



Investigating the geothermal potential of northern mines and communities

Kuujuaq Mining Workshop

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Institut nordique
du Québec
Ensemble pour le Nord

INRS
UNIVERSITÉ DE RECHERCHE

Energy production and utilization in the North, Province of Québec

Communities

- Electricity supplied by Hydro-Québec with local grids feed by diesel generators
- Heat produced individually with fossil fuel furnaces

Mines

- Electricity produced independently with diesel generators
- Heat produced with fossil fuels and/or recovered from generators



Energy cost in northern Québec

Hydro-Québec local grids over the Plan Nord territory

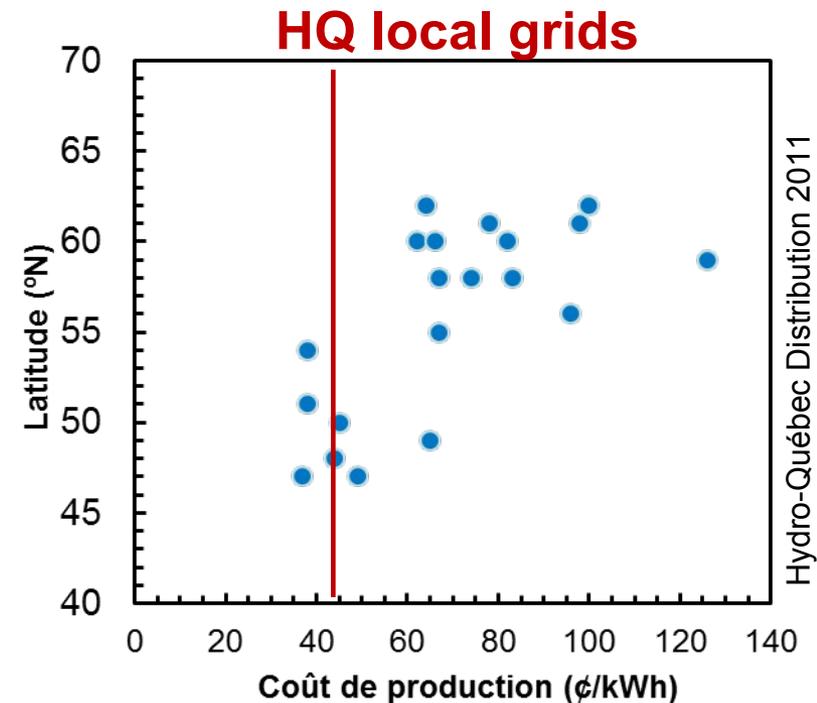
- 21 diesel generators
- 52.4 MW power
- 0.43 \$/kWh and more

Arctic diesel for space heating

- 1 to 2 \$/L
- Furnace efficiency ~80%
- 0.16 \$/kWh thermal for diesel at 1.4 \$/L

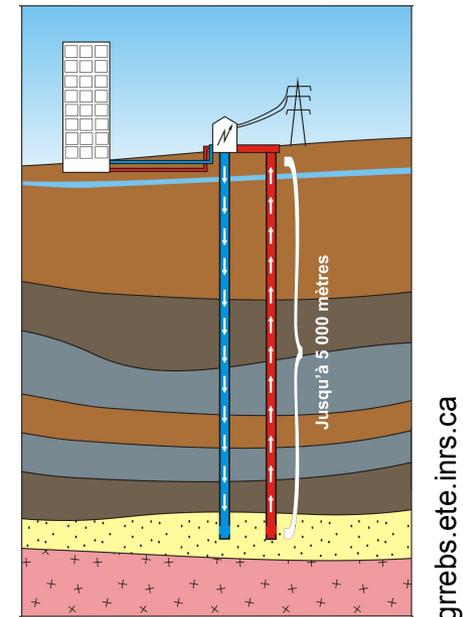
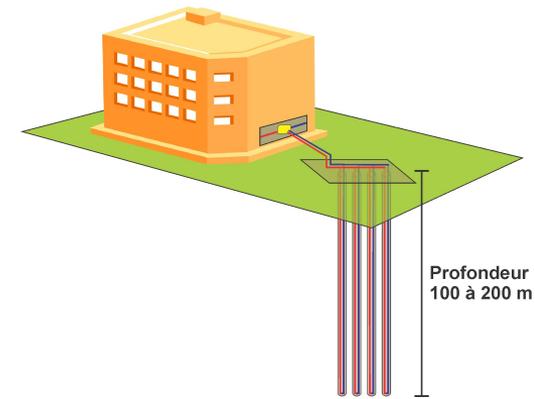


aptnnews.ca



Geothermal energy, a local solution for heat production in North?

- **Thermal energy** sustainably extracted from the Earth
- **Low Carbon** emissions
- **Shallow resources** - short-term solution
 - Reduce energy consumption (~50 %)
 - 100-200 m deep boreholes
 - Low temperature <math>< 0\text{ }^{\circ}\text{C}</math> (possible operation in permafrost)
 - Gas and electric heat pumps (HP) available
- **Deep resources** - medium-term solution
 - Direct utilization of hot aquifers >math>60\text{ }^{\circ}\text{C}</math>
 - 2-5 km deep boreholes
 - Power plants and district systems

