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Reliable Heat and Power from Low-Grade Geothermal Systems

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…and colleagues and students…

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The Four Geothermal Pillars

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1. **High-grade geothermal** where steam is generated to drive turbines: ~T>150°C
2. **Warm fluids** in porous and permeable strata: ~T = 70-150°C - **SedHeat**
3. **EGS** – Enhanced Geothermal Systems, warm, low permeability: ~T = 70-150°C
4. **Shallow, heat-pump based geothermal**, storage of heat in the upper ~500 m
   - ⇨ Below ~70°C – "district heating" or direct use of heat for drying, greenhouses, etc.

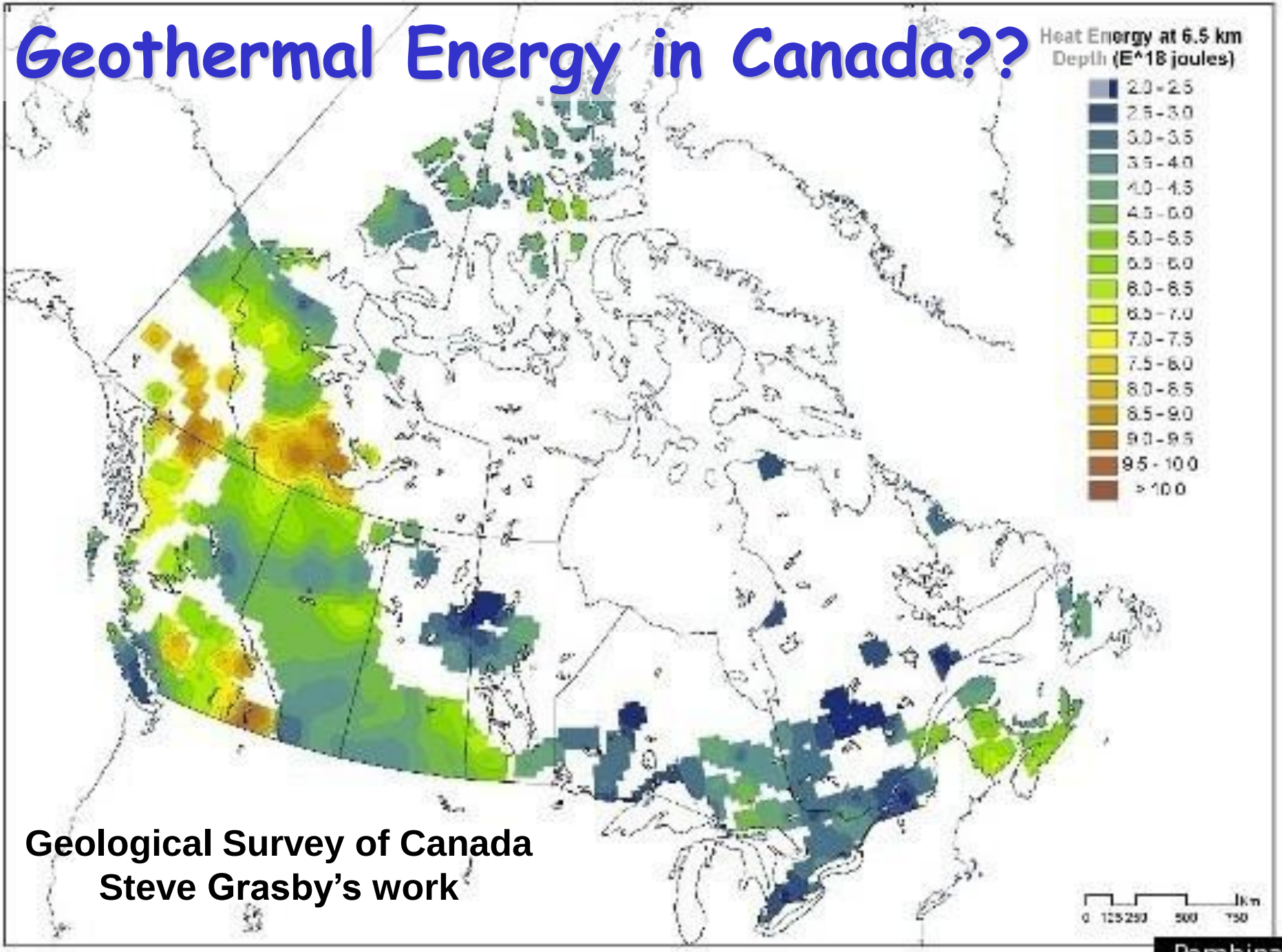
High-Grade Geothermal Energy

Hudson Ranch, Imperial valley, CA, USA

Some Facts…

- Canada is cold! Even at 4-5 km depth.
- Currently – heat = diesel, CH_4, power…
  - ⇨ But even power is largely fossil-fuel based
- Ground-source heat pump geothermal cannot mine ground heat effectively
- We must replenish and store heat
- …or, just burn more diesel, with GHG, fragile supply lines, massive subsidies…

Geothermal Energy in Canada??



