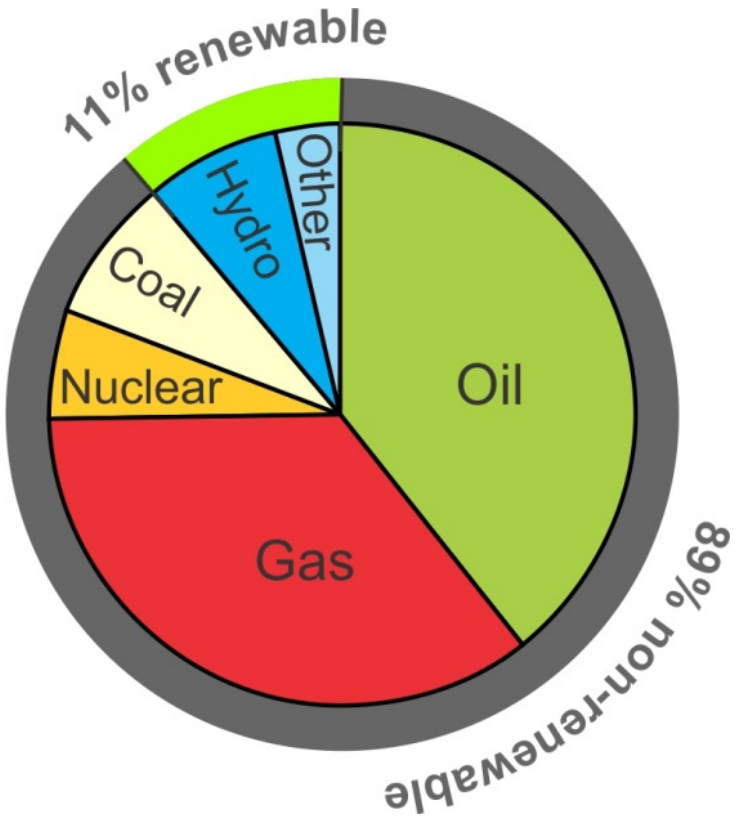
NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

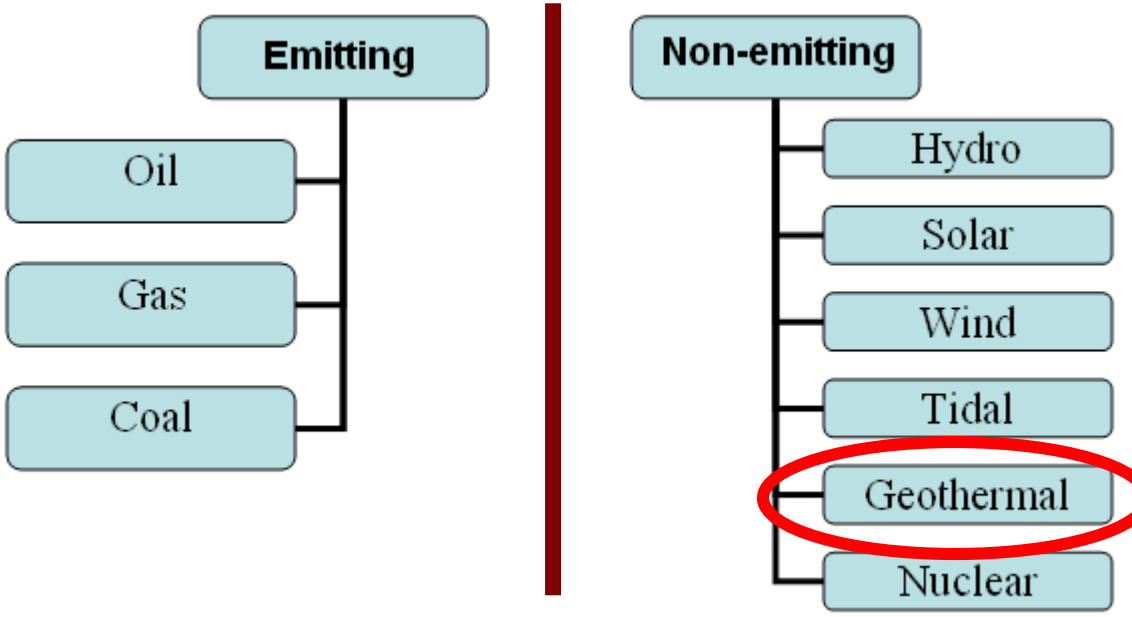
State of Geothermal Research in Canada

Stephen Grasby

Geological Survey of Canada

Reducing greenhouse gas emissions

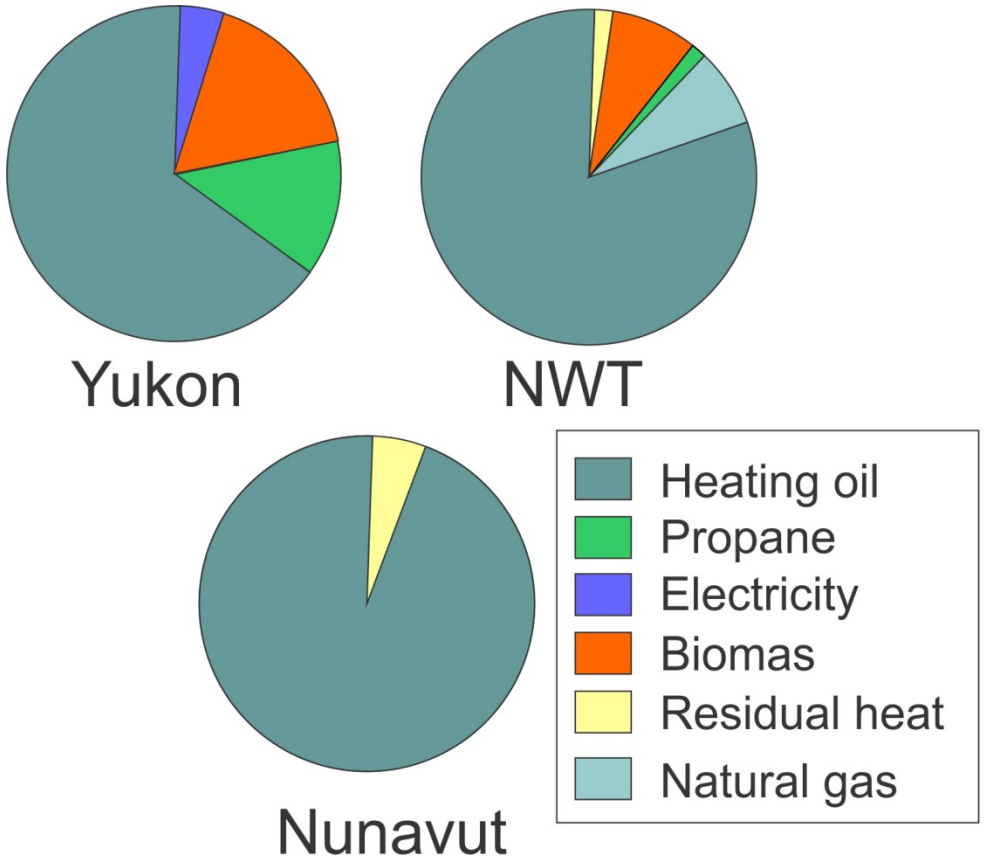




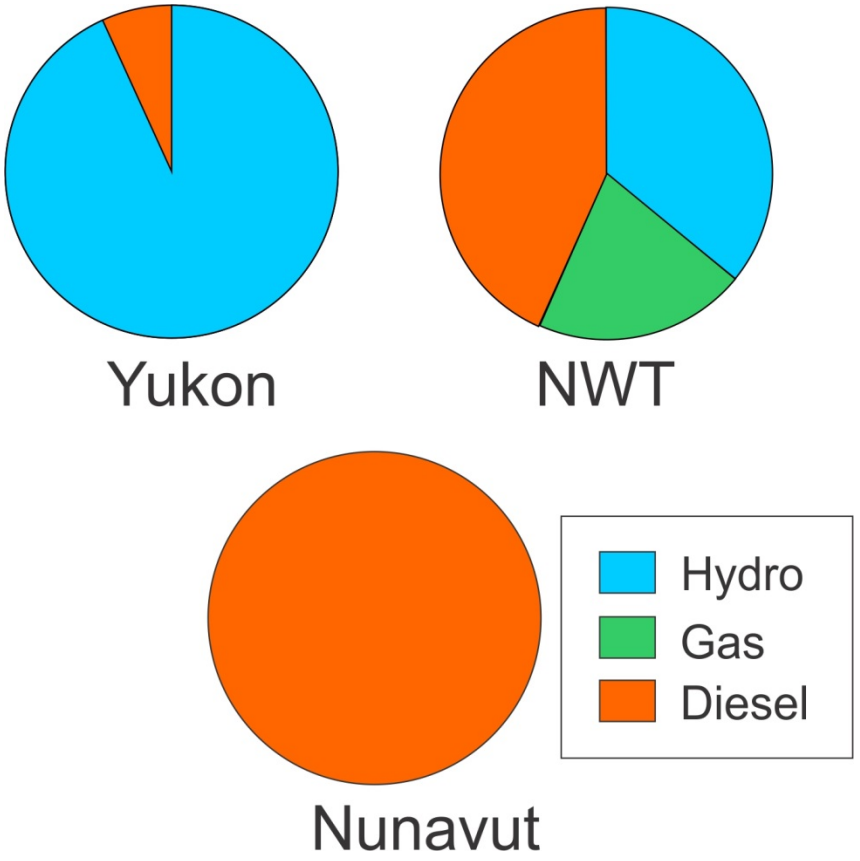
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Northern energy

