



NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Geothermal Resources of the Garibaldi Belt

Stephen Grasby

Geological Survey of Canada

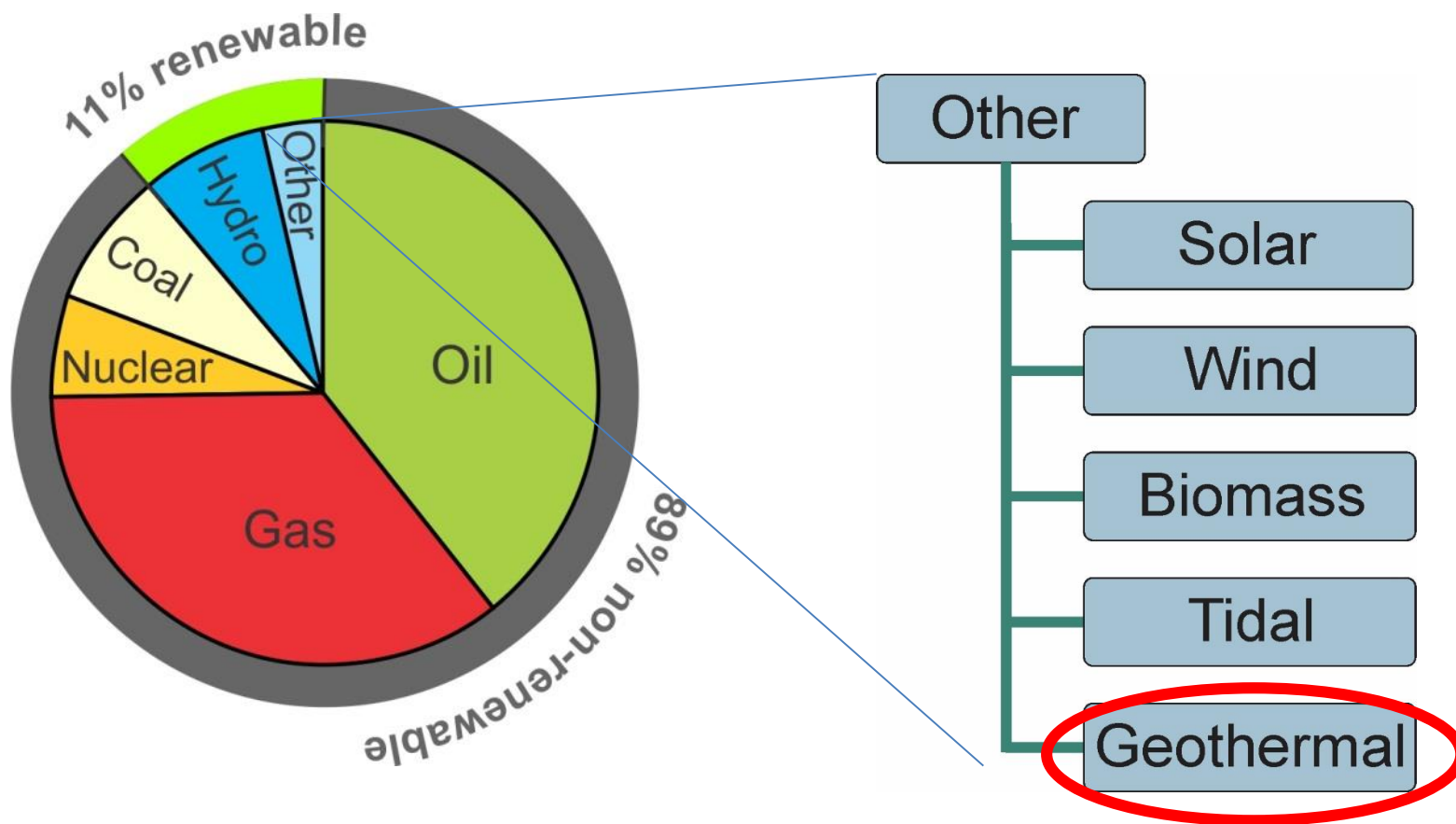


Natural Resources
Canada

Ressources naturelles
Canada

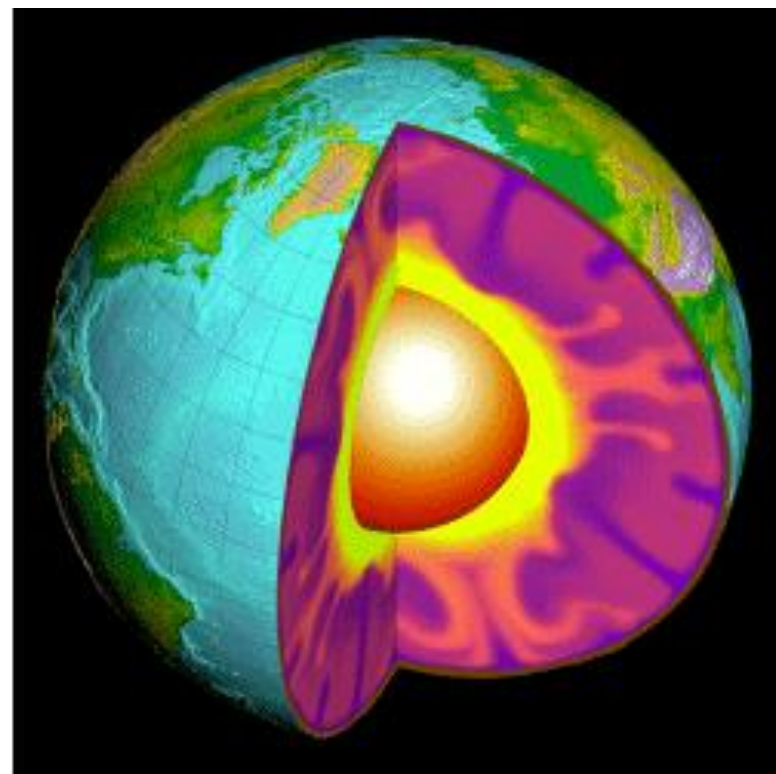