Geological Survey of Canada
Steve Grasby's work

EGS and GSHP

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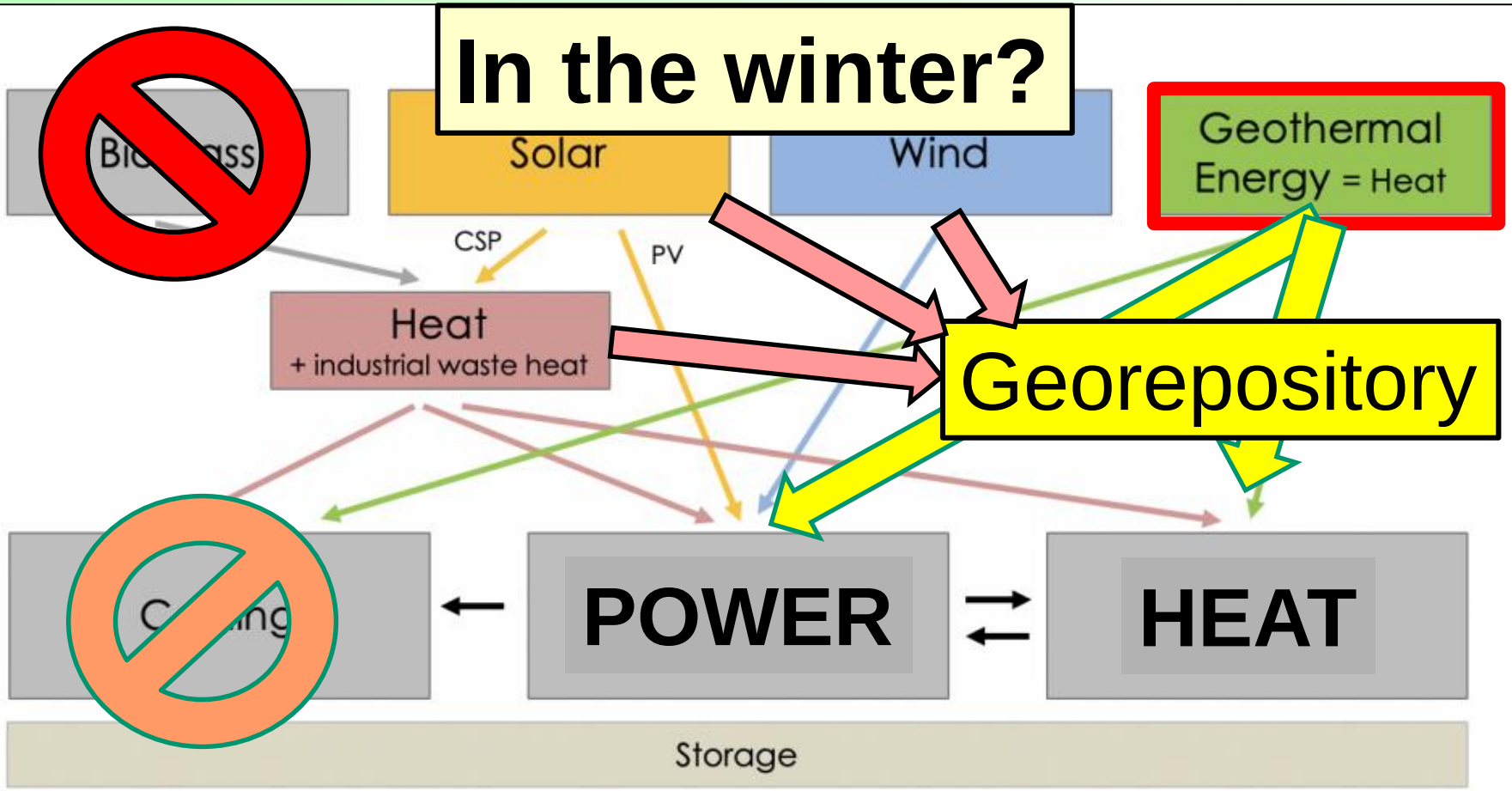
- **EGS** from deep, warm, dry rock
  - ⇨ Little to no permeability (i.e.: HF needed)
  - ⇨ Heat exchange to a circulating fluid needed
  - ⇨ At least two wellbores are needed
- **GSHP** – Ground-Source Heat Pumps
  - ⇨ Shallow heat exchange (5-1000 m deep)
  - ⇨ BUT! Ground cools as we extract heat in winter!
- Integrating EGS and GSHP
  - ⇨ EGS provides a bit of power, enough for habitats
  - ⇨ Heat also used, or stored in a georepository
  - ⇨ Waste heat, summer solar heat, etc. also stored

In Northern Canada Climates…

- Different sources of energy will be needed to achieve decarbonization.



