maximum draw on the heat resource and using an appropriately sized serge tank and expanding the market to take full advantage of the developed resource capacity).

The annual heating demand of the Downtown Golden is estimated at 100,000 to 150,000 GJ. While the entire town can be heated by geothermal energy, an incremental development (starting with a less ambitious objective of delivering 10,000 GJ of geothermal heat per year) is practical and recommendable as the first step. We have used the value of 10,000 GJ (as a self-contained system) to calculate the savings on fuel costs and carbon emissions (Tables 3 and 4). A total of 10 to 15 of such systems can provide heat to the entire town.

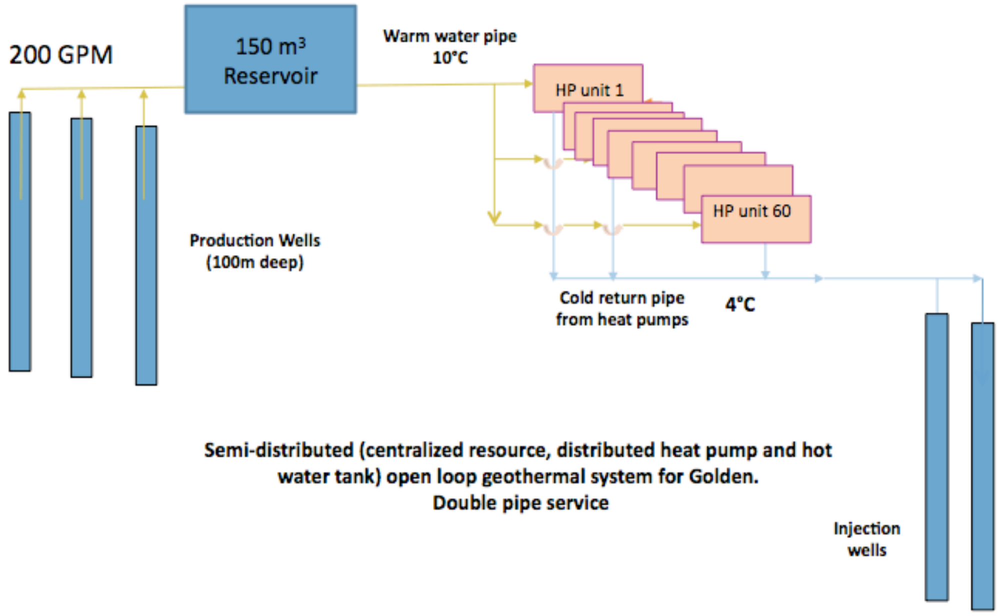

Fig. 4. Conceptual design of a semi-distributed open-loop system for Golden, with centralized resource and distributed heat pumps.

Table 2. Capital costs for a single semi-distributed open loop system for Golden

Cost Estimate (Golden), 250 kW for 50 to 70 residences	
Entier system (resource and distribution)	$
Piping (servicing 60 residences)	70000
Pumps (for production wells)	8000
Hot watert tank upgrade (for 60 residence	60000
Wells (5 wells to a maximum depth of 100	100000
Electrical system	10000
Piping improvement (inside residences)	50000
Control Equipment	15000
Insulation	15000
Installation	50000
Upgrades and interface with existing heating system	60000
Heat Pumps (for 60 residences)	120,000
Design and Engineering	70000
Contingency 15%	97968
Total	**725968**

Comparative fuel costs are given in Table 3. The fuels alternative to geothermal would be heating oil and propane (wood being banned for new developments). The operating costs (including electricity costs for heat pumps) and savings (on fuel costs) and carbon credits are calculated on the basis of 10,000 GJ, as a start-up system (Table 4). Similar systems can be added for future expansion.