Canada

Reducing greenhouse gas emissions



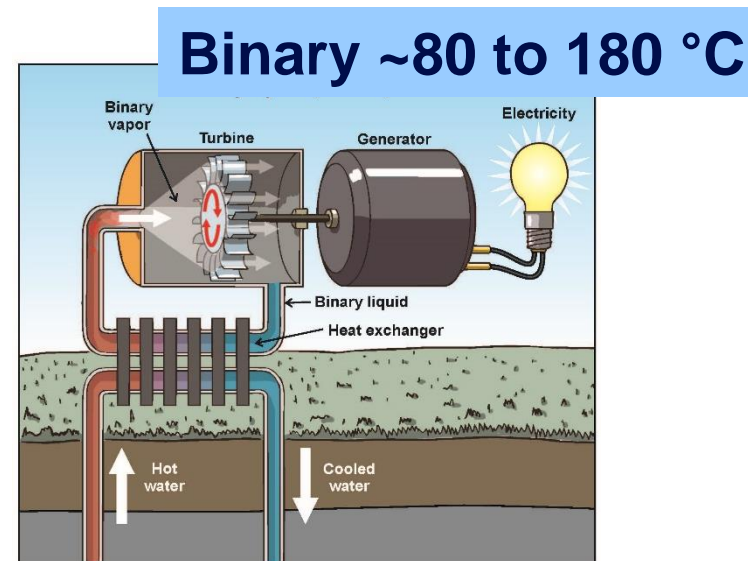
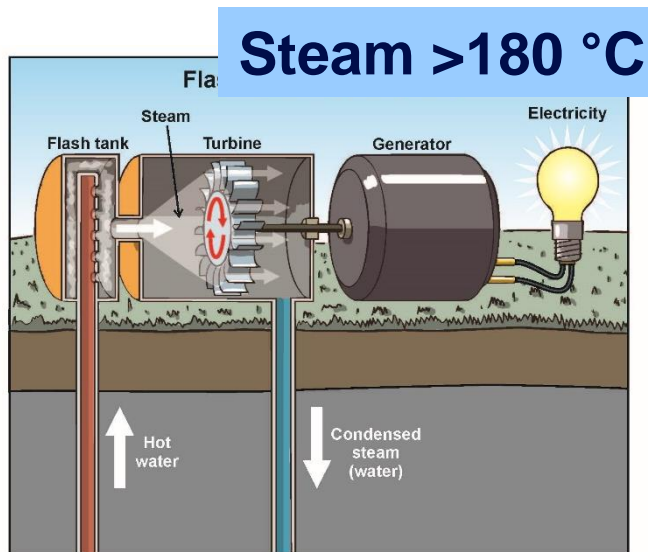
Geothermal energy

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

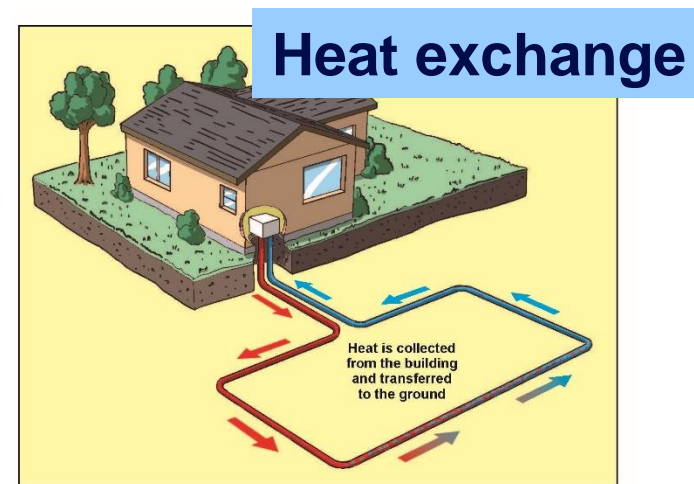
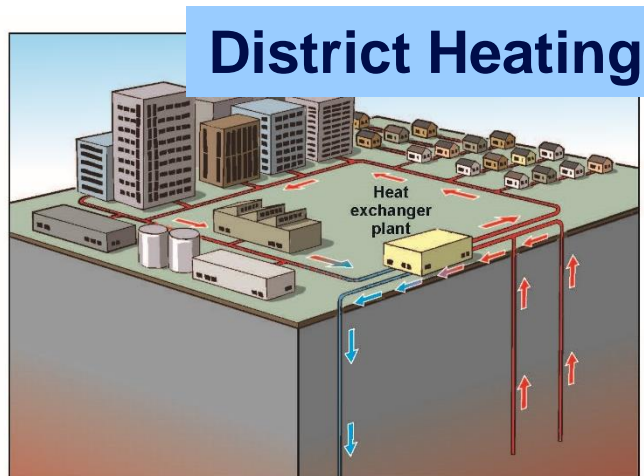