Solar and Wind in the North?

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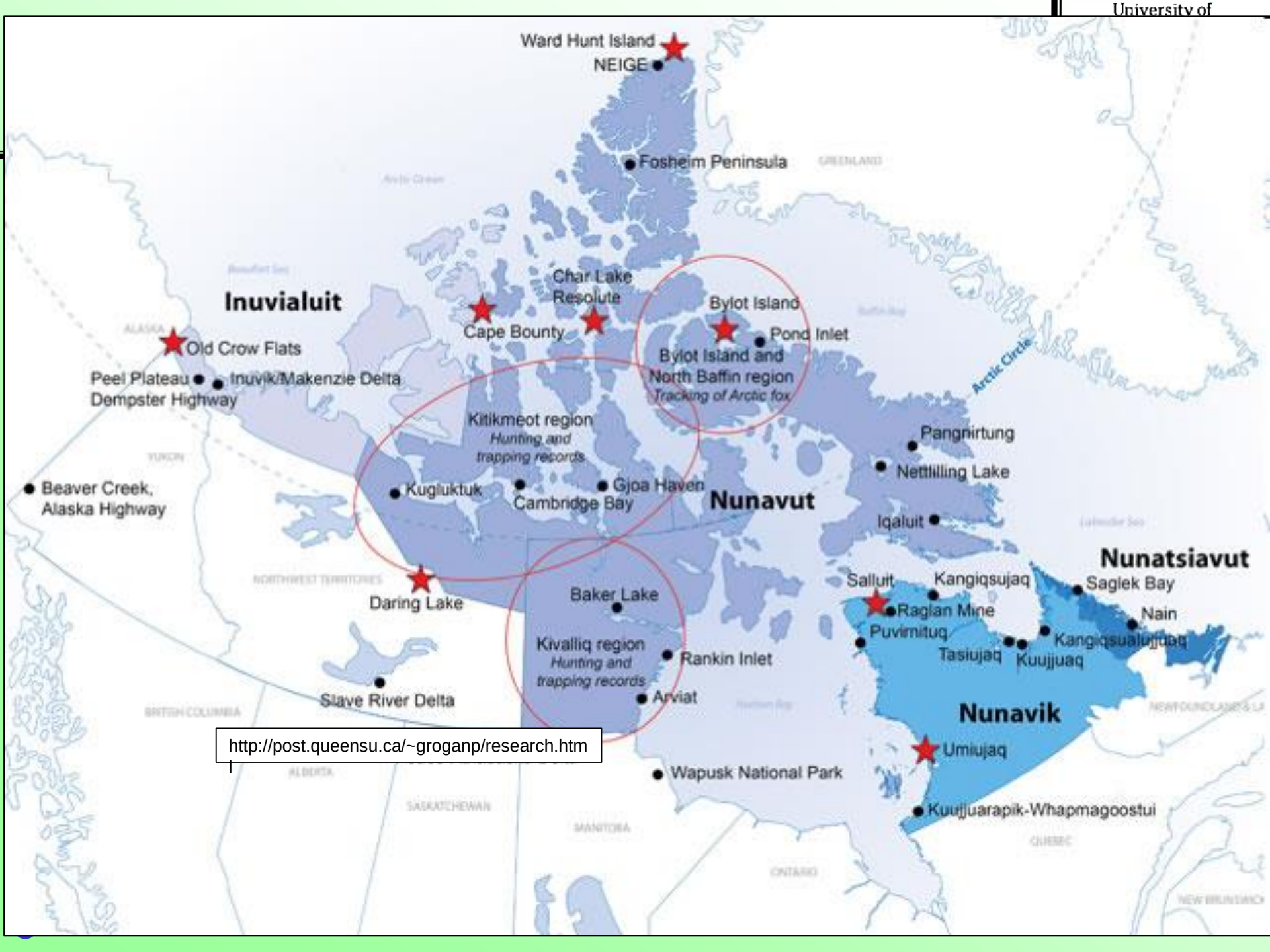
- No sun? No solar, little wind power…
- No chances for tidal or hydro power
- No biomass
- **What is left??**
- **Geothermal**
- Renewable energy source use depends on climate, population, purpose, etc.
- **AND ENERGY STORAGE IS VITAL**


