Low Enthalpy Geothermal Energy from Mine Water & Sea Water

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- Low-enthalpy thermal
- Why do we need low-enthalpy thermal?
- Springhill – from coal mining town to geothermal pioneers
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- Key takeaways

Low-Enthalpy Thermal

Geothermal Enthalpies

- Geothermal energy systems can be classified into high, medium, or low enthalpy resources
- **HIGH ENTHALPY** – high pressure, & temperature above 150°C
  - Commonly used for electric power generation
- **MEDIUM ENTHALPY** – temperature between 100-150°C
- **LOW ENTHALPY** – temperature below 100°C
  - Most abundant systems, located at shallower depths <400m, with great potential to develop direct-use technology

Distribution of Geothermal Potential in Canada

High Temperature Electrical Generation

- Hot dry rock
- Hot water - volcanic
- Hot sedimentary basins

Low Efficiency Electrical

- Warm sedimentary basins

Direct Heat/Heat Exchange

- Moderate sedimentary basins
- Cool sedimentary basins
- Fractured rock
- Low potential/future EGS

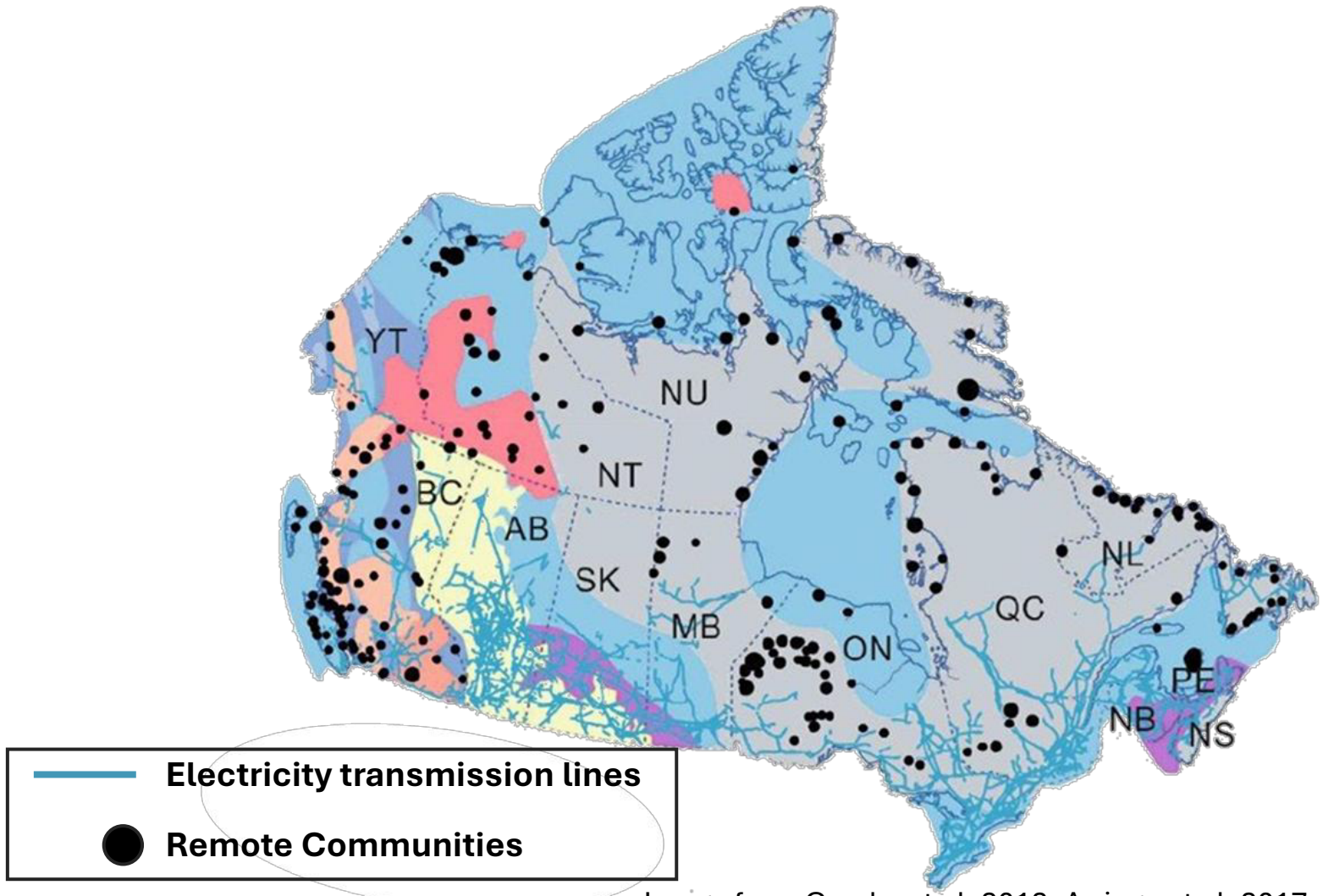


Image from Grasby et al. 2012; Arriaga et al. 2017

Springhill – Coal Mining

Humble Beginnings

Nova Scotian Coal

- Commercial coal mining in Nova Scotia began in Cape Breton in 1720, with evidence of mining dating back to the 1690s
- With over 400 million tonnes of coal mined since then, coal was a significant contribution to the socio-economic development of the province
- Coal was mined from three areas: Cumberland & Pictou counties, & Cape Breton

Image from NS Archives

History of Springhill

- The town of Springhill, in Cumberland County, played a key role in the golden age of NS coal mining & industrialization, fueling railways and manufacturing from the 1870s to 1940s
  - Abraham Gesner was the first to record coal in Springhill in the 1830s
    - He also discovered the method of distilling kerosene
- 60 coal seams, 5 were mined extensively