Heat

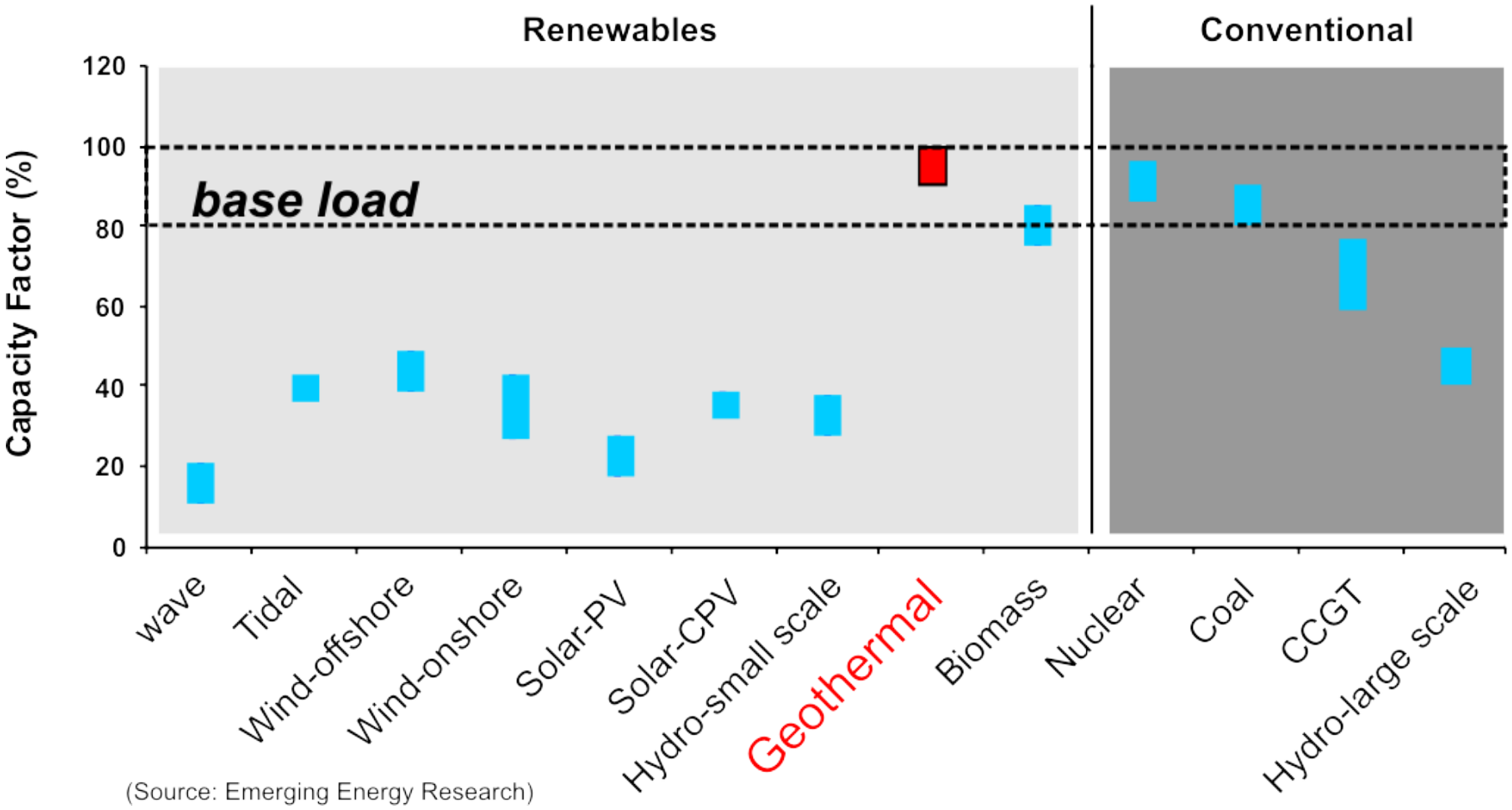


Electricity



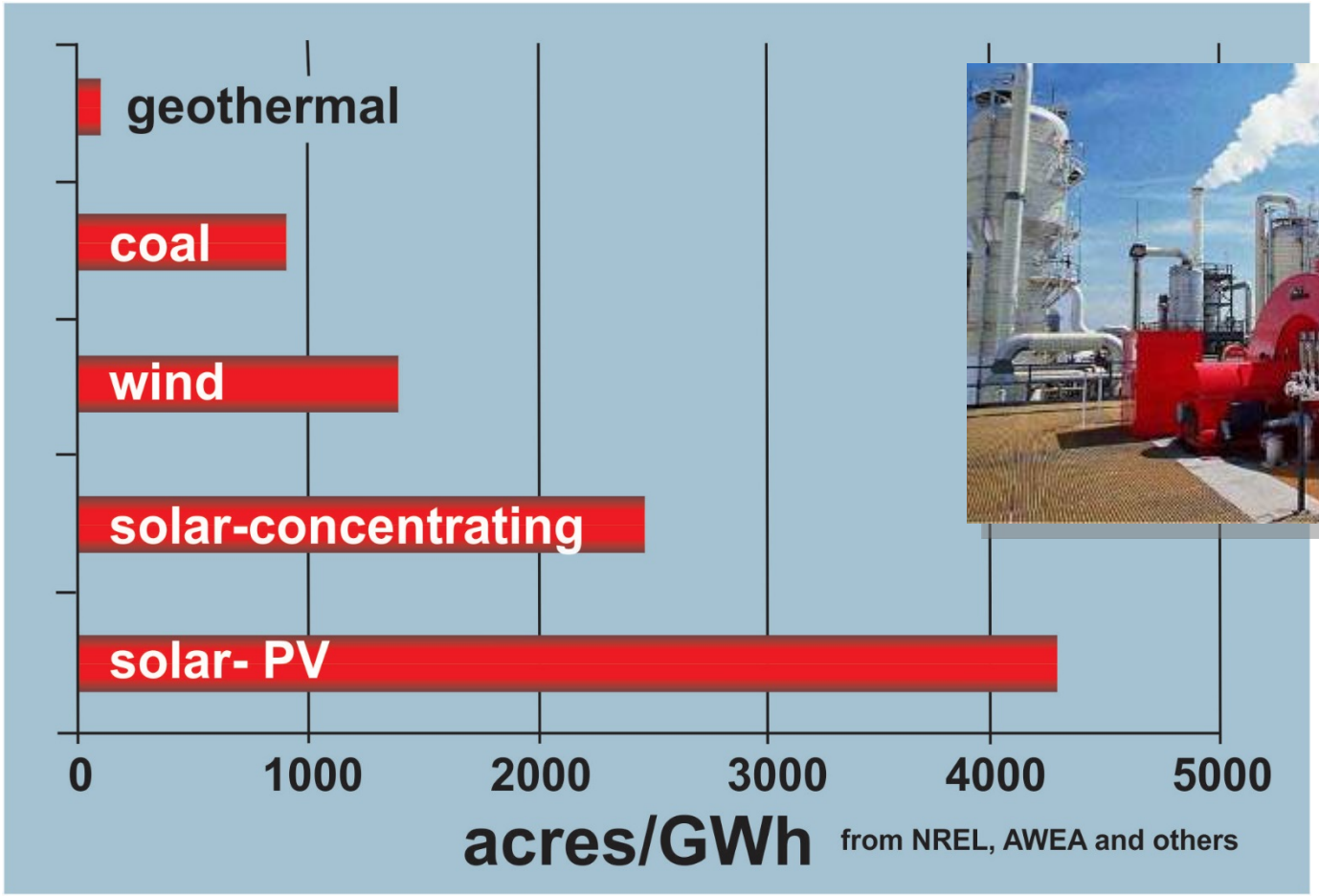
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Energy reliability



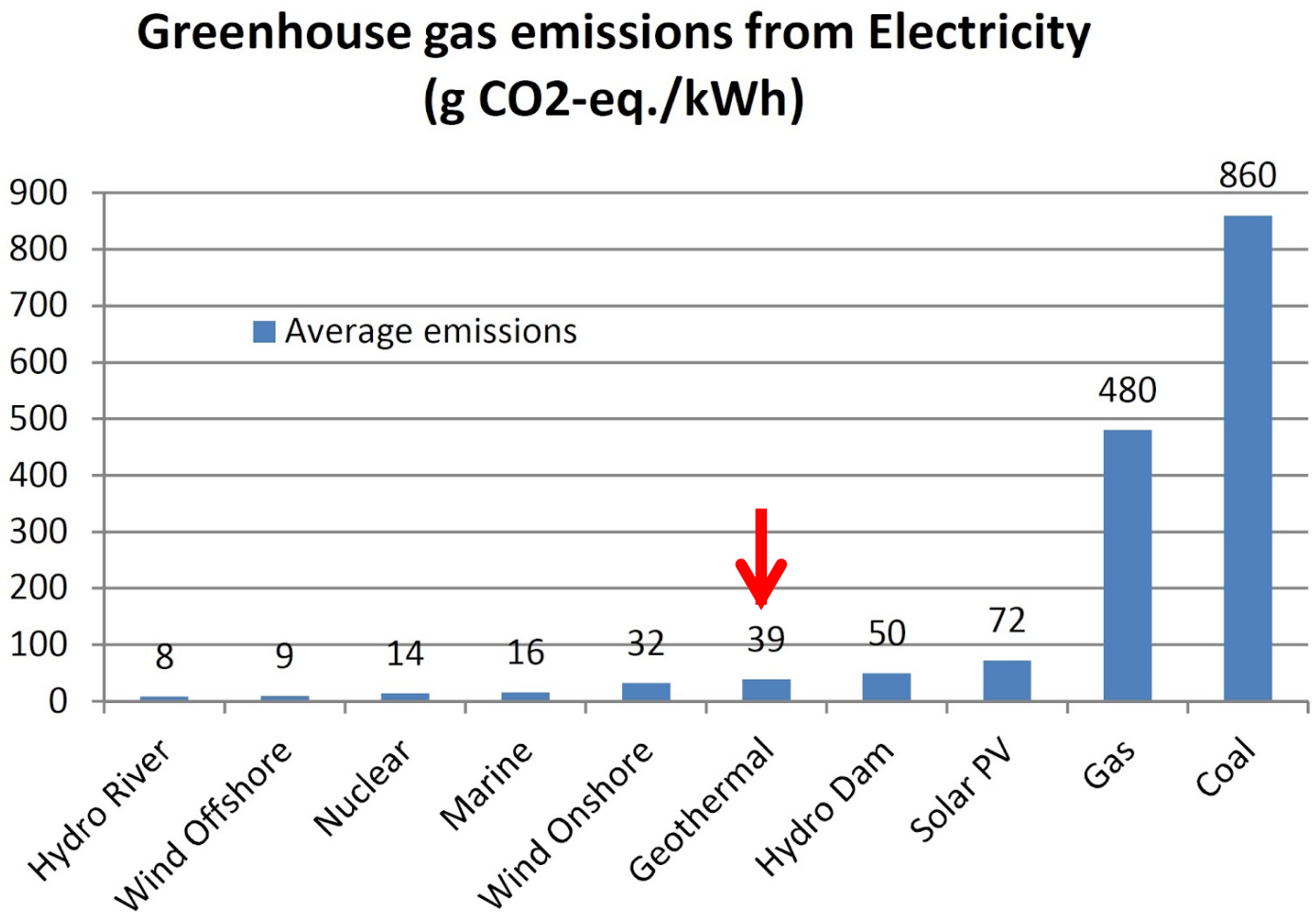
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Environmental footprint



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Emissions

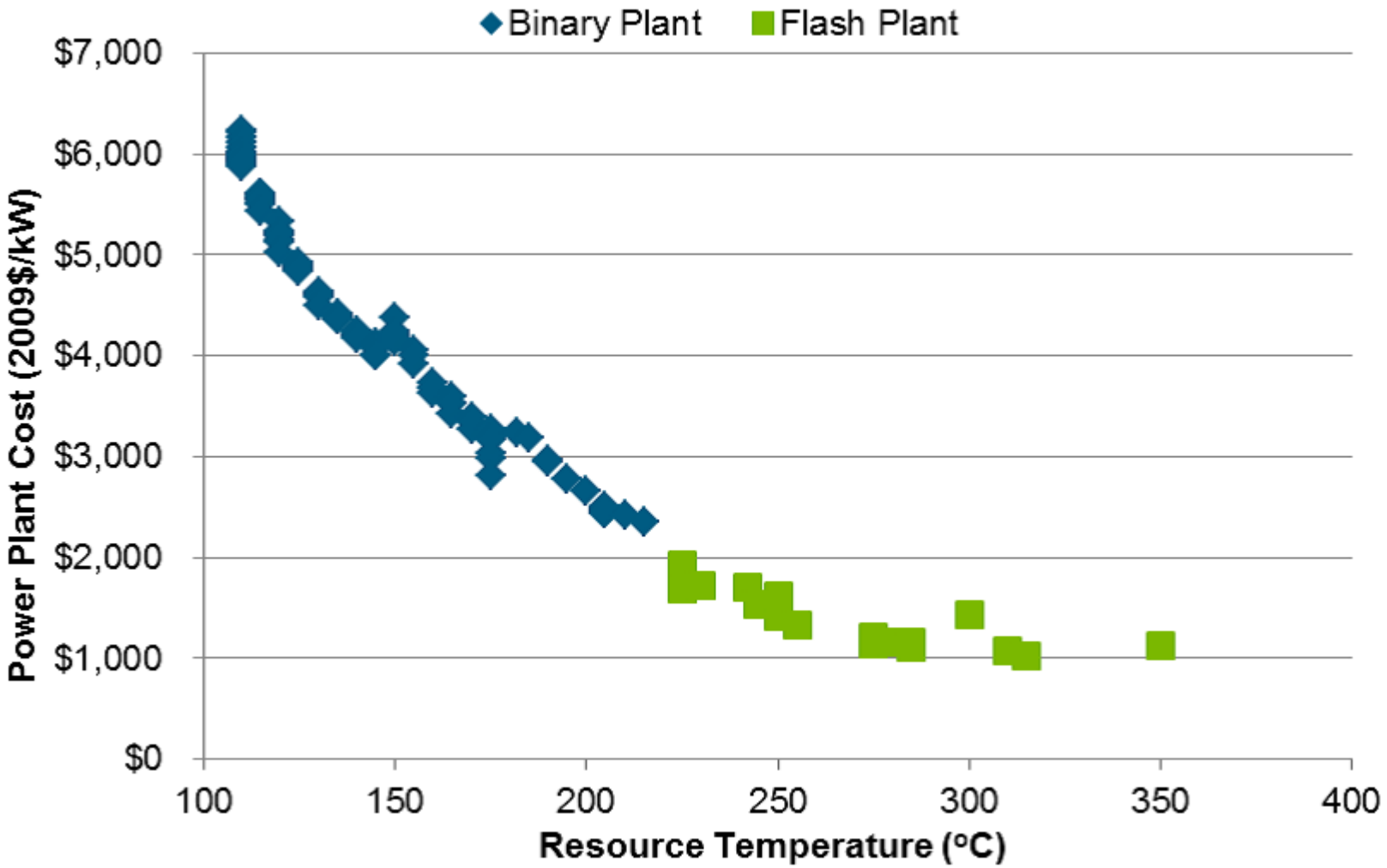


Source: UK Parliament 2011

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

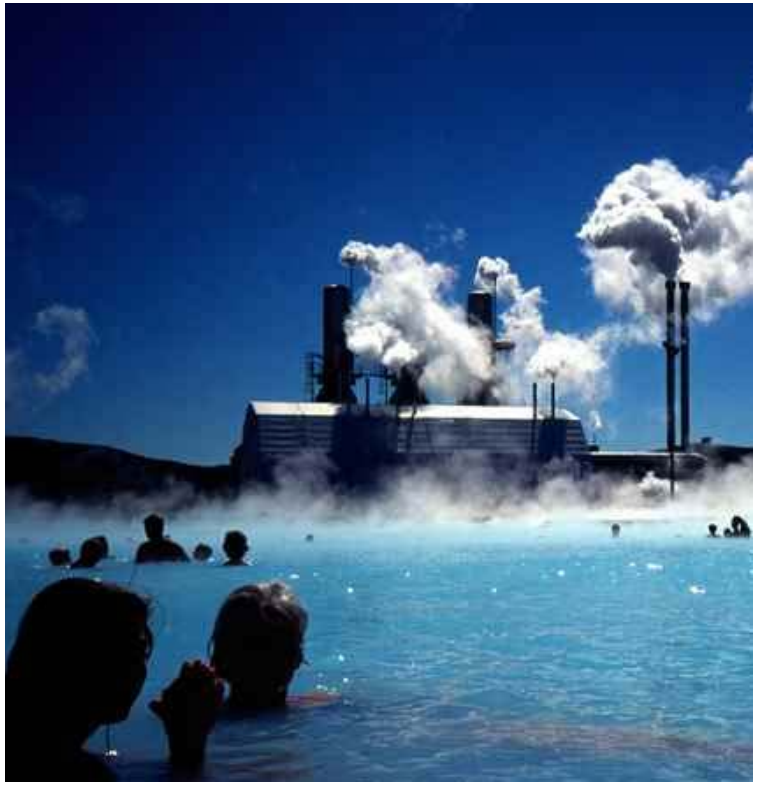
Installation costs

National Renewable Energy Laboratory, 2012



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Electrical use



Bathing in geothermal ‘waste’

	GWh
United States	16,600
Philippines	9,646
Indonesia	9,600
New Zealand	7,000
Mexico	6,071
Italy	5,660
Iceland	5,245
Turkey	3,247
Kenya	2,868
Japan	2,687
Canada	**0**
Global	73,689 (Bertani, 2016)

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Direct heat use

	GWh/yr
China	48,435
Iceland	7,422
Japan	7,259
Germany	5,426
Finland	5,000
France	4,408
Canada	**3,227**
Hungary	2,852
Italy	2,412
New Zealand	2,395