Ward Hunt Island
NEIGE
Fosheim Peninsula
Char Lake
Resolute
Cape Bounty
Bylot Island
Pond Inlet
Bylot Island and
North Baffin region
Tracking of Arctic fox
Inuvialuit
Old Crow Flats
Peel Plateau
Inuvik/Makenzie Delta
Dempster Highway
Arctic Circle
Kitikmeot region
Hunting and
trapping records
Pangnirtung
Nettlilling Lake
Beaver Creek,
Alaska Highway
Kugluktuk
Cambridge Bay
Gjoa Haven
Nunavut
Iqaluit
Nunatsiavut
Salluit
Kangiqsujaq
Saglek Bay
Raglan Mine
Nain
Puvirnituq
Tasiujaq
Kuujjuaq
Kangiqsualujjuaq
Baker Lake
Daring Lake
Kivalliq region
Hunting and
trapping records
Rankin Inlet
Arviat
Slave River Delta
Nunavik
Umiujaq
Wapusk National Park
Kuujjuarapik-Whapmagoostui
http://post.queensu.ca/~groganp/research.htm

Recharging a Thermal Battery

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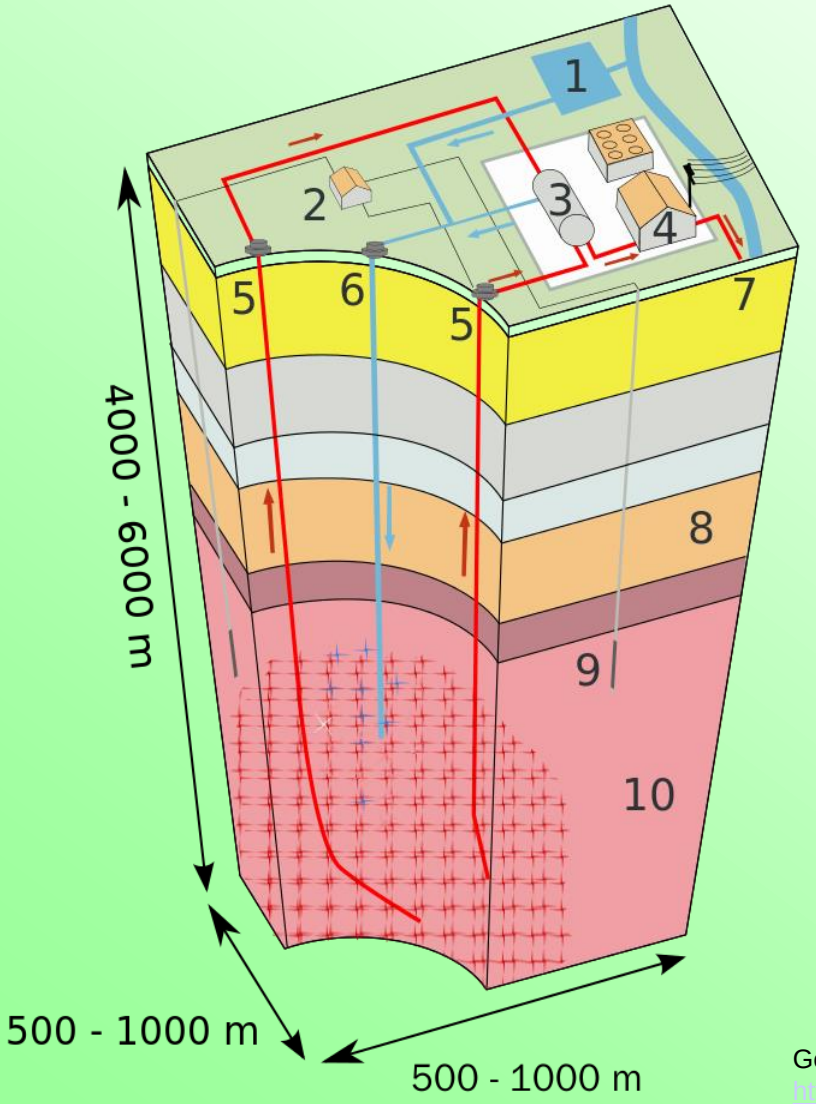
- Heating: 5× - 10× more heat needed in Northern climates than cooling!
- The ground will cool each season with GSHP shallow geothermal…
- …and efficiencies plummet.
- Solution: **Recharge** the Thermal Battery
- Recharging options…
  - ⇨ Waste heat
  - ⇨ Solar heat
  - ⇨ Deep geothermal heat (EGS)