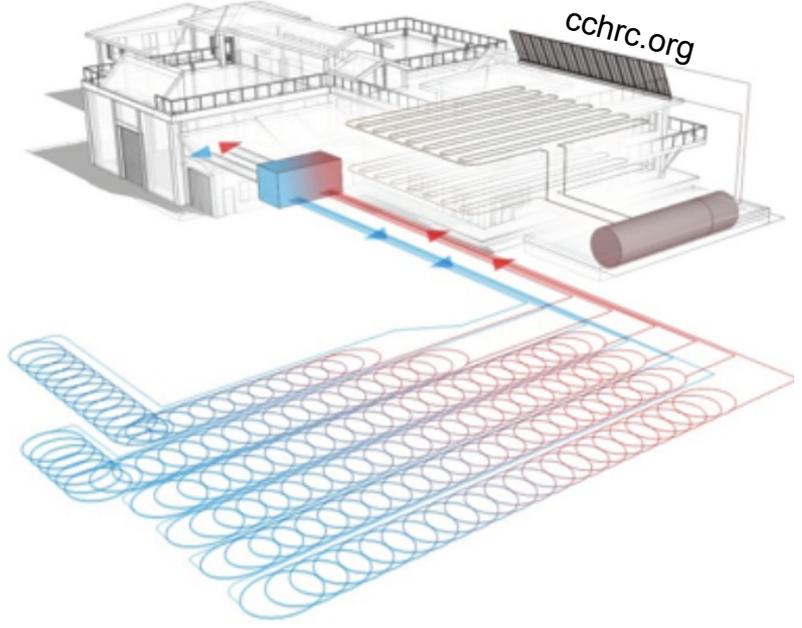


Geothermal systems examples in northern environments

rockenergy.no



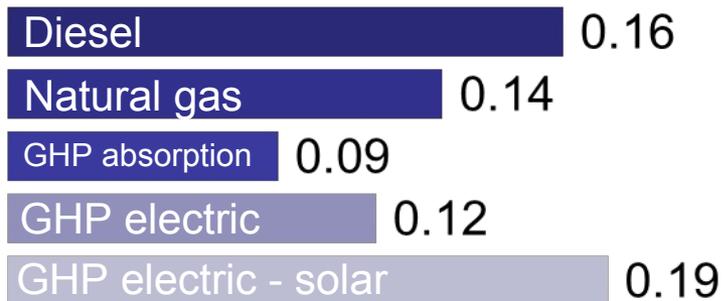
5000 m wells, Rock Energy, Oslo - Norway



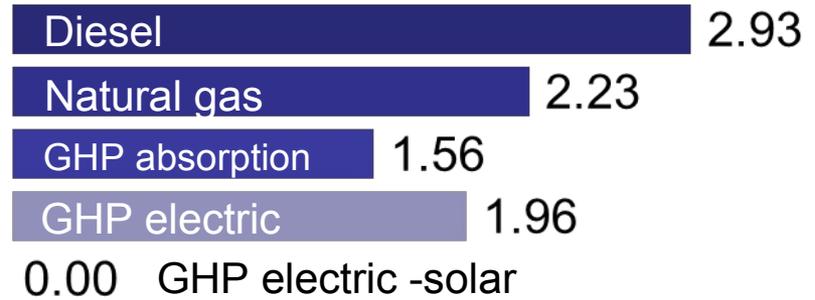
Cold Climate Housing Research Center, Fairbanks - Alaska

Cost and impact of heat production in the north

Cost of heat production (\$/KWh)



GHG emissions (tCO2/10 MWh)