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

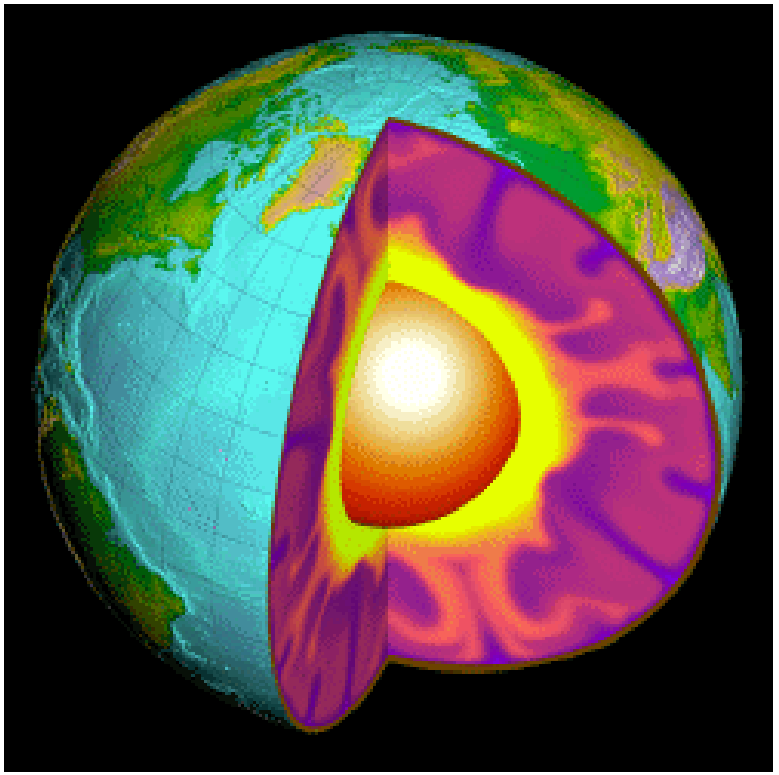
Geothermal barriers…

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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

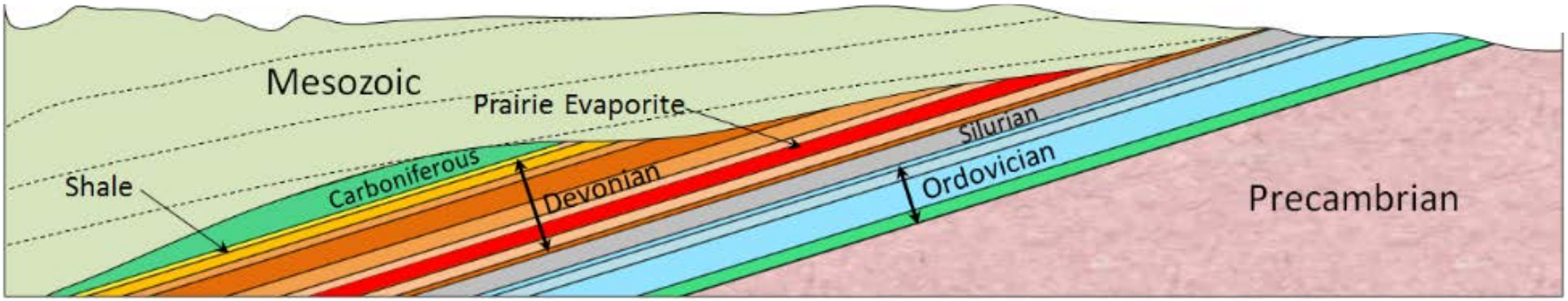
Geothermal energy

- Heat is constantly generated by radioactive decay of U, Th, K in the crust and flows to surface (83%)
- Mantle cooling (17%)



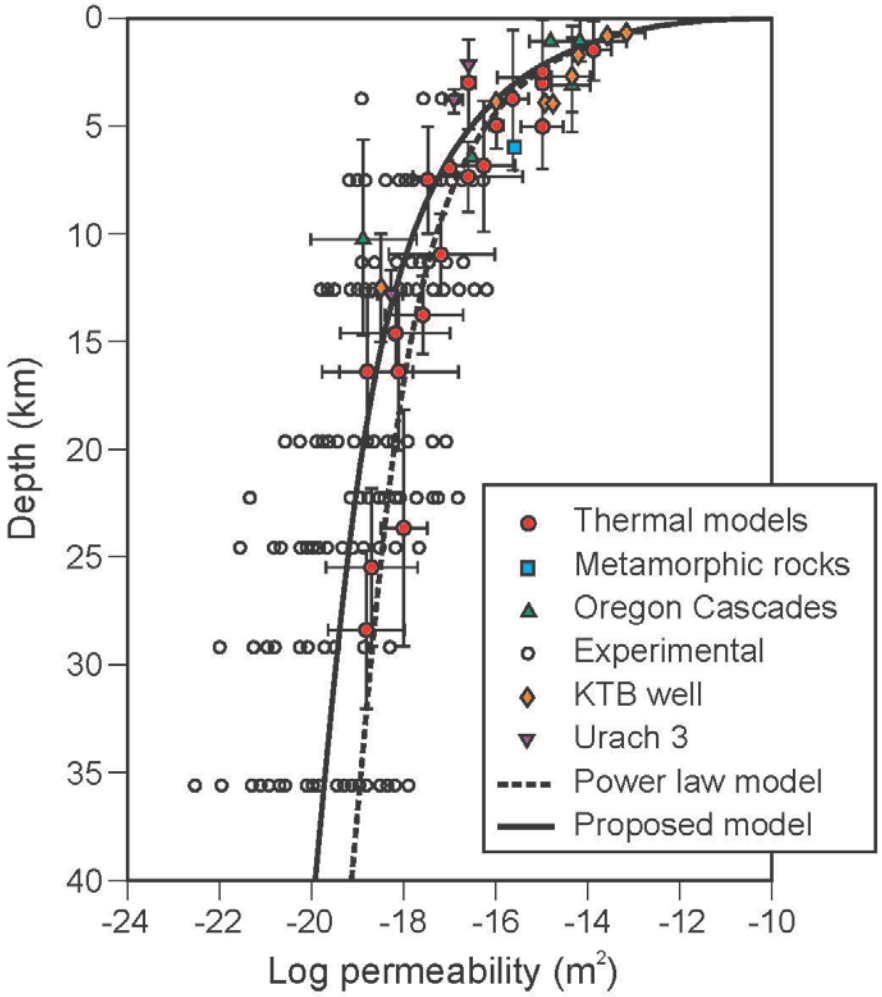
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