Geothermal usage

Electrical Generation



Direct use



© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2010

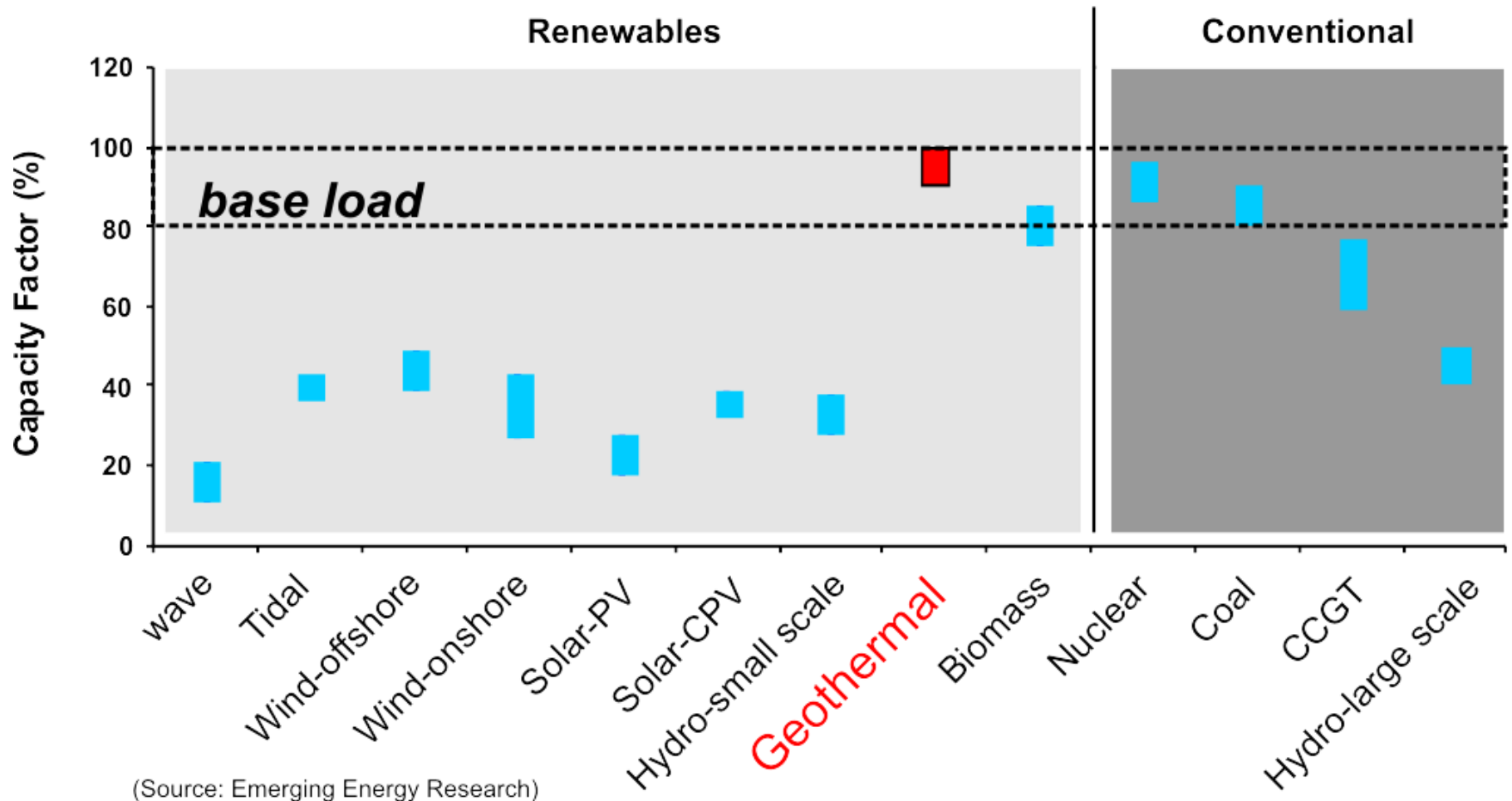


Natural Resources
Canada

Ressources naturelles
Canada

Canada

Energy reliability



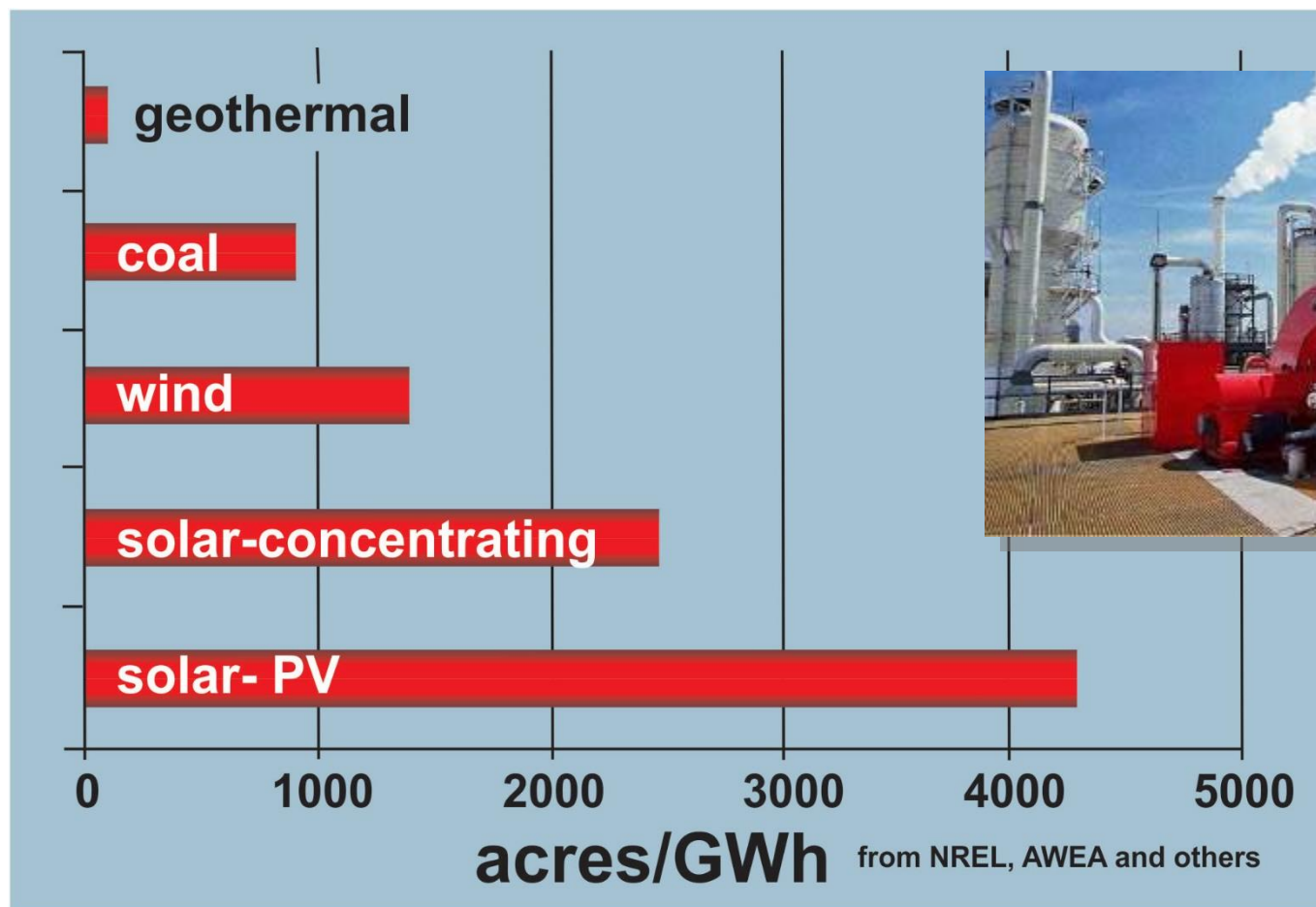
© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2016