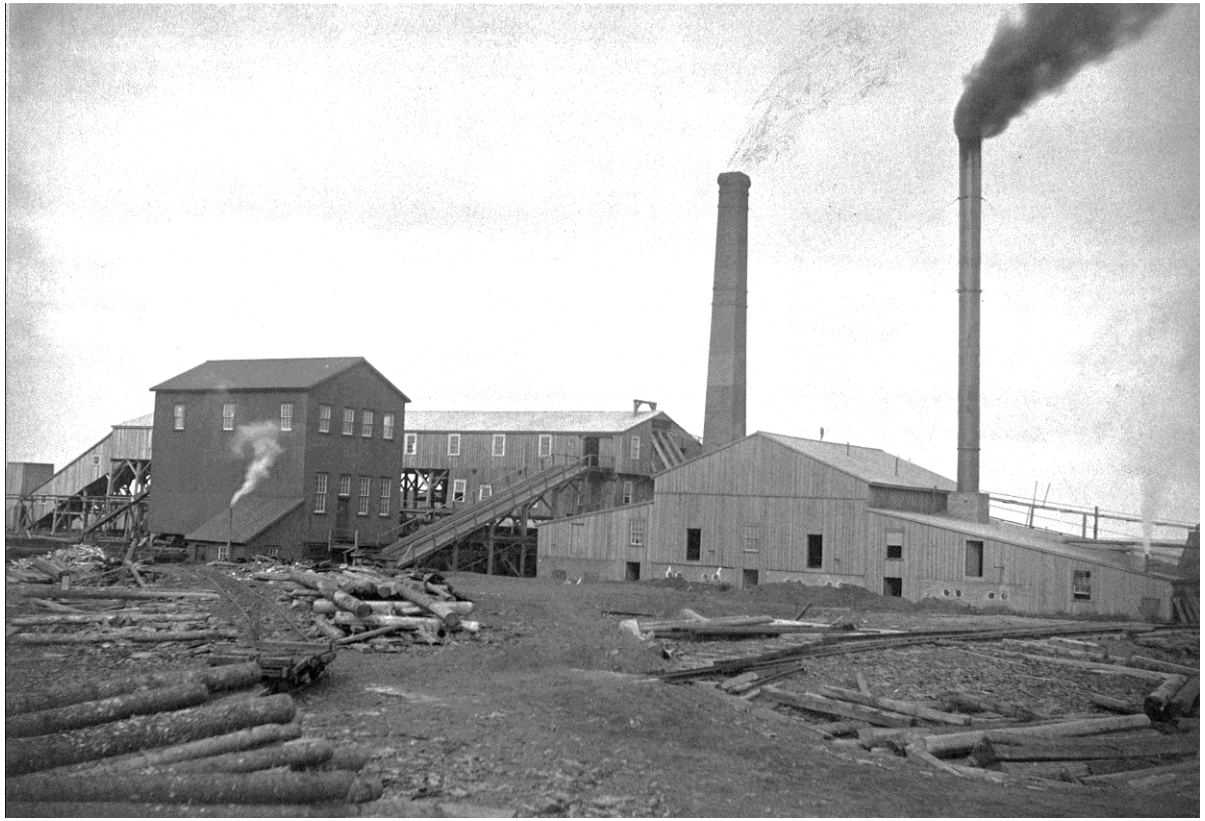


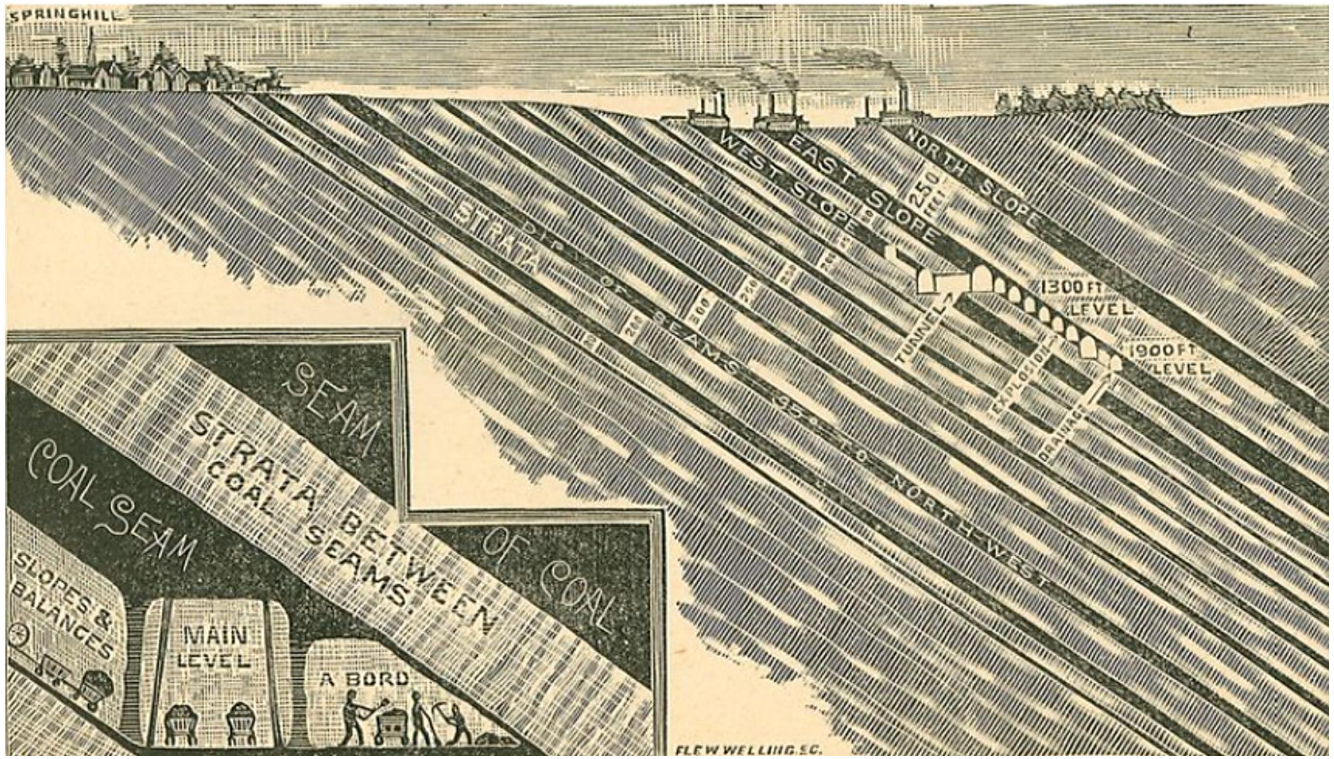
Image from National Archives of Canada

History of Springhill

Image from Wikipedia

- 5 major mines: No.1, No.2, No.3, No.4, & the Syndicate Mine
- The mines officially closed in 1970, all that remains are the sealed pitheads for the No.2 and No.4 mines, & the entrance to the Syndicate Mine which opens seasonally as a museum
- The mine was designated a National Historic Site in 1998

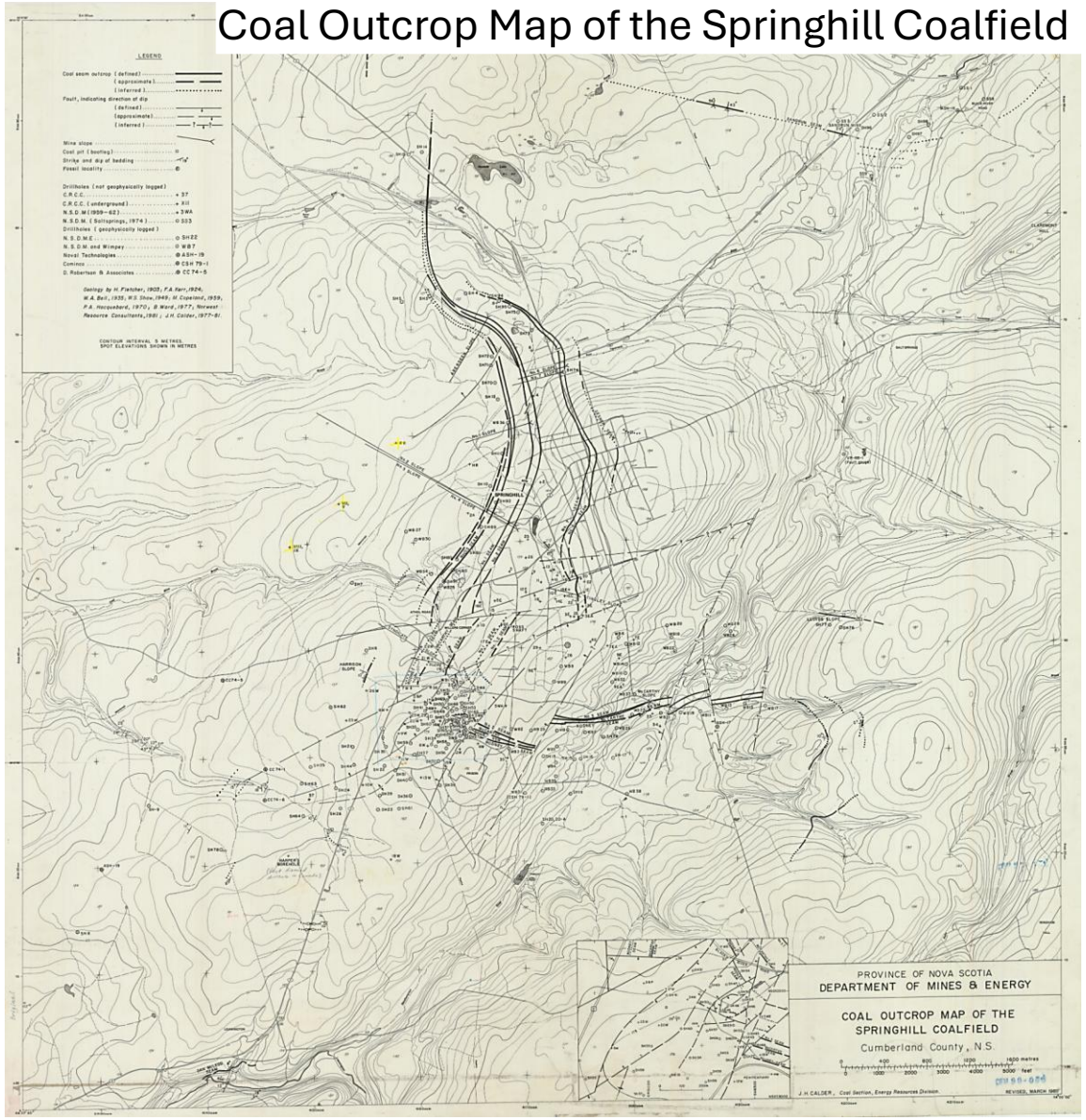
Springhill Coal Mines



This illustration published in R.A.H. Morrow, *Story of the Springhill Colliery Explosion: Comprising a Full and Authenic Account of the Great Coal Mining Explosion at Springhill Mines, Nova Scotia, February 21st, 1891 … Fully illustrated* (Saint John, NB, 1891).

Image from NSDNRR

Coal Outcrop Map of the Springhill Coalfield



Springhill Mining Disasters

- As with many coal mines back in the day, Springhill was not immune to risks & ensuing disasters, with 3 major fatal events
- 1891 Explosion
  - Accumulated coal dust resulted in a fire, sweeping through the connected No.1 and No.2 collieries, killing 125 miners including several child workers- at age 12 you could be in the mines taking care of the ponies or working as “trapper boys”, moderating air flow
  - Scale of the disaster was unprecedented for the time for the Canadian mining history
  - The ignition source of the explosion was never determined, despite identifying the general location

Image from NS Archives

Springhill Mining Disasters

- 1958 “bump” 8 pm on Oct. 3rd
  - Underground seismic event known as the “bump”, was the most severe bump in North American mining history
  - Initial small bump (7pm) was ignored as a common occurrence – an hour later, a second but much larger bump severely impacted structural walls in the No.2 colliery
  - 75 of the 174 miners were killed
  - Survivors were found 4,100m level (measured along the slope, 1200m below surface) below surface, with Drägermen coming from around the province, and 75 miners surfaced within 8 hours
  - After 51/2 days, 12 survivors were rescued after a tunnel was dug to reach them behind a 49m rockfall. The remaining survivors were rescued 11 days later Sunday Nov 2nd (“7-Up”) after over a week trapped underground, led by the “Singing Miner”, Murice Ruddick

Maurice Ruddick, after the Springhill Mine disaster, 1958.
Image: Nova Scotia Archives/photographer Robert Norwood/no. 1305-26.2.