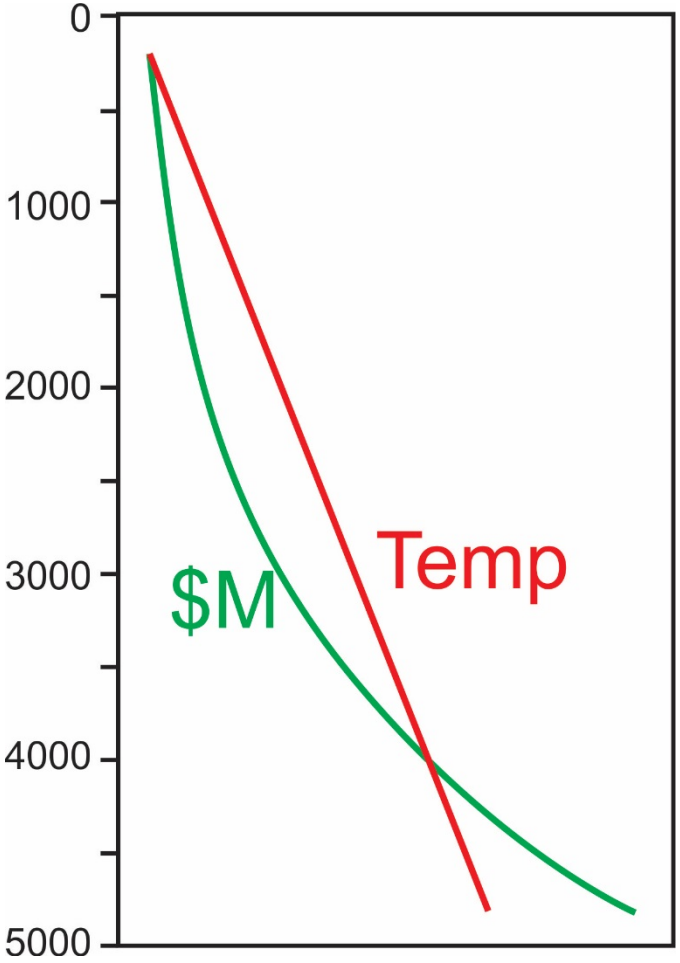
Thermal blanket effect



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

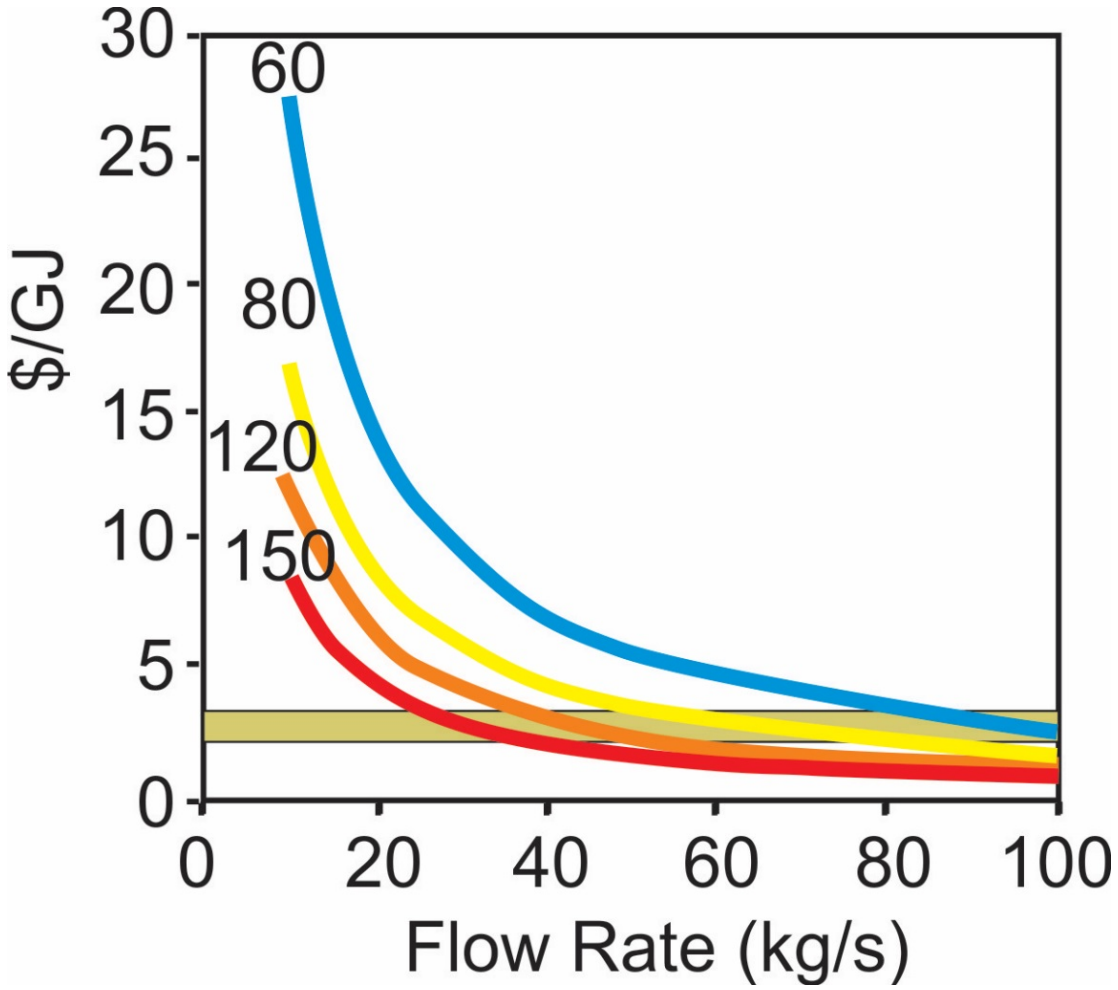
Depth barriers





© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Fluid production



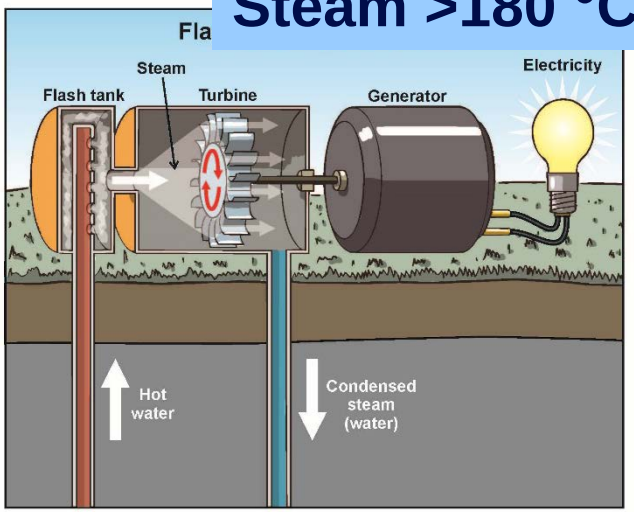
after Majorowicz and Grasby in review

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

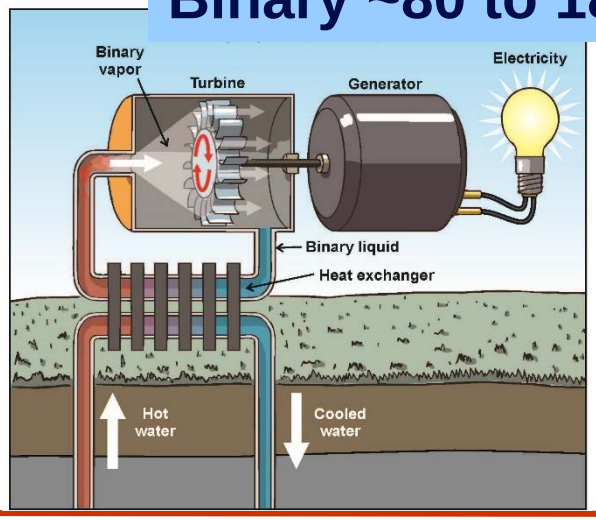
Resource production

Electrical Generation

Steam >180 °C

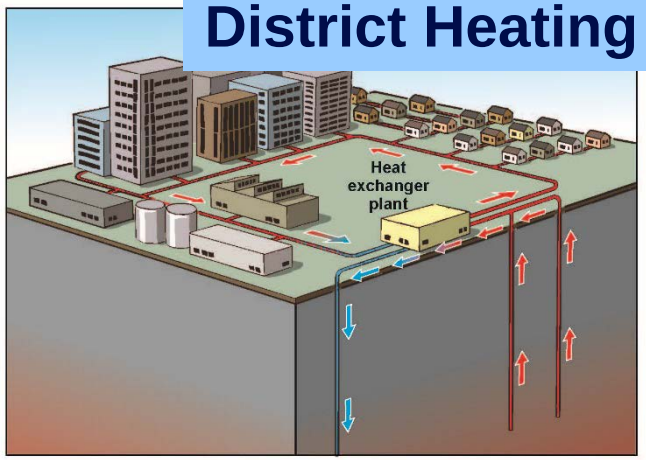


Binary ~80 to 180 °C

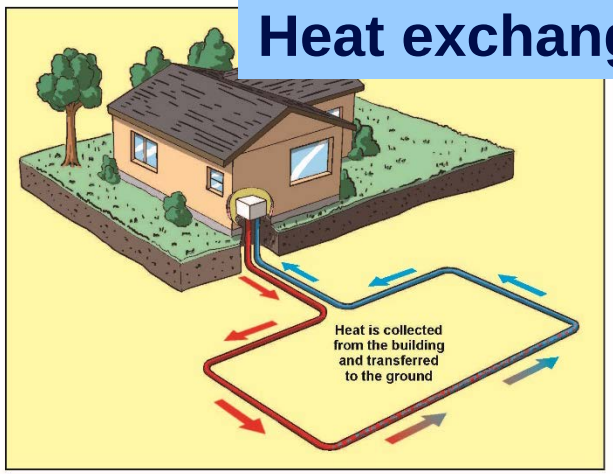


Direct use

District Heating



Heat exchange



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

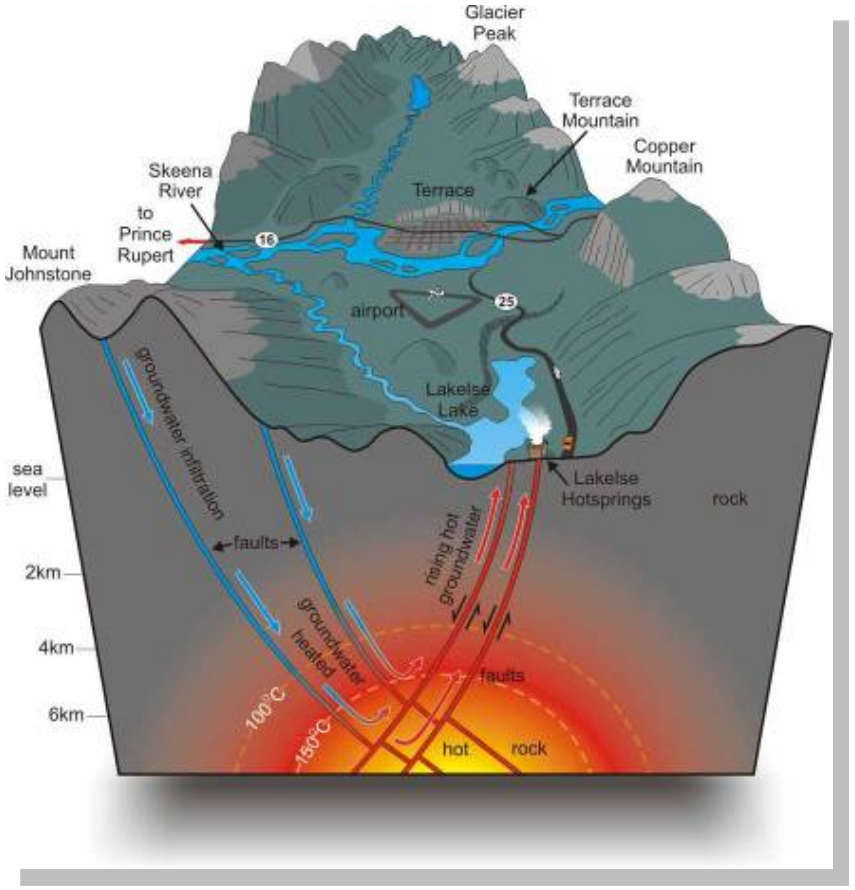
Northern opportunities

- 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
- ΔT advantage!

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Geothermal exploration

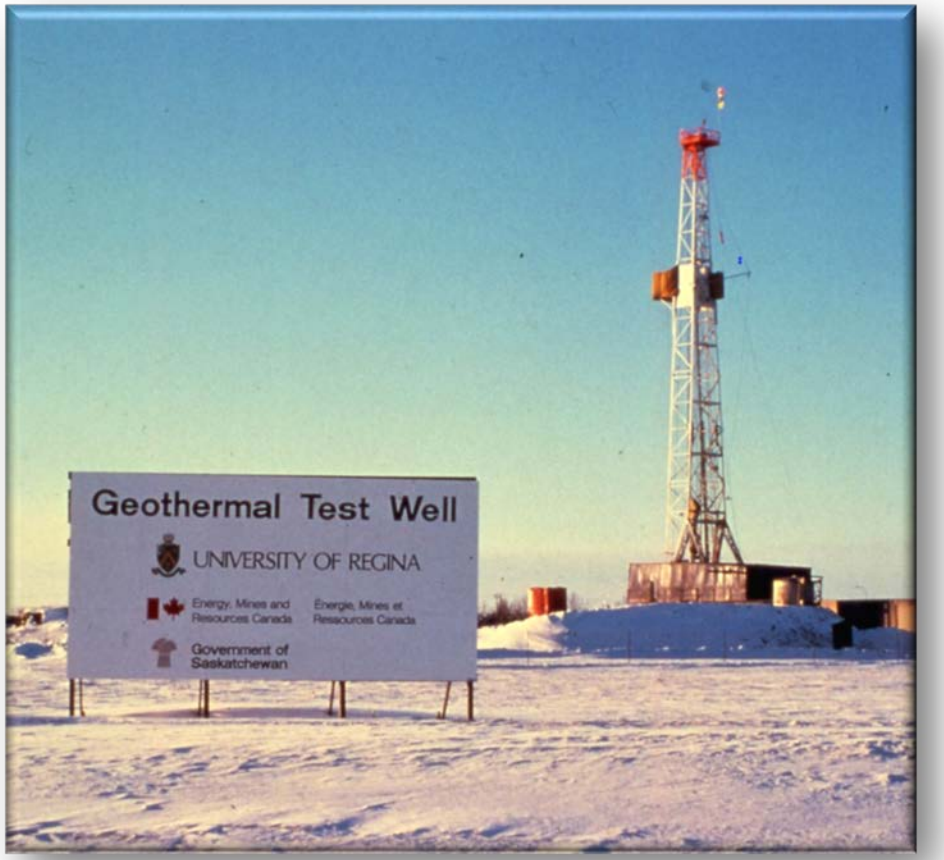
- **Heat source**
- **Heat trap**
- **Fluid**
- **Permeability**
- **Depth$$**



geoscience data is needed to reduce exploration risk!

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

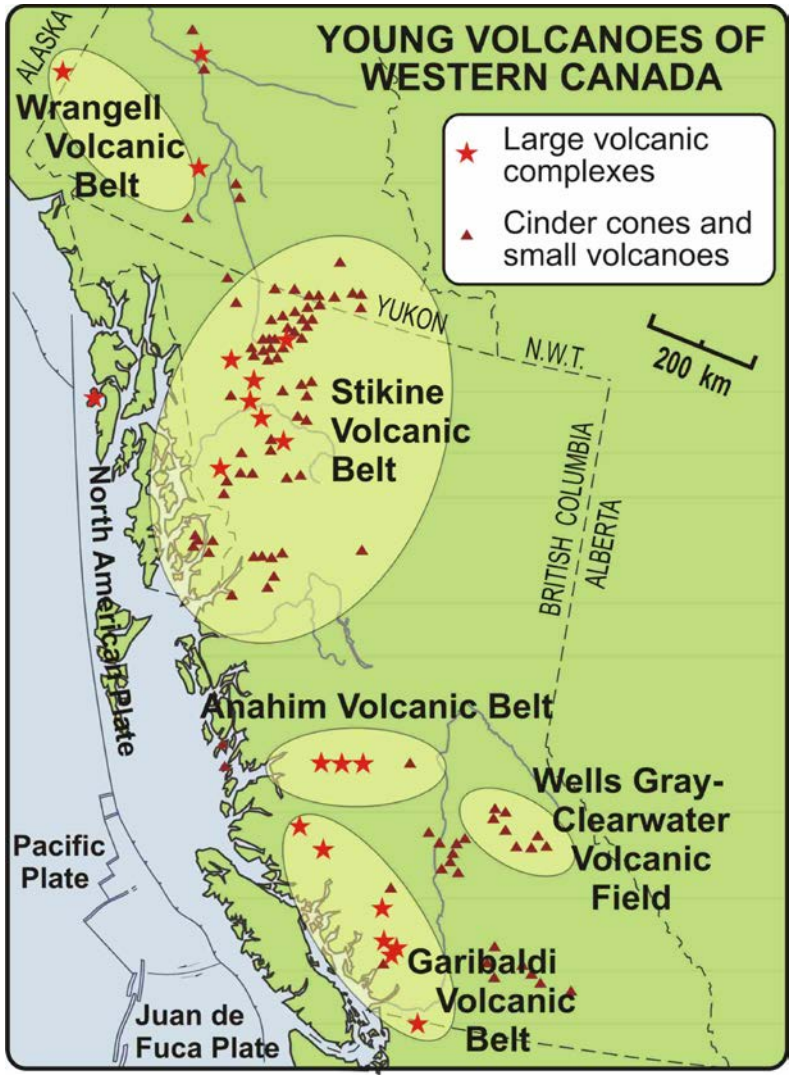
Geothermal research in Canada



- **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**

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Volcanic belts



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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Mount Meager research well

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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Hot young rocks

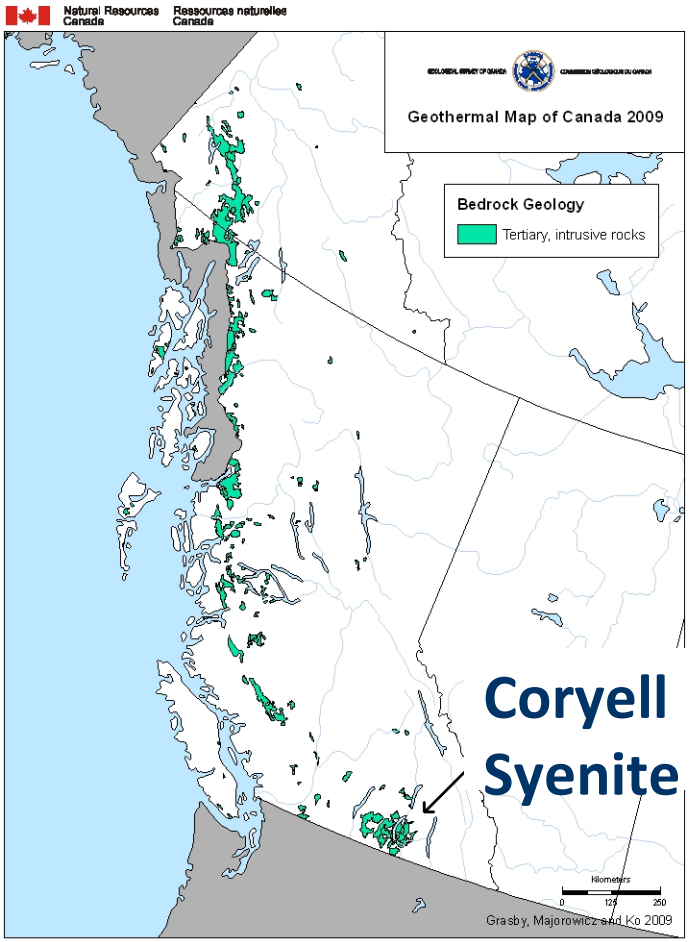
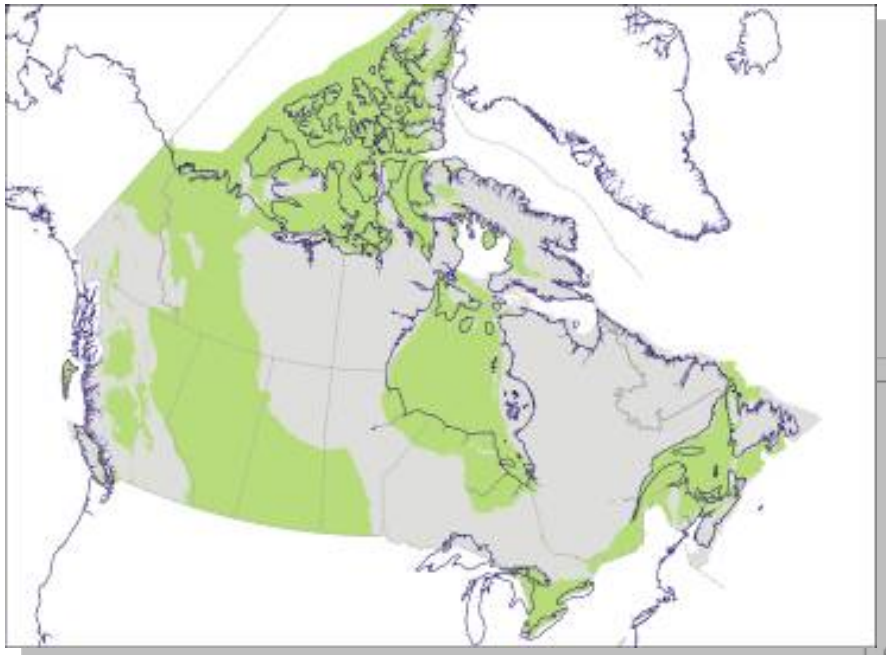