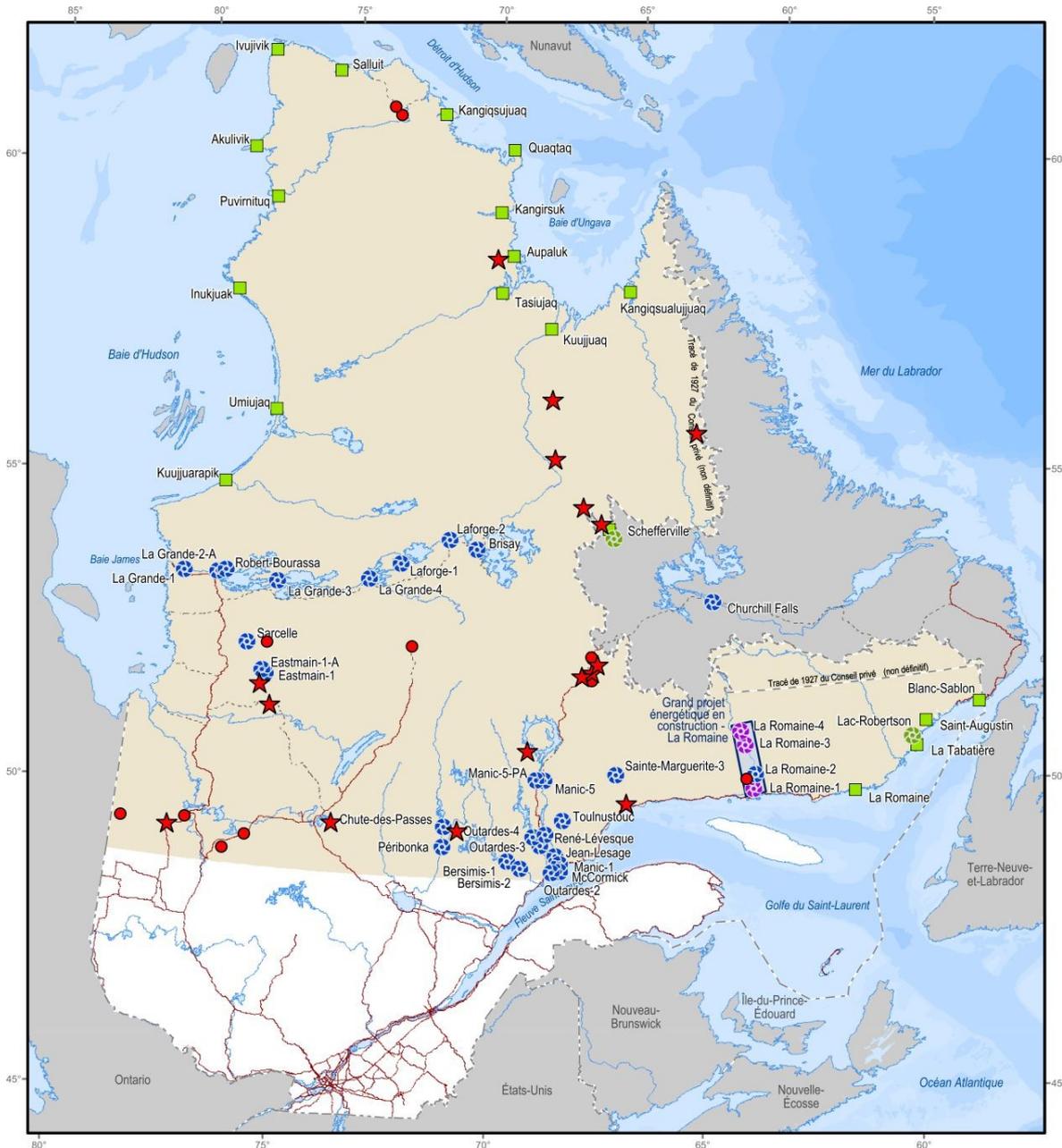
Hypothesis - cost

- Diesel 1.4 \$/L
- Natural gas 1.2 \$/m³
- Electricity
 - 0.43 \$/kWh (diesel)
 - 0.70 \$/kWh (solar PV)

Coefficient of performance

- Diesel furnace 0.8
- Natural gas furnace 0.8
- GHP absorption 1.5
- GHP electric 3.5

Electricity generation in Northern Quebec



Active mines



Mining projects



Area covered by the Plan Nord



Independent power stations



Hydroelectric



Thermal (diesel)

Hydroelectric stations of 50 MW or more



In operation



Under construction

0 200 km



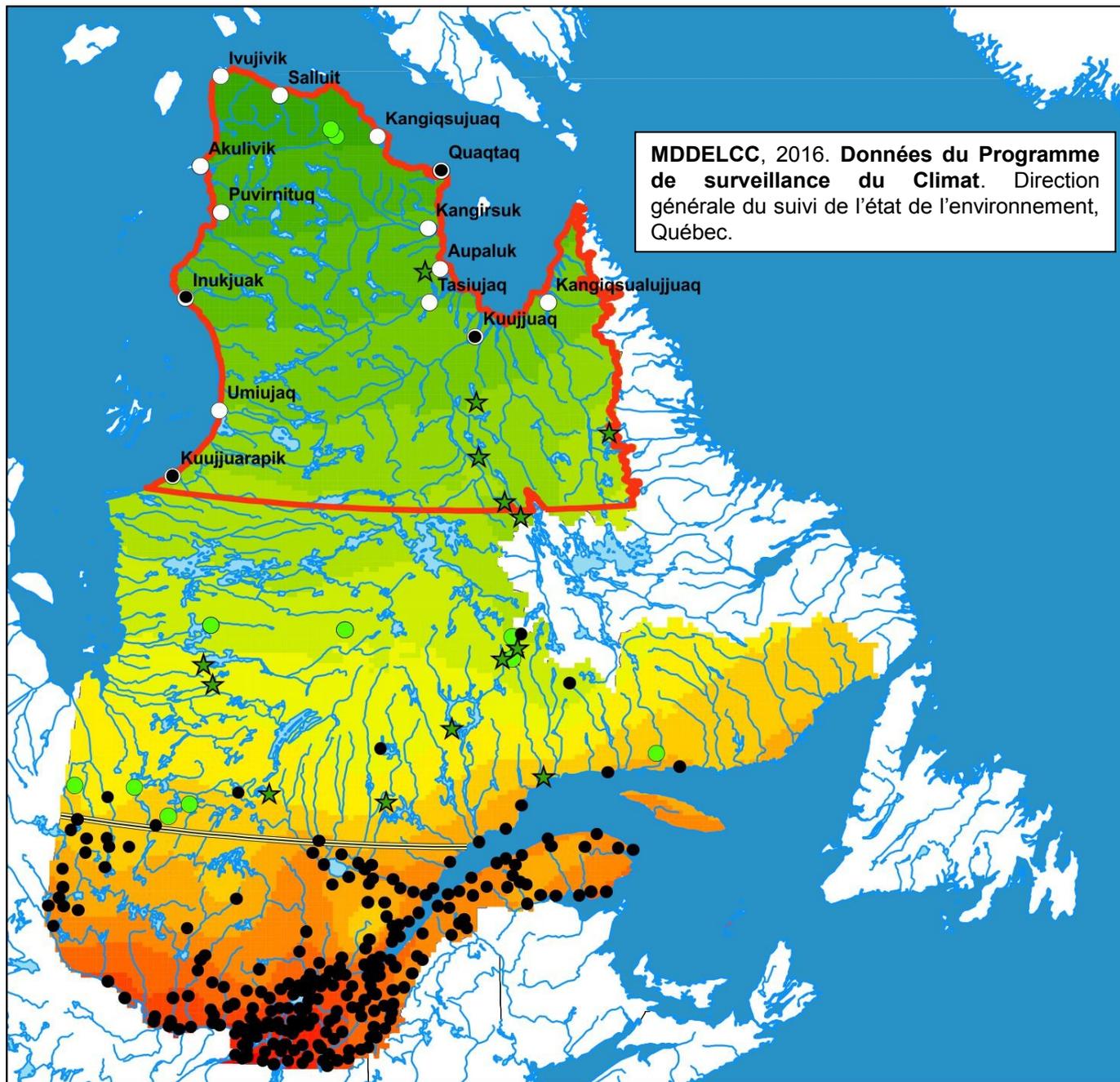
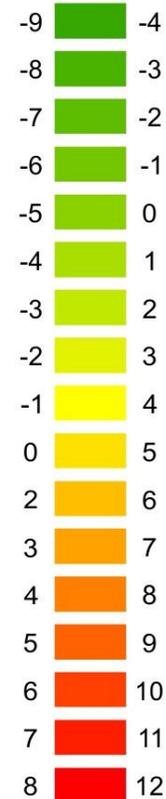
Weather