Springhill Mining Disasters

- With the 1956 & 1958 disasters, operations were significantly downscaled and eventually closed altogether
- Closing of the mines significantly disrupted the town's economy, with impacts for decades to come
- With the mines being abandoned since the 1970s, many workings began to flood with water
- Methane emissions diminished with end of mining

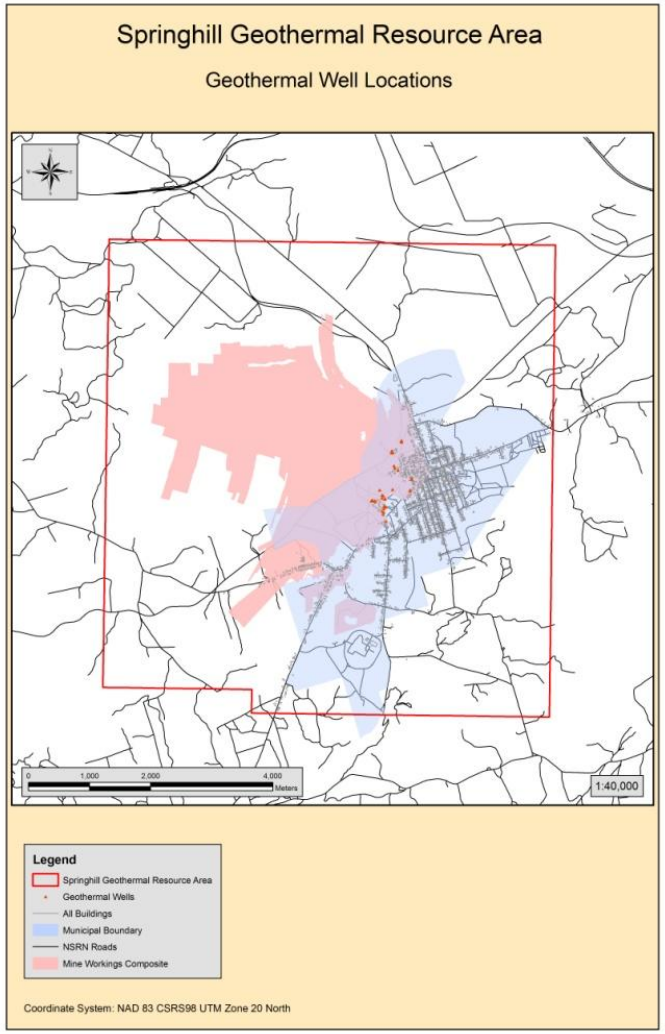
Image from NS Archives

Springhill Geothermal

Geothermal Resources

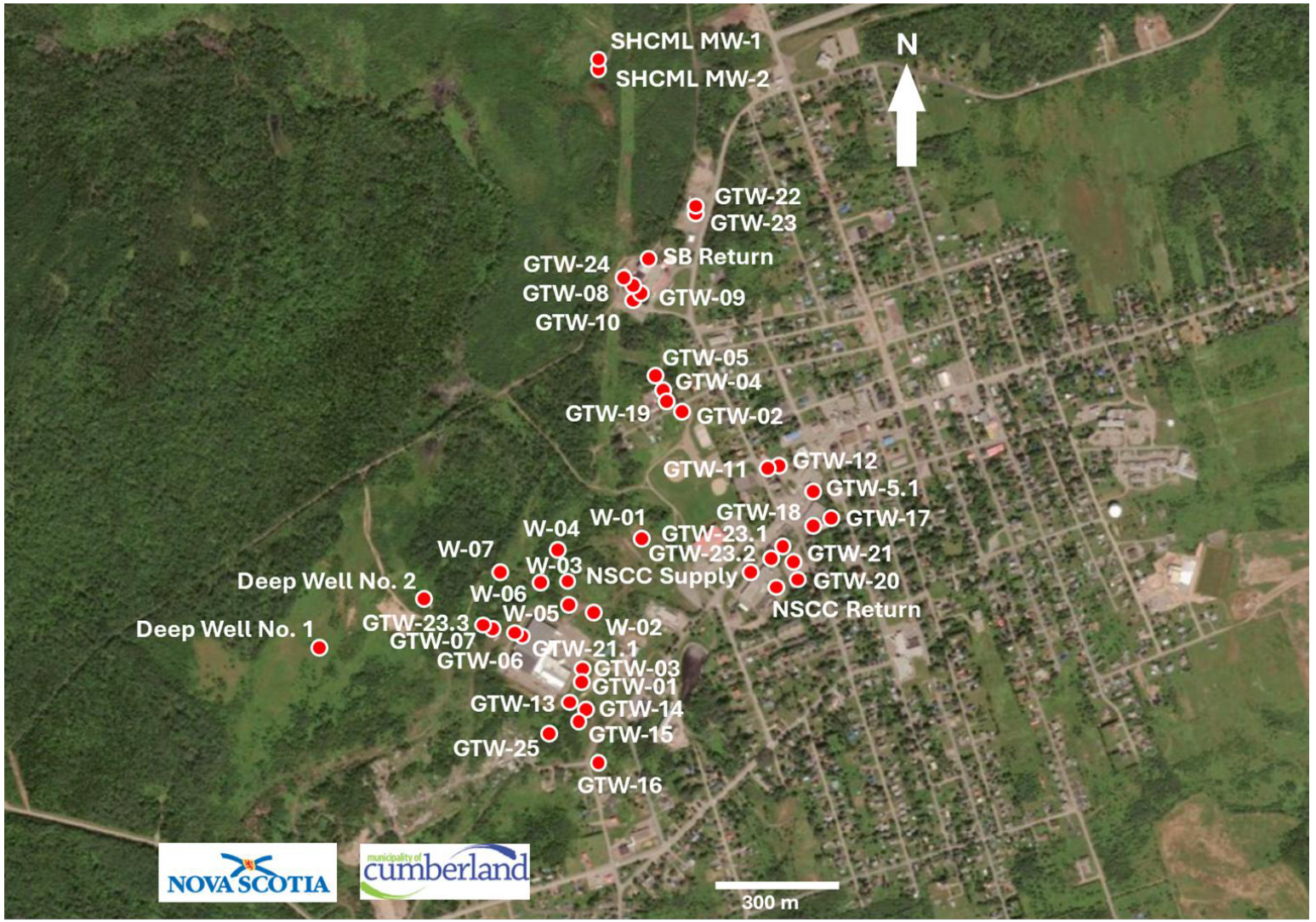
Nova Scotia Geothermal - Springhill

- Abandoned mine openings are flooded by groundwater inflow & warmed below the surface
  - Warmed water can be exploited as a source of geothermal energy
- Geothermal wells have been drilled in the area since the 1990s, 17 are currently utilized
- Wells are maintained and operated by either the community of Springhill or private owners for heating & cooling



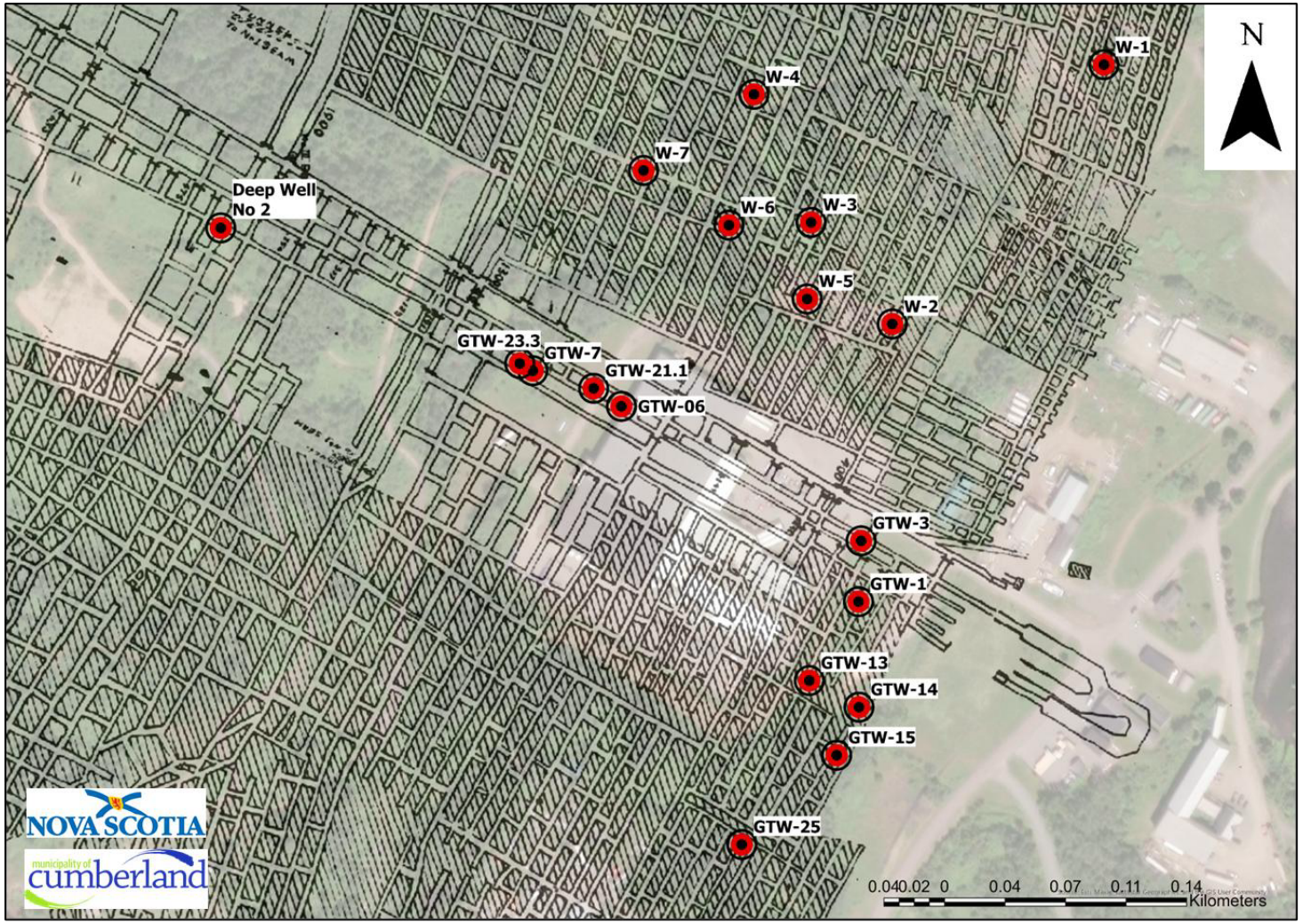
Geothermal Borehole Locations in Springhill

