zebx DecarbLunch Series

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Building Decarbonization in Cold Climates

Fri Jan 24, 2025
12 - 1pm PST
Free Webinar
zebx.org

B2E Building to Electrification Powered by zeic

FALCON ENGINEERING INGENUITY DELIVERED

CREATIVENERGY
YOUR COMMUNITY ENERGY PARTNER

CITY OF VANCOUVER

Natural Resources Canada | Ressources naturelles Canada

Canada

BC Hydro

Electrification in Colder Climates

Case Study

Orion: Real-Life Performance of a Step 4, All-Electric Building

Nov 24, 2022

Case Study

Is Using a Heat Pump in the North Feasible?

Jun 8, 2022

Resource

Scalable Decarbonization Opportunities in Commercial Buildings

May 25, 2023

Electrification in Colder Climates

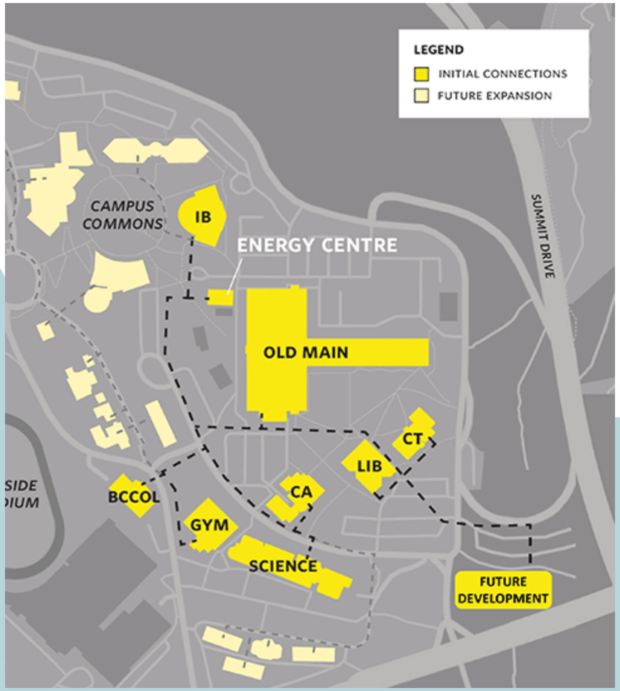

Image Sources: TRU and Falcon Engineering

COLD CLIMATE DECARBONIZING

Geoexchange Applications in Harsh Climates

Jeff Quibell, P.Eng.

January 24, 2025

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ZERO EMISSIONS BUILDING EXCHANGE

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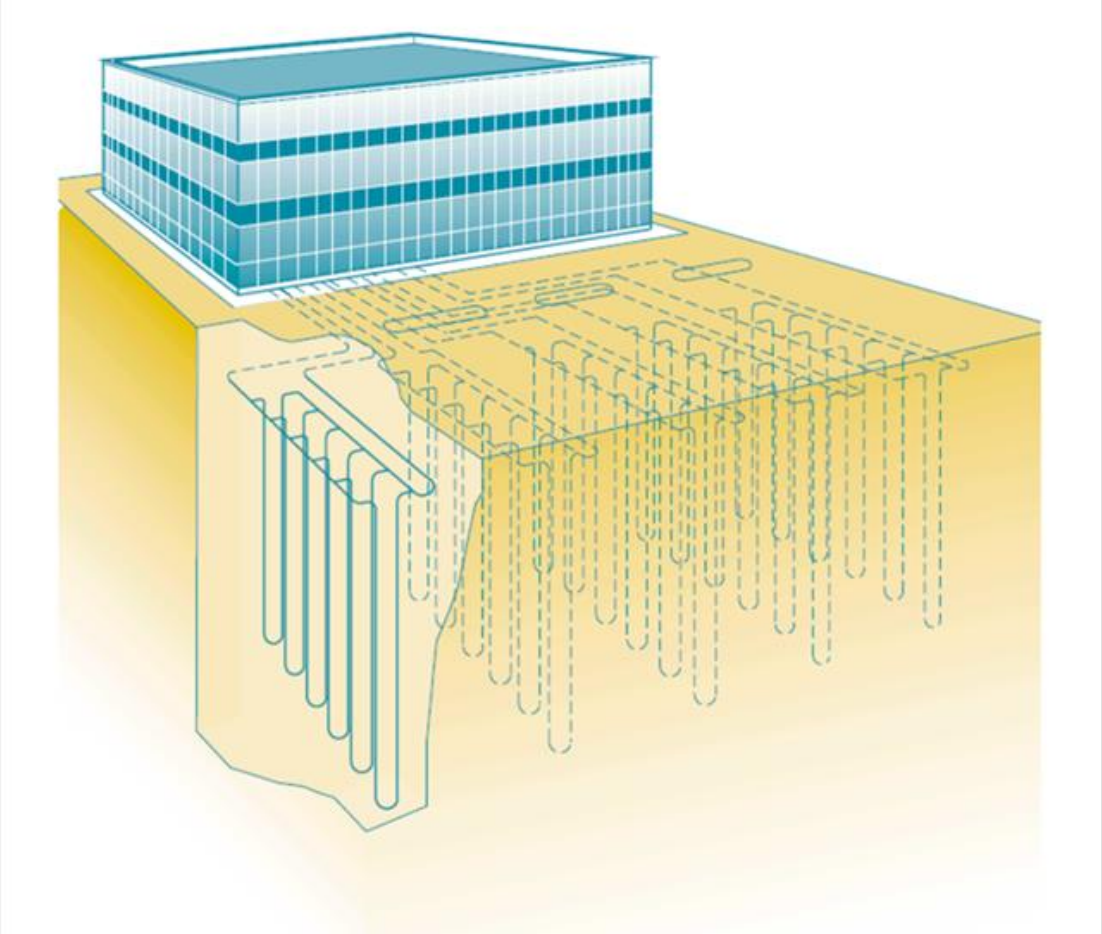
Objectives this Afternoon

1. Climate zones – BC distribution
2. Challenges to decarbonize in harsh climates
3. Geoexchange heat pumps…..***Ultimate Cold Climate Heat Pumps***
4. Design adaptations for harsh climates
5. Misperceptions
6. Obstacles and pathways to overcome

Geoexchange Fundamentals

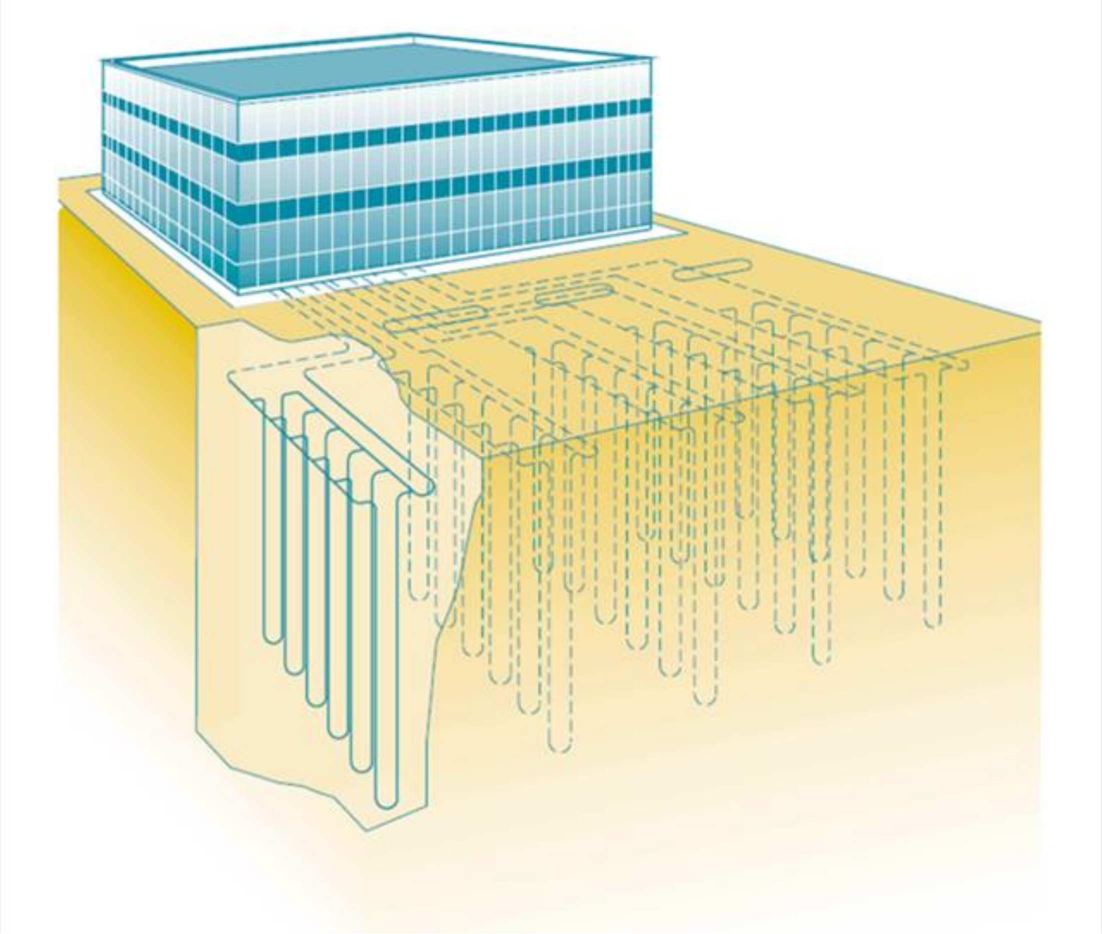


Source: Natural Resources Canada

Terms

- Geoexchange
- Geothermal
- Ground Source Heat Pump (GSHP)
- Earth Energy Systems