Natural Resources
Canada

Ressources naturelles
Canada

Environmental footprint



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

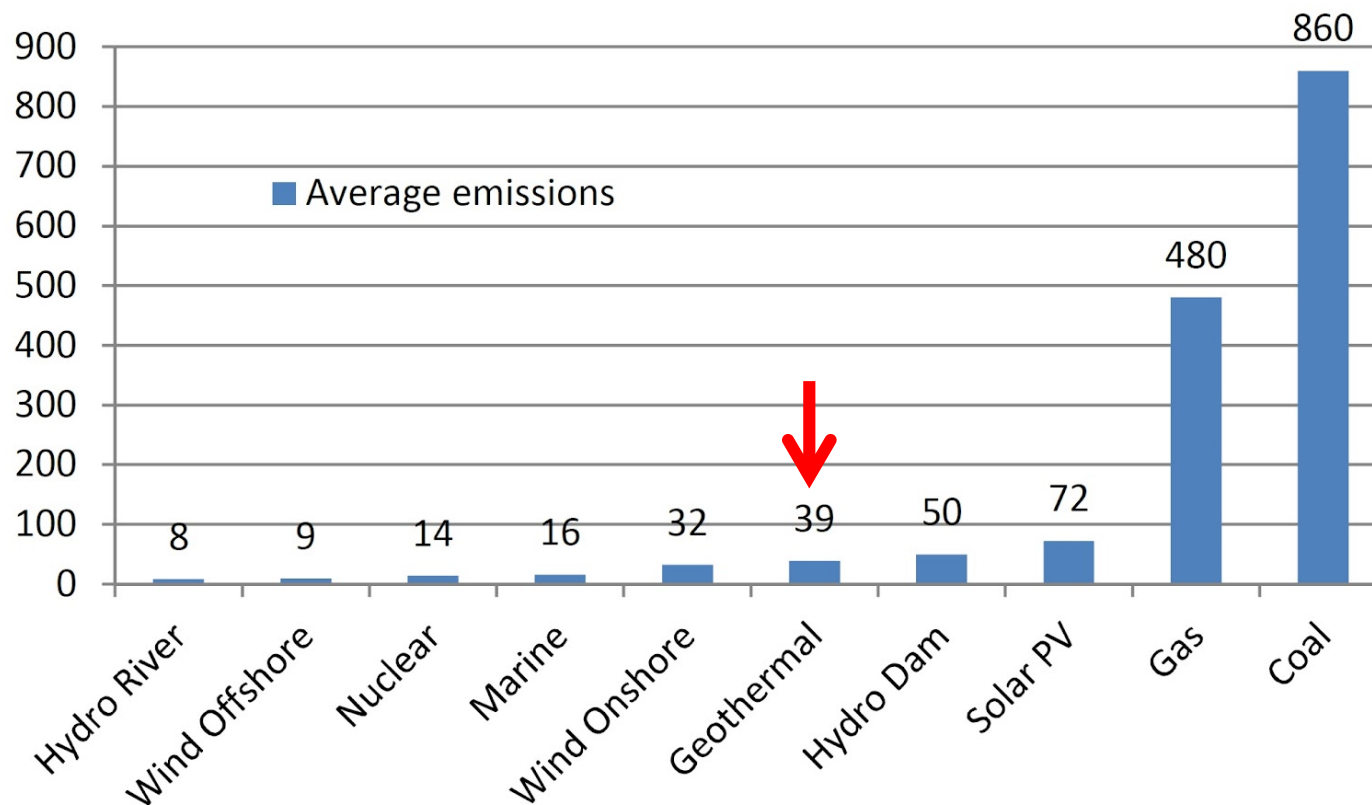


Natural Resources
Canada

Ressources naturelles
Canada

Emissions

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



Source: UK Parliament 2011

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



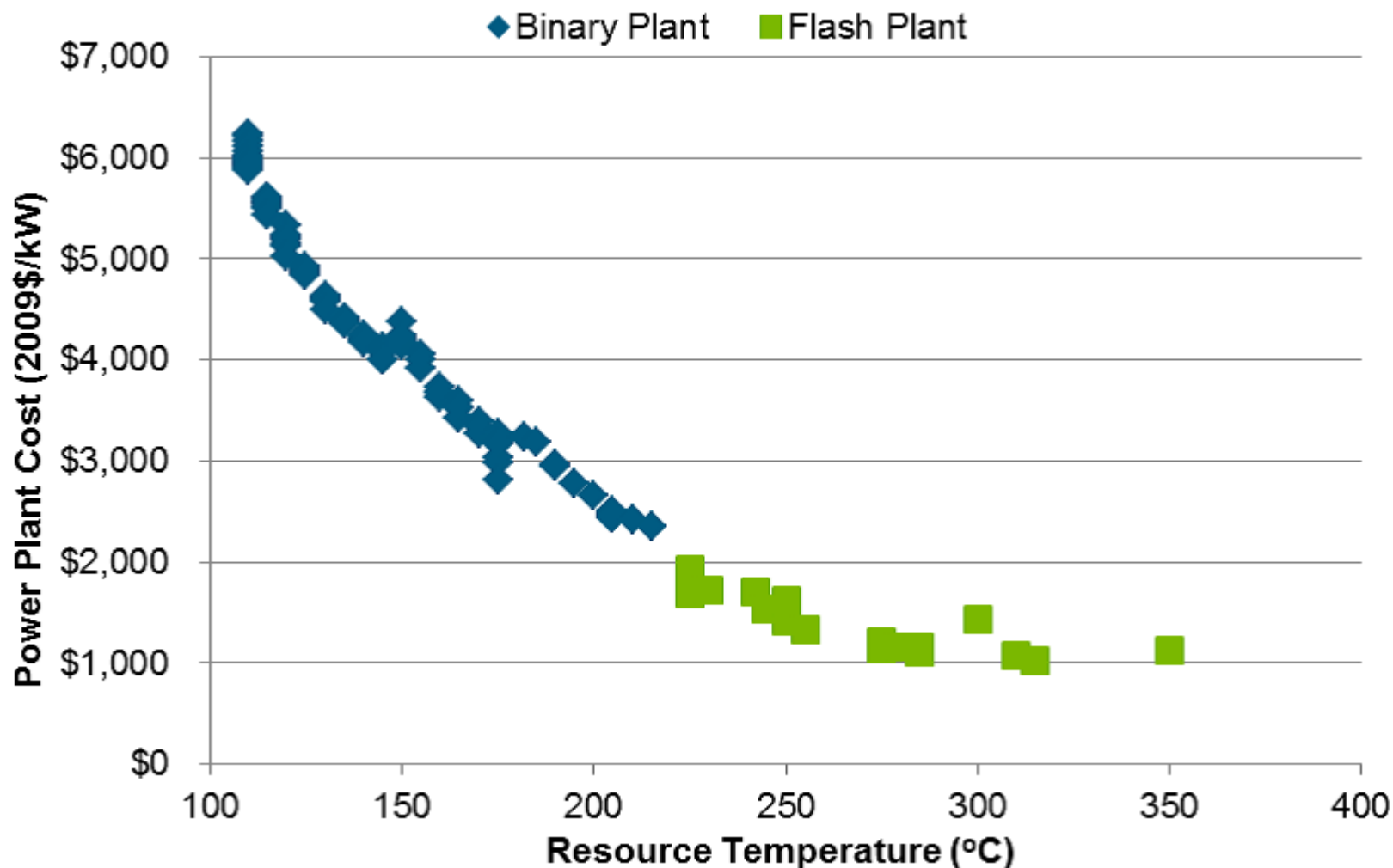
Natural Resources
Canada

Ressources naturelles
Canada

Canada

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’