EGS System Elements

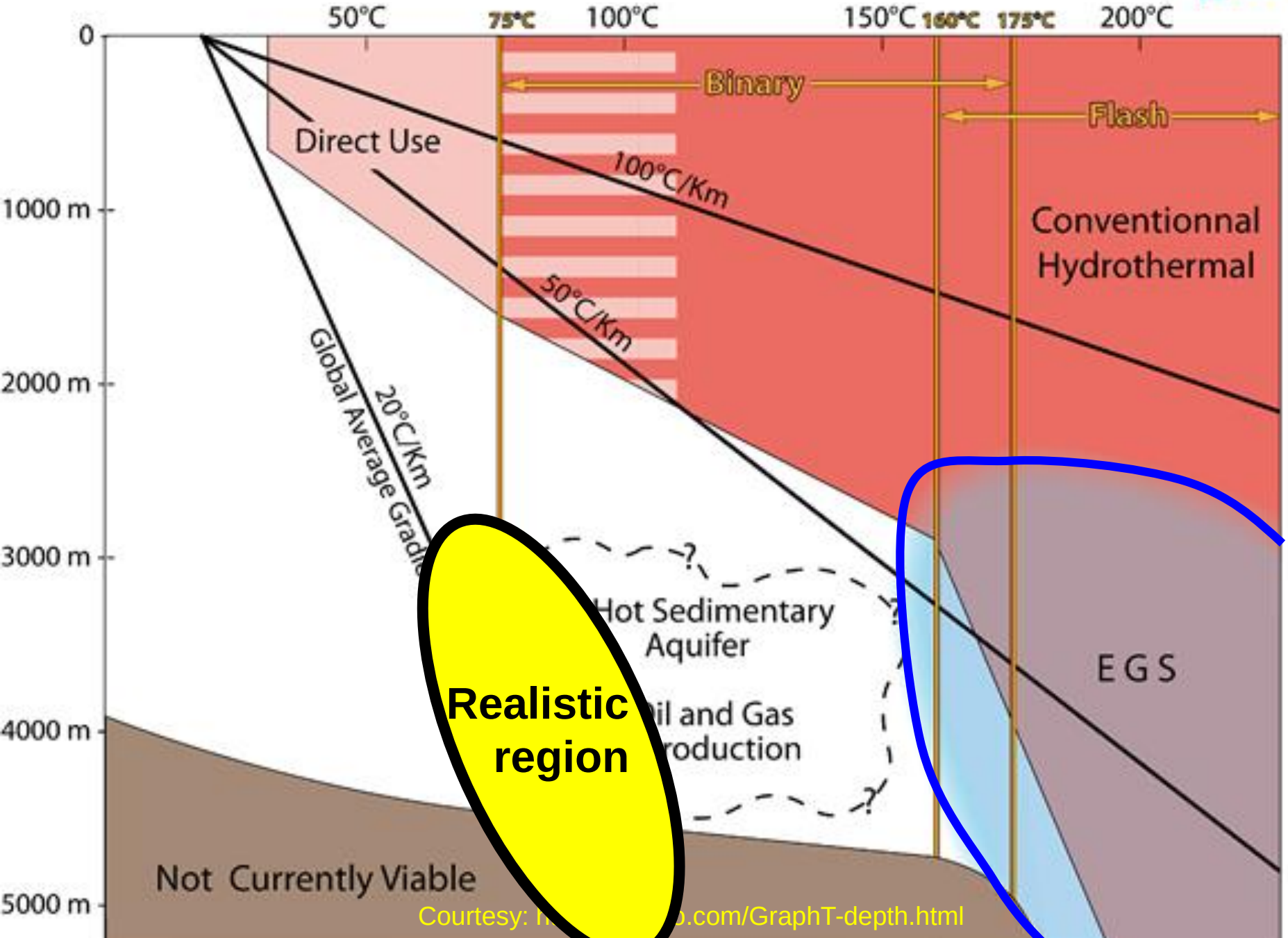


1 Water lagoon
2 Pump house
3 Heat exchanger
4 Turbine hall
5 Production well
6 Injection well
7 Hot H_2O district heating
8 Porous sediments
9 Observation well
10 Crystalline bedrock

Geothermie_Prinzip.svg: *Geothermie_Prinzip01.jpg: "Siemens Pressebild"
derivative

From Wikipedia

Z-T Plot for Geothermal Resources



Deep EGS in Cool, Low-k Rocks

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- The Major Issues…
  - **Cost of deep drilling** to 4-7 km
  - Hydrofrack **well stimulation** required
  - **Fluids** cannot be disposed in rivers, lakes
  - **Scaling** of pipes
  - **Large rock volume** to make it viable for >30 years
  - Must meet January needs **0.3-3 MW**/community ?