Geoexchange Fundamentals



Source: Natural Resources Canada

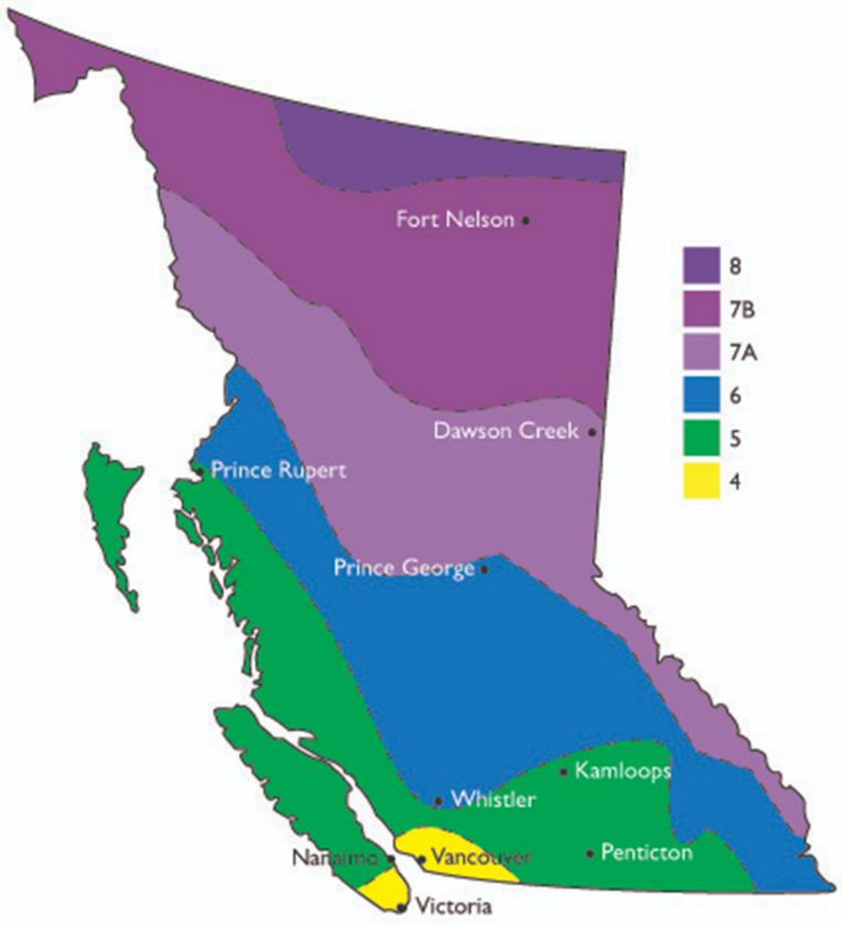
Attractive Features

- Avoided noise, improved architectural aesthetics
- Season-to-season energy store
- District-scale energy leveraging benefits
- Very efficient – including extreme conditions
- ***Ultimate Cold Climate Heat Pump***

Big Nation… *Lots of Harsh Climate*

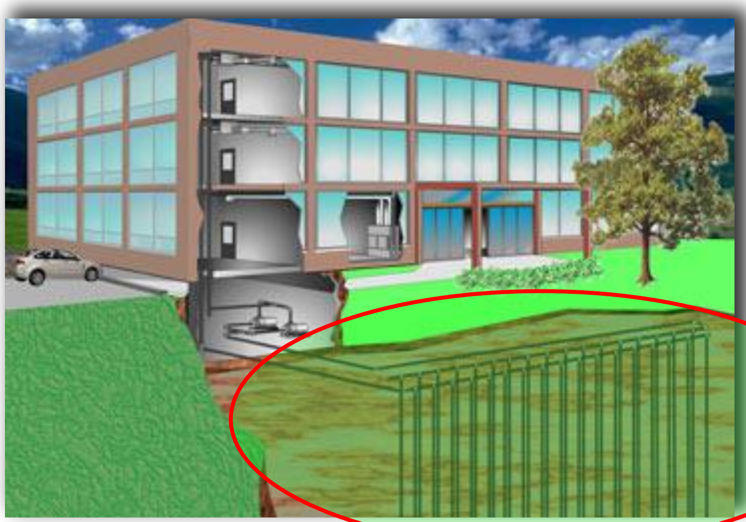
Adapted from National Research Council of Canada

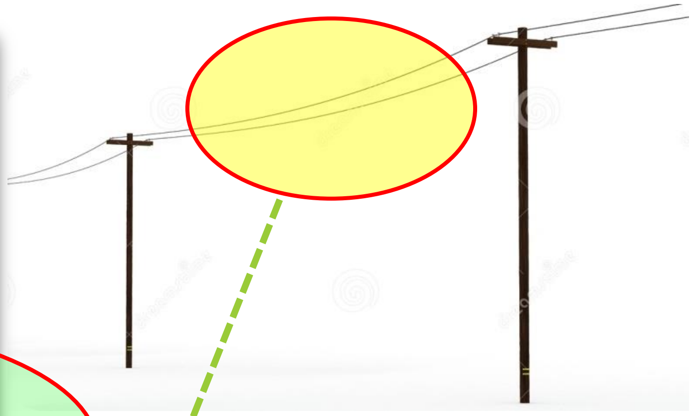
Big Province... *Lots of Harsh Climate*



Adapted from National Research Council of Canada

Leveraging Ratio - Coefficient of Performance (COP)





3 units
Renewable heat
absorbed from ground

+

1 unit
electricity
from utility

=

4 units
Heat Delivered to
Building

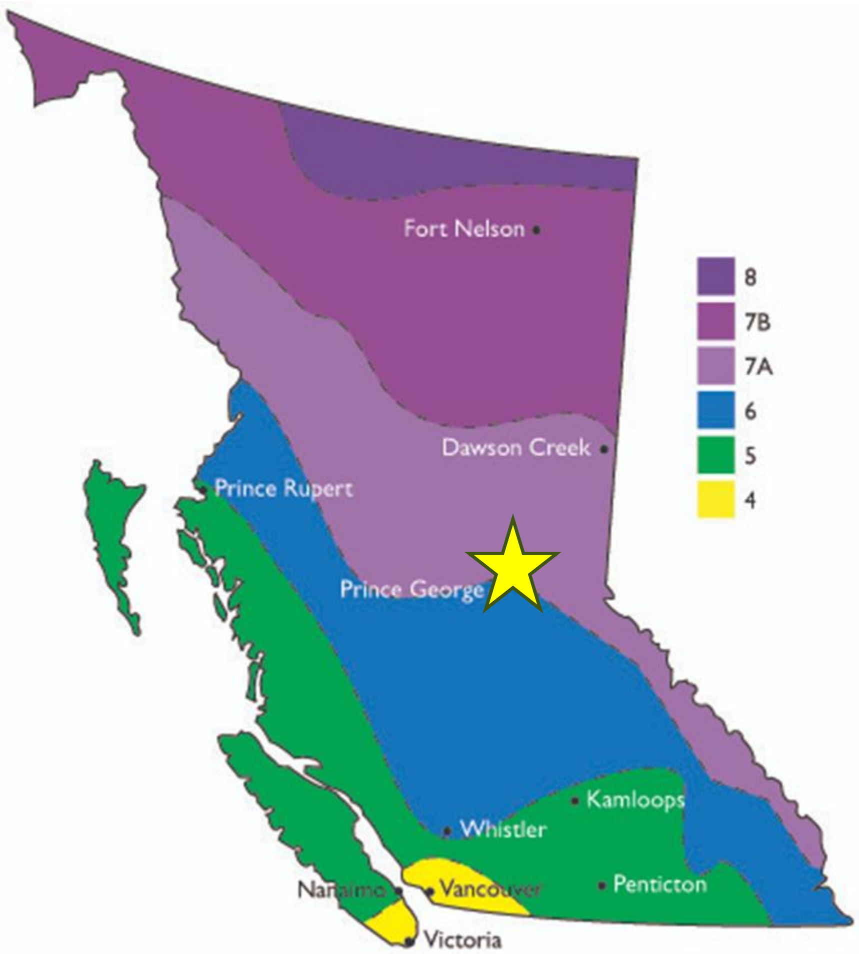
$$\text{Coefficient of Performance} = \frac{\text{Heat Delivered (4.0 units)}}{\text{Electricity Used (1.0 unit)}} = 4.0$$