- Northern villages
- Active mines
- ★ Mining projects
- Weather stations
- 49th parallel North
- Limits of the territory of Nunavik

MDDELCC, 2016. Données du Programme de surveillance du Climat. Direction générale du suivi de l'état de l'environnement, Québec.

Annual mean Undisturbed ground

Temperature (°C)



Permafrost

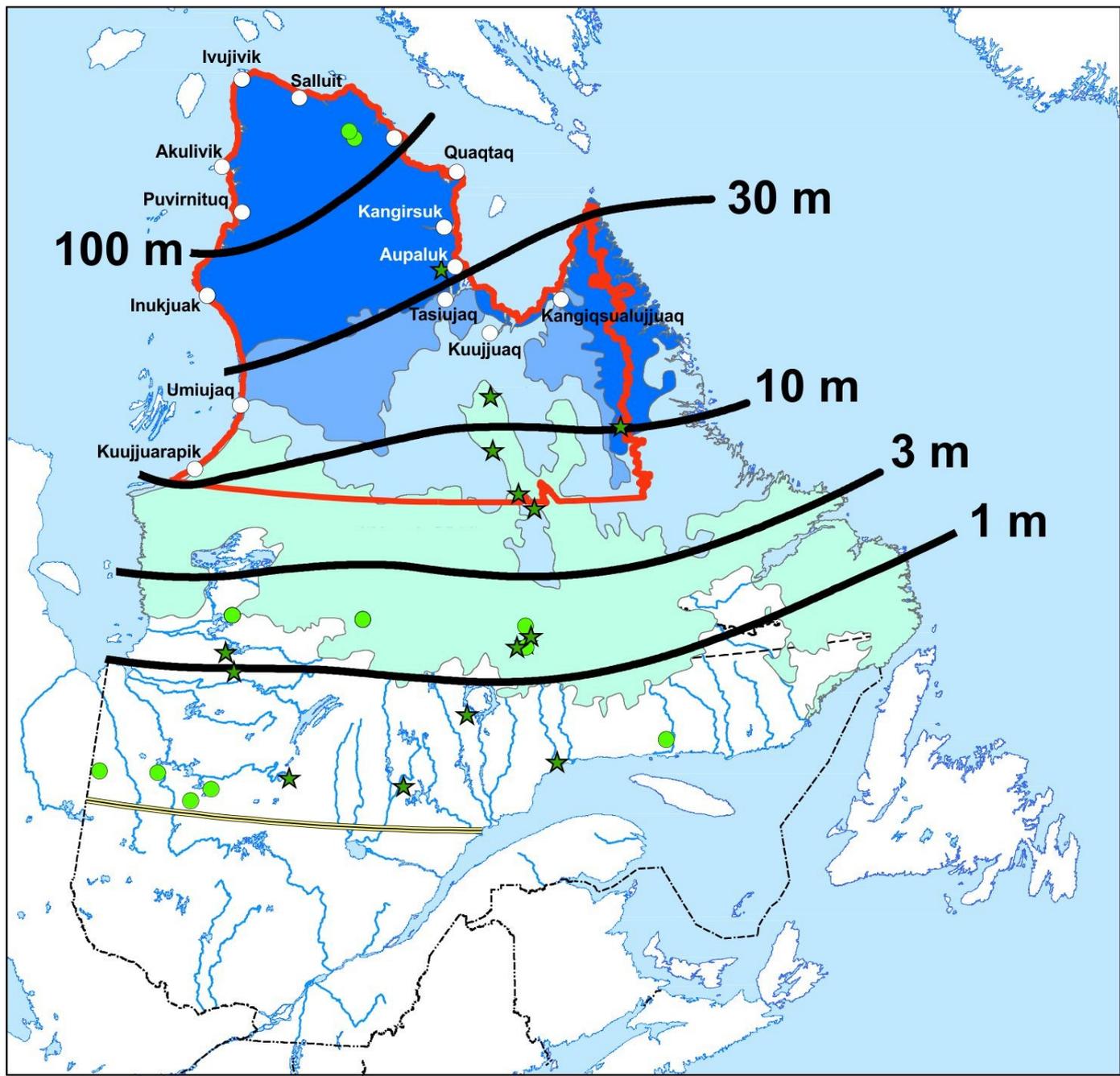
Legend

- Northern villages
- Active mines
- ★ Mining projects
- 49th parallel North
- Limits of the territory of Nunavik

Lemieux, J.-M., et al., 2016. Groundwater occurrence in cold environments: examples from Nunavik, Canada. Hydrogeology Journal, Volume 24, Issue 6, pp 1497–1513.