- Springhill active & inactive geothermal borehole locations
- Over 40 geothermal boreholes drilled
- Mix of extraction, reinjection, & monitoring wells
- Many are no longer in use due to borehole integrity issues, businesses closing, or insufficient water volumes



From Dr. Trevor Kelly

Geothermal Borehole Locations in Springhill



- No. 2 Mine room & pillar workings detail and some of the geothermal boreholes (GTW)
- GTW-01 GTW-06 penetrate the main slope, others penetrate the room & pillar workings
- W-boreholes (community centre), penetrate the room & pillar workings.
- Some boreholes missed the room and drilled into the pillars (no water)
- Many boreholes are no longer in use due to hole integrity issues, businesses closing, or insufficient water volumes

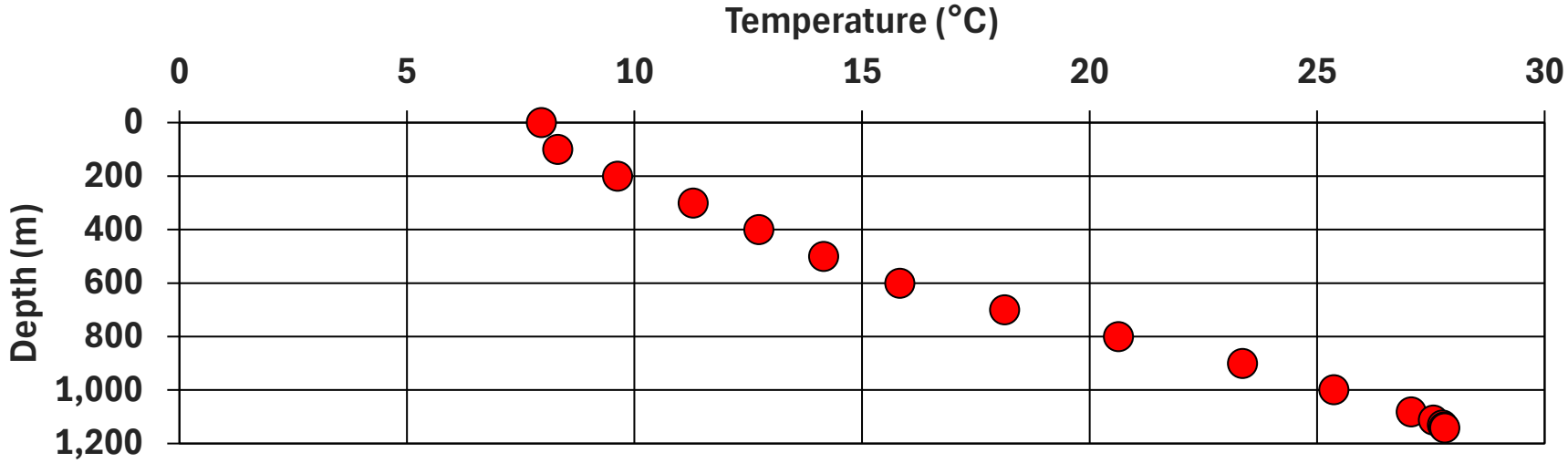
From Dr. Trevor Kelly

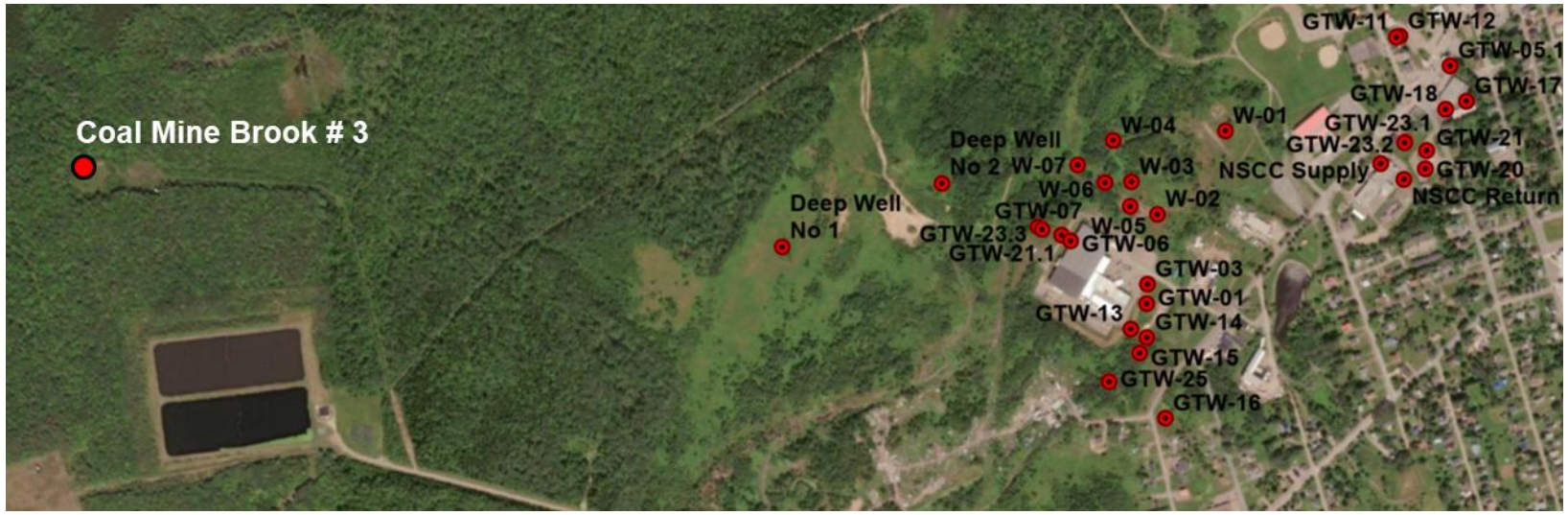
Coalbed Methane Coal Mine Brook No. 3

Depth (m)	Temp. (°C)
0.0	8.0
100.0	8.3
200.0	9.6
300.0	11.3
400.0	12.7
500.0	14.2
600.0	15.8
700.0	18.1
800.0	20.6
900.0	23.4
999.0	25.4
1,082.0	27.1
1,112.0	27.6
1,131.0	27.8
1,138.0	27.8
1,142.0	27.8

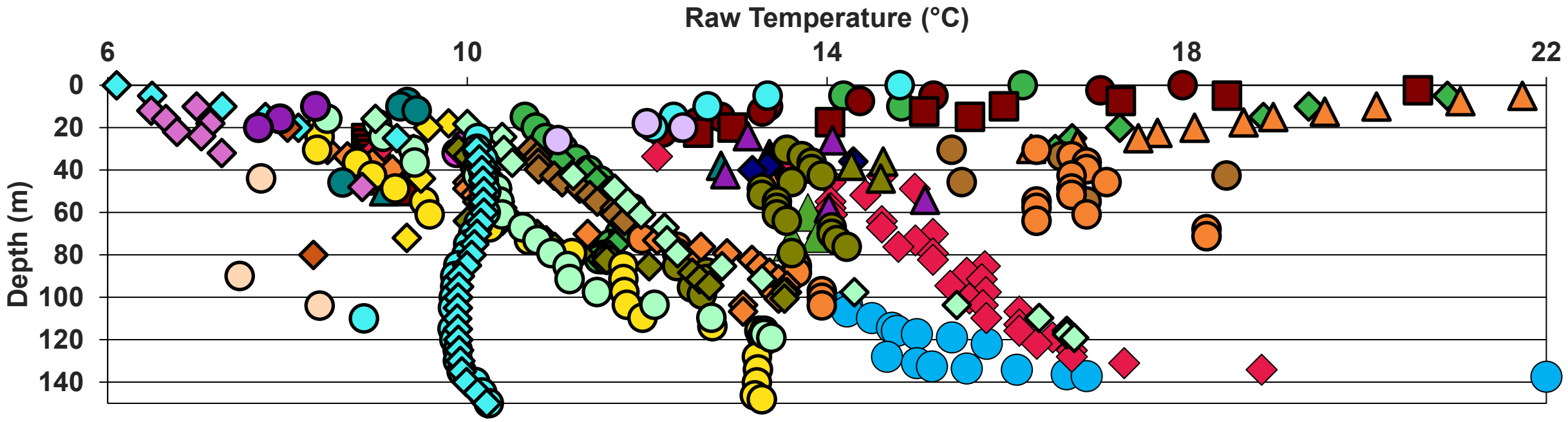
*temperature values are corrected

Source: Coal bed methane borehole summary report





Temperature Data from Select Boreholes



From Dr. Trevor Kelly

Source: Numerical geothermal reports & Brian Herteis (2008

Temperature Data from Select Boreholes

- Raw temperature–depth profiles shown for selected Springhill boreholes
- Most boreholes labelled GTW-# in drilling order
- NSCC Cumberland Campus includes a supply/return pair for geothermal training
- SH-99 was a mineral exploration hole with temperature data
- SHCML wells were drilled to monitor a proposed (never developed) open-pit coal project
- Shallow anomalous temperature readings are unreliable

From Dr. Trevor Kelly

Surrette Battery

Springhill Community Center

- The Dr. Carson & Marion Murray (Anne Murray's parents) Community Center is another example of successful use of water from former mine workings as a source of energy
  - The largest facility in Atlantic Canada to rely on geothermal energy for heating & cooling
- Use geothermal energy from flooded abandoned mines to chill the ice surface in their arena, with waste heat from this process being used to provide radiant heat to the building