New Build School - Northern BC

Shas Ti Kelly Road Secondary School, Prince George, BC

- 9,595 m^2
- 280 kW Geoexchange Heat Pump System

Source: HMCA Architecture, SD57



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Shas Ti Kelly Road Secondary School, Prince George, BC

Utility Data	Actual GeoX 2021	Conventional Comparable
Natural Gas	7 kWh/m^2	110 kWh/m^2
Electricity	68 kWh/m^2	110 kWh/m^2
Combined Gas + Elec	75 kWh/m^2	220 kWh/m^2
GHG Emissions (CO_2e)	19.7 tonnes/yr	201 tonnes/yr
Energy Savings	$83,600/yr	-
Avoided GHG Emissions	181 tonnes/yr	-

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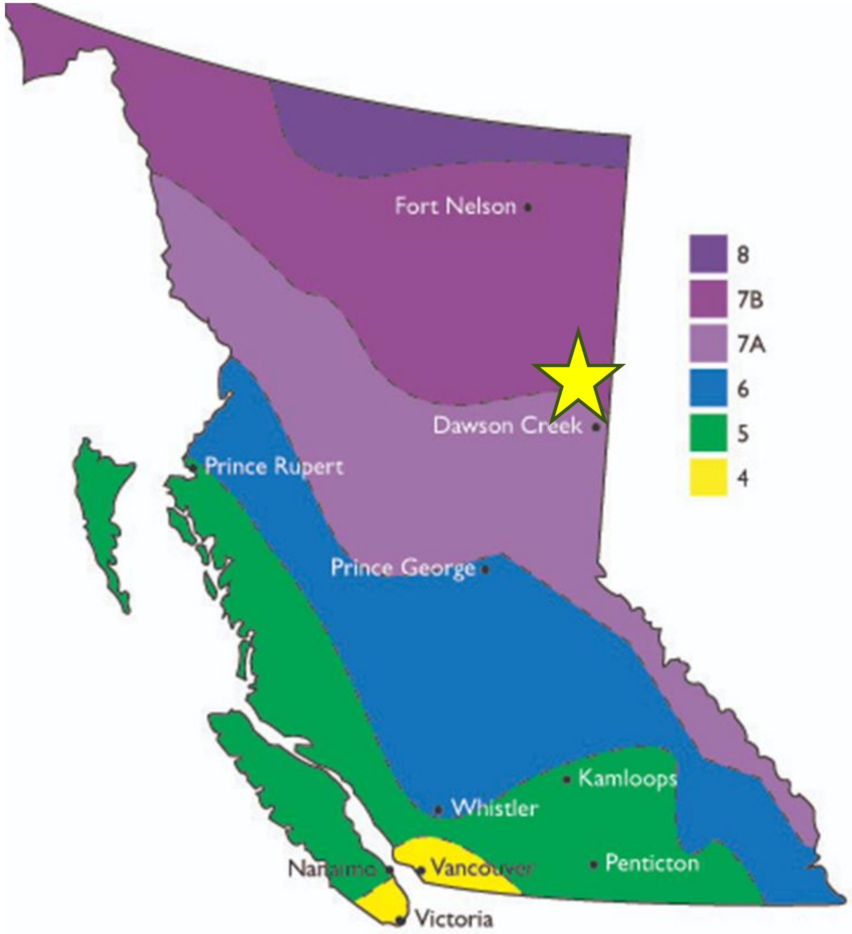
Retrofit GeoX Upgrade - Northern BC

Ecole Frank Ross Elementary, Dawson Creek, BC

- 5,100 m^2
- 210 kW Geoexchange Heat Pump System
- 1950s era original wing, 1960s era addition



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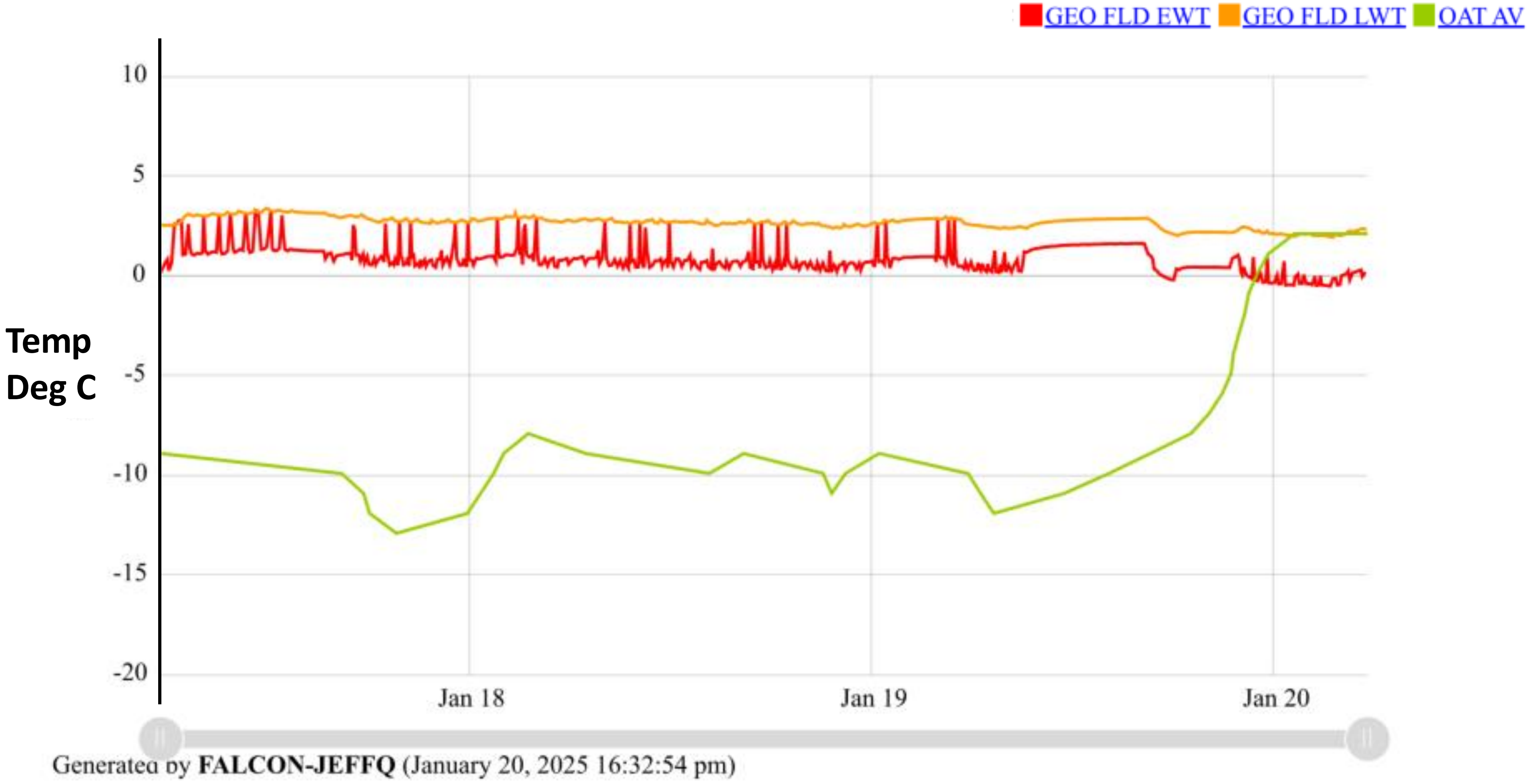
Ecole Frank Ross Elementary, Dawson Creek, BC