Permafrost zones

- Continuous
- Discontinuous, but widespread
- Discontinuous, but scattered
- Sporadic



Heat flow

Legend

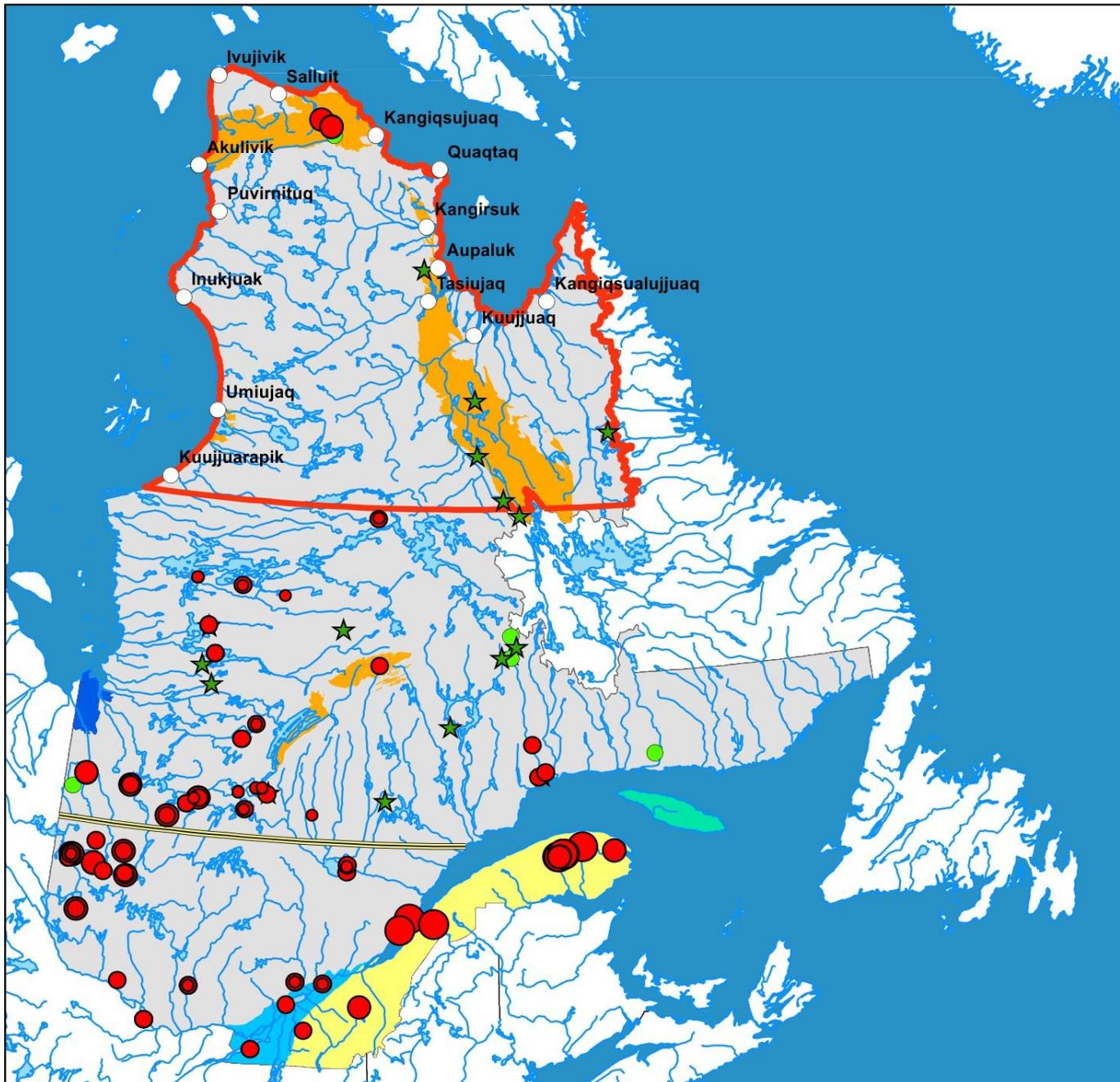
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Heat Flow (mW/m²)