Image from Green Municipal Fund

Springhill Community Center

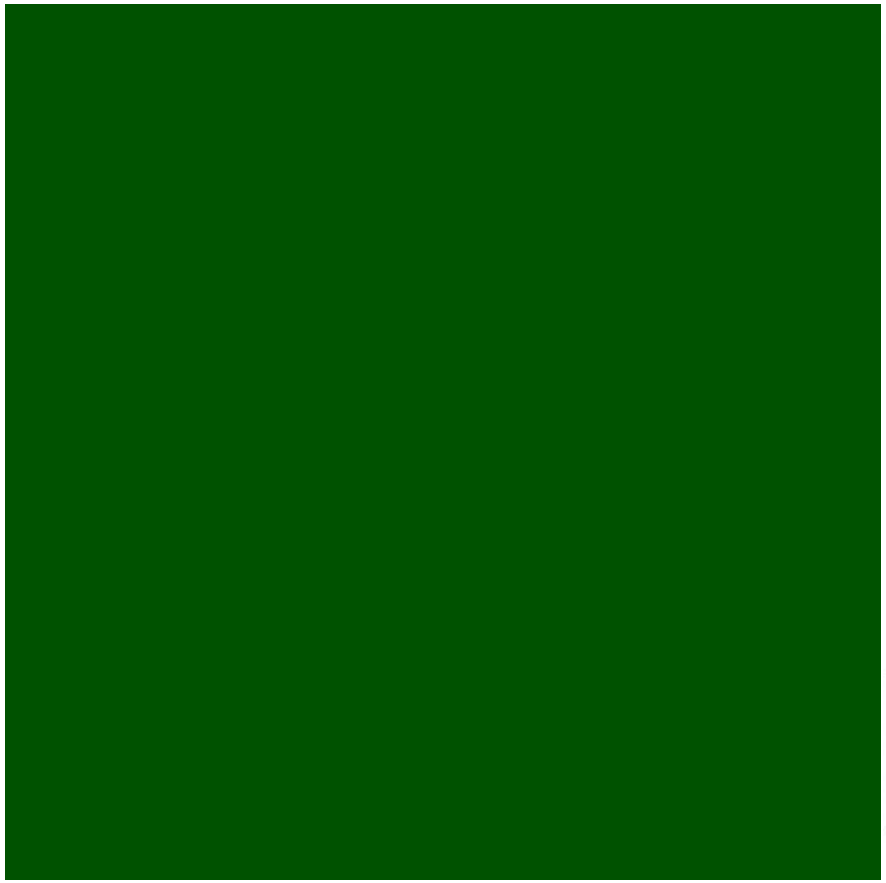
Low-Enthalpy Water-Based Thermal Energy

Case Studies

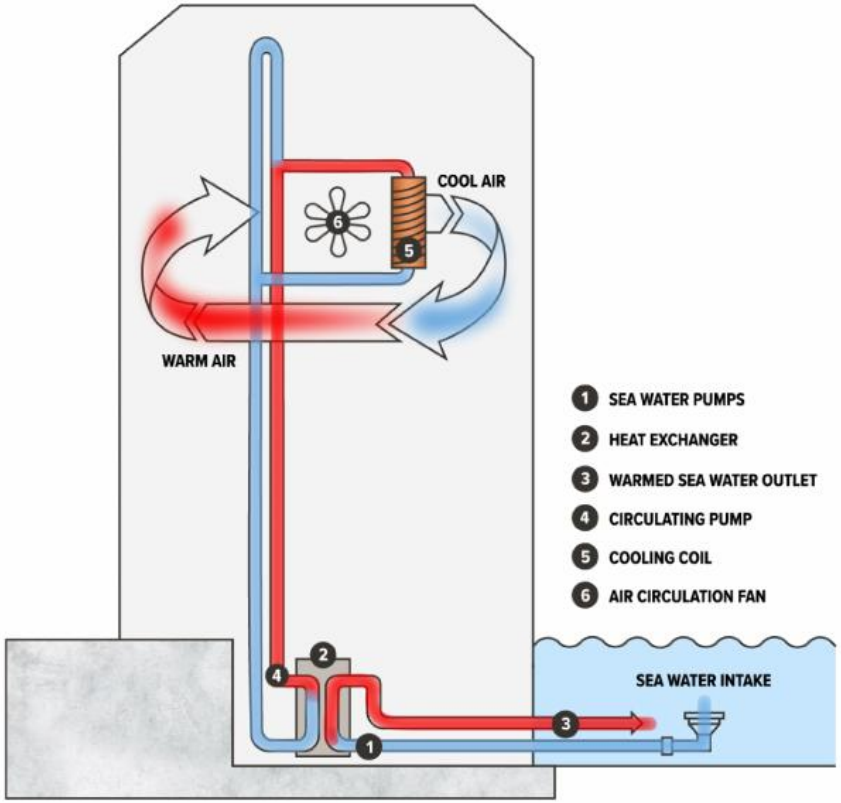
Purdy's Wharf

- Purdy's Wharf on Halifax Harbour uses low-enthalpy seawater cooling for the entire complex
- Site includes two office towers (18 & 22 storeys), a 4-storey retail centre, parking garage, & walkway network
- Deep-water cooling system engineered by Smith + Anderson
- Cool harbour water is pumped through heat exchangers to provide year-round cooling for most of the site

Purdy's Wharf



Video from Smith + Anderson



- Chilled-water coils operate at higher temperatures, extending seawater free-cooling to ~10 months/year
- Electric chillers only needed for ~2 months
- Seawater is filtered & treated to prevent mollusk fouling & system clogging

Purdy's Wharf

- Natural gas was unavailable during construction, so oil-fired boilers provided hot-water heating
- Mechanical design included natural-gas piping & a planned boiler swap for future conversion

Image from GWLRA

Queen's Marque

Image from Nic Lehoux

- Harbour water provides free cooling in summer & drives heat-pump heating in winter
- Higher upfront cost than conventional HVAC but eliminates cooling towers, removes fossil-fuel use, & runs solely on building electricity
- Intake system designed for future sea-level rise, with fish screens & anti-fouling coatings to prevent barnacle buildup

Queen's Marque

- Queen's Marque is a 500,000 ft^2 mixed-use waterfront development that uses a seawater-based cooling system similar to Purdy's Wharf
- A 600-m intake line draws seawater from 12 m depth, where temperatures remain stable year-round, at roughly 4,900 L/min (1,300 gal/min)
- The seawater loop feeds a large-scale heat-pump plant, supported by fully redundant gas-fired condensing boilers for peak & backup heating
- Buildings are oriented on a north–south axis to maximize passive energy efficiency & reduce heating/cooling loads

Canadian Coast Guard College Sydney, C.B.

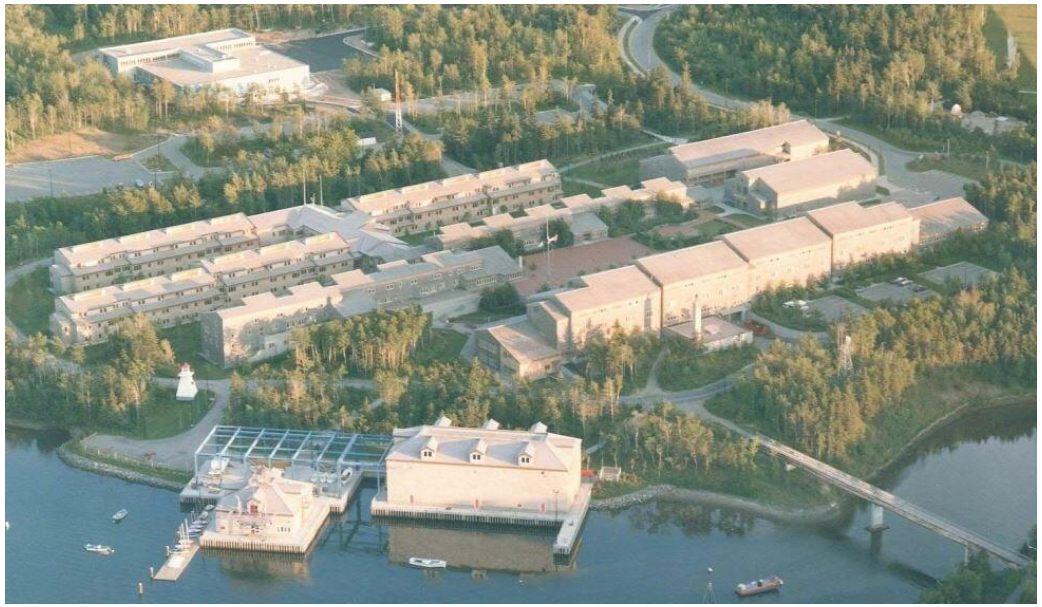
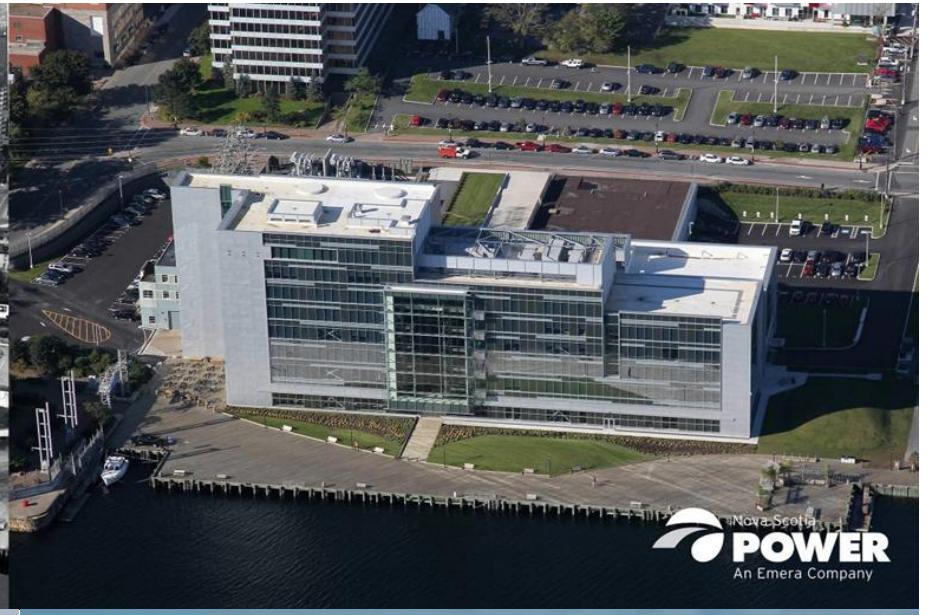