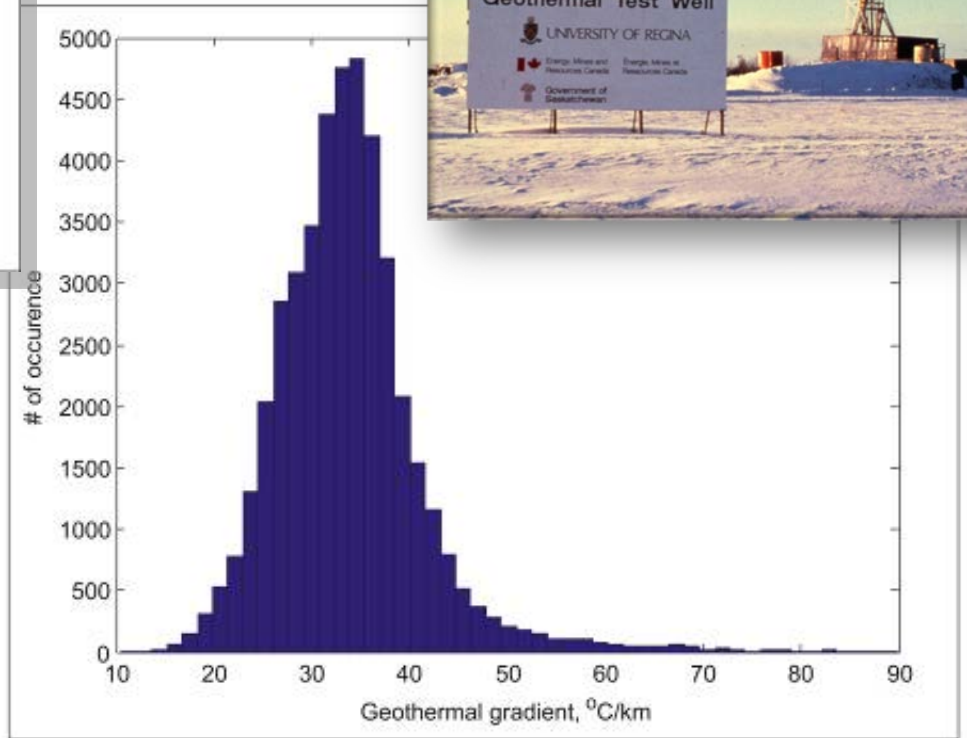
Figure 27

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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Sedimentary basins

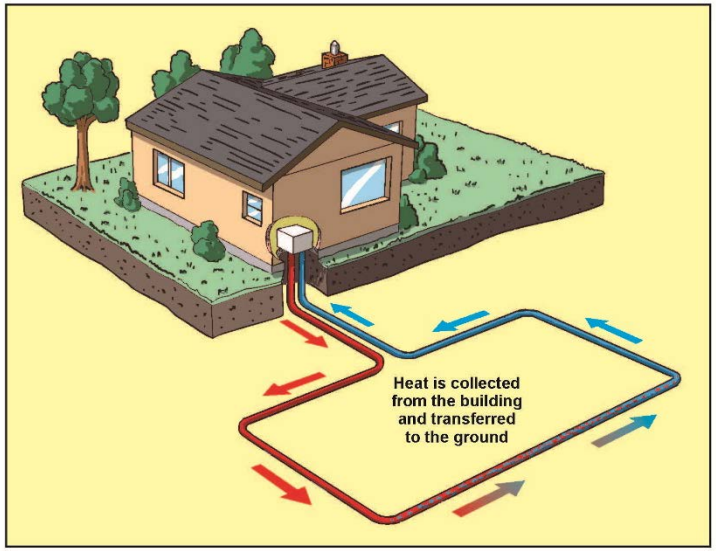


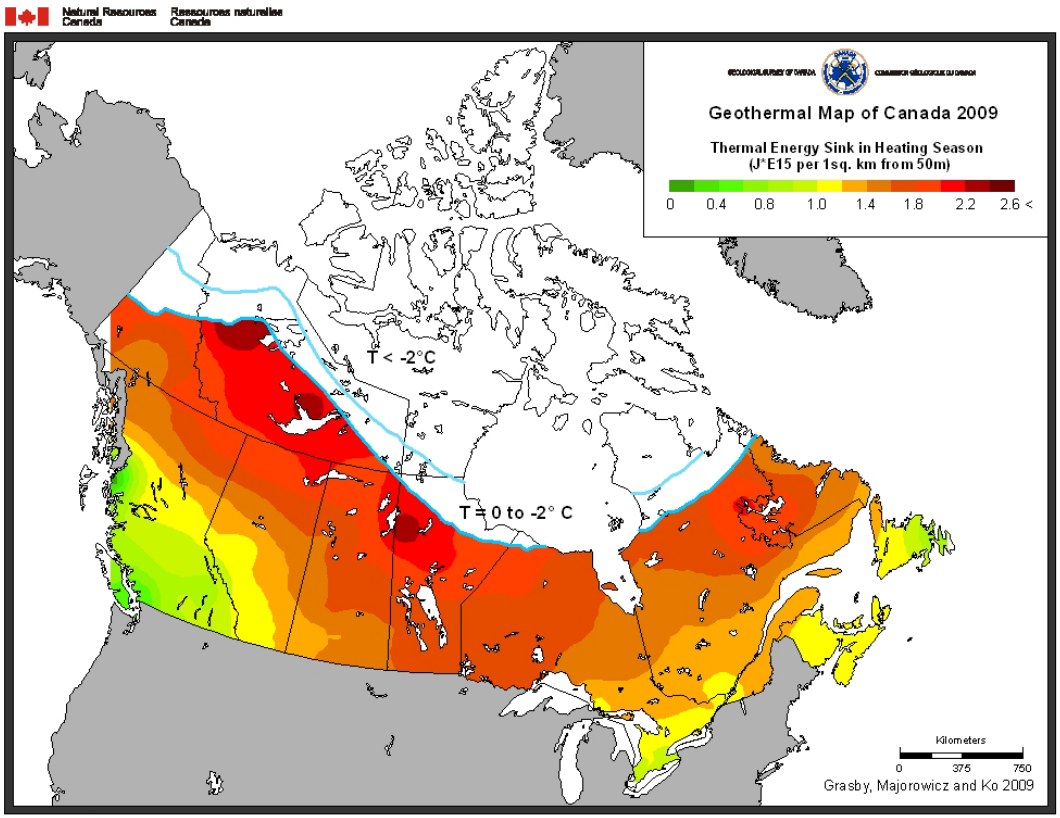


© Her Majesty the Queen in Right of Canada, as represented by the Ministe

Heat exchange systems

Heat exchange

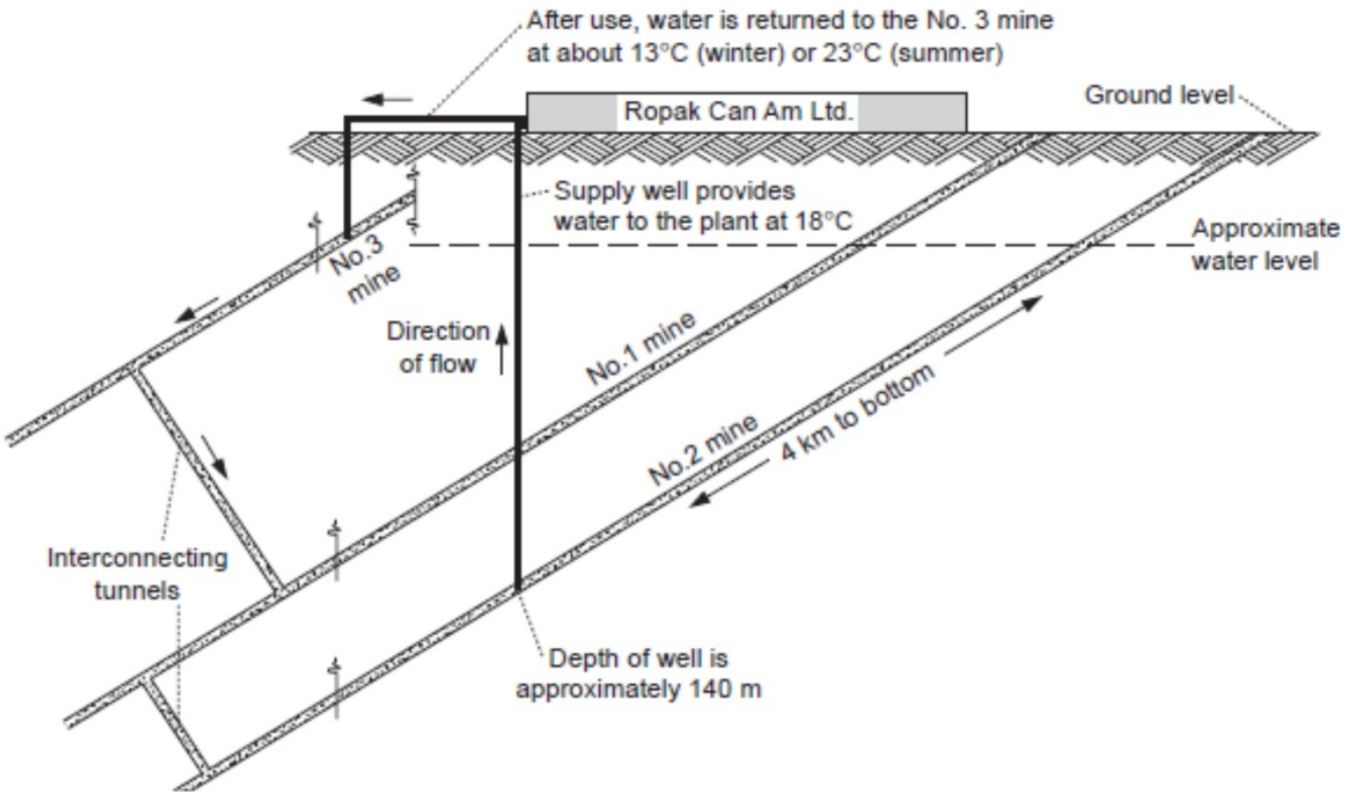




© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Abandoned mines

Springhill Nova Scotia



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Emerging technologies

Enhanced Geothermal Systems (EGS)

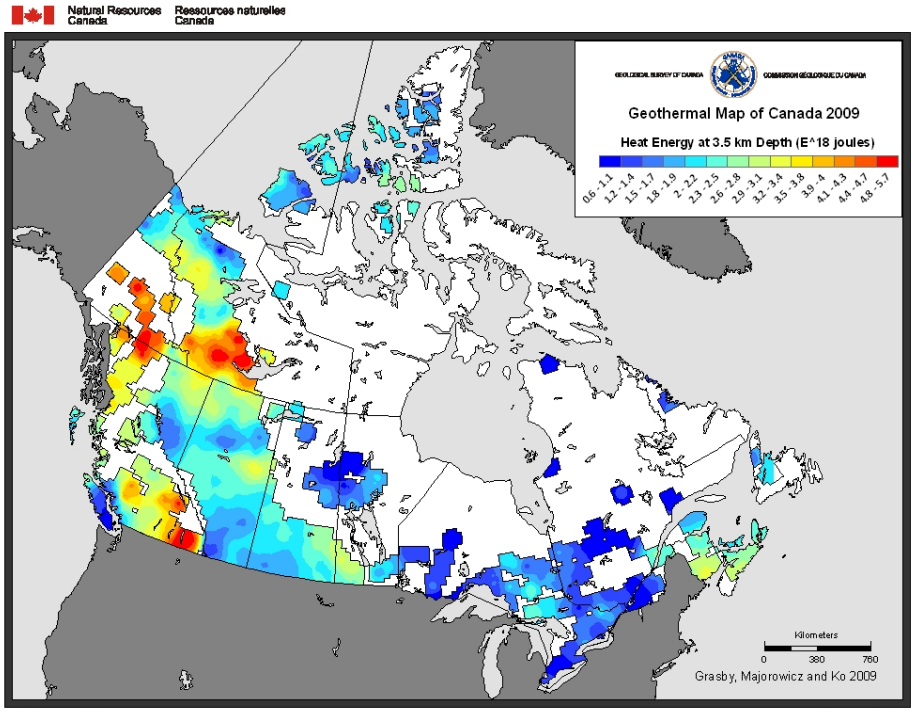
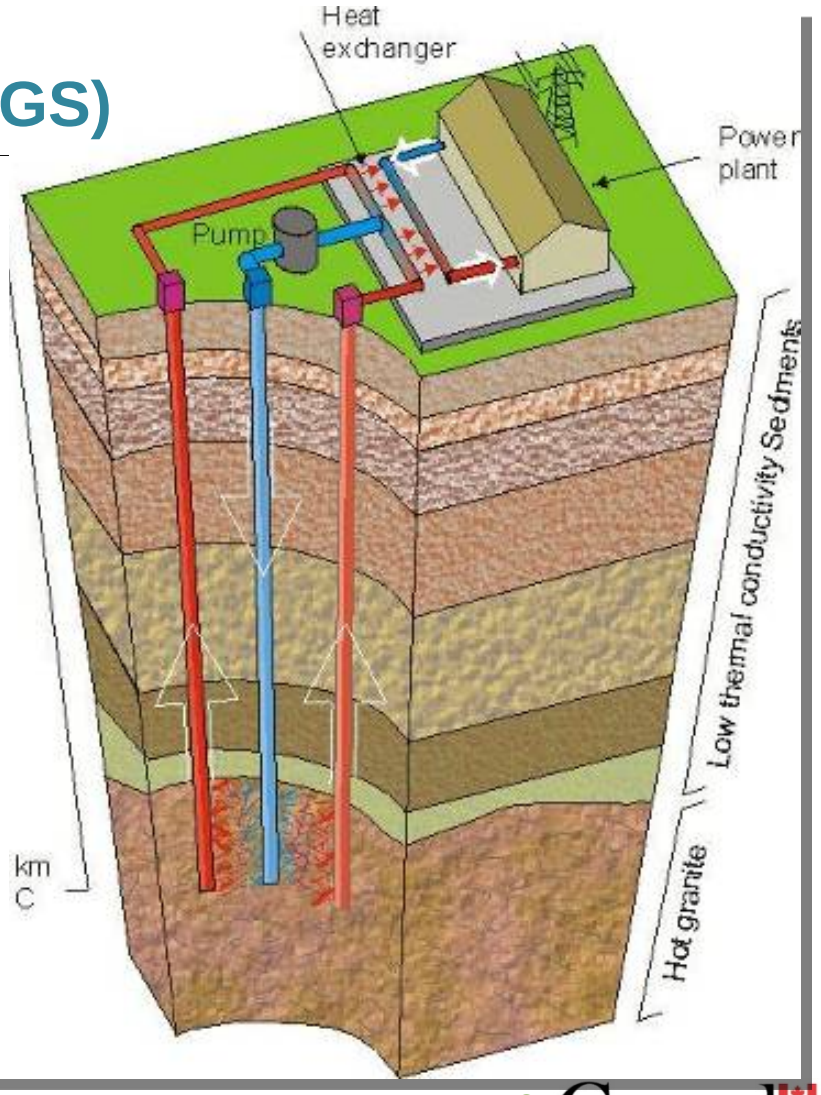