…and, we must design for the extremes in Dec - Feb

So Here is the Problem…

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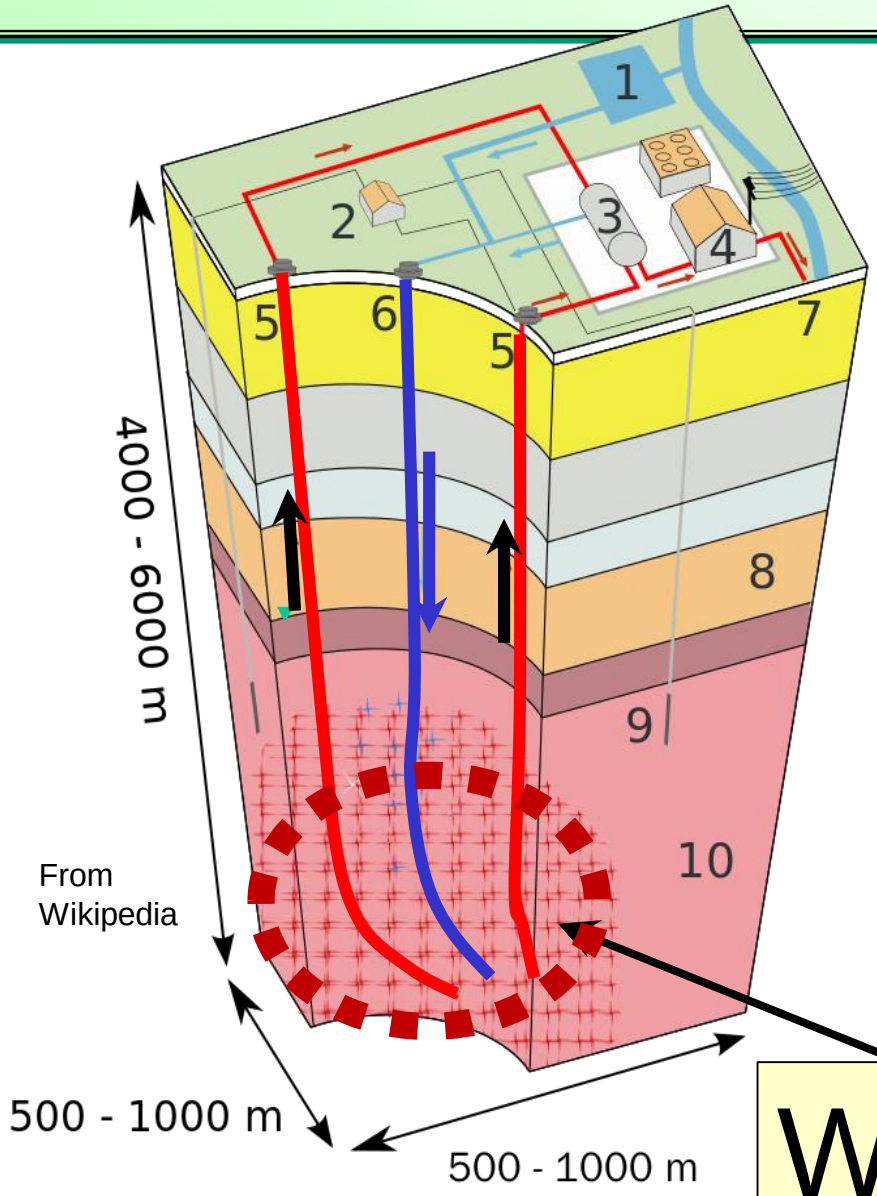
- Need a high enough T for co-generation – **power + heat**
- 3-4 km deep to get 60-70°C
- In GSHP ground cools so E degrades
- If Ground T is maintained annually – heat pumps have a COP of 3 to 4!!

Storing Heat Seasonally…



From Wikipedia

Deep rock volume source for some power and heat.

It also can serve as a heat repository, seasonally.

Or… shallower GSHP can be designed to store heat

What V is needed?