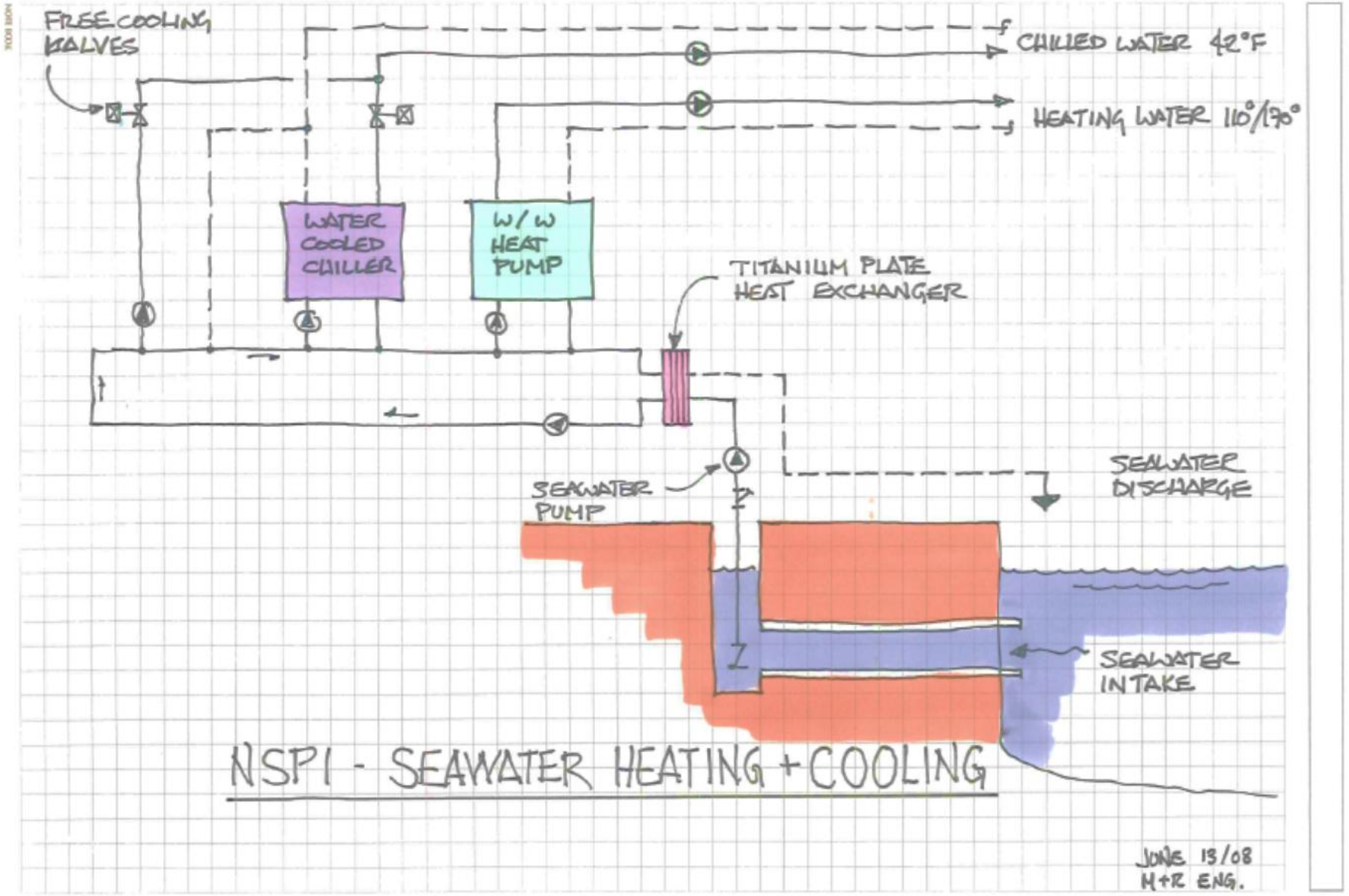
Image from M&R Engineering Ltd.

- Completed a $90-million campus renewal, including a full HVAC modernization & heat-pump integration
- A seawater-source heat-pump system now draws energy from Sydney Harbour
- Designed for full heat recovery & fully electrifies campus heating, positioning the facility for a zero-carbon future
- Combined efficiency upgrades have already reduced campus emissions by more than 20%

Nova Scotia Power

- Former coal plant (60+ years) with hazardous waste
- Waste sealed in concrete to remediate site
- Buildings reused for NSPI HQ & Discovery Centre
- Seawater heat pump pays back in ~7 years




FREE COOLING VALVES
CHILLED WATER 42°F
HEATING WATER 110°/170°
WATER COOLED CHILLER
W/W HEAT PUMP
TITANIUM PLATE HEAT EXCHANGER
SEAWATER PUMP
SEAWATER DISCHARGE
SEAWATER INTAKE
NSPI - SEAWATER HEATING + COOLING
JUNE 13/08
M+R ENG.

Key Takeaways

Key Takeaways

- Low-enthalpy geothermal has significant potential to be implemented on a wider scale, reducing impacts of heating & cooling on emissions & climate change
- Abandoned mine openings are flooded by groundwater inflow & warmed below the surface, providing opportunity for low-temp geothermal
- Water bodies, rivers, lakes & sea water provide significant renewable low-enthalpy energy solutions for heating & cooling

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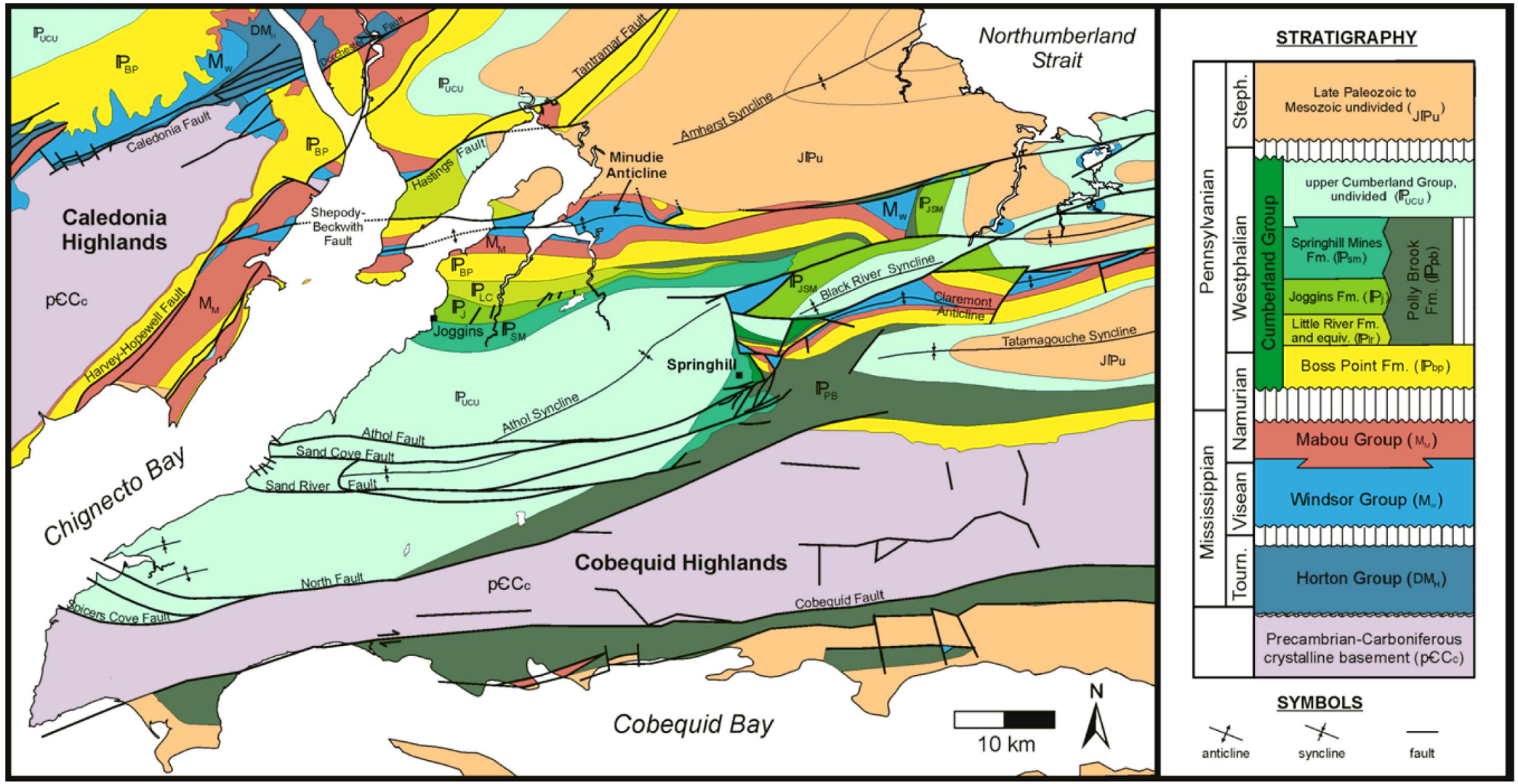
Thank You

Questions?