Utility Data	Actual GeoX 2022	Pre-Retrofit Comparison
Natural Gas	11 kWh/m^2	215 kWh/m^2
Electricity	79 kWh/m^2	44 kWh/m^2
Combined Gas + Elec	90 kWh/m^2	259 kWh/m^2
GHG Emissions (CO_2e)	14.2 tonnes/yr	198.5 tonnes/yr
Energy Savings	$18,300/yr	-
Avoided GHG Emissions	184 tonnes/yr	-

Ecole Frank Ross – Temperature Monitoring – Dawson Creek

This week: 4-day Period Jan 17 to Jan 20, 2025



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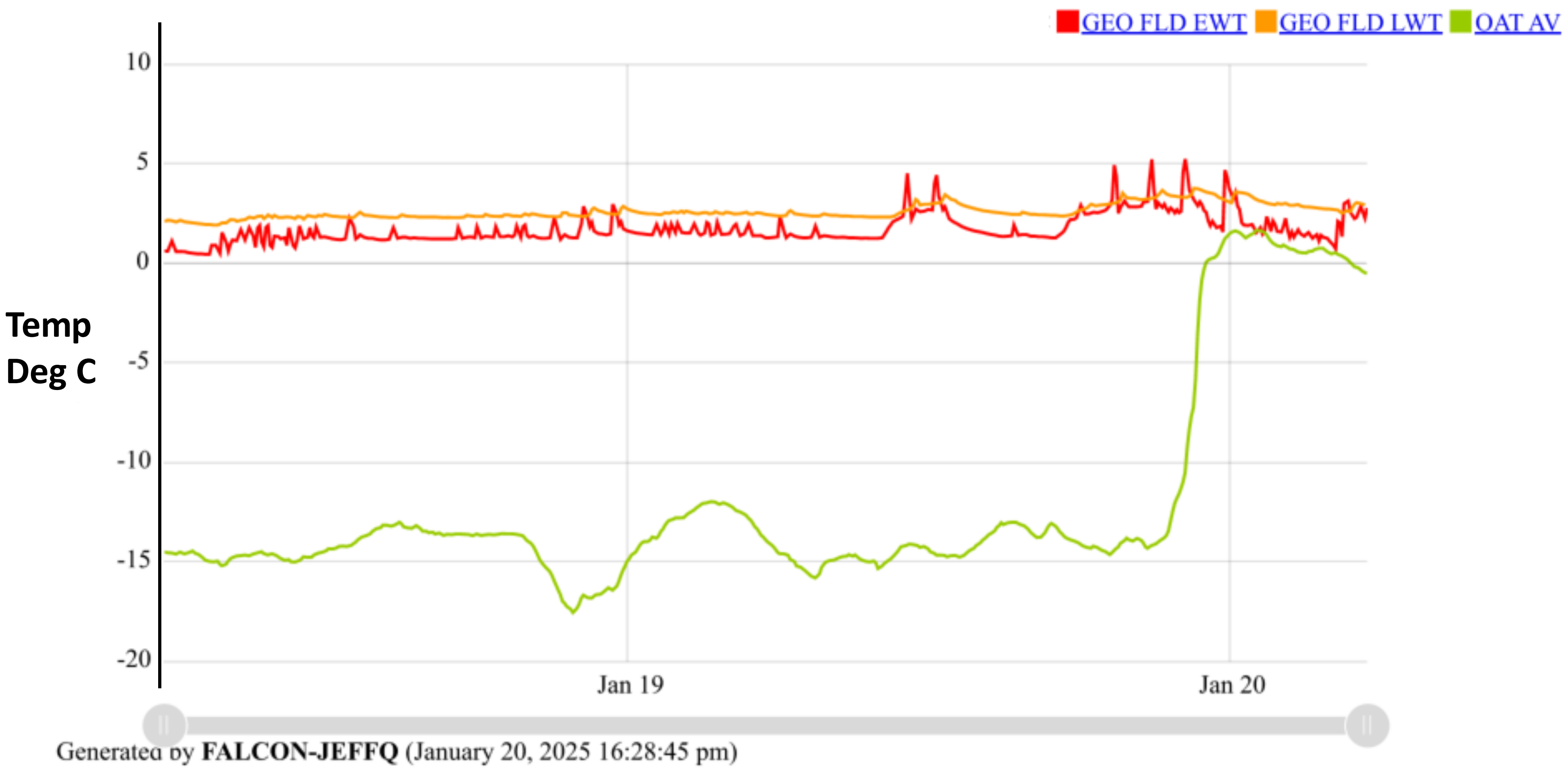
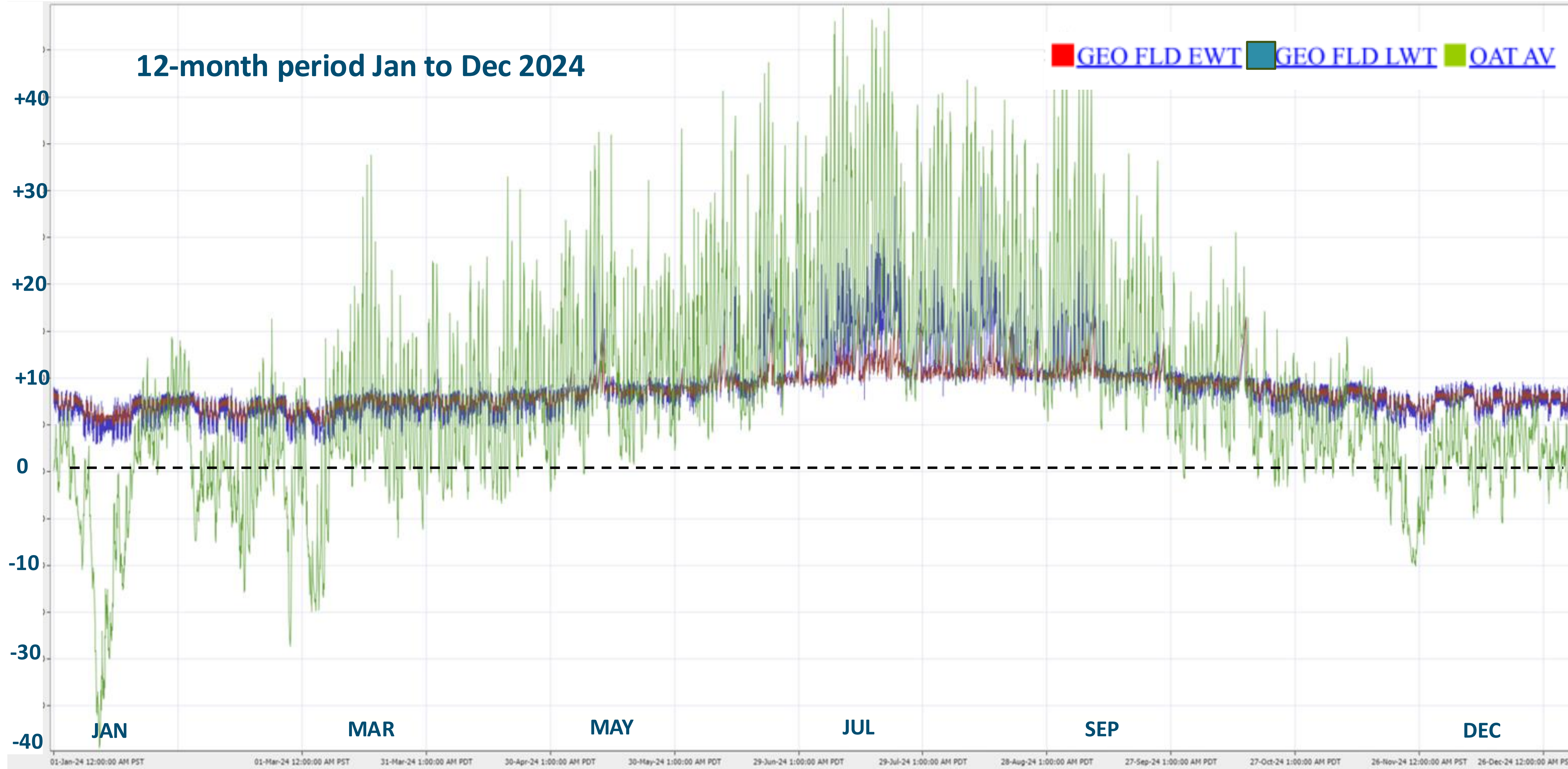
South Peace Secondary – Temperature Monitoring – Dawson Creek