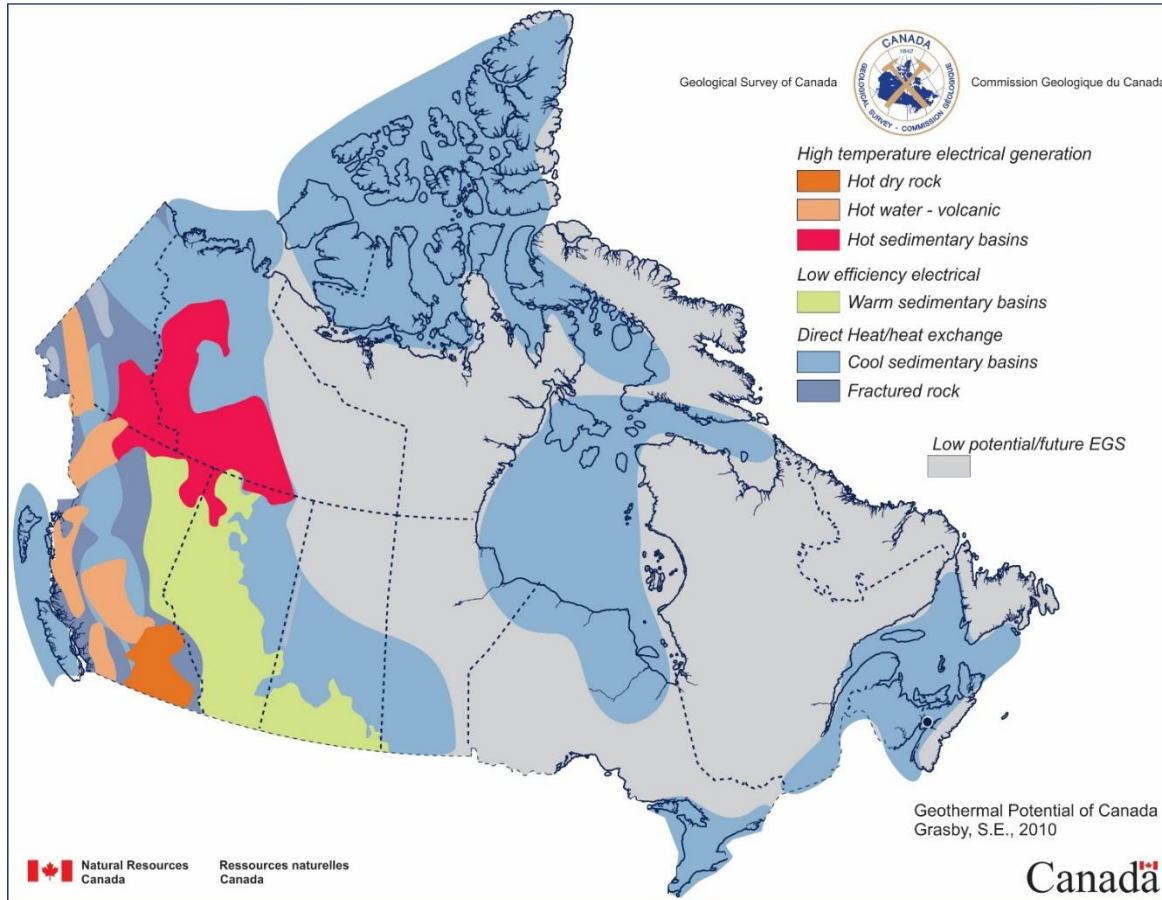
	GWh
United States	16,600
Philippines	9,646
Indonesia	9,600
New Zealand	7,000
Mexico	6,071
Italy	5,660
Iceland	5,245
Turkey	3,247
Kenya	2,868
Japan	2,687
Canada	0
Global	73,689 (Bertani, 2016)

Direct heat use

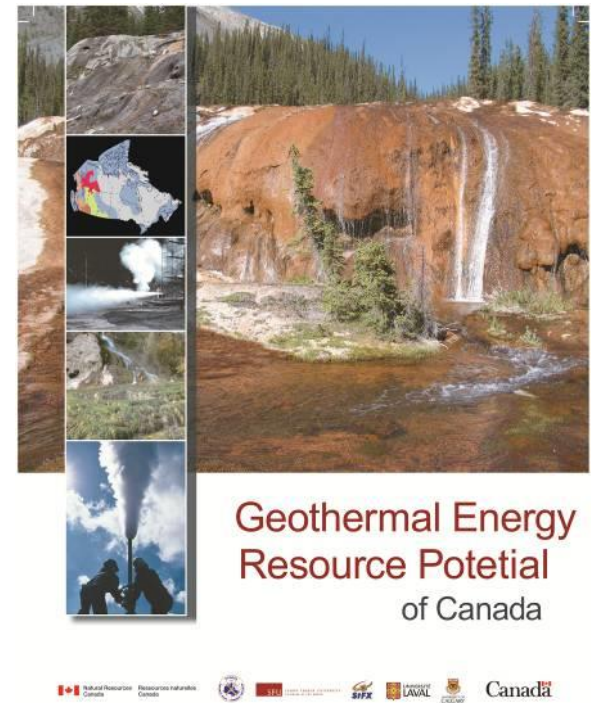


	GWh/yr
China	48,435
Iceland	7,422
Japan	7,259
Germany	5,426
Finland	5,000
France	4,408
Canada	3,227
Hungary	2,852
Italy	2,412
New Zealand	2,395