- 15 - 25
- 26 - 35
- 36 - 45
- 46 - 55
- 56 - 338

Geology

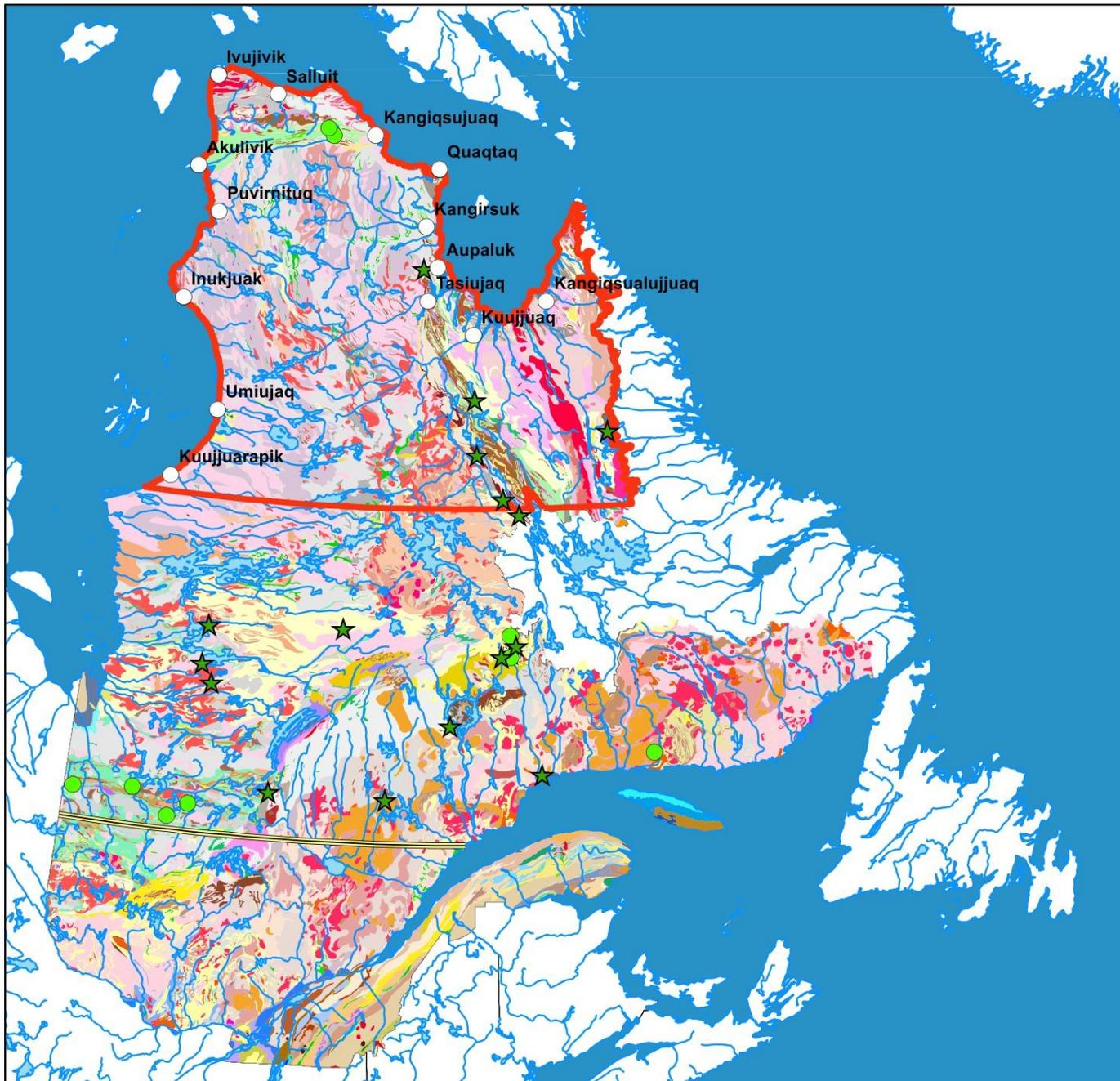
- Hudson Bay Platform
- Anticosti Platform
- St. Lawrence Lowlands Basin
- Appalachians Province
- Proterozoic sedimentary basins
- Canadian Shield



Geology

Legend

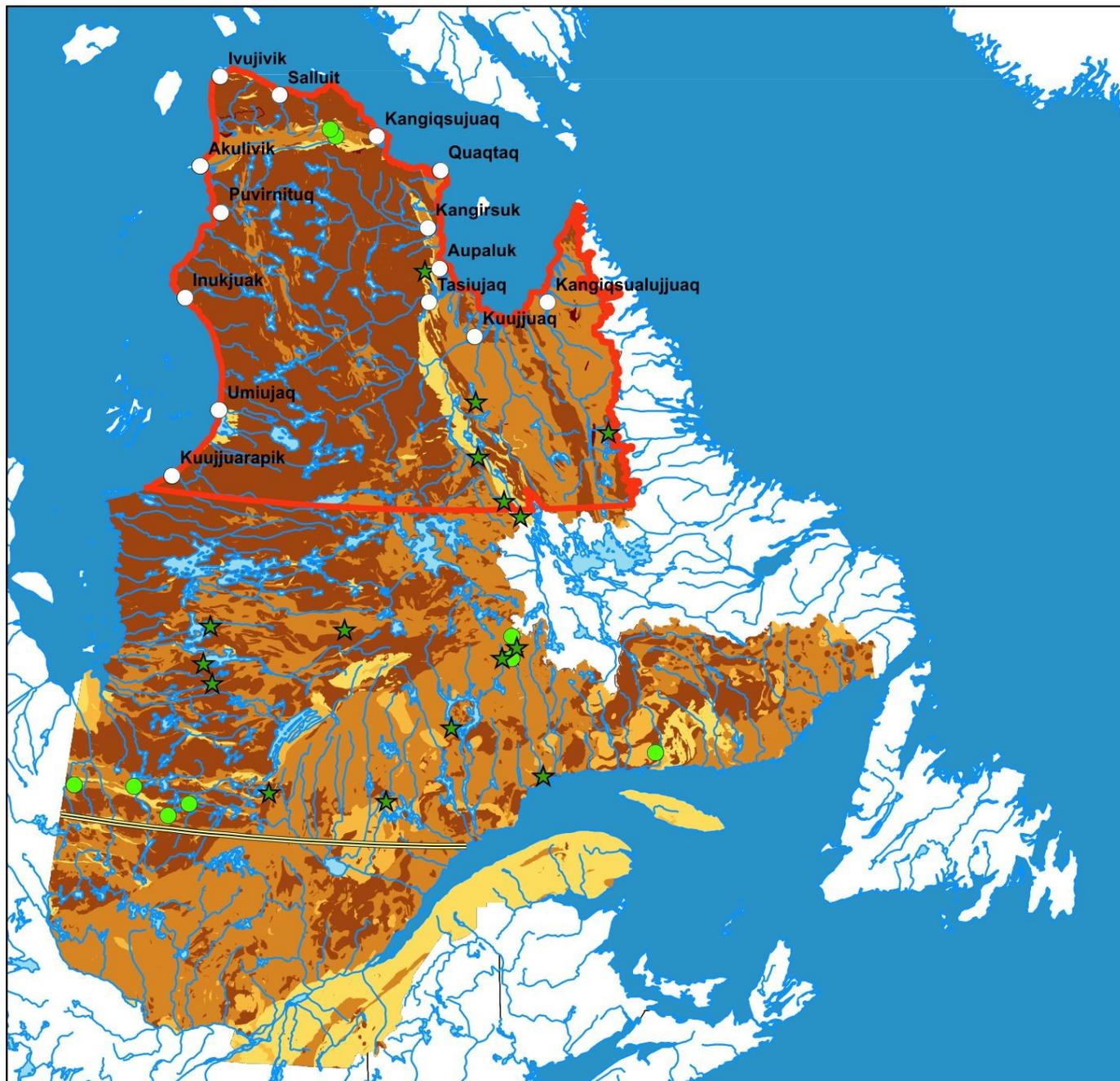
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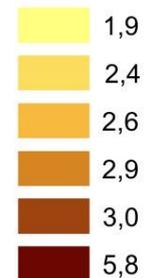
Conductivity