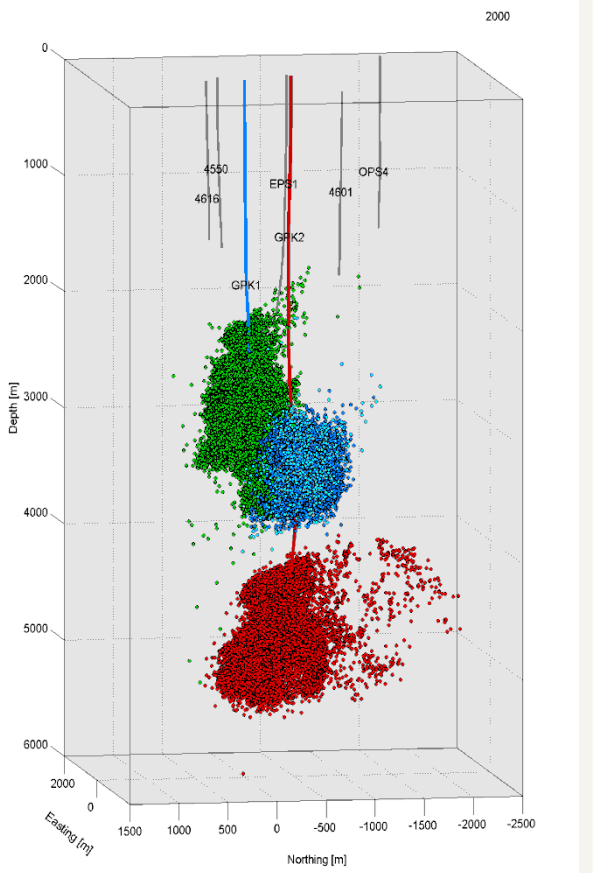
Figure 21

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



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural R

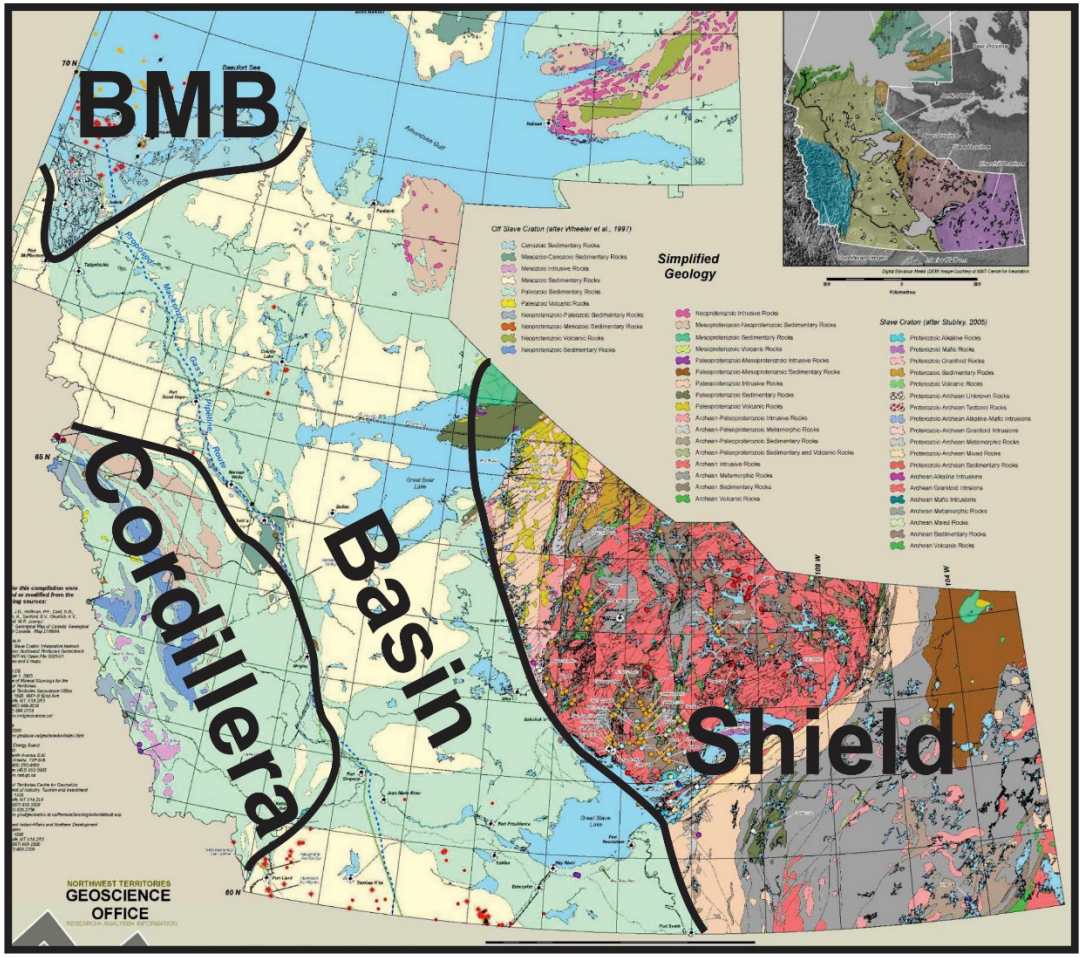
EGS technology challenges



- Directional Drilling (5+ km)
- Fracture stimulation (>1km^3)
- Microseismic monitoring and control
- Injection/production well connectivity
- Controlled water loss
- Regional stress fields

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Geothermal potenetial of NWT



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

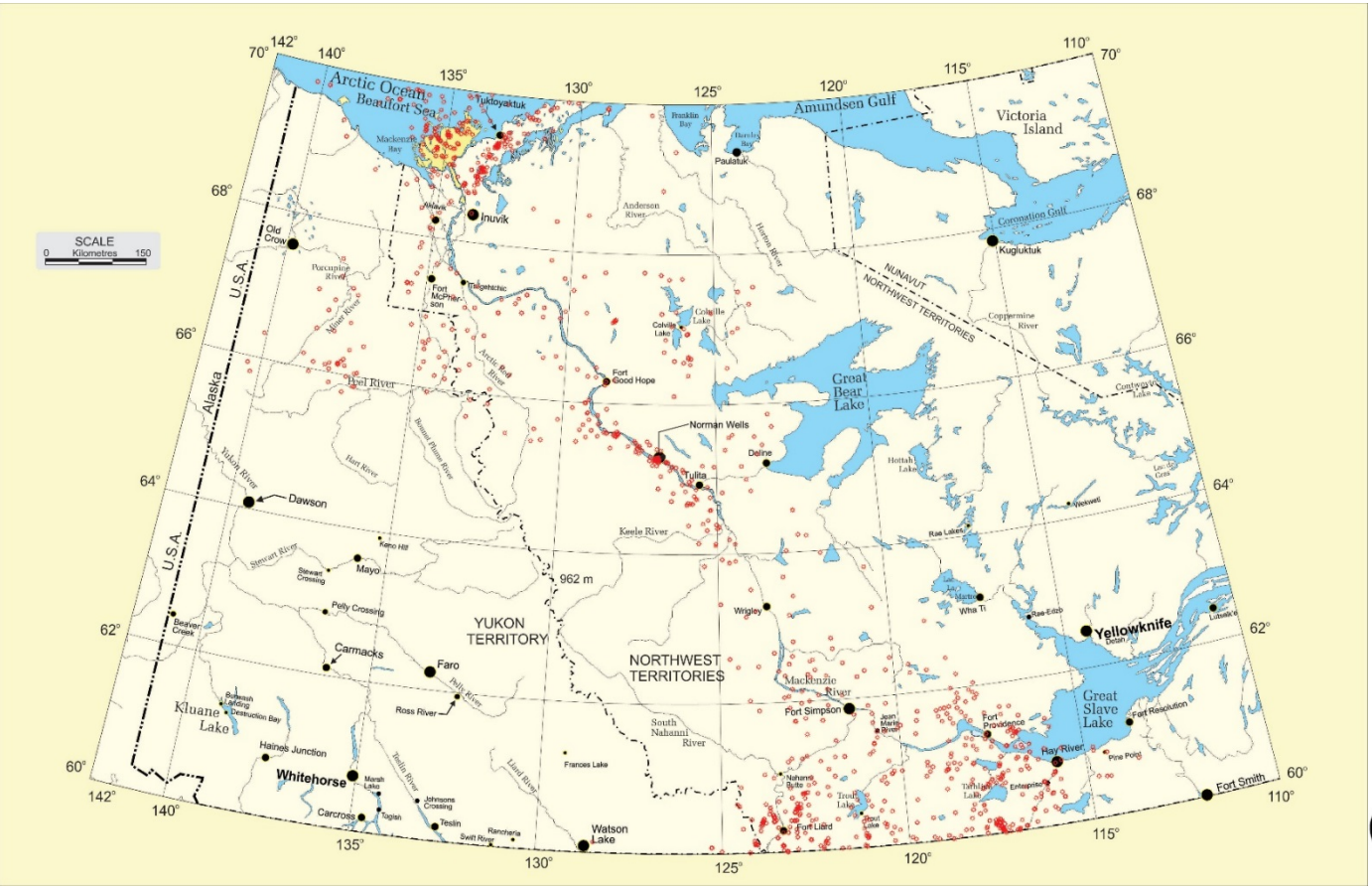
Cordillera

- Numerous thermal springs
- Localised thermal anomalies related to high heat generation of plutons

