Nahanni Butte, NWT – Right Sizing Geothermal Development

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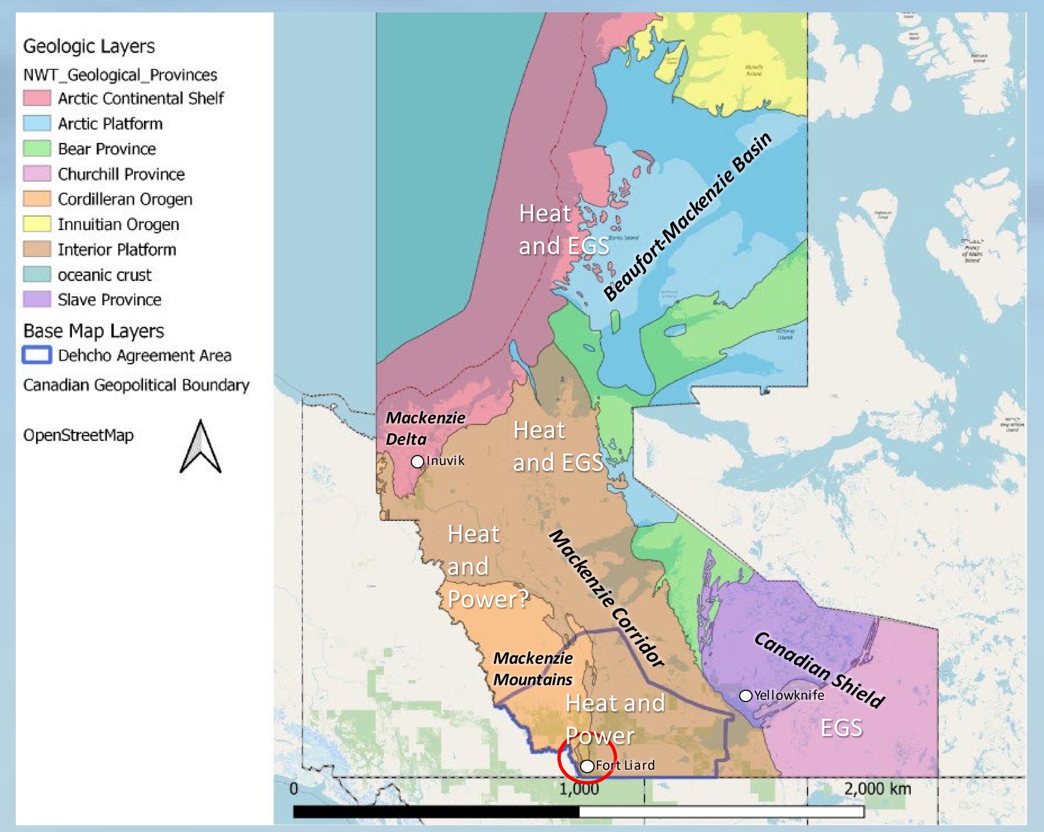

Figure 1: The geologic provinces of the Northwest Territories and their geothermal potential. The red circle highlights the Nahanni Butte area.