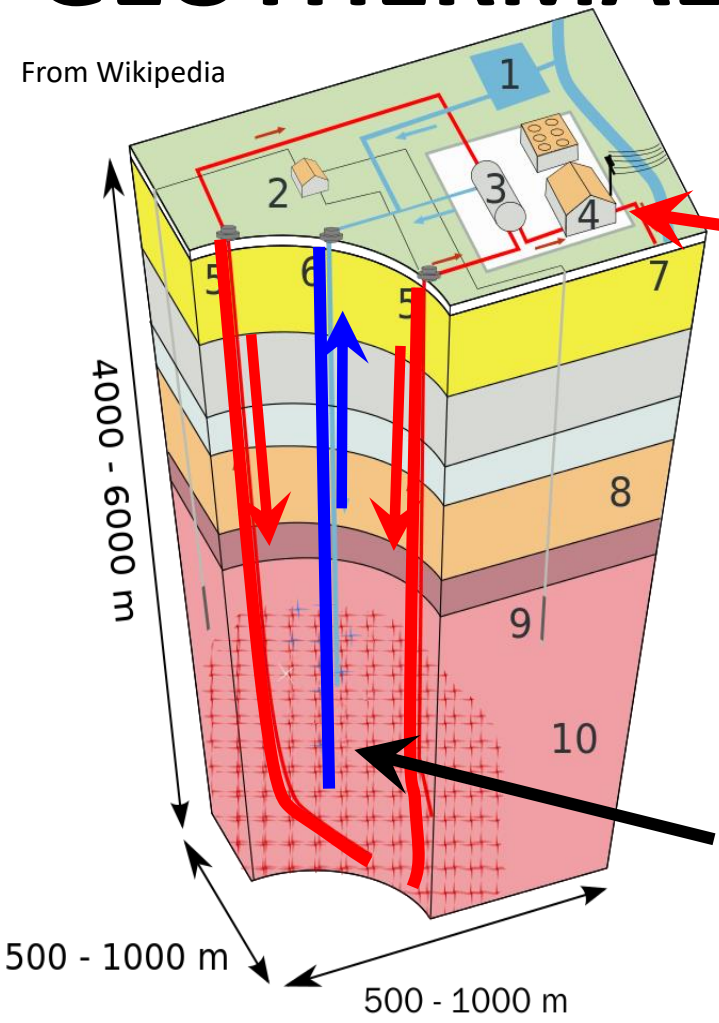
And some Additional Issues

- Energy remains cheap in Canada
- Communities in the North are small
- Distances are great, but…!
- The competition is diesel fuel, shipped in great distances
  - ⇨ Long supply lines
  - ⇨ Environmental, fire, risks… exist with diesel
  - ⇨ However, diesel is also greatly subsidized
- Can **hybrid & integrated** EGS and GSHP systems be competitive?

