Current Status of Direct Utilization of Geothermal Energy in Canada

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Ground Source Heat Pumps  Hot Springs

Conclusions
- Installed capacity 1,458 MWe
- Energy used 11,386 TJ/yr
- 0.4% of energy consumed in the residential and commercial sector
- 12th World rank for direct use
- Publications 975 / 7th World rank

Data available in Raymond et al. 2015
World Geothermal Congress
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Ground Source Heat Pumps
Hot Springs
Ground Source Heat Pumps

Hot Springs
- 9,984,670 km²
- Population 35.8 M (Stat Can, 2015)
- GDP 1.99 G$ (Stat Can, 2015)
- Energy 11,407 PJ/yr Total / 26 % in the residential and commercial sectors (Nat Ener Board, 2016)
Ground Source Heat Pumps

2006 to 2008: growth rate 40%/yr
2009: peak installation 15,913 units
  - Increase in oil and gas prices
  - Financial incentives from governments

2010 to 2012: downturn
  - Financial crisis
  - Decrease in oil and gas prices
  - End of many government incentives

2013: Back to growth?

Geothermal heat pump units installed in Canada from 1990 to 2013 (Tanguay, 2014)
Ground Source Heat Pumps

Geothermal system type
- Surface water 6.4%
- Ground water 13.0%
- Vertical closed loop 24.2%
- Horizontal closed loop 56.4%

Energy replaced
- Wood 1.4%
- Wood pellets 0.6%
- Electricity 39.1%
- Fuel oil and wood 2.0%
- Fuel oil and electricity 0.6%
- Natural gas 7.2%
- Propane 10.1%

Distribution of geothermal heat pump systems certified by the Canadian GeoExchange Coalition (CGC)

Ground Source Heat Pumps
Installed capacity and energy used...
# Ground Source Heat Pumps

## Installed capacity and energy used

<table>
<thead>
<tr>
<th>Year</th>
<th>Units installed</th>
<th>Replacements (%)</th>
<th>New installations</th>
<th>Cumulative new installations</th>
<th>Total capacity (MW)</th>
<th>Energy use*** (TJ yr⁻¹)</th>
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</thead>
<tbody>
<tr>
<td>1990</td>
<td>450 (90%)</td>
<td>2</td>
<td>441</td>
<td>6</td>
<td>46</td>
<td>3.5 COP 3,000 hr/yr</td>
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<tr>
<td>1991</td>
<td>491</td>
<td>2</td>
<td>931</td>
<td>19 (14 kW)</td>
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<td>5</td>
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<td>5</td>
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<td>8,809</td>
<td>5</td>
<td>41,221</td>
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<td>8</td>
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<td>2009</td>
<td>14,038</td>
<td>12</td>
<td>68,963</td>
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<td>7,400</td>
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<tr>
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<td>7</td>
<td>79,451</td>
<td>1,112</td>
<td>8,527</td>
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<tr>
<td>2011</td>
<td>8,825</td>
<td>7</td>
<td>88,276</td>
<td>1,236</td>
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<td>2012</td>
<td>7,410</td>
<td>7</td>
<td>95,686</td>
<td>1,340</td>
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<td>5</td>
<td>103,523</td>
<td>1,449</td>
<td>11,111</td>
<td></td>
</tr>
</tbody>
</table>

*Assuming 50% of systems installed 17 years before were replaced in 2006 and after, ** Average system capacity was estimated to 14 kW, *** Average coefficient of performance and heating hours at full load were assumed to 3.5 and 3,000 hr yr⁻¹**
Hot Springs

1880's: Commercial exploitation of the hot springs began after First Nations
1841: George Simpson (Hudson's Bay Company) visited Radium Hot Spring

Construction of bathhouses and hotels
1886 - Banff
1913 - Miette
1914 - Radium

Location of the commercially exploited hot springs (red) and thermal water (blue) in Canada