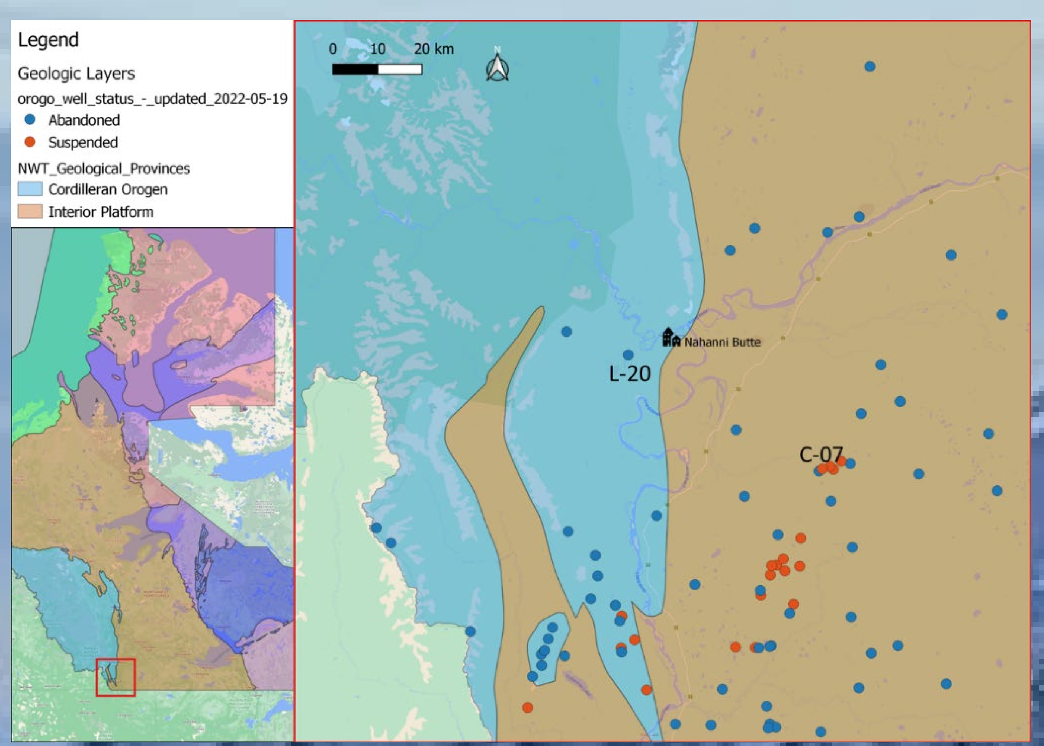

Figure 2: Nahanni Butte is located on the margin of the Liard Basin (Interior platform) and the Mackenzie Mountains (Okulitch et al. 2017). The right figure shows the location of oil and gas wells drilled in the area. Red wells are suspended and may pose an opportunity to relog during abandonment (Smejkal et al., 2023)