This week: 3-day Period Jan 18 to Jan 20, 2025

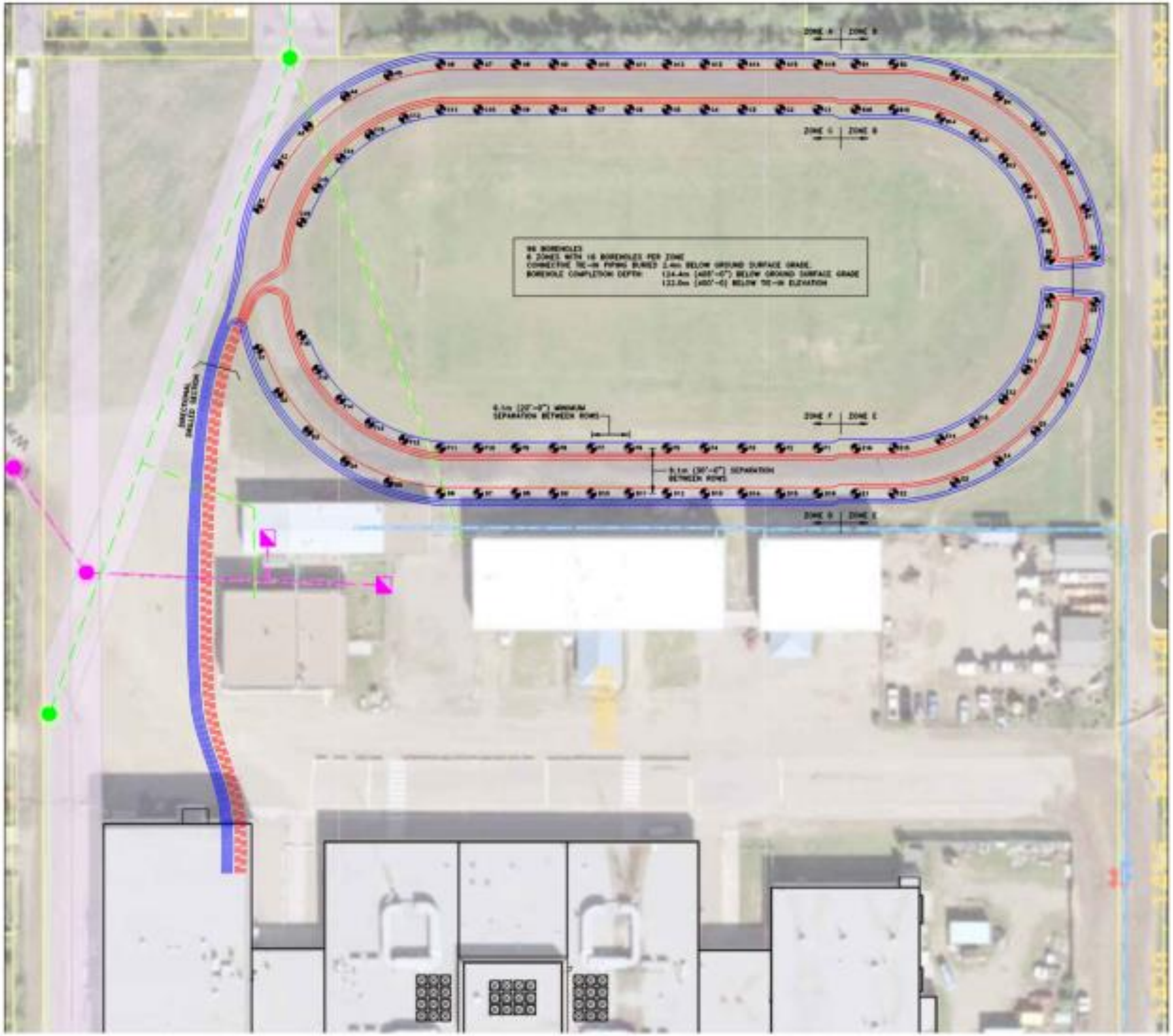


Annual Temperature Monitoring – Williams Lake Example



Cold Climate Design Considerations

- Elongated open borehole layouts
- Reduce bore-to-bore interference



Uptake Obstacles…and Opportunities

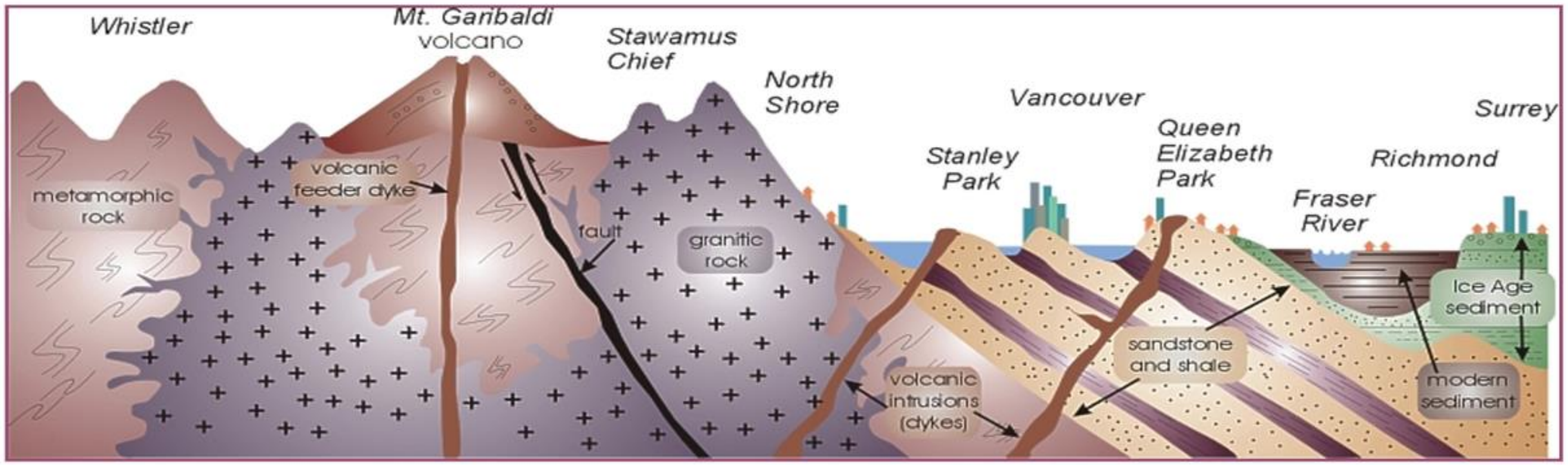
Heat Pumps.... Not Drop-in Replacements for Boilers

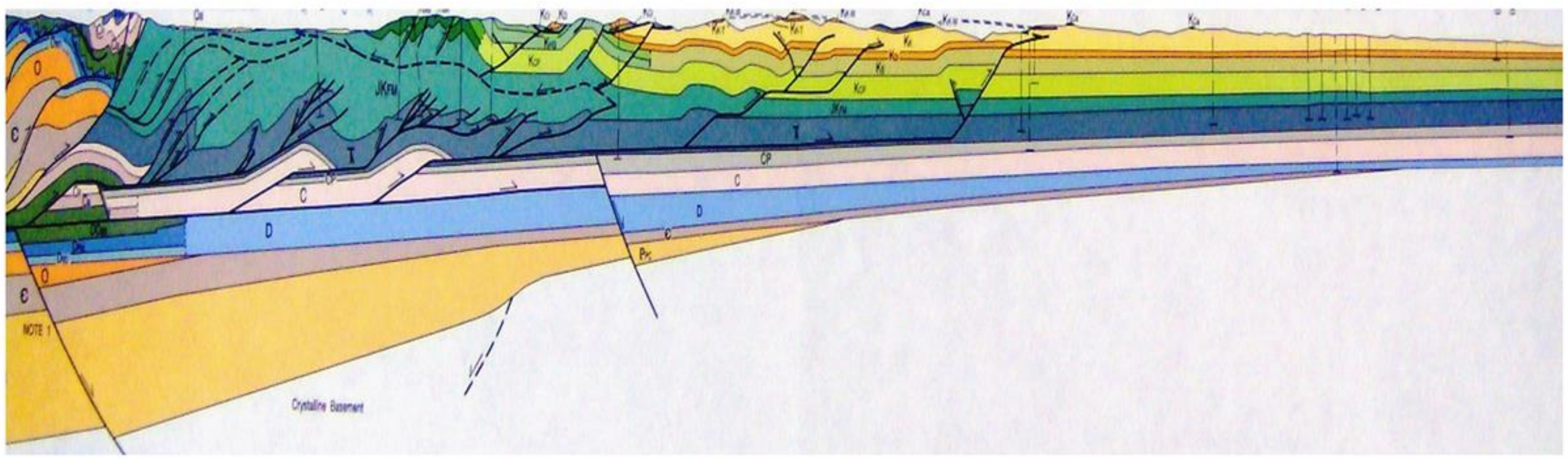
≠

Boilers

Heat Pumps

BC Geology Settings – Adapt Designs to Suit Settings





Rocky Mountain Front Ranges | Foothills | Prairies

Recap

- Geoexchange is suited in many settings for different reasons
- Exceptional cold climate performance leads to attractive suitability in northern regions – ***Ultimate Cold Climate Heat Pump***
- Demonstrated high-performance outcomes
- High-performance conditional on appropriately adapted designs

Take-aways:

1. Geoexchange warrants routine consideration in northern settings
2. Geoexchange has unique potential to significantly decarbonise heating in northern climates

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DESIGN CONSIDERATIONS FOR AIR SOURCE HEAT PUMPS SYSTEMS IN COLD CLIMATES

Keith Bate P.Eng.