Additional Slides

Geology



From Rygel 2005

M&R ENGINEERING

5151 Terminal Road

HVAC Upgrade - Seawater Heat Pump

Nova Scotia Power- Terminal Road

- Designed to perform 60% better than the National Energy Code for Buildings.
- Achieved LEED Platinum—the first project in Atlantic Canada to do so.
- Recipient of the 2013 Lieutenant Governor’s Award for Engineering Excellence.
- Adaptive reuse of a former power-plant site, avoiding costly full remediation of 60 years of fossil-fuel contamination.
- Hazardous materials were safely encapsulated in concrete, enabling reuse of the power plant and boiler house as the new NSPI Headquarters & Discovery Centre.
- Seawater heat-pump system required higher upfront investment but is projected to pay back in only seven years.

Low-Enthalpy Geothermal

- High-enthalpy geothermal excels at electricity generation, but its global distribution is limited
- Low-enthalpy geothermal is far more widespread & can be deployed at scale to cut heating & cooling emissions
- Ideal for residential, commercial, & community-level applications, not just industrial settings

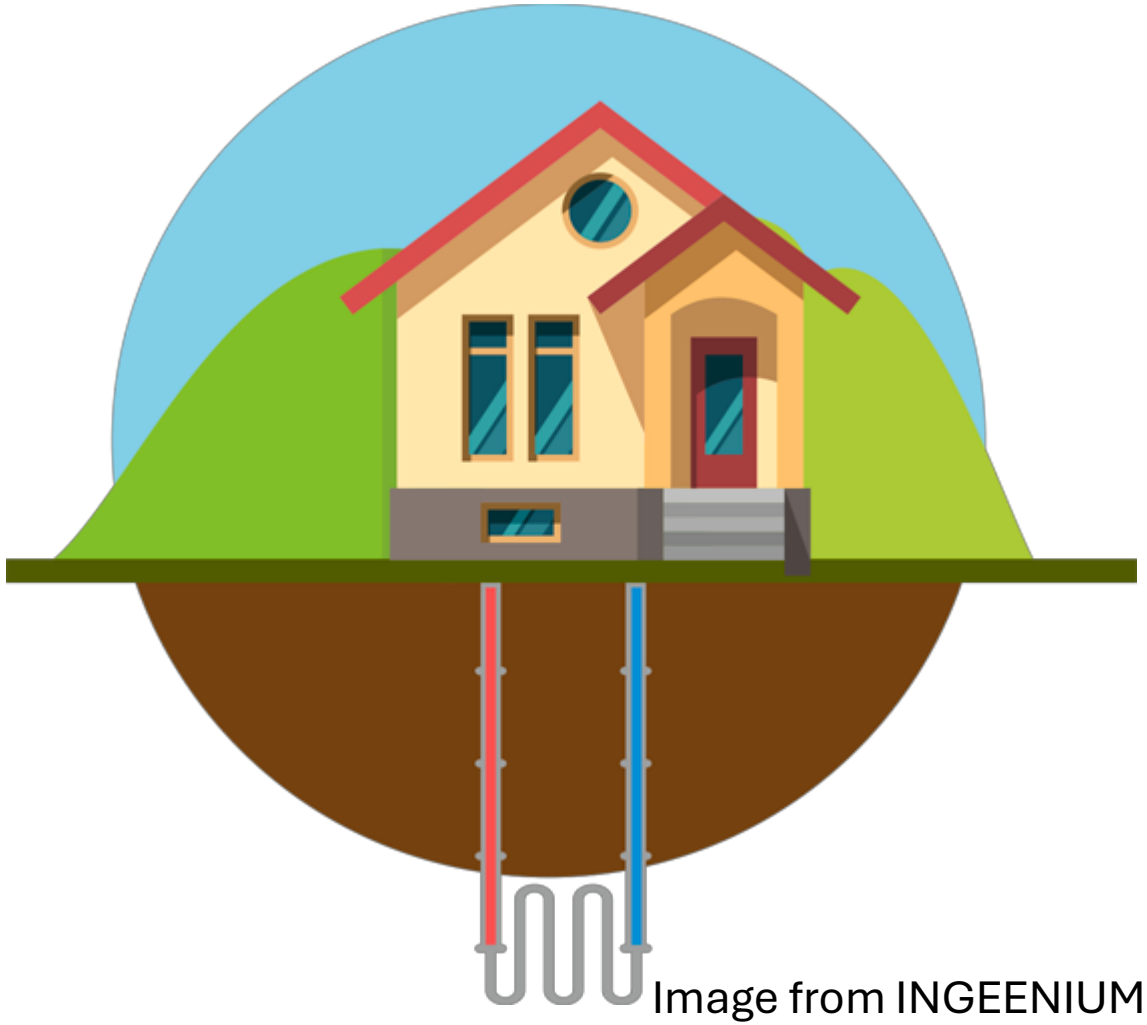
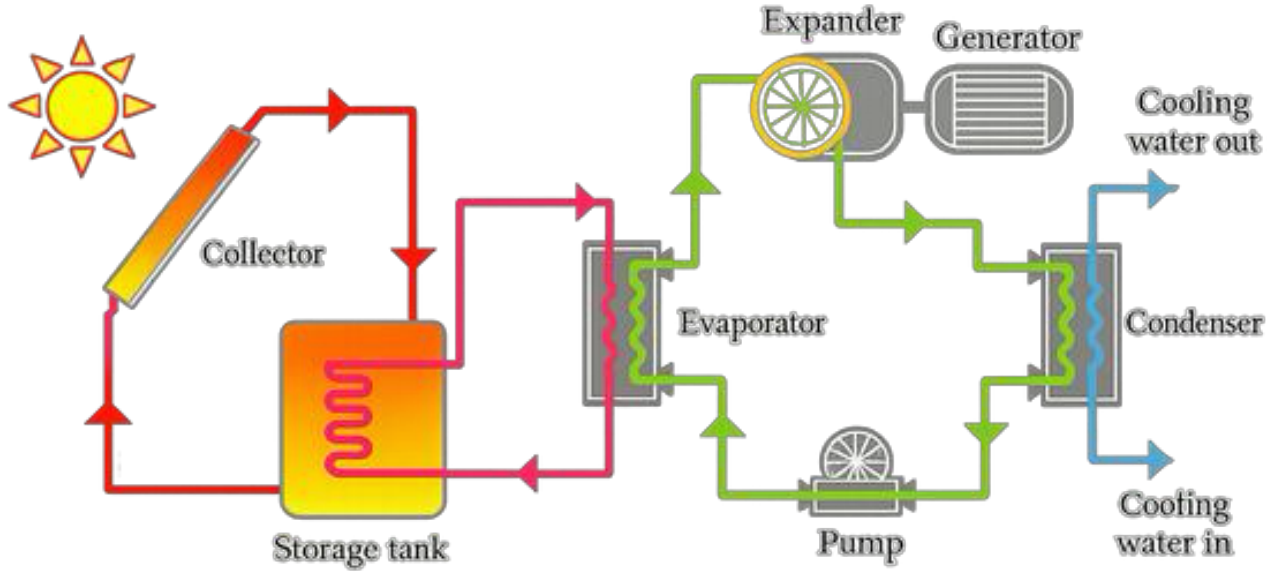


Image from INGEENIUM

Low-Temperature Geothermal

Organic Rankine Cycle



Technology that converts low-temperature heat sources into mechanical energy

- Low to medium temperature heat sources (80-350°C)
- Small to medium applications at any temperature
- Sedimentary, igneous, & metamorphic rocks