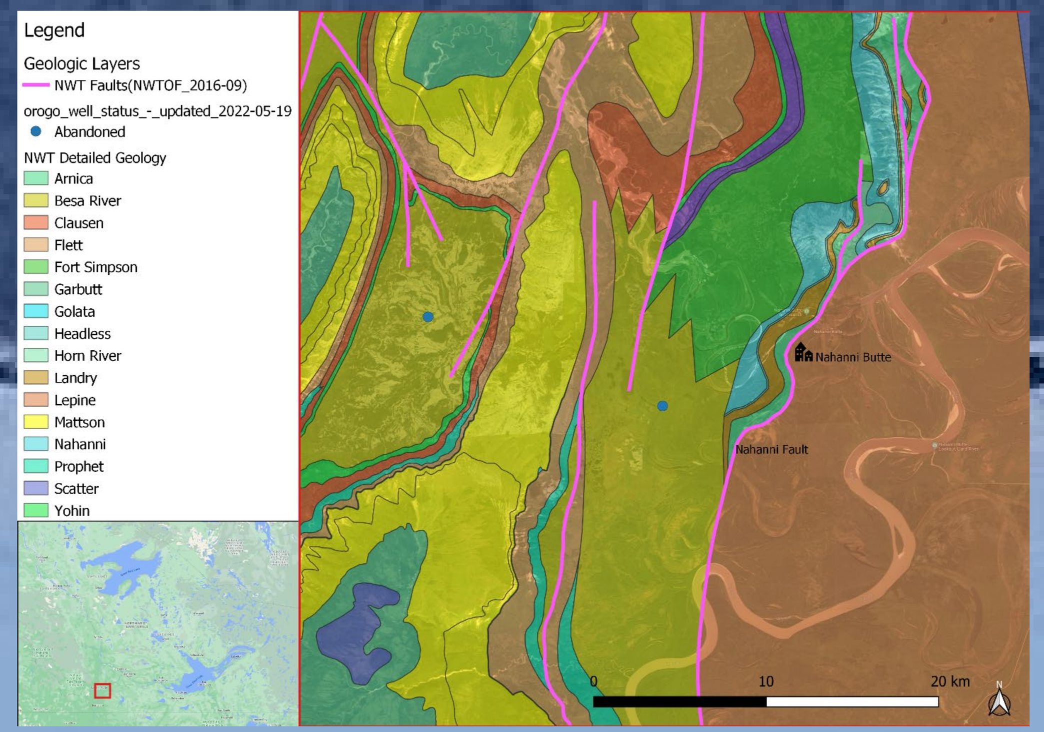

Figure 3: Nahanni Butte is located where there is an offset of the major faults running parallel to the structural grain of the Mackenzie Mountains, offsetting the "front ranges" by about 20 kilometers eastward, forming the arcuate eastern margin of the Mackenzie Mountains. Additionally, the hamlet of Nahanni Butte is located on the geomorphological divide between the sedimentary Liard Basin (interior platform) and the Cordillera (Figure 2). (Okulitch et al. 2017).

Summary

Nahanni Butte is a small community of under 100 people in the south-west corner of Northwest Territories. Presently, the electricity needs of the community are supplied by a diesel generator. The heat for the community is provided by oil fired furnaces, oil fired hydronic systems in larger buildings (c.f., Band office and sports/gym building), and combustion of wood in individual residences. To increase the community's energy stability and reduce their carbon emissions, geothermal energy was evaluated for both heat and power generation. Conventional geothermal energy was evaluated for the community, however, the upfront capital cost on a per person basis for this small community made this solution unlikely at this point in time. As an alternative, a deep, closed loop, borehole heat exchanger was evaluated for heat production. Ceraphi Energy's proprietary closed loop CeraPhiWell™ (monobore) system was evaluated. The advantage of this system is it can be deployed in a single, small diameter borehole. Locally available diamond drill rigs running relatively inexpensive drill bits as small as 64 mm could be used. This type of system will require engineering considerations to handle the baseload, low temperature flows (20 – 30°C) and is likely best suited for new construction. Existing buildings in the hamlet run on hydronic systems with set temperatures of 80°C, so are unlikely to be good candidates for retrofitting. This limits the applicability of this technology (within this community) to new residential and community or commercial buildings. There is an opportunity to use this technology for vehicle and equipment storage buildings (for example) or where snow melting is required to keep community walkways and entrances clear and where the heating systems can be designed for the lower temperature fluids circulated by the district heating system. While this area of the NWT has good geothermal potential for higher temperature systems, the technology implemented needs to be "right sized" by considering the community's needs and future development plans in order to find the best application of renewable energy solutions whether it be geothermal technology, or hybrid systems such as waste heat recovery from existing diesel generation, and lower cost thermal systems providing base-load heating on a multidecadal time frame.

Geothermal potential

Extraction of fluids with temperatures high enough to produce electricity in this specific location in NWT, will likely need to target fracture permeability for an open-loop solution, or be designed as an enhanced geothermal system (Hickson et al. 2023). Given the experience of development of Alberta No. 1 (Hickson et al. 2021), designed as a conventional (open-loop) geothermal power and thermal facility, a similar small development (<10 MWe) is projected to cost between \$50 million and \$100 million. Costs closer to the larger figure would be expected given Nahanni Butte's northerly location and the need to mobilize a large capacity rig and crew from Alberta in addition to drilling during winter months due to access and environmental considerations.

For the community to reduce its fuel costs and Greenhouse gas (GHG) emissions, a "right sized" solution is needed. The first is waste heat recovery from the diesel generation that currently serves the community. Engineering details are currently being investigated, but it is likely that sufficient waste heat recovery is possible to heat at least one of the community's larger buildings. The sports/gym facility is currently on an independent heating oil fired boiler hydronic system, with an inlet temperature of 80°C. Calculations show that the waste heat recovery from the diesel generators will be around 90°C. Given the potential heat loss between the heat exchanger and the piping required to the facility (~300 m), this temperature is a good fit for conversation of the sports/gym building to waste heat, keeping the fuel oil boiler as backup.