January 24th, 2025

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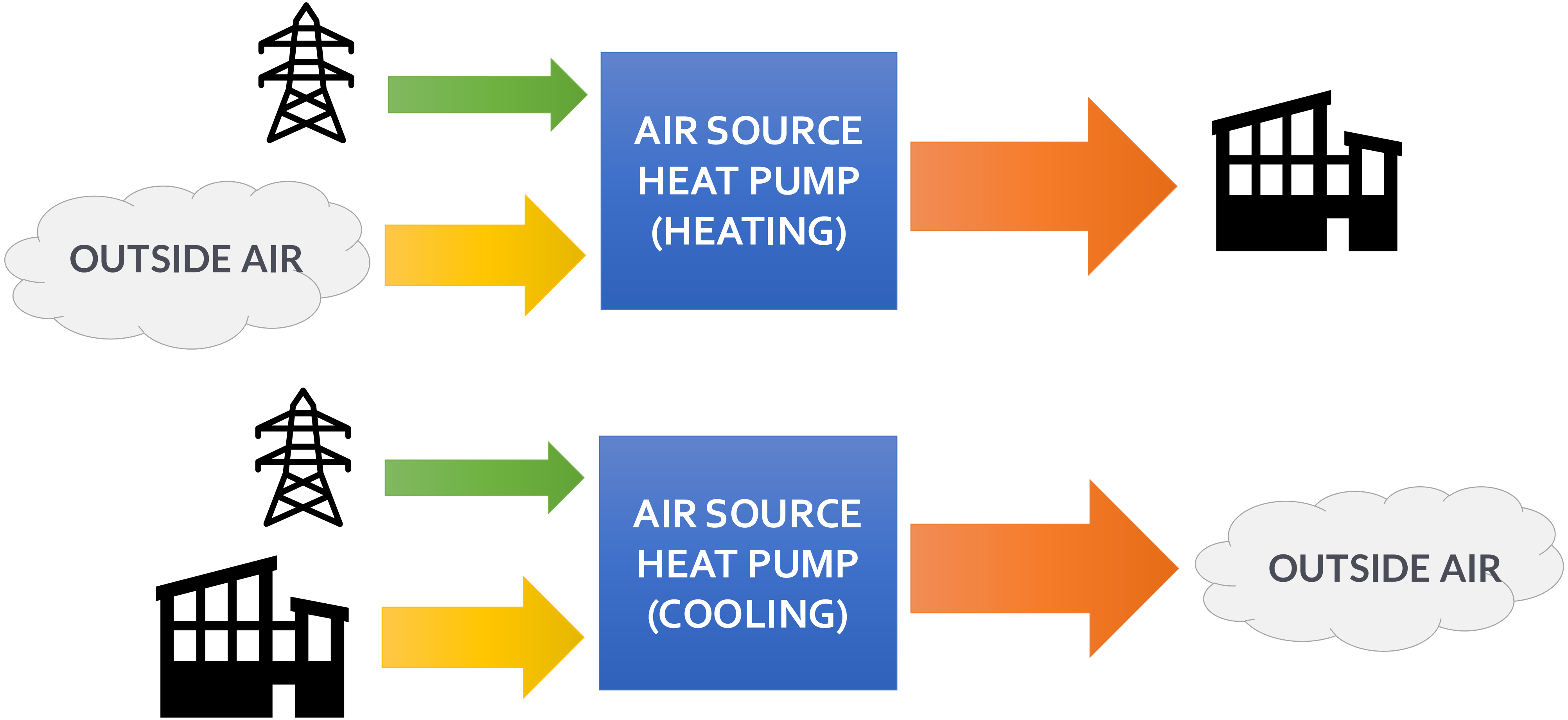
Building to Electrification Coalition



$$Coefficent\ of\ Performance\ (CoP) = \frac{HEATING\ (or\ COOLING)\ ENERGY\ SUPPLIED}{ELECTRICAL\ INPUT}$$