Table 3. Comparison of conventional fuel costs (propane and oil for Golden)

Fuel name	(lbs/MMBtu)	(g/MJ)
Natural gas	**117**	**50.3**
Propane	**139**	**59.76**
Liquefied petroleum gas	139	59.76
Aviation gasoline	153	65.78
Automobile gasoline	156	67.07
Kerosene	159	68.36
Fuel oil	**161**	**69.22**
Tires/tire derived fuel	189	81.26
Wood and wood waste	195	83.83
Coal (bituminous)	205	88.13
Coal (subbituminous)	213	91.57
Coal (lignite)	215	92.43
Petroleum coke	225	96.73
Coal (anthracite)	227	97.59

Table 4. fuel costs for different energy options compared with geothermal. Two geothermal options are considered (100% geothermal and 70% geothermal). Also is given the operating cost of 100% electricity for heating (which is about 20% less than heating oil but significantly higher than geothermal).

Operating costs and carbon savings/credits for Golden (for a typical 10000 GJ/y district heating project)

	mix	Electricity	Geothermal	Demand	NG	Electricy	Cost	saving	GHG	GHG sv	GHG crd	Total sv
Fuel Mix	%	%	%	GJ/Y	$/GJ	$/KWh	$/y	$	ton/y			
NG *	100	0	0	10000	6	0.075	73171	0	398	0	0	0
electricity	100	100	0	10000	6	0.075	208500	-135329	0	398	7950	-127379
geotehrmal	100	25	75	10000	6	0.075	52125	21046	0	398	7950	28996
geo** + NG	100		**70**	10000	6	0.075	58439	14732	119	278	5565	20297
NG efficincty		75%		* NG is not used in Golden. The table provides a Canadian baseline reference								
GHG credit		$20/ton		** the 70% geothermal includes the 25% electricity required for heat pumps								

Operating costs and carbon savings for Golden (for a 10000 GJ/y project)

	mix	Electricity	Geothermal	Demand	Prop*	Electricy	Cost	saving	GHG	GHG sv	GHG crd	Total sv
Fuel Mix	%	%	%	GJ/Y	$/GJ	$/KWh	$/y	$	ton/y			
propane *	100	0	0	10000	20	0.075	243902	0	555	0	0	0
electricity	100	100	0	10000	20	0.075	208500	35402	0	555	11100	46502
geotehrmal	100	25	75	10000	20	0.075	52125	191777	0	555	11100	202877
geo** + NG	100		**70**	10000	20	0.075	109658	134244	167	389	7770	142014
Propane efficincty		75%		* propane is a common fuel in Goldn, used in this table as baseline								
GHG credit		$20/ton		** the 70% geothermal includes the 25% electricity required for heat pumps								

Operating costs and carbon savings for Golden (for a 10000 GJ/y project)

	mix	Electricity	Geothermal	Demand	Oil#2*	Electricy	Cost	saving	GHG	GHG sv	GHG crd	Total sv
Fuel Mix	%	%	%	GJ/Y	$/GJ	$/KWh	$/y	$	ton/y			
oil #2 *	100	0	0	10000	22	0.075	268293	0	424	0	0	0
electricity	100	100	0	10000	22	0.075	208500	59793	0	424	8480	68273
geotehrmal	100	25	75	10000	22	0.075	52125	216168	0	424	8480	224648
geo** + NG	100		**70**	10000	22	0.075	116975	151317	127	297	5936	157253
Oil #2 efficincty		80%		* Oil #2 is a common fuel in Golden, used in this table as baseline								
GHG credit		$20/ton		** the 70% geothermal includes the 25% electricity required for heat pumps								

Carbon credits are calculated on the basis of \$20 per ton (as estimated for the time of the completion of the project). For 10,000 GJ per year, the total savings amount to \$150,000 per year. If the system services 60 residences, each residence will save \$2500 per year (which means that the capital investment will be paid back in 5 years). The risk for such an investment is minimal to non-existent, as the resource is secure and the technology is off-the-shelf.

Such a semi-distributed system can be developed incrementally starting with a demonstration system at the city hall, providing heat to its own building and other close-by commercial and residential facilities. The second system can be developed at the near-by sky resource village (Kicking Horse Mountain Resource).