In order to supply additional heat to the community at a lower per capita cost than deep geothermal, other options need to be explored. Drilling costs remain the largest hurdle to geothermal development, whether it be for geothermal, geoexchange, heat storage, or Enhanced Geothermal Systems (EGS); drilling remains a significant capital cost for projects. This area is unsuitable for geoexchange because the community is built on fine grained river sediments. This also makes it unsuitable for shallow heat storage. Conventional open-loop geothermal, targeting temperatures suitable for direct-use (40 - 80°C), are an option. Unfortunately, the large well bores would still require mobilizing of a rig and crew from a long distance and have a CAPEX that is unlikely to be supported by local and regional government.

An option investigated in this project, is the installation of a monobore system (CeraPhiWell™). UK based CeraPhi Energy, has been developing a downhole heat exchanger system that can be used in a small well bore (as small as 64 mm). Additionally, diamond drill rigs are generally available with less mobilization requirements (including smaller crews) than larger rigs. Currently under investigation is the drilling of a 1.5 km 88.9 mm (HQ) borehole to provide heat to an under consideration 10 Unit apartment complex. The Ceraphi system overcomes issues related to EGS that require two well bores (Figure 5), thus further reducing CAPEX requirements.

The economic evaluation of this monobore system is currently underway but drilling and installation of the system is likely to be under \$3 million. A fuel cost and GHG reduction assessment is required to evaluate whether this system will provide sufficient returns to support construction. Because of the low fluid temperatures, the systems stabilize at (25 - 30°C), hydronic heating must be sized to provide sufficient flow for the heating requirements of the building. This will necessitate larger pipes and pumps and is unlikely to be cost effective for retrofitting existing buildings, with the exception of the vehicle and equipment storage buildings, walkways And parking areas. However, the temperatures are high enough to be a valuable source of base-load energy given the cold climate and significant ΔT between the outside winter temperature and the dwelling temperature required (Hickson et al. 2023); (Hickson et al. 2023).