Technology this presentation is not about…

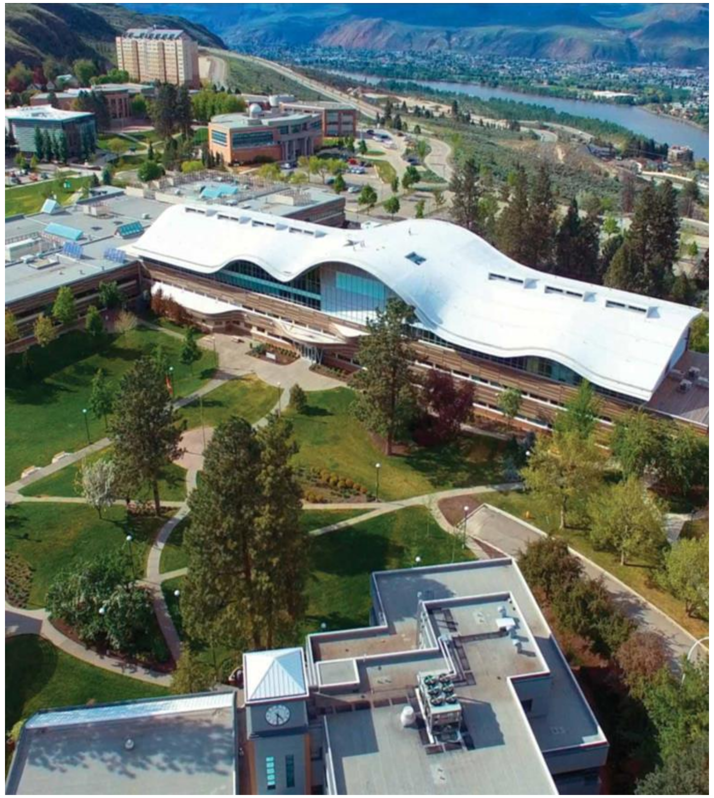
Individual split heat pump systems

VRF (Variable Refrigerant Flow) systems

Gas absorption heat pumps

Thompson Rivers University Project Overview

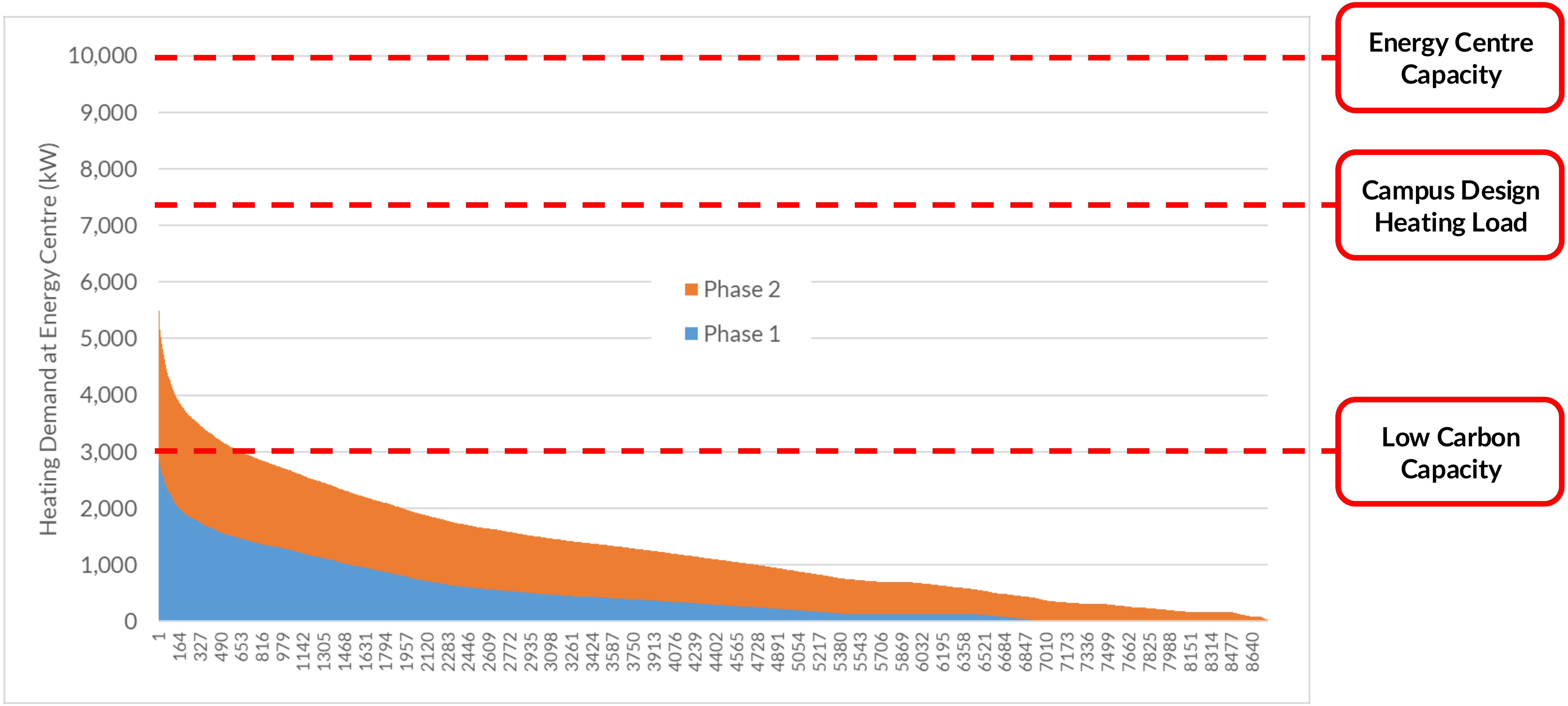
- University founded in 1970 in Kamloops, BC
- Winter 1% design temp of -25°C (-13°F)
- Existing buildings with gas boilers and gas roof top units
- Variety of terminal units
- Design heating water temperatures of up to 90°C



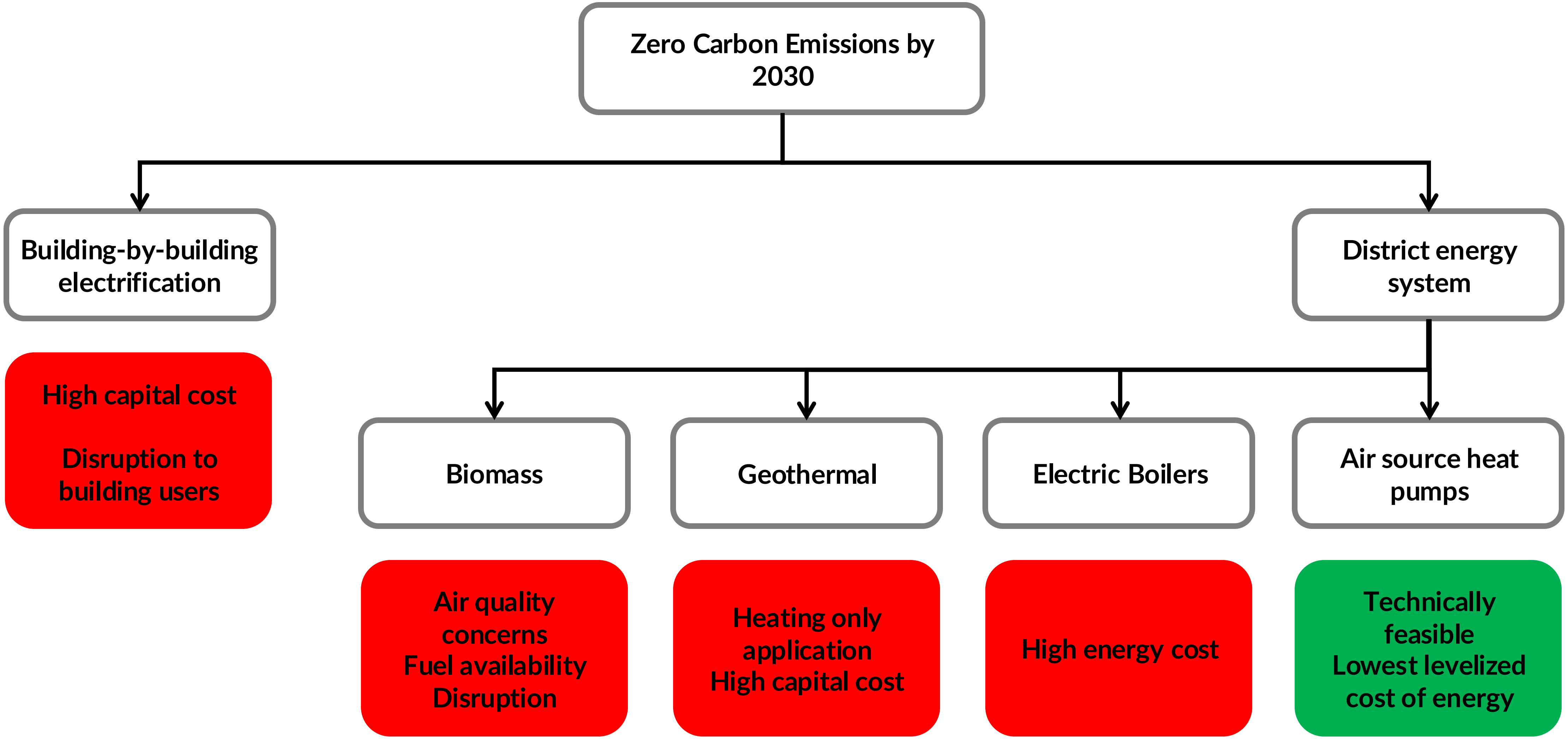
System Design Considerations

- 'Stress test' identified that most buildings could work at 65°C but system needed to be capable of higher temperature operation
- 7.5MW peak heating demand
- 3MW of low carbon capacity achieves 95%+ GHG reductions
- Limit on electrical service of 2.5 MVA to avoid BC Hydro upgrade