Geothermal potential of Canada



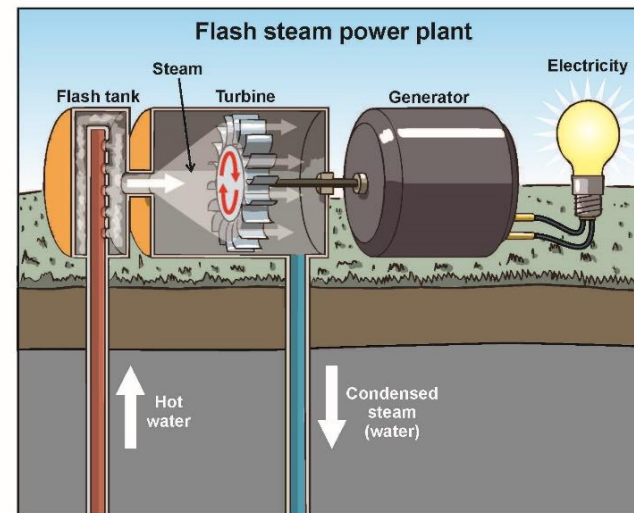
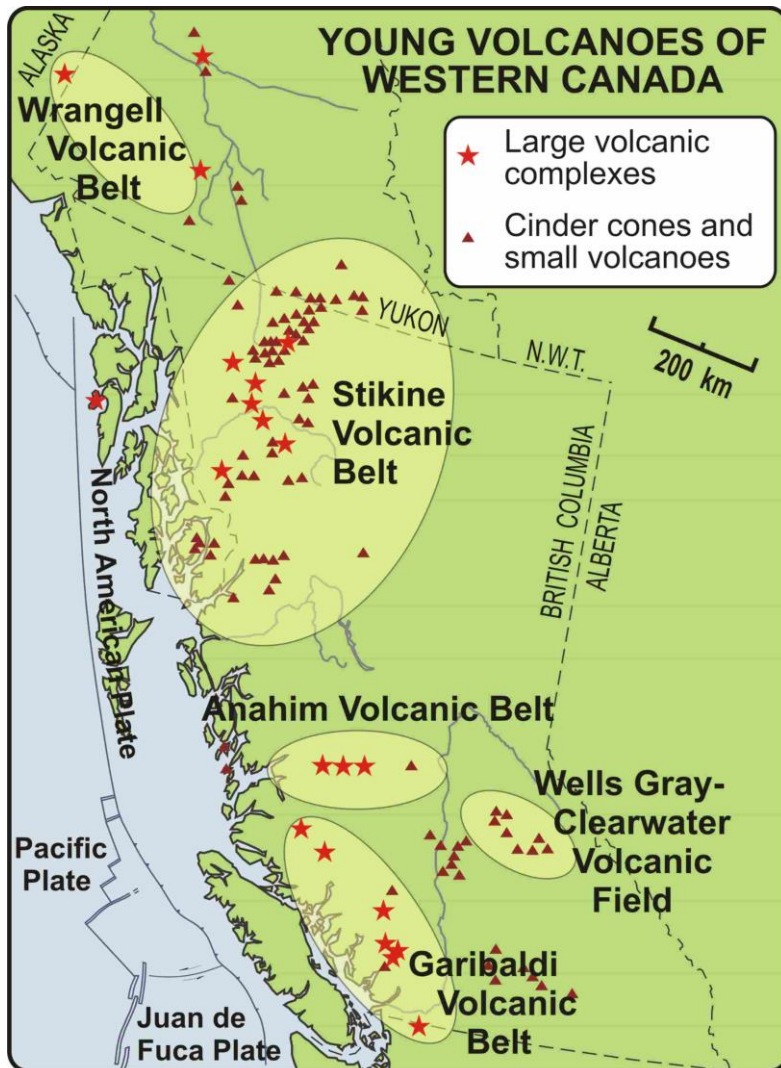
- **Enormous potential!**



Grasby et al. 2012

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

Volcanic belts



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



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Mount Meager research well



- **BC Hydro and NRCan research well drilled in the 80's**
- **First geothermal power production in Canada**
- **Waters > 240 °C**
- **Fluid flow insufficient to make it economic**

New data collection

24 people from 6 Institutions

- 11 researchers/university professors
- 2 Post Docs
- 6 PhD students
- 1 MSc student
- 4 undergraduates



SIMON FRASER
UNIVERSITY



Project Goal - Reducing Exploration Risk

Predicting Permeability

- fracture/stress system analyses
- aquifer systems

Heat Resources

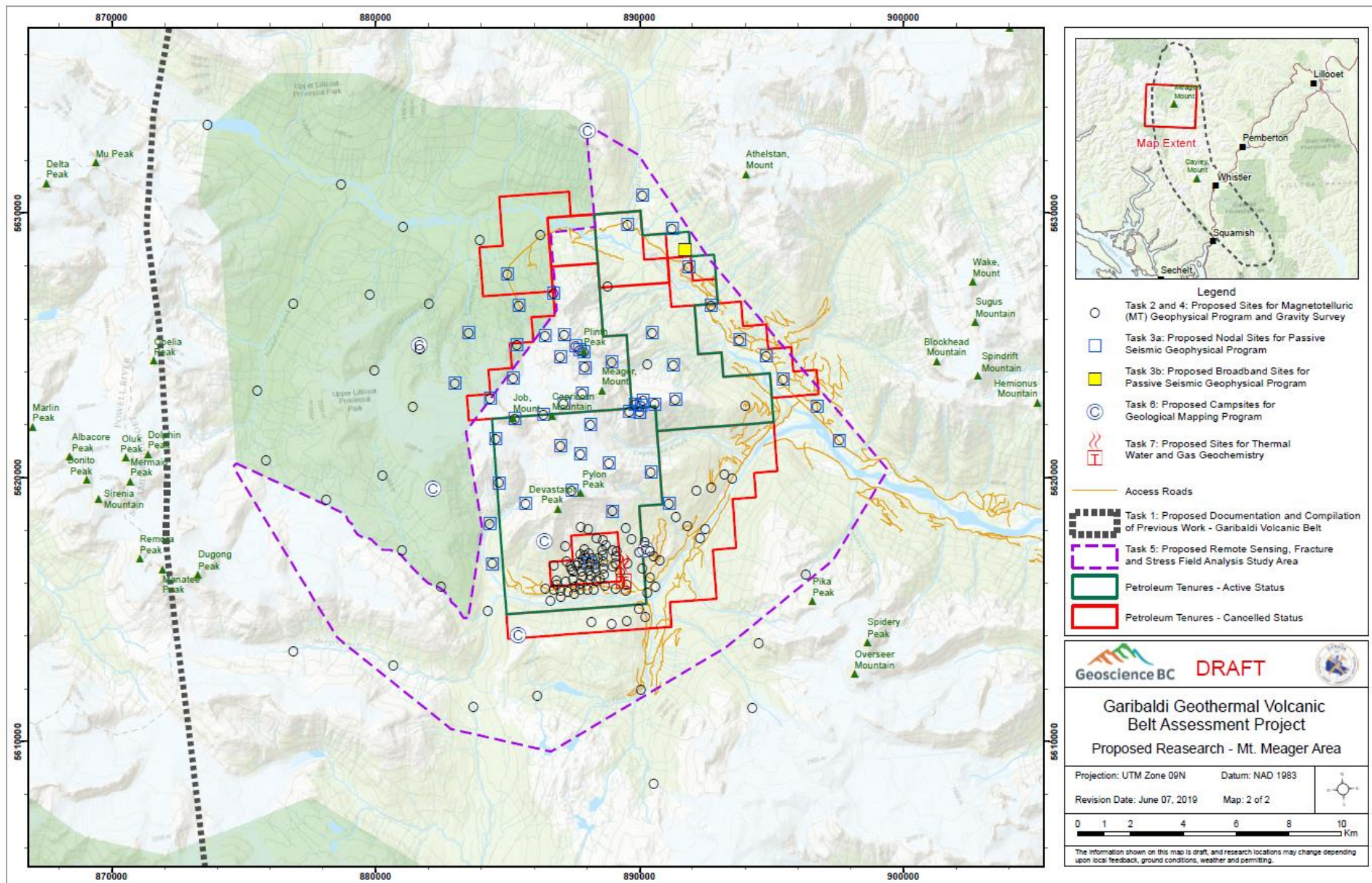
- regional thermal properties/volcanic history