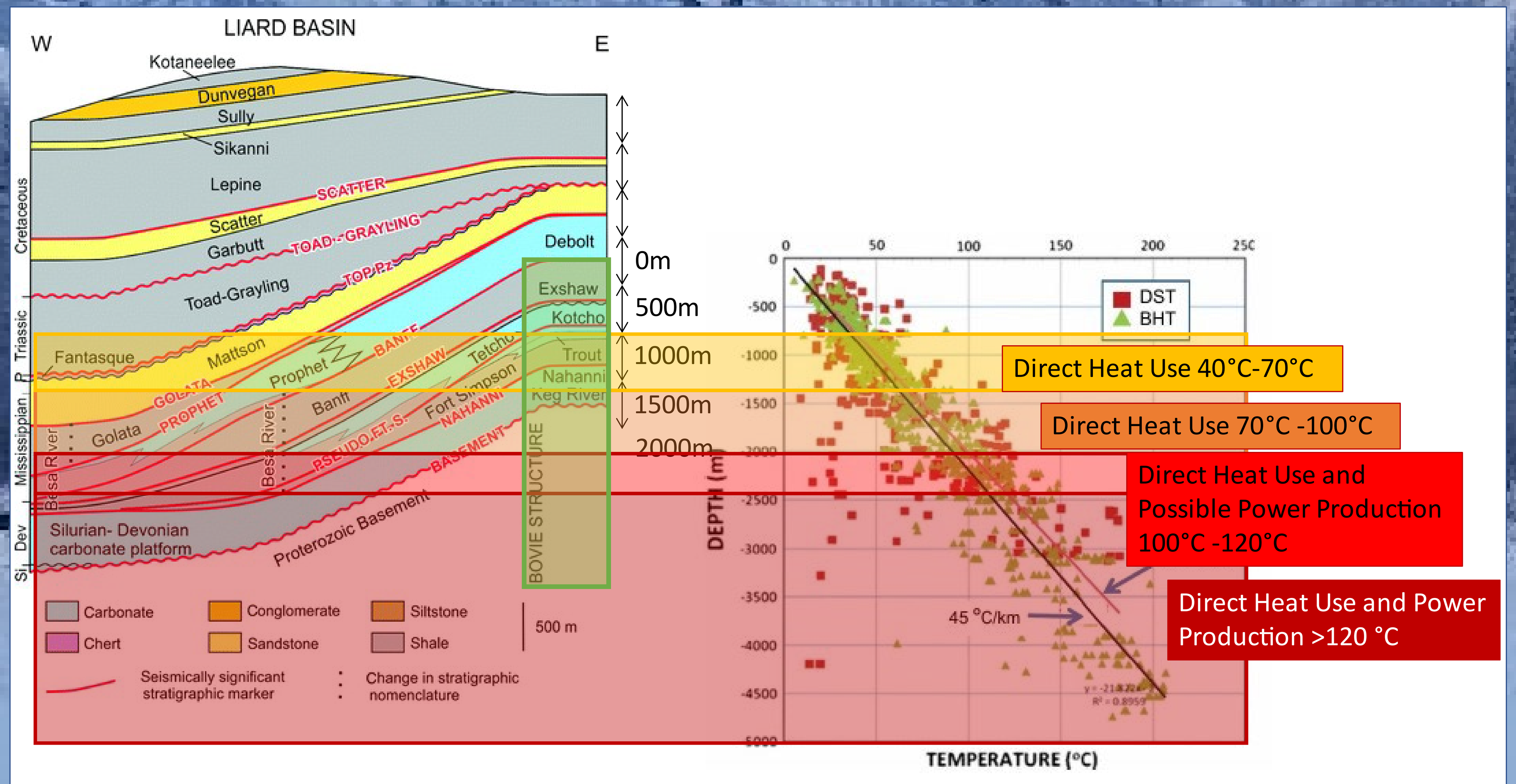

Figure 4: Schematic Liard Basin stratigraphic section, with temperature gradient data (Majorowicz et al. 2014), shown superimposed with approximate geothermal temperatures and their resource potential (Smejkal et al. 2023). Our compilation studies show that the main hydrocarbon target, the Nahanni Formation, is a tight limestone and is unlikely to be a successful open-loop geothermal target due to its lack of permeability. The overlying Matteson Formation has better permeability but the temperatures likely in this formation are useful for direct-use, not electrical generation. Within the Nahanni Formation, (deep enough to produce fluids and temperatures high enough for electrical generation) is the Manetoe Facies, a hydrothermal dolomite, with higher (~8%) permeability. However, the regional extent of these facies is not well understood and needs further investigation.

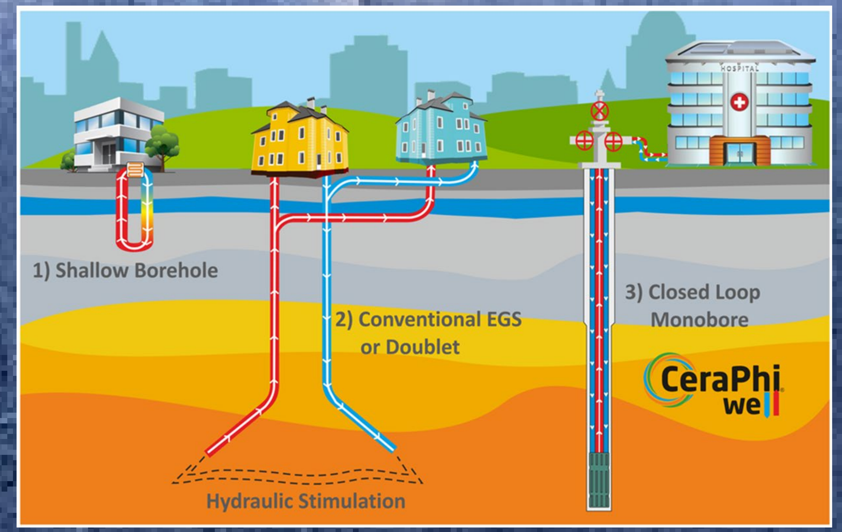

Figure 5: (1) Geoexchange, shallow closed-loop system (2) open-loop EGS system and (3) Ceraphi's monobore systems compared (https://ceraphi.com/).