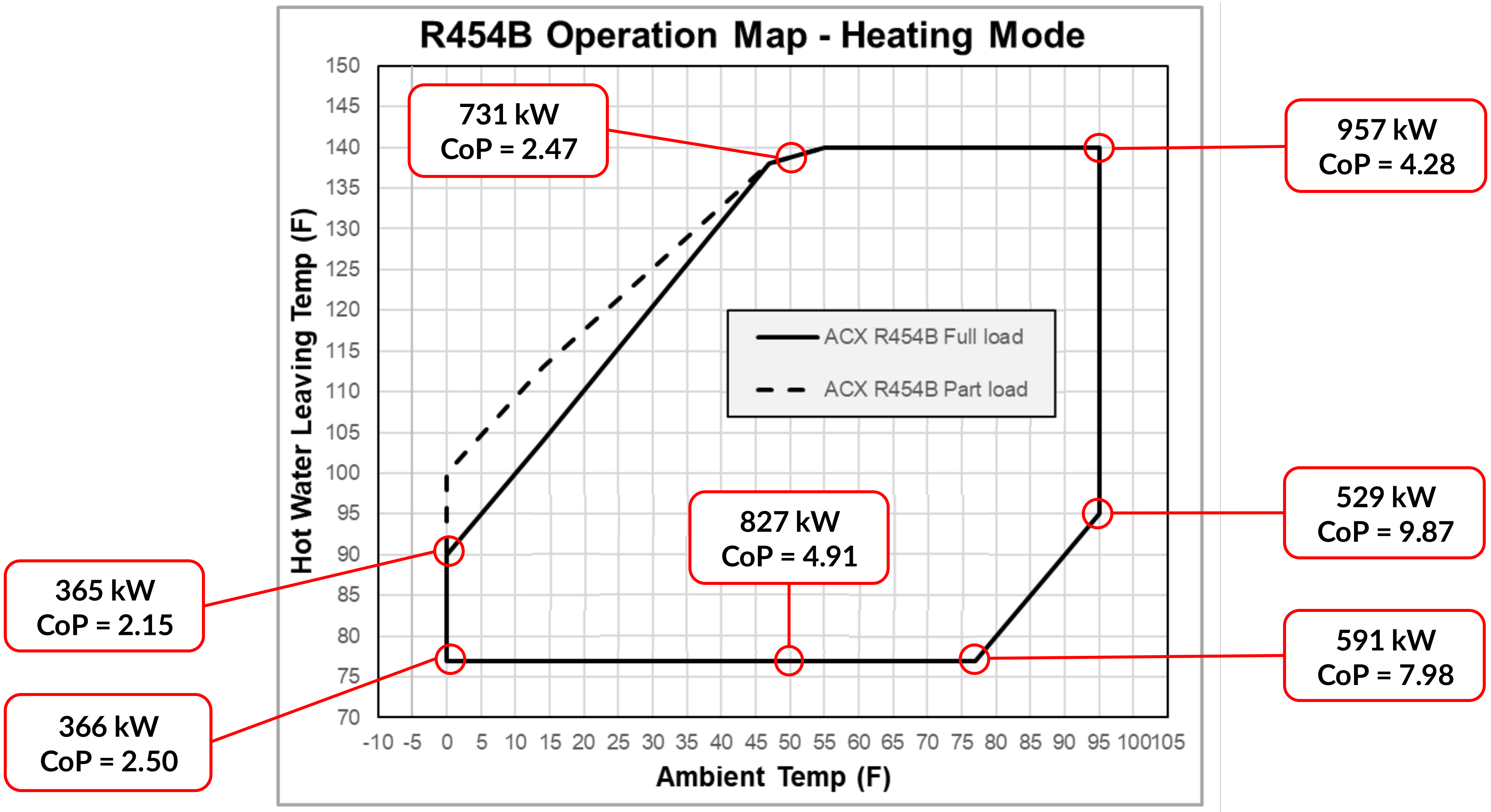
Load Duration Curve – Typical Weather



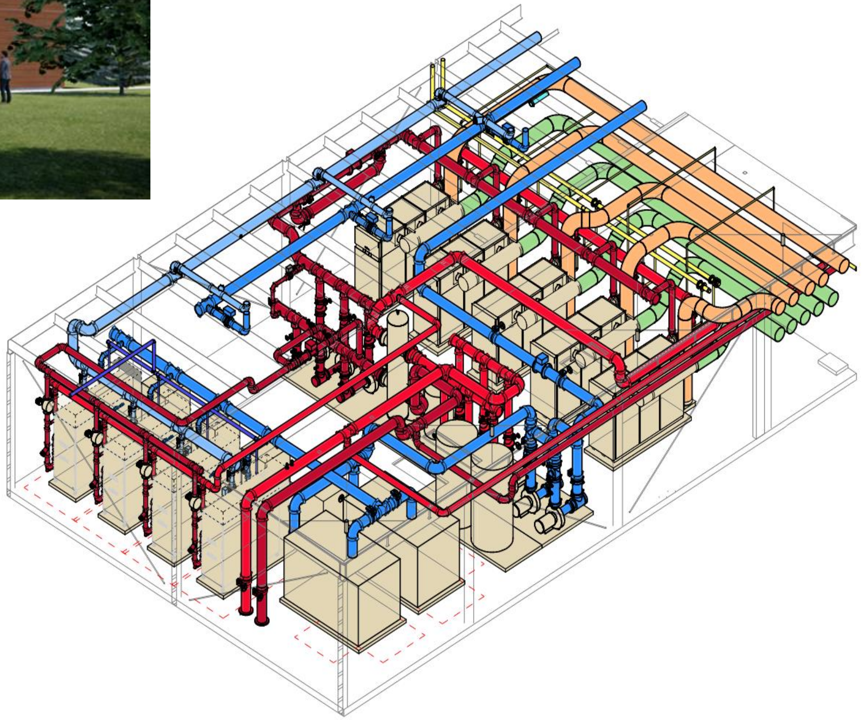
Options assessment



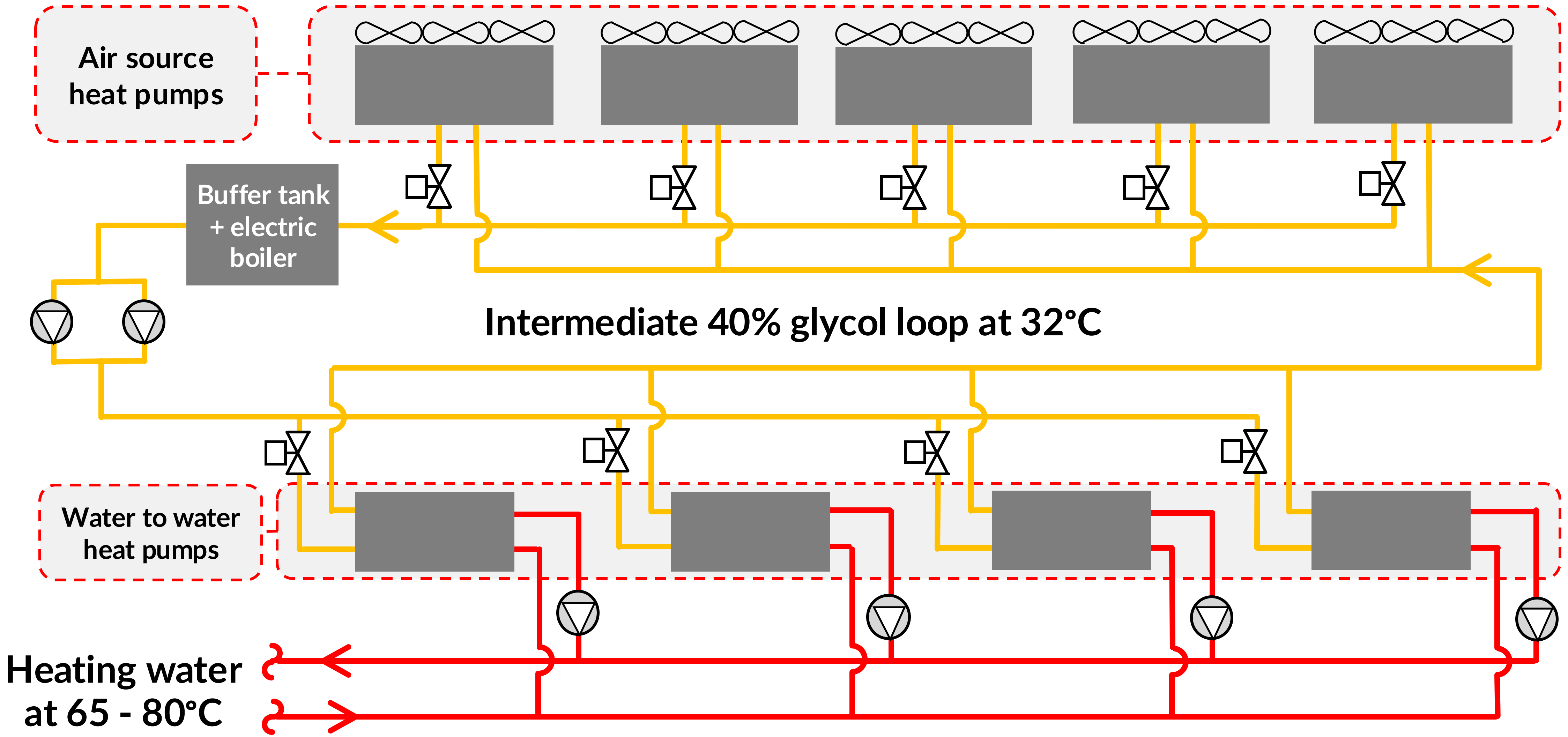
ASHP Operating Limits, Capacity and Coefficient of Performance



Two Stage Heat Pump Solution

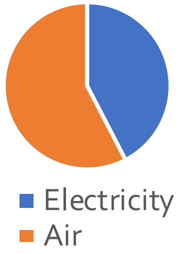


Two Stage Heat Pump Solution

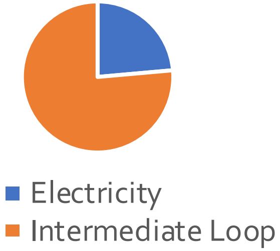


Net CoP Comparison

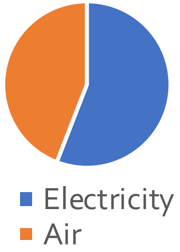
at -15°C



CoP of 2.36