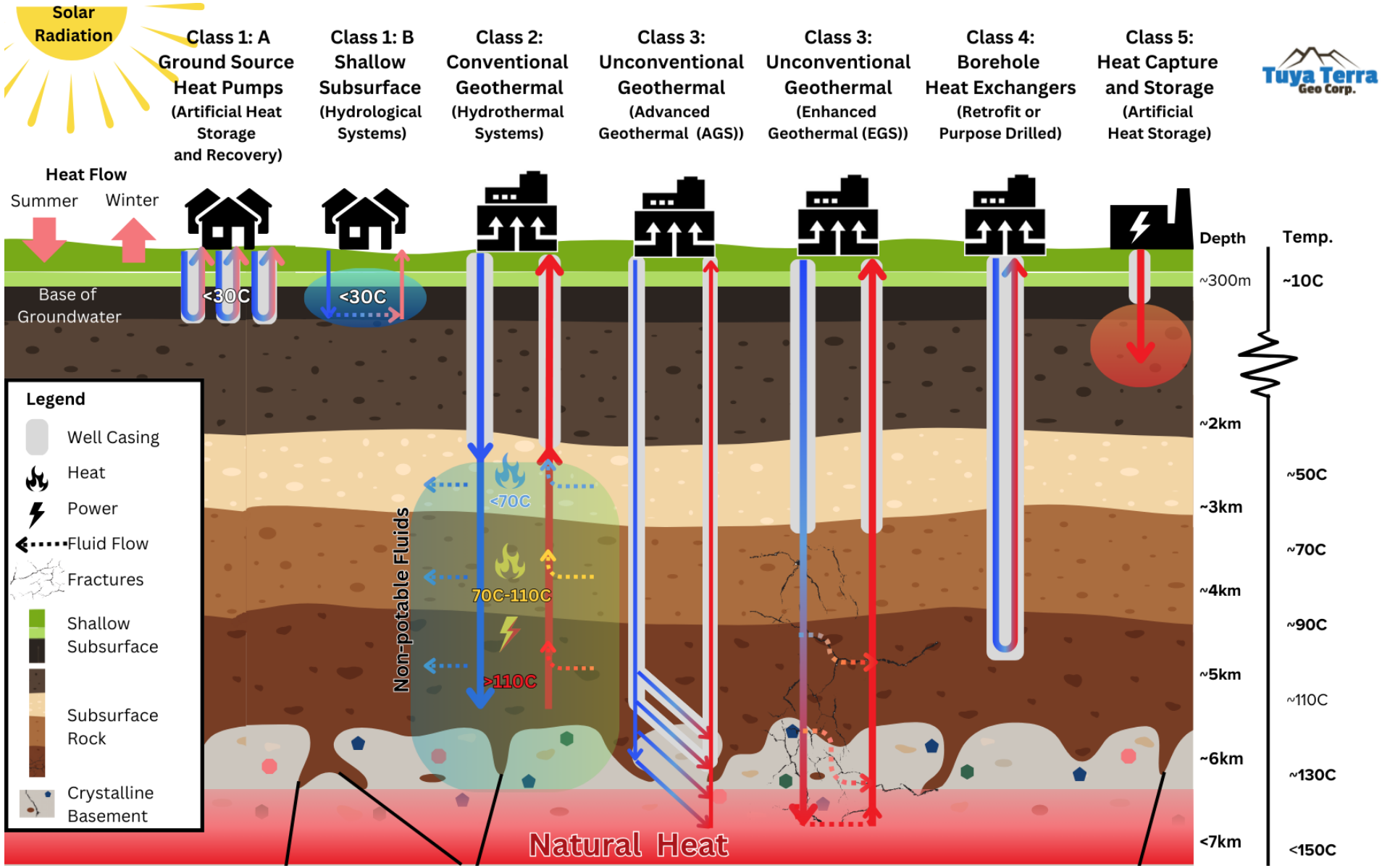
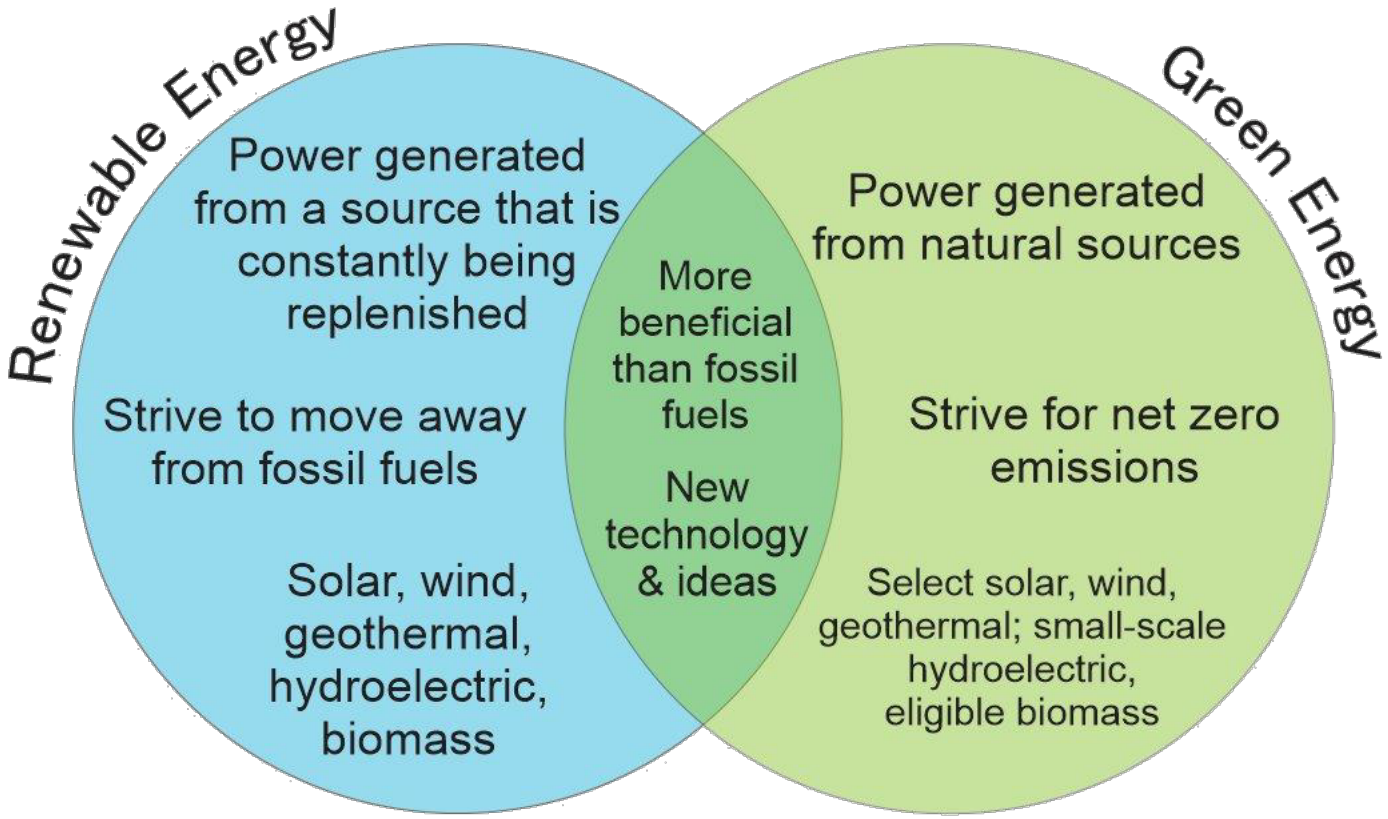


Image from Hickson & Smejkal 2024

Green Energy vs. Renewable Energy



Global High-Enthalpy Geothermal Distribution

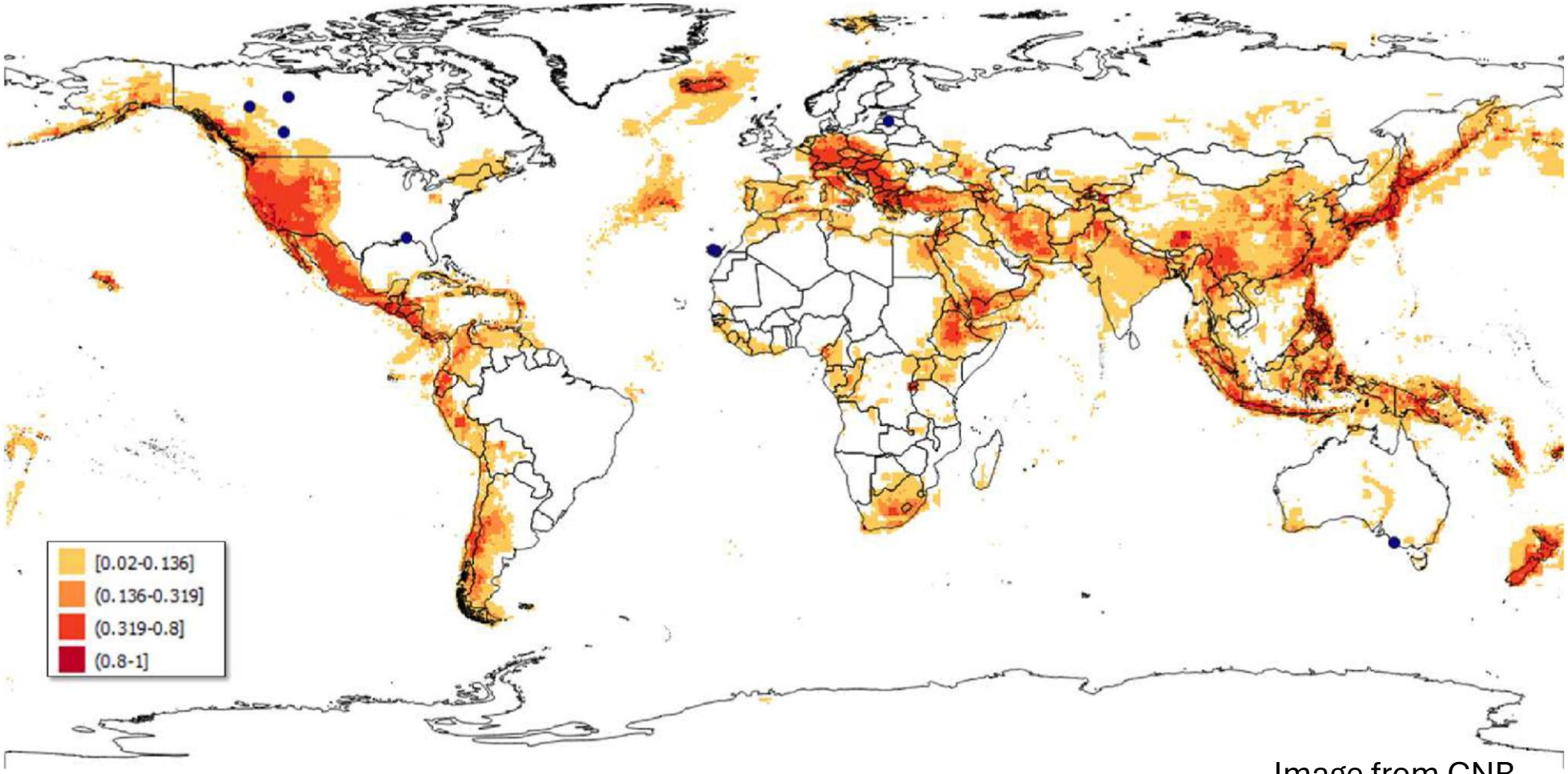


Image from CNR