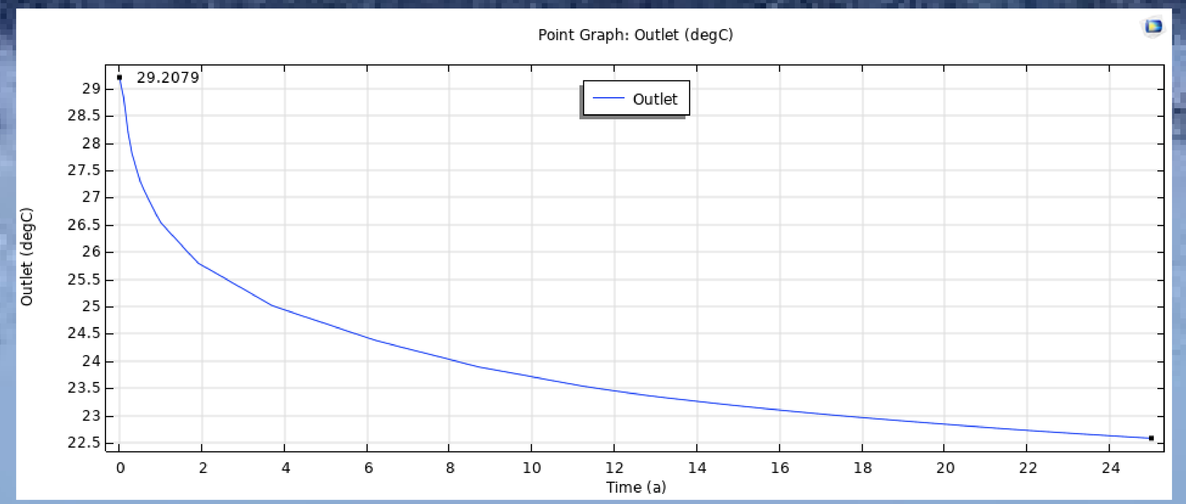

Figure 6: Modelling results for a well bore 1,200 m in depth with a BHT of 60°C. Modelling of the thermal output of two scenarios shows the temperature decline over the 25-year time frame operating 8,760 hours annually at full capacity. The output is also limited by the narrow borehole diameter given that there are no large drilling rigs available. Scenario 1, stabilizes at 21.5°C, and Scenario 2 at 31.4°C in 25 years (CeraPhi internal communication 2022). This is consistent with modelling of other systems by Guo et al. (2020), Eyerer et al. (2021), Guo et al. (2021).

Conclusions

The significant ΔT found in northern communities creates opportunities for novel and innovative heating solutions that will result in reduced fuel costs and lowered GHG when implemented. These solutions need to consider waste heat capture from existing infrastructure, and already built infrastructure and challenges to retrofit the built infrastructure with new systems.

Geoexchange and heat storage (and generation of heat from solar and wind facilities to store) systems need to be carefully considered and matched the community's geological location and the potential for ground ice and other subsurface issues that might arise. Geothermal power systems are still challenged by very high CAPEX, especially when put into the context of very small communities. An electrical power project providing geothermal energy to numerous settlements in the region would introduce economies of scale, making the importing of a large enough drilling rig to the area viable and reducing costs per community. However, vast distances between communities, and cost to build transmission will require investments of 100's of millions of dollars if not billions. Thermal only energy solutions have significantly lower CAPEX; Underscoring the importance of "right sized" community-based solutions.

Retrofitting costs will often exceed the value of the building stock so future development and -community-based decision making is critical to not miss opportunities to implement heating solutions that may not make sense from a retrofitting perspective but are applicable to new buildings, community and commercial developments. While the Nahanni Butte area of the NWT has good geothermal potential for higher temperature systems, the technology implemented needs to be "right sized" . The conclusion of this project is recommending a waste heat recovery system in the short term, and with future development, the community should consider a monobore, downhole heat exchanger system to provide new construction with base-load heating on a multi-decadal time frame; "right sized" for the community.

Acknowledgements

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