Resource Production

- deep fluid flow

Resource Assessment Methodology

- sustainable development/environmental protection



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



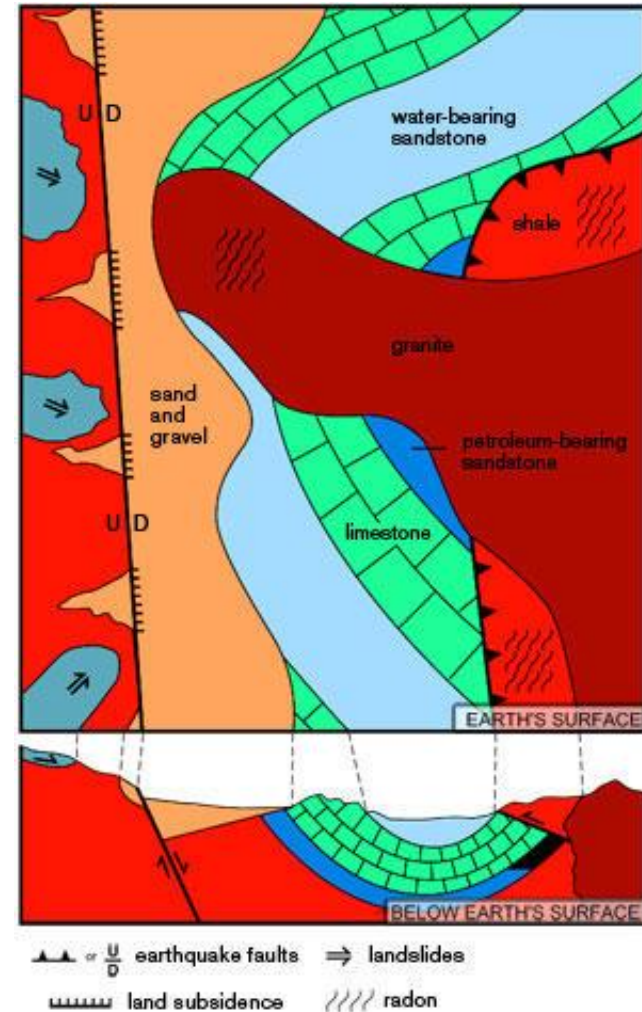
Natural Resources
Canada

Ressources naturelles
Canada

Canada

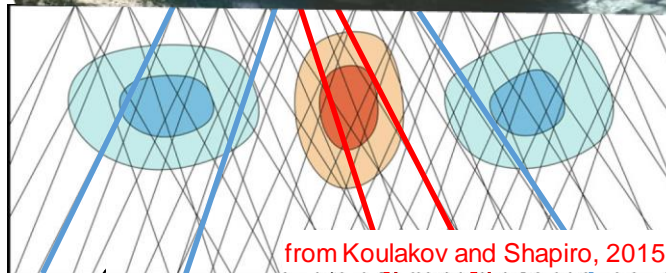
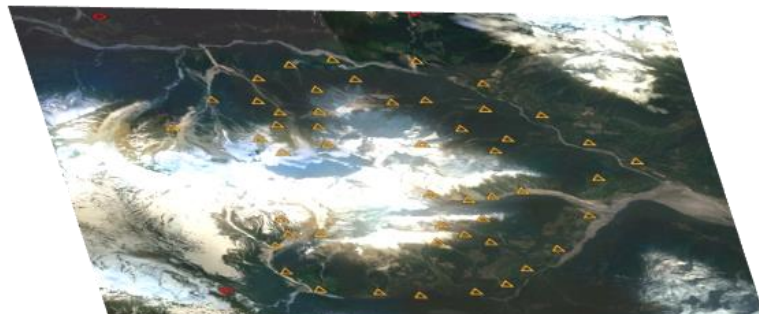
Geological mapping

- Mapping surface Geology such as rock type, faults and folds provide us knowledge and history of former events such as
 - Location and time of previous Volcanoes
 - Location and time of previous Earthquakes
 - Location and time of previous Landslides
 - Clues to the subsurface