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resou

Sedimentary Basins

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

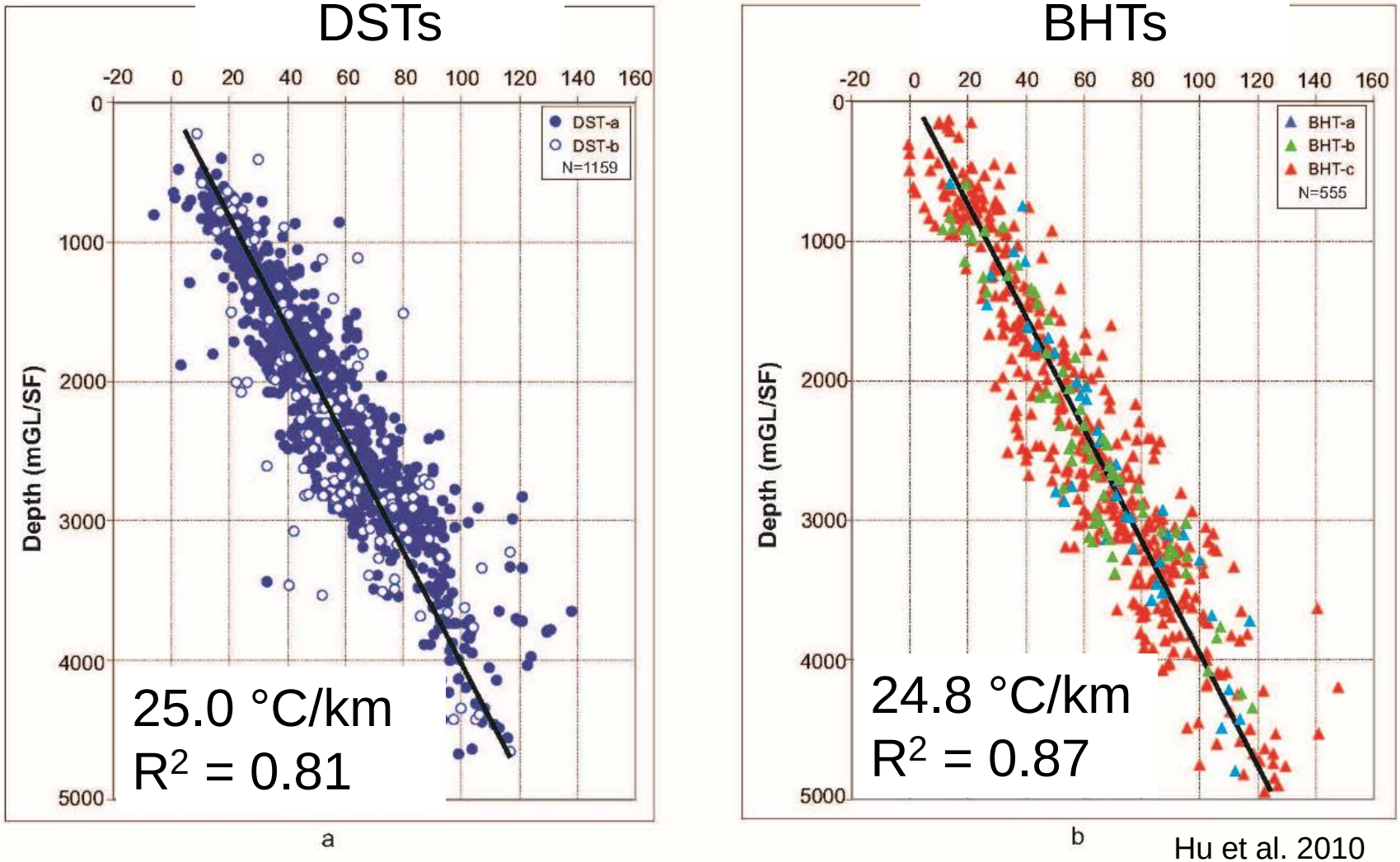


© Her Majesty th

Natur
Canad

Canada

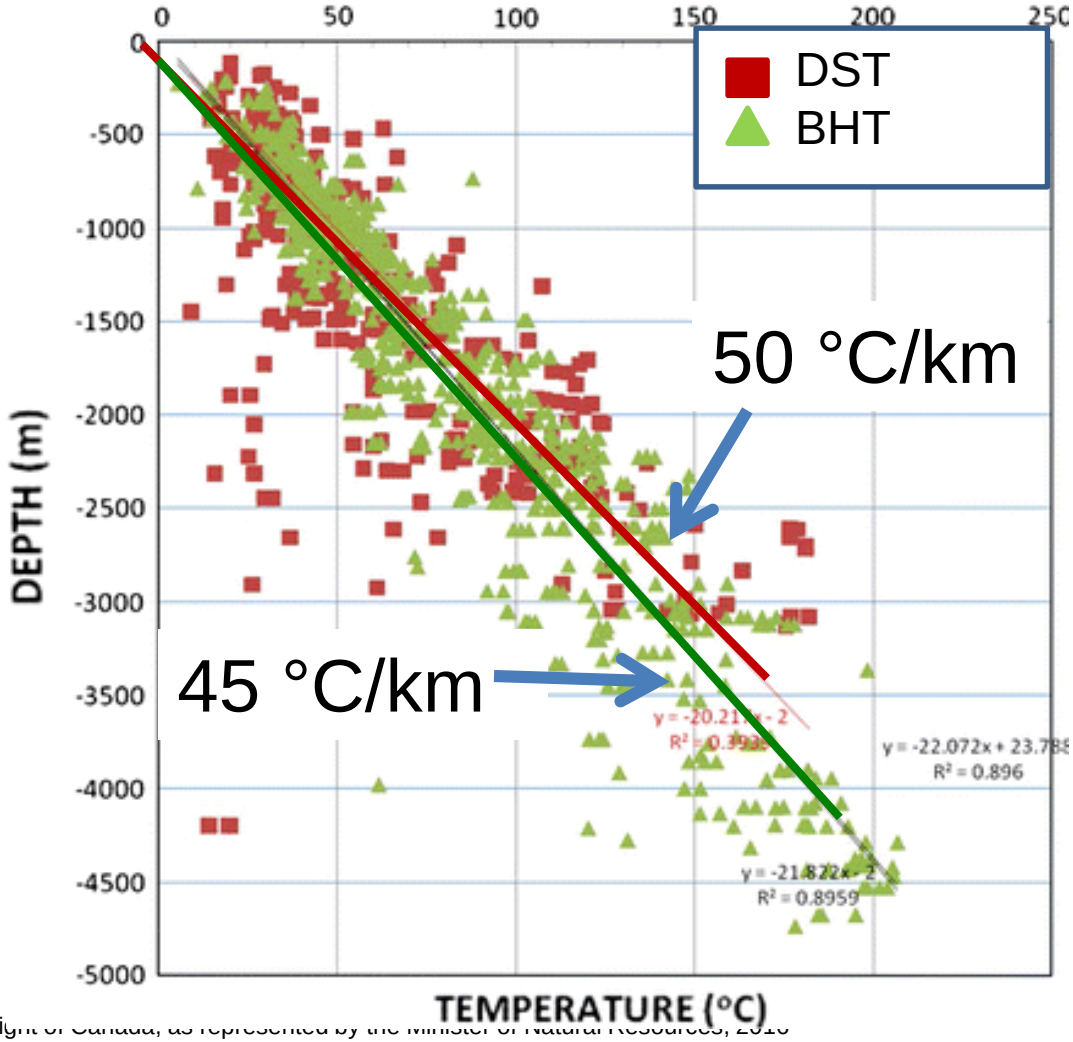
Beaufort Mackenzie



Hu et al. 2010

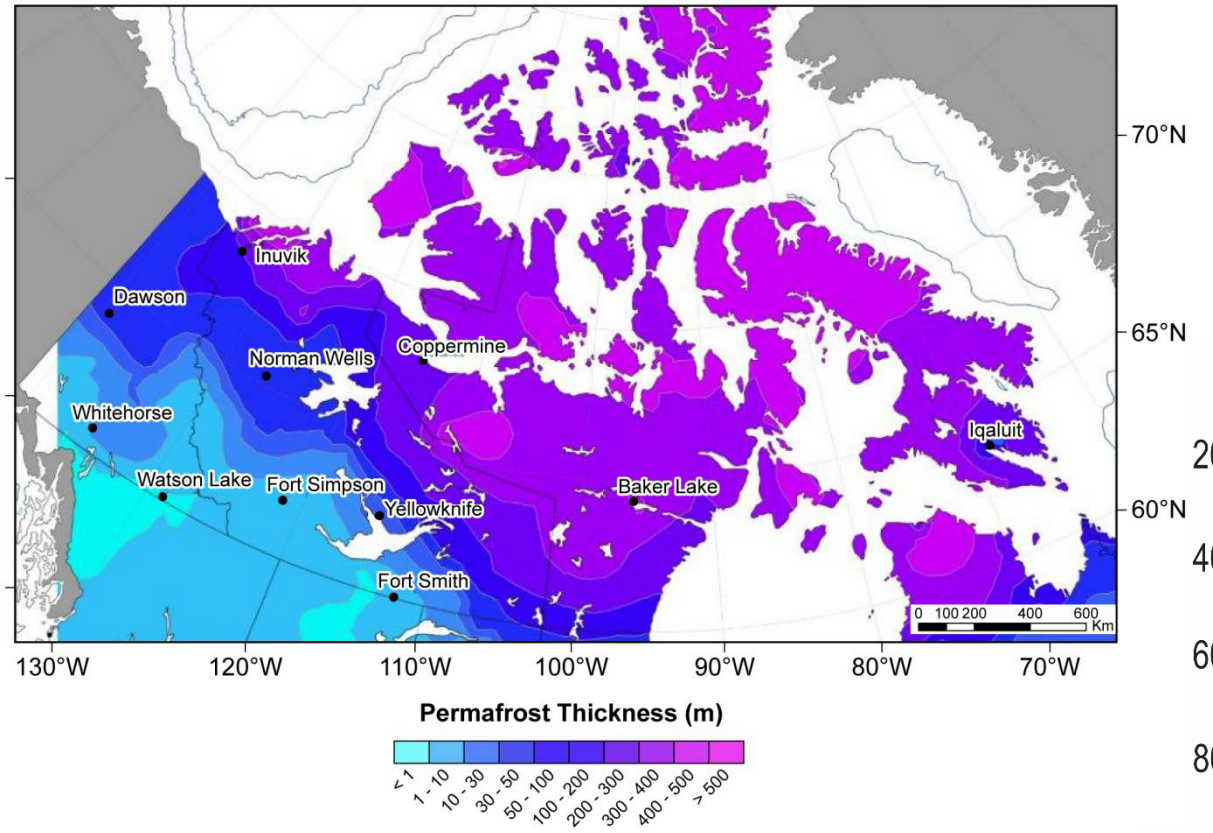
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Southern NWT



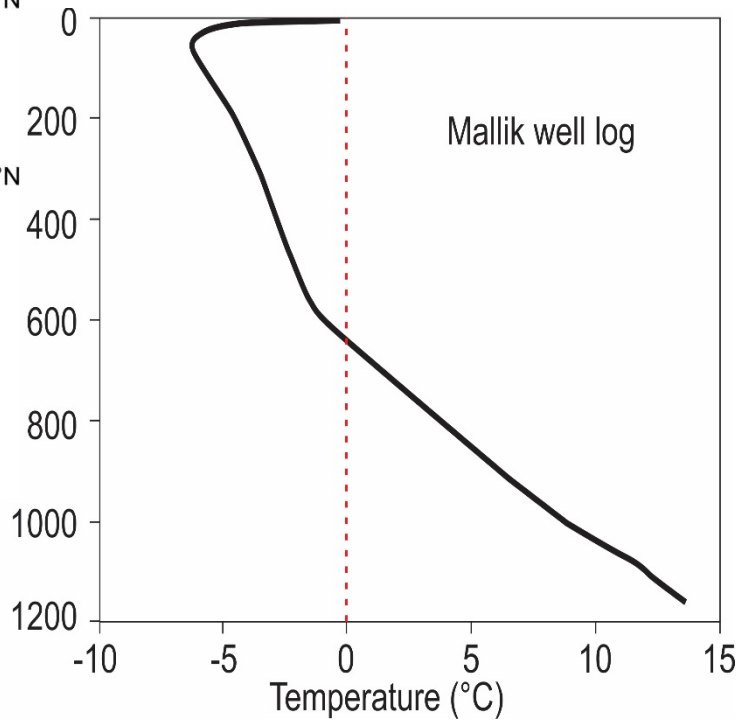
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Permafrost challenges…