Deep Geothermal Heat Storage

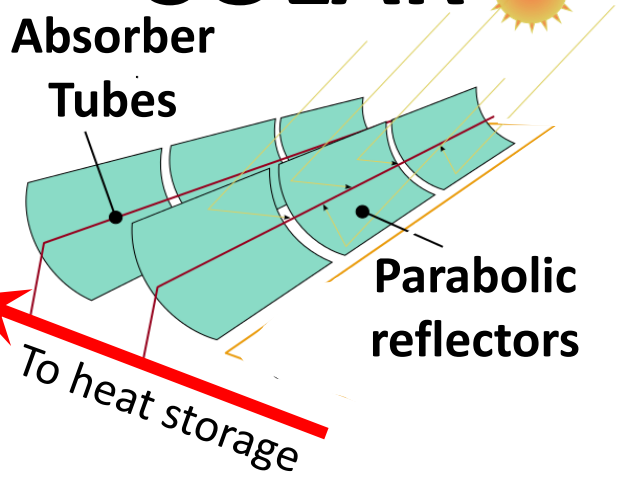
GEOTHERMAL

From Wikipedia

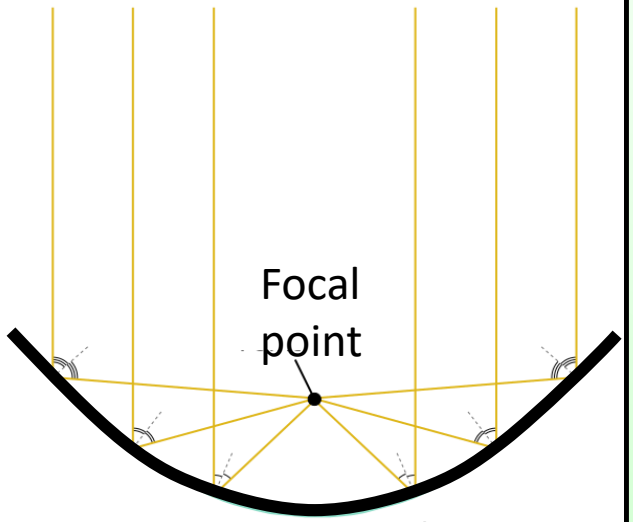


Deep reservoir 0.5 km³

SOLAR



https://upload.wikimedia.org/wikipedia/commons/b/b5/Parabolic_trough.svg



Geothermal Energy Systems

IIT-B

Canada North and Geothermal

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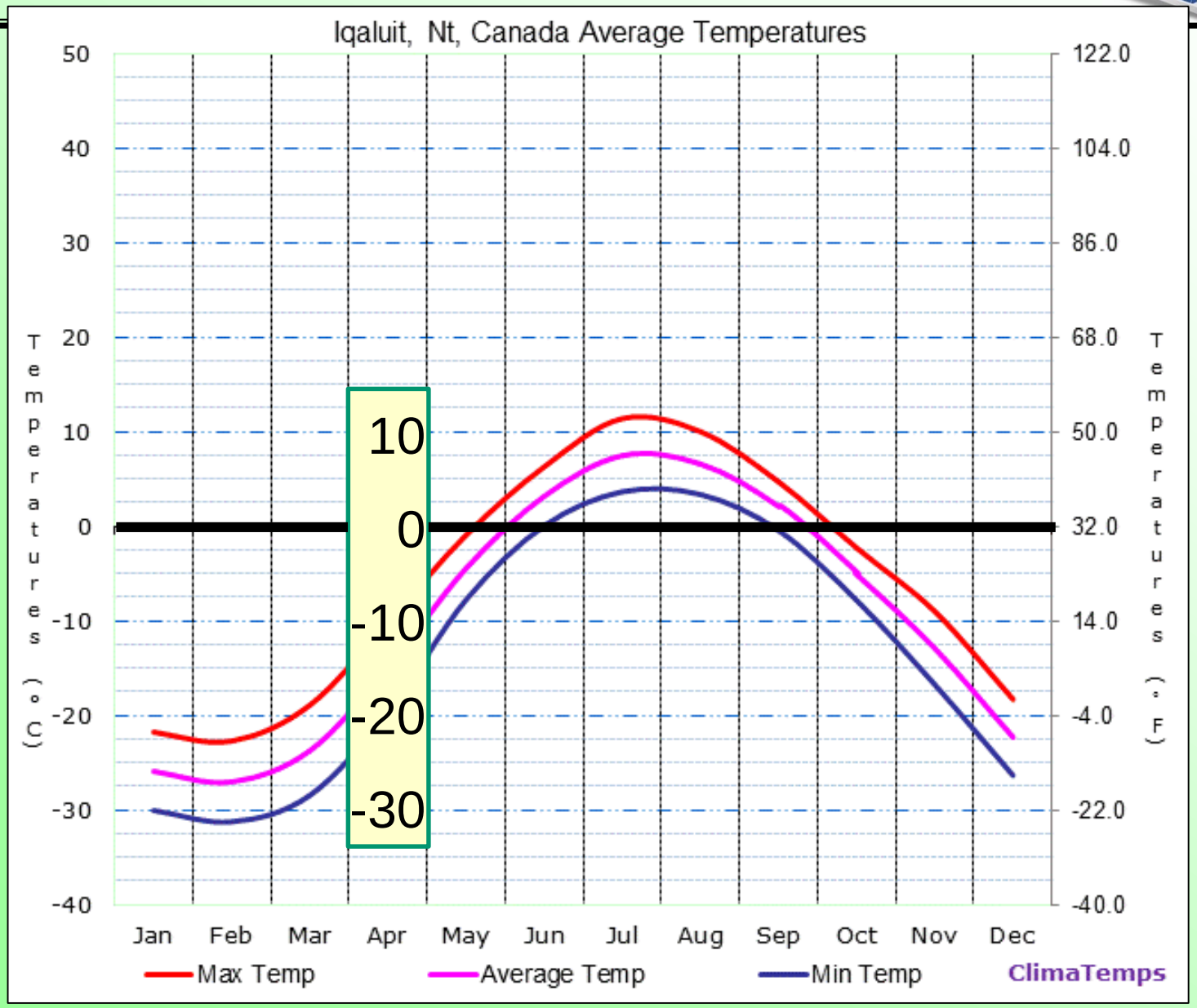
- Power, heat must meet WINTER needs)
- Geothermal use across Northern Canada means T(liquids) < 70-80°C
- Can we generate some power?…

Rankine Cycle engines for electricity

Direct heat use for buildings and homes

Iqaluit NV Annual Temperature



Geothermal Energy Systems

Rankine Cycle Use

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- Rankine cycle use depends on
- T of fluids
- Ambient T
- Cycle ΔT
- Liquid rate

Site	Yellowknife	Estevan SK
Fluid T	70°C	115°C
Ambient T	-20°C (winter)	+20°C (summer)
Efflux T	20°C	65°C
Delta-T	**50°C**	**50°C**

- Rankine cycle efficiency is OK at low T!
- Low-T condensing fluid needed
- Efflux has a reasonable T
- We can **recharge the thermal battery** and also generate EGS power in winter!

Environmental Rock Mechanics

Thanks to WISE for the Workshop