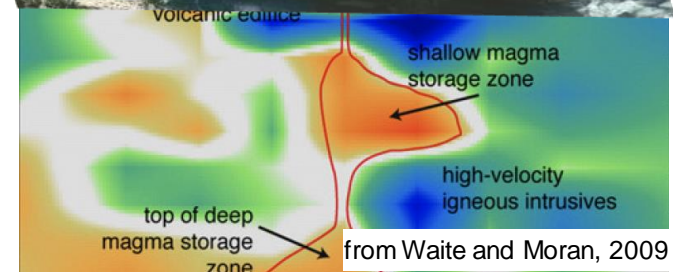
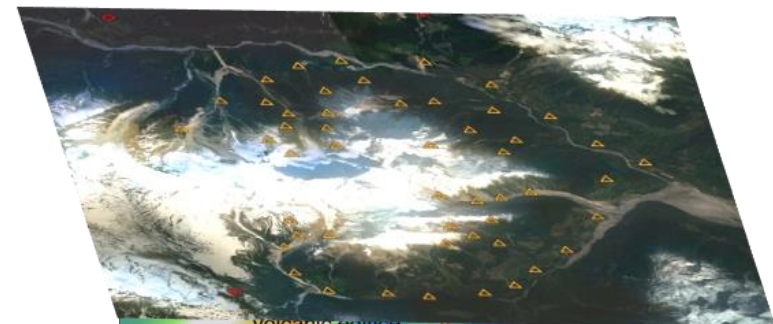
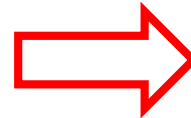


Passive Seismic

Scan deep inside of Mt. Meager using earthquake waves



measure **high** and **low** speed
earthquake waves traveling through
zones of **cold** and **warm** rocks



Find **magma** chambers or other
sources of

Magnetotellurics (aka 'MT'): Survey

Magnetic and electric field variations naturally arise from the impact of solar wind and distant thunderstorms on the Earth's magnetic field.



Measuring these natural variations involves digging shallow holes to bury magnetic field sensors and electrodes. and refill all holes.

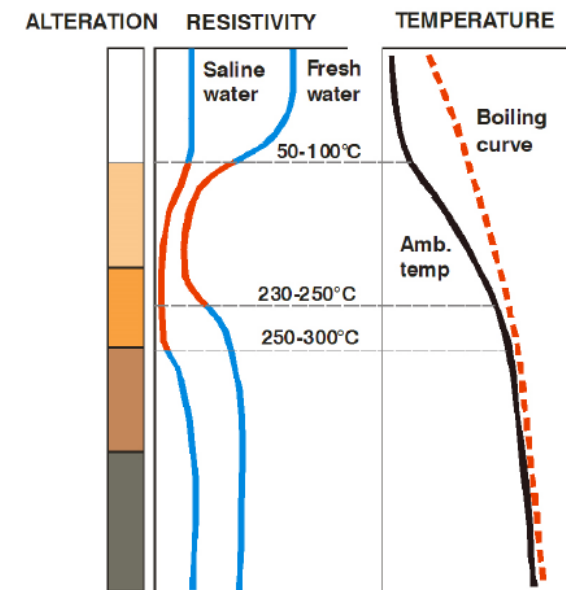
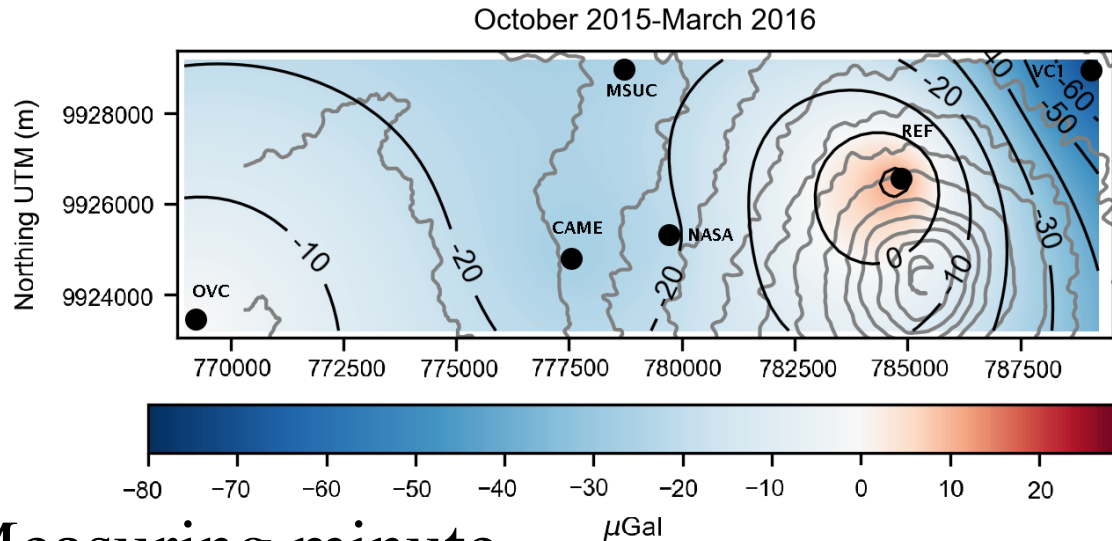
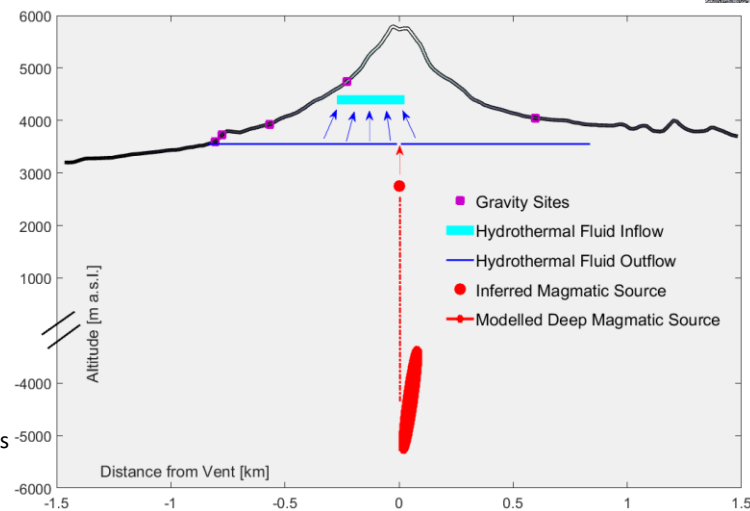


FIGURE 3: Resistivity of rocks and its as and temperature (Árnason et

Gravity survey



- Measuring minute changes in gravity at different locations.
- Provides image of subsurface bodies



Increasing our understanding of volcanic hosted geothermal systems – from this....



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



Natural Resources
Canada

Ressources naturelles
Canada

Canada

To this...