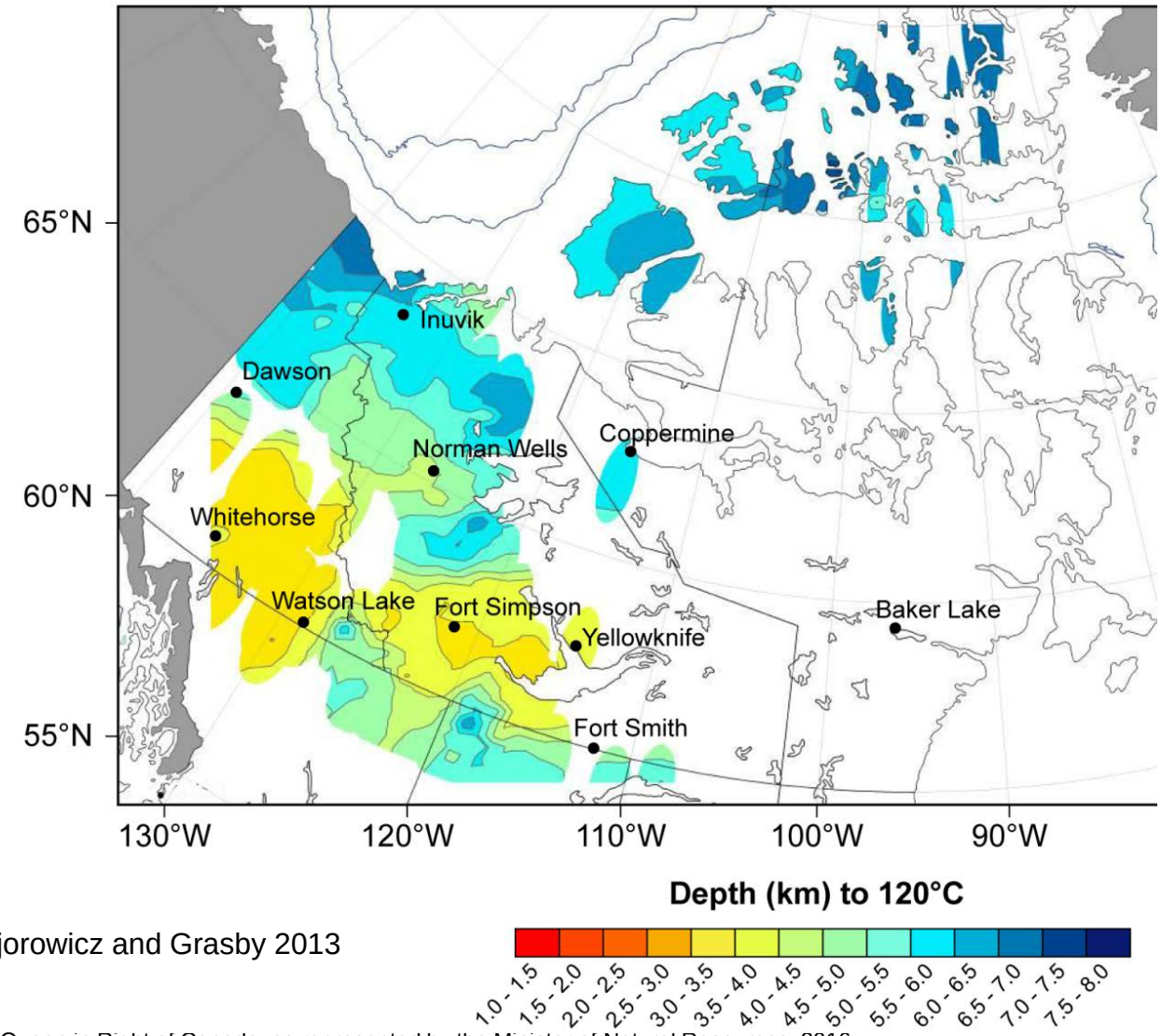
From Majorowicz and Grasby 2013

From Osadetz et al. 2015



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

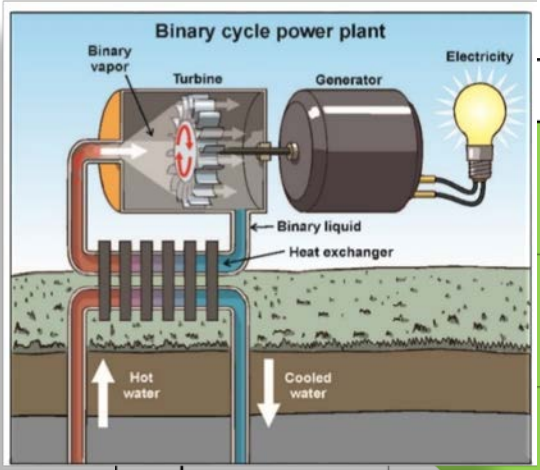
Depth constraints

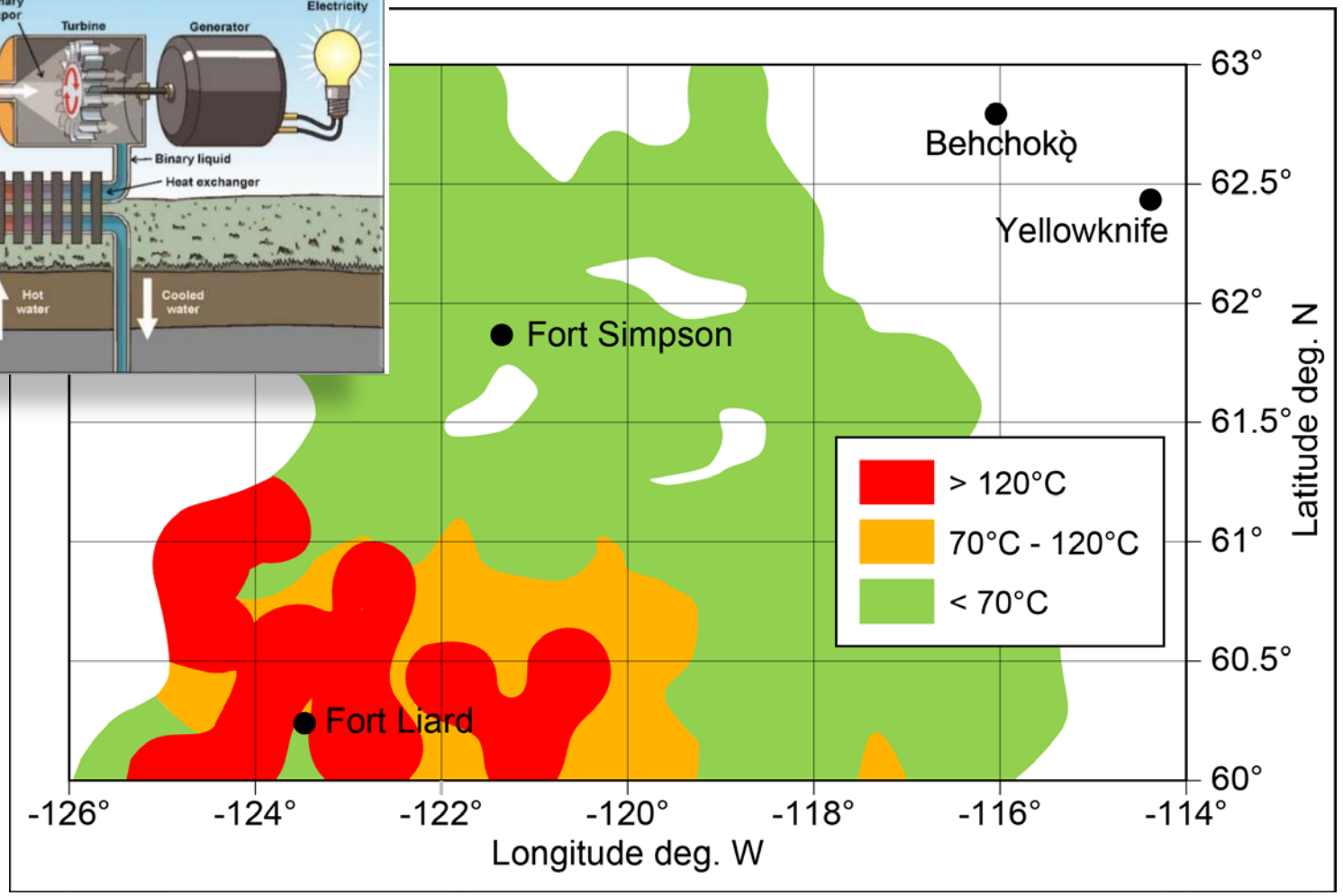


From Majorowicz and Grasby 2013

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Southern NWT

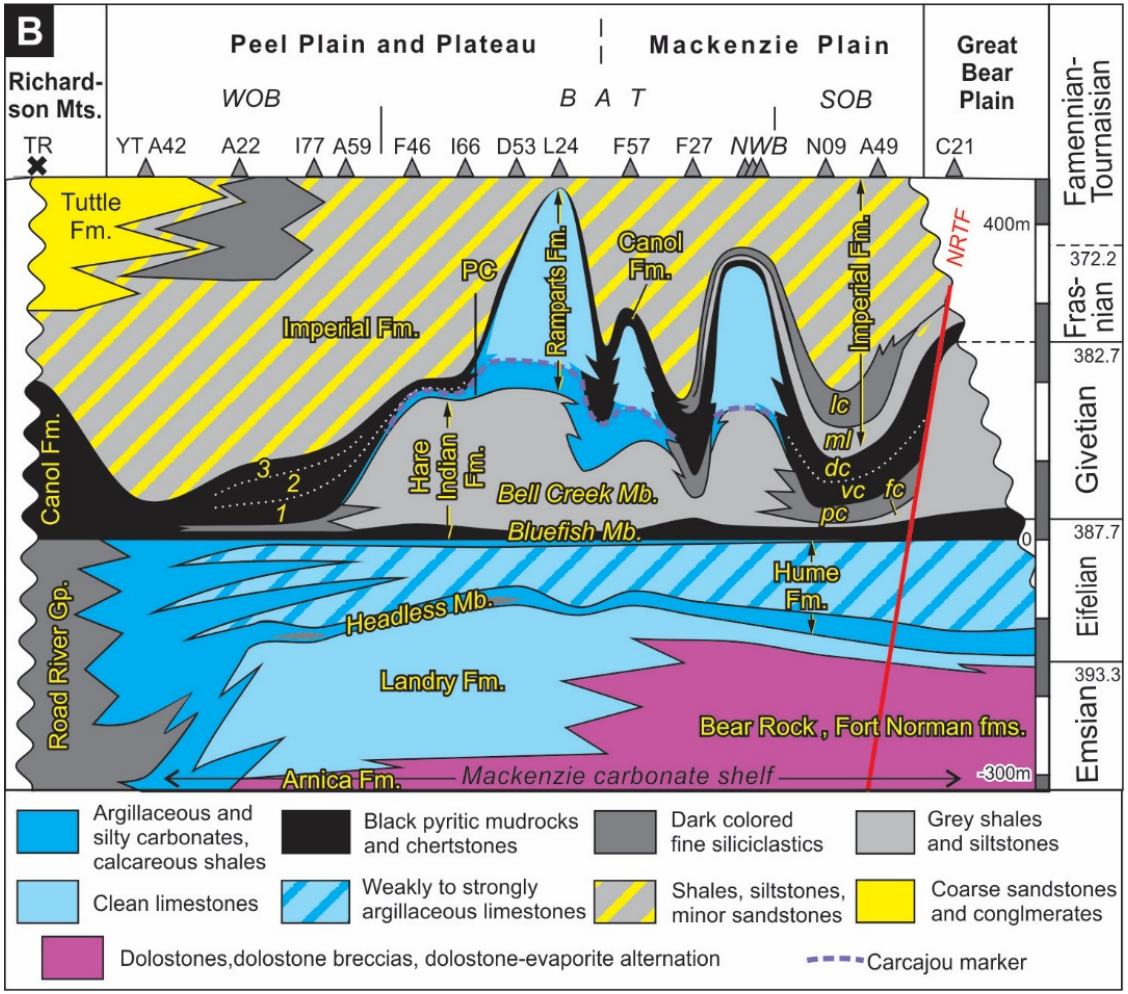




From Majorowicz and Grasby in review

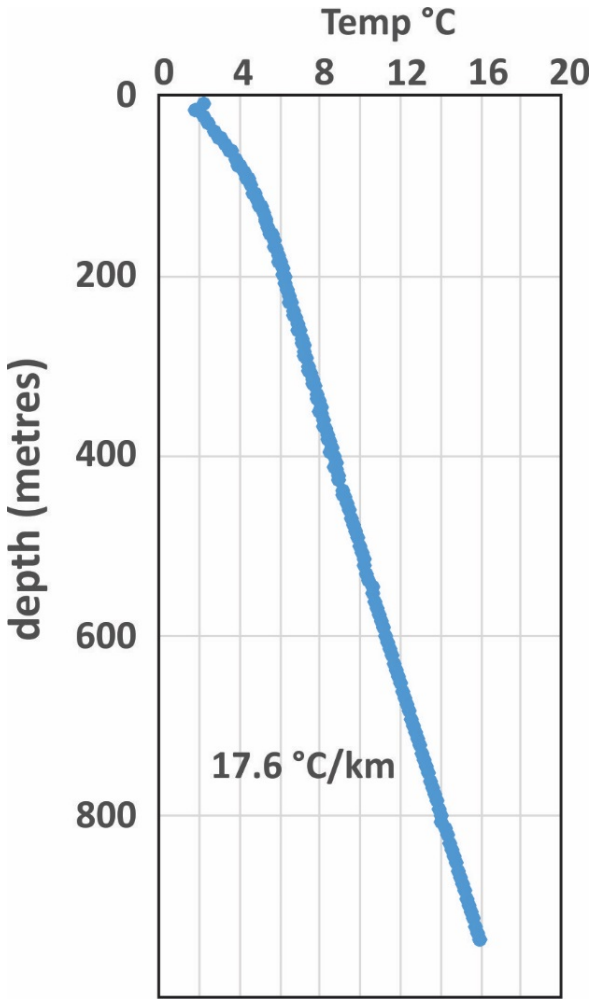
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Deep aquifers



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Shield



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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Con Mine – Open Loop

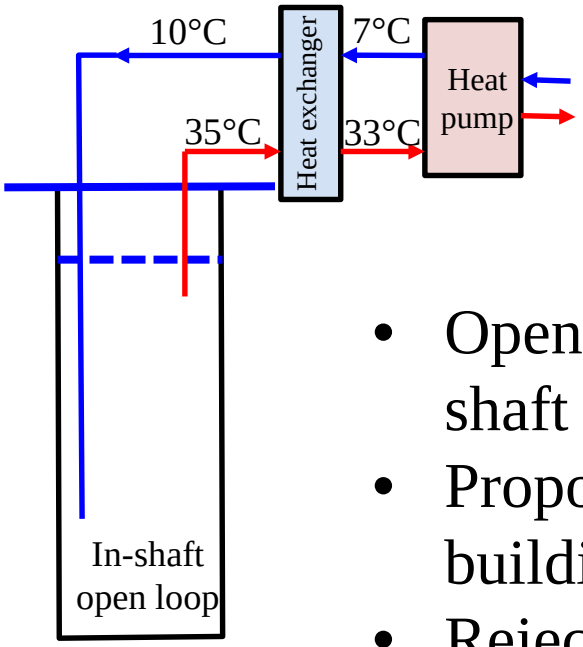
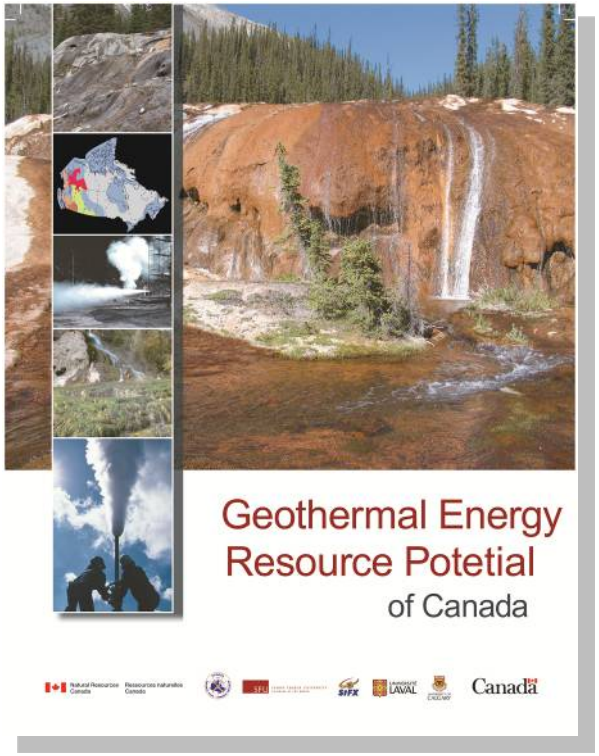


Photo: Bob Wilson

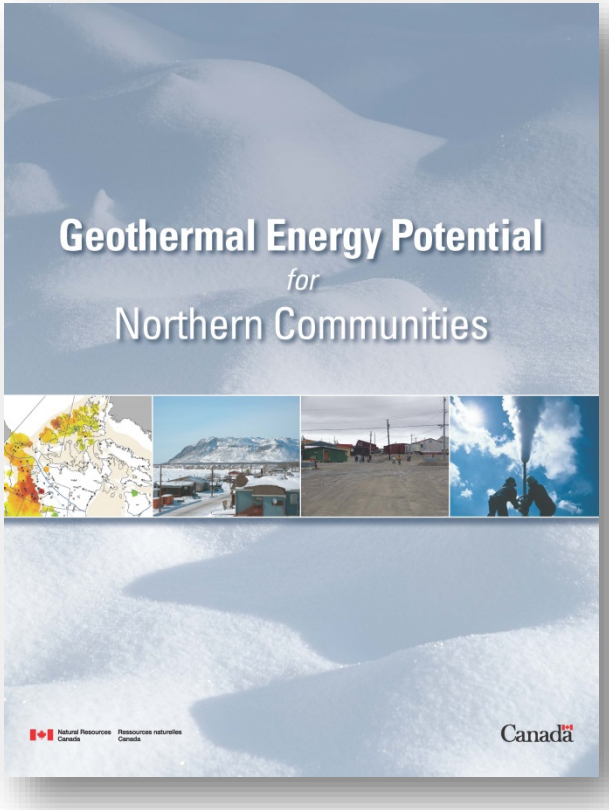
- Open loop system using the mine shaft as geothermal resource.
- Proposal to heat downtown core buildings.
- Rejected in public plebiscite

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

More reading…



doi.org/10.4095/292840



doi.org/10.4095/291488

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

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

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016

Tungsten Thermal Spring, NWT

© Her Majesty the Queen in Right of Cana