Legend

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Thermal conductivity (W/m·K)



Research to identify geothermal resources and adapt existing technologies to the North

Mines – FRQ-NT – 3 years

- Inventory of resources available at northern mine sites
- Case study at Éléonore to replace propane burners heating the underground mine



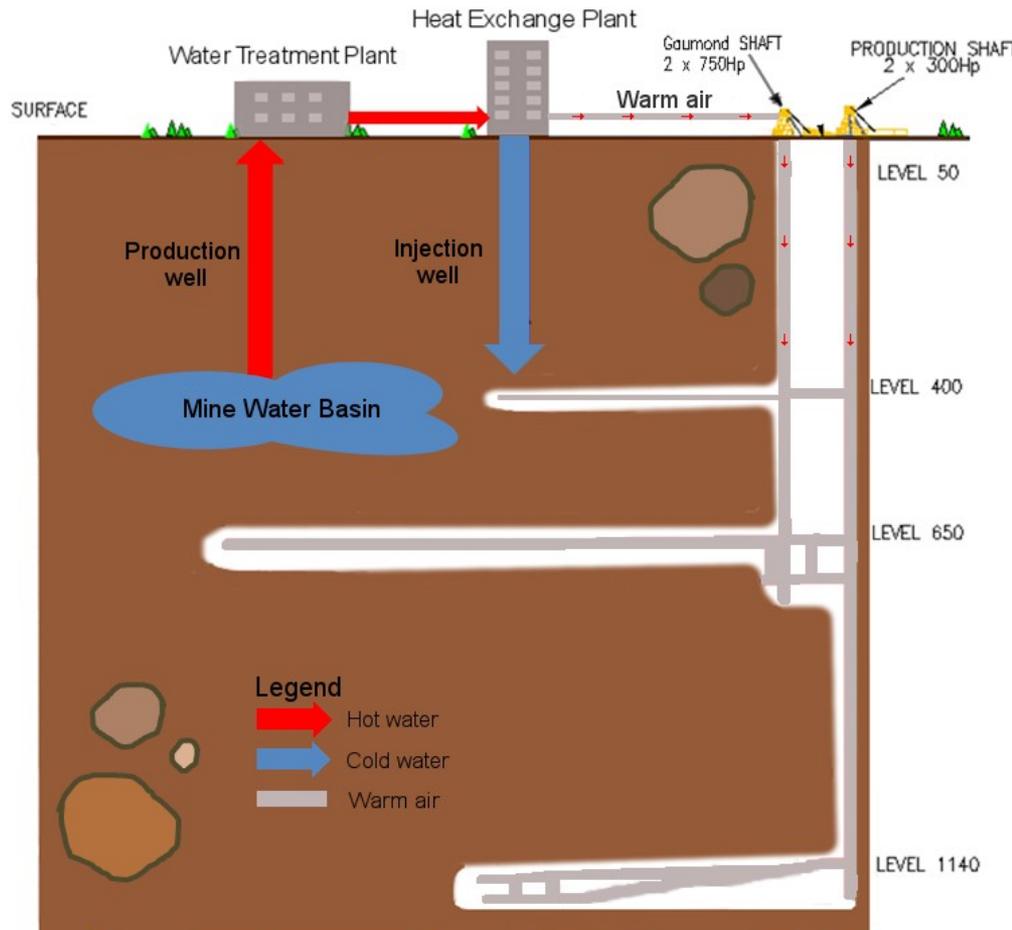
www.goldcorp.com

Communities – INQ – 3 years

- Adapt technologies to heat buildings, including greenhouses for northern agriculture
- Cases studies
 - Jamésie - Geothermal potential of flooded abandoned mines
 - Kuujuaq – Shallow and deep geothermal resources of the most important Inuit community in Québec

