State of Geothermal Research in Canada

Stephen Grasby
Geological Survey of Canada
Reducing greenhouse gas emissions

Graph showing the percentage of renewable and non-renewable energy sources, with a focus on non-emitting sources such as hydro, solar, wind, tidal, and geothermal.
Northern energy

Heat

Yukon

NWT

Nunavut

Electricity

Yukon

NWT

Nunavut

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Energy reliability

(SOURCE: Emerging Energy Research)

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Environmental footprint

- geothermal
- coal
- wind
- solar-concentrating
- solar-PV

acres/GWh from NREL, AWEA and others

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Emissions

Greenhouse gas emissions from Electricity (g CO2-eq./kWh)

Source: UK Parliament 2011

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Installation costs

National Renewable Energy Laboratory, 2012

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## Electrical use

<table>
<thead>
<tr>
<th>Country</th>
<th>GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>16,600</td>
</tr>
<tr>
<td>Philippines</td>
<td>9,646</td>
</tr>
<tr>
<td>Indonesia</td>
<td>9,600</td>
</tr>
<tr>
<td>New Zealand</td>
<td>7,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>6,071</td>
</tr>
<tr>
<td>Italy</td>
<td>5,660</td>
</tr>
<tr>
<td>Iceland</td>
<td>5,245</td>
</tr>
<tr>
<td>Turkey</td>
<td>3,247</td>
</tr>
<tr>
<td>Kenya</td>
<td>2,868</td>
</tr>
<tr>
<td>Japan</td>
<td>2,687</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td><strong>Global</strong></td>
<td><strong>73,689</strong> (Bertani, 2016)</td>
</tr>
</tbody>
</table>

*Bathing in geothermal ‘waste’*

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## Direct heat use

<table>
<thead>
<tr>
<th>Country</th>
<th>GWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>48,435</td>
</tr>
<tr>
<td>Iceland</td>
<td>7,422</td>
</tr>
<tr>
<td>Japan</td>
<td>7,259</td>
</tr>
<tr>
<td>Germany</td>
<td>5,426</td>
</tr>
<tr>
<td>Finland</td>
<td>5,000</td>
</tr>
<tr>
<td>France</td>
<td>4,408</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td><strong>3,227</strong></td>
</tr>
<tr>
<td>Hungary</td>
<td>2,852</td>
</tr>
<tr>
<td>Italy</td>
<td>2,412</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2,395</td>
</tr>
</tbody>
</table>
Geothermal barriers...

- Regulatory
- Policy
- Awareness
- Geothermal data
- Basic geoscience
Geothermal energy

• Heat is constantly generated by radioactive decay of U, Th, K in the crust and flows to surface (83%)

• Mantle cooling (17%)
Thermal blanket effect
Depth barriers
Fluid production

after Majorowicz and Grasby in review
Resource production

Steam $>180 \, ^{\circ}\text{C}$

Binary $\sim80$ to $180 \, ^{\circ}\text{C}$

Electrical Generation

Direct use

District Heating

Heat exchange

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Northern opportunities

• 87 in the territories (27 Yukon, 33 NWT, 27 Nunavut)
• 58/87 rely on diesel generators
• 801,000 MWh power demand
• Subsidized costs up to 10x national average
• $\Delta T$ advantage!
Geothermal exploration

- Heat source
- Heat trap
- Fluid
- Permeability
- Depth

Geoscience data is needed to reduce exploration risk!
Geothermal research in Canada

- NRCan (EMR) Geothermal Program 1975-85
- Motivated by energy crisis
- ~$10M over 10 years
- Defined enormous potential in Canada
- Ended when price of oil collapsed in 1985
Volcanic belts

- Canada has abundant, volcanoes
- Largely dormant since the Holocene (12,000 y.a.) or earlier
Mount Meager research well

- First geothermal power production in Canada
- Waters > 200 °C
- Fluid flow insufficient to make it economic
Hot young rocks

intrusives with high heat generation (U, Th, K)

Coryell Syenite
Sedimentary basins
Heat exchange systems

Heat exchange

Heat is collected from the building and transferred to the ground

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Abandoned mines

Springhill Nova Scotia

After use, water is returned to the No. 3 mine at about 13°C (winter) or 23°C (summer)

Ropak Can Am Ltd.

Supply well provides water to the plant at 18°C

Ground level

Approximate water level

Direction of flow

No. 3 mine

No. 2 mine 4 km to bottom

No. 1 mine

Interconnecting tunnels

Depth of well is approximately 140 m

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Emerging technologies

Enhanced Geothermal Systems (EGS)

Estimated in place heat energy at 3.5 km depth is $3.8 \times 10^{11}$ GWh

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EGS technology challenges

- Directional Drilling (5+ km)
- Fracture stimulation (>1km³)
- Microseismic monitoring and control
- Injection/production well connectivity
- Controlled water loss
- Regional stress fields
Geothermal potential of NWT
Cordillera

• Numerous thermal springs
• Localised thermal anomalies related to high heat generation of plutons
Sedimentary Basins

- >1000 wells provide temperature data
- drill stem tests (DSTs)
- Bottom Hole Temperatures (BHTs)
Beaufort Mackenzie

DSTs

25.0 °C/km
$R^2 = 0.81$

BHTs

24.8 °C/km
$R^2 = 0.87$

Hu et al. 2010
Southern NWT

- DST: 50 °C/km
- BHT: 45 °C/km

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Permafrost challenges...

From Majorowicz and Grasby 2013

From Osadetz et al. 2015

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Depth constraints

From Majorowicz and Grasby 2013

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Southern NWT

From Majorowicz and Grasby in review

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Deep aquifers
Shield

- Con Mine water?
- 130 kilometres of workings to a depth of 1,900 metres
- >35 °C at depth
Con Mine – Open Loop

- Open loop system using the mine shaft as geothermal resource.
- Proposal to heat downtown core buildings.
- Rejected in public plebiscite
More reading...

doi.org/10.4095/292840

doi.org/10.4095/291488

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Conclusions

Geothermal Energy in Canada:
• Enormous potential that is virtually untapped
• Clean source of energy
• Small environmental footprint
• Highly reliable
• Geoscience needed to move it forward
• New technology needed to reduce risk
Tungsten Thermal Spring, NWT