©A Durno (Miette)
# Hot Springs

**Commerci ally exploited**

<table>
<thead>
<tr>
<th>Name</th>
<th>Province</th>
<th>Flow rate (L/s)</th>
<th>Springs temperature (°C)</th>
<th>Pool outlet temperature (°C)</th>
<th>Capacity (kW)</th>
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</thead>
<tbody>
<tr>
<td>Banff Upper</td>
<td>AB</td>
<td>14.9</td>
<td>47</td>
<td>38</td>
<td>563</td>
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<tr>
<td><strong>Miette</strong></td>
<td>AB</td>
<td>15.3</td>
<td>54</td>
<td>37</td>
<td><strong>1092</strong></td>
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<td>Ainsworth</td>
<td>BC</td>
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<td>47</td>
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<td>Fairmont</td>
<td>BC</td>
<td>20.9</td>
<td>46</td>
<td>44</td>
<td>176</td>
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<tr>
<td>Halycon</td>
<td>BC</td>
<td>3.5</td>
<td>54</td>
<td>32</td>
<td>323</td>
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<td><strong>Harrison</strong></td>
<td>BC</td>
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<td>40</td>
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<td><strong>Liard</strong></td>
<td>BC</td>
<td>30.0</td>
<td>52</td>
<td>30*</td>
<td><strong>2,772</strong></td>
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<td>Nakusp</td>
<td>BC</td>
<td>1.2</td>
<td>57</td>
<td>30</td>
<td>136</td>
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<tr>
<td>Mount Layton (Lakelse)</td>
<td>BC</td>
<td>9.9</td>
<td>41</td>
<td>30</td>
<td>457</td>
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<tr>
<td><strong>Radium</strong></td>
<td>BC</td>
<td>28</td>
<td>40</td>
<td>32</td>
<td><strong>941</strong></td>
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<td>Skookumchuck (St. Agnes)</td>
<td>BC</td>
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<td>35</td>
<td>30</td>
<td>67</td>
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<tr>
<td>Takhini</td>
<td>YT</td>
<td>5.7</td>
<td>40</td>
<td>35</td>
<td>120</td>
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<tr>
<td>Temple Gardens Mineral Spa</td>
<td>SK</td>
<td>5.7</td>
<td>46</td>
<td>30</td>
<td>383</td>
</tr>
</tbody>
</table>

| Abbreviations: AB, Alberta; BC, British Columbia; SK, Saskatchewan; YT, Yukon. *Assumed temperature as water flows in swamps. |

\[
\text{Capacity (kW)} = \times \left( \text{Flow rate (L/s)} \times \left( \text{Springs temperature (°C)} - \text{Pool outlet temperature (°C)} \right) \right)
\]

**Total capacity (kW):**

\[
8,780
\]

**Energy use (TJ yr⁻¹):**

\[
277
\]

**All year 24/7**
Research Contributions

Scopus search with “geothermal” in title abstract or keywords from 1990 to 2015: 23,143 scientific publications

Author affiliations
1- United States (6,033)
2 - China (2,469)
3 - Germany (1,586)
7 - Canada (975)

2004 to 2014:
Average growth of 12 %/yr

Publications with “geothermal” in title, abstract or keywords having one or more Canadian affiliations
Research Contributions - High Impact
Ground source heat pumps - Hot Springs

Lamarche, Beauchamp, 2007; 145 citations
• A new contribution to the finite line-source model for geothermal boreholes

Lamarche, Kajl, Beauchamp, 2007; 127 citations
• A review of methods to evaluate borehole thermal resistances in geothermal heat-pump systems

Grasby, Hutcheon, Krouse 2000; 44 citations
• The influence of water-rock interaction on the chemistry of thermal springs in western Canada

Research Contributions - INRS
Ground source heat pumps
Research Contributions - INRS

Ground source heat pumps

Objective: better understand heat transfer mechanisms in complex geological environments to improve system efficiency

Activities orientation:

- Characterization of favorable geological environments to host geothermal systems
  - Flooded mines - open loop
  - Urban districts - closed loop

- Improvement of design and operation methods

- Development of new technology

Goal: decrease installation cost
Characterization of Favorable Geological Environments
The St. Lawrence Lowlands Basin

- 20 000 km² in Québec
- Undeformed Cambro-Ordovician platform
Thermostratigraphic Assessment

- 45 outcrop samples
- Needle probe method

- >4 W/mK
  Potsdam Group and Theresa Formation

- 3 - 4 W/mK
  Beauharnois Formation, Queenston and Lorraine groups

- <3 W/mK
  Trenton, Black River, Chazy, Utica and Sainte-Rosalie groups
GeoExchange Potential and Borehole Length

- Sizing calculations for a residential system based on each sample
  - < 130 m: Potsdam Group and Theresa Formation
  - 130 to 160 m: Beauharnois Formation, Queenston and Lorraine groups
  - > 160 m: Trenton, Black River, Chazy, Utica and Sainte-Rosalie groups
Urban District Scale Assessment to the North of Montreal

- 4 **thermal response tests** with a heating cable
- 10 **laboratory measurements** with transient plane source
- 27 **synthetic data points** from regional **thermostratigraphy**
- Work performed for **Marmott Énergies**
Stochastic Thermal Conductivity Distribution

Sequential Gaussian simulations to interpolate values

1) Method

1) Pick non-simulated cell at random (i=6)
2) Compute kriging estimate and variance
3) Draw a random value \( x_k \) from the kriging distribution
4) Treat simulated \( x_k \) as additional control point
5) Go back to 1) until entire grid is simulated

2) Single realization

3) Mean of ten realizations

4) Variance of ten realizations
Conclusions
- Installed capacity 1,458 MWt
- Energy used 11,388 TJ/yr
- 0.4% of energy consumed in the residential and commercial sector
- 12th World rank for direct use
- Publications 975 / 7th World rank
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