Dewatering geothermal potential to heat the Éléonore Mine

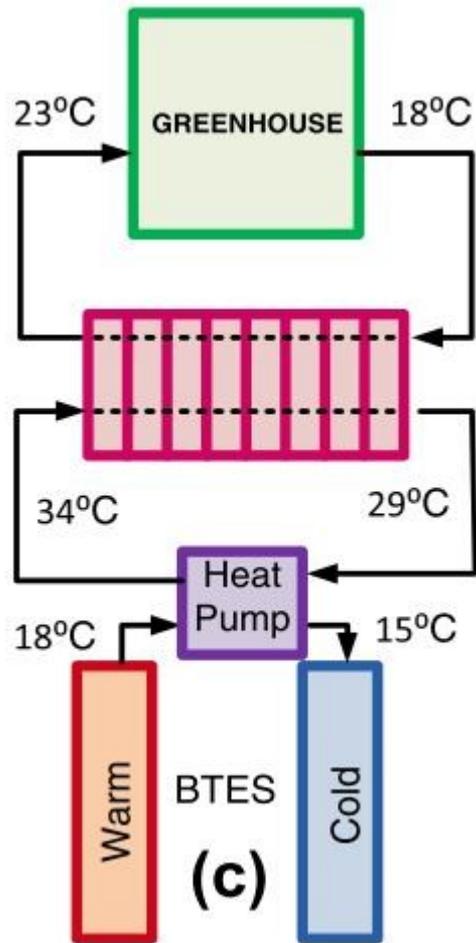
Objective: Evaluate the potential contribution of a geothermal heat pump system to the heating requirements of the mine



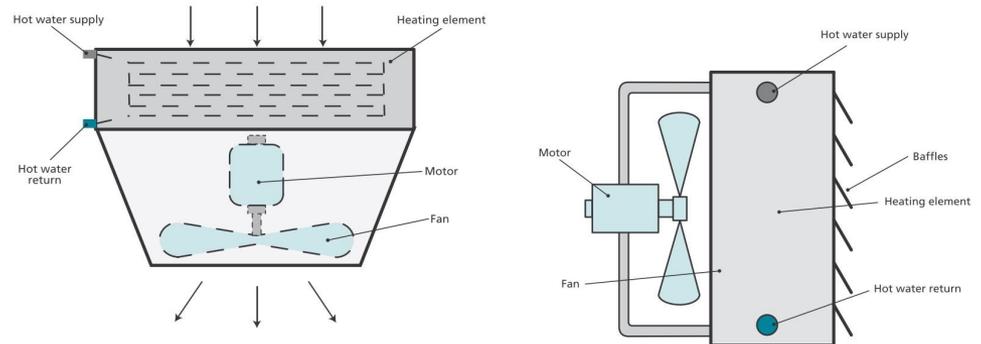
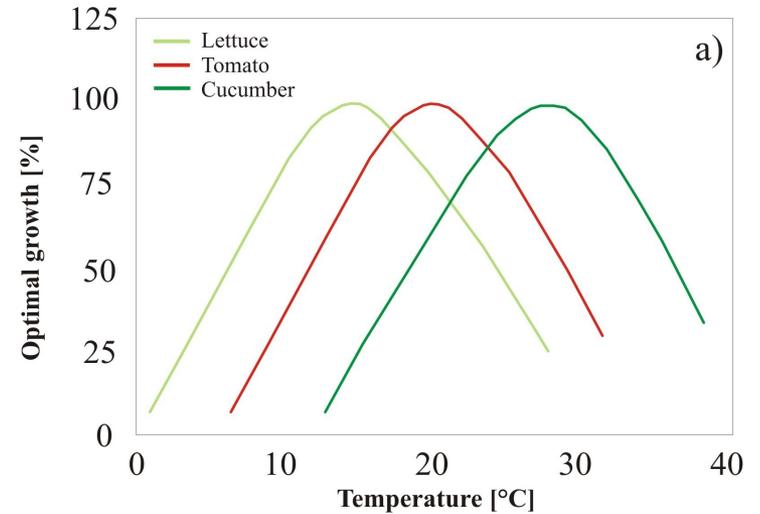
Method: energy balance calculation, design of a geothermal system using mine water, numerical modeling

Results: heating costs could be reduced by at least 20%

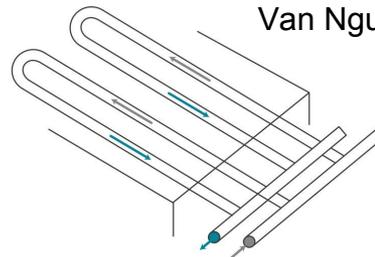
Northern greenhouse heating provided by underground thermal storage systems



Vadiee and Martine (2013)



Van Nguyen et al. (2015)



Training of highly qualified personnel to solve northern energy issues

- **Geothermal resources for mines of the Plan Nord**
 - Felix-Antoine Comeau (Research associate)
- **Geothermal potential of the Eleonore Mine**
 - Edgardo Alvarado (M.Sc. INRS)
- **Geothermal potential of flooded mines in Jamésie**
 - Andrea Morgan (M.Sc. Reykjavik University)
- **Geothermal heat pumps in Kuujjuaq**
 - Inès Kanzari (M.Sc. INRS)
- **Nunavik deep geothermal resources**
 - Mafalda Miranda (Ph.D. INRS)
- **Inventory of geothermal technologies for northern climate**
 - Patrick Belzile (Postdoc ÉTS)
- **Underground thermal storage and greenhouse**
 - Nicolás Giordano (Postdoc INRS)



lapresse.ca



Geothermal open lab (GOL)

CFI support – Leaders fund

- Development of a core lab
- Apparatus to measure thermal and hydraulic properties of rocks
 - Infrared scanner
 - Heat flux meter -10 to 100 °C
 - Porosimeter and permeameter 10 000 PSI





Research partnerships



Reykjavik – 8 octobre 2016