2.2. Open loop Geothermal (OLG) for Golden's Municipal Building

As opposed to closed loop, an open loop geothermal system for the Municipal Centre is possible with minimum disturbance to the land and the city activities. A semi-distributed system (as described above) with 2 to 3 production wells can provide heat for the municipal centre and buildings around it. Alternatively, a small system (consisting of one production well and one injection well) can be developed to provide heat only for the city center. In both alternatives, ground water will be brought to surface, passed through heat pumps and re-injected to the ground.

In summer, heat pumps can dump heat into the ground (providing cooling, if needed) and in winter heat is extracted from the groundwater. All produced waters are recommended to be re-injected to the ground at an appropriate distance from the production wells. The heat pump and water pumps are expected to require 1 KW of electricity for every 4 KW of heat delivered (in the heating mode). An Intelligent control/communication system based on fuzzy logic is needed to maximize the output energy with lowest operating costs [2].

Water wells have a very low footprint and therefore involve no significant disturbance to the land or buildings. Drilling can be carried out in a short period (4 weeks including drilling, completion and testing) in the park area of the Centre (causing no significant disturbance to the Municipality activities). Installation of heat pumps and the interface with the existing heating system is better to be carried out during the summer to avoid any interruption in the heat delivery to the building. The installation can be carried out also during the cold season, with minimum disturbance to the heating regime, if installation and interfacing with the existing system is carried out during weekends.

Heat pumps will replace 90% of the heating capacity and will be located at the boiler room to allow easy interface with the exiting HVAC system. The installed OLG will save up to 100 percent of the conventional fossil fuel helping with significant reduction in the city's carbon footprint.

In order to size properly and design a cost-effective OLG for the Municipality Centre in downtown Golden, the existing system at the Centre needs to be inspected and its efficiency and operating costs evaluated. The main preliminary data items required are:

a- Existing heating system (type, capacity efficiency, fuel, number of units, etc) and costs.
b- Existing cooling system (type, capacity , efficiency, units, number of units, etc) and costs.
c- Total occupied space (in square meter) and total occupancy

It is highly recommended that the OLG resource of the Municipality be sized and designed to service not only the municipal facility but also the surrounding buildings to provide a showcase for future developments (i.e. the first 10,000 GJ/y system as described for downtown). Such an OPG system will also demonstrate the applicability of geothermal for large-scale facilities in similar urban environments in Canada (making the project a viable candidate for ICE funds).

2.3. Management

A public private partnership (3P) can act as geothermal utility to install the systems and provide geothermal heat to buildings. Considering that GHP needs electricity (1kW for each 4 kW of heat), the demand for electricity will obviously rise, especially in winter. It is therefore important that the city make proper arrangements with the Hydro-electricity company of the province of British Columbia to supply the predicted required electricity. One way to do that is to encourage BC hydro to buy green power (e.g. micro-hydro) from local independent power producers (IPP).
Canadian hydro and power authorities encourage such integrated green developments projects and provide incentives [3,4].

3. Conclusion

Open loop geothermal resources for district heating are available in the downtown area of Golden. Semi-distributed systems (consisting of several medium-scale resource developments for different sections of the town) can provide heat to the entire downtown area. Installation of such systems can lead to more than 60% savings in energy costs and 90% to 100% reduction in carbon emissions.
An open loop resource development (with geothermal surge tank and re-injection) is environmentally safe and does not have any negative impact on the ground water system. District heating using closed loop is not recommended due to high capital costs and possibility of leakage of antifreeze liquids into the ground water system.
Capital cost for a geothermal district heating system producing 10,000 GJ/y (for 60 homes) is estimated at $725,000. The first system is recommended to be developed in and around the Municipal Centre as a demonstration project. The cost of this system will be paid back in 5 to 6 years. A second demonstration system can be developed in the resort area (Kicking Horse Mountain Resort) to provide heat to the village. The recommended semi-distributed system allows gradual development and system management through a private public partnership.

Acknowledgment

Nastarn Arianpoo (PhD. Student at UBC) kindly helped with map preparation in GIS. This study also greatly benefited from discussions with Christina Benty, the Mayor of Golden, and members of the Golden Area Initiative, especially Ron Oszust and Laura Archer and James Knoop from Council of Canadians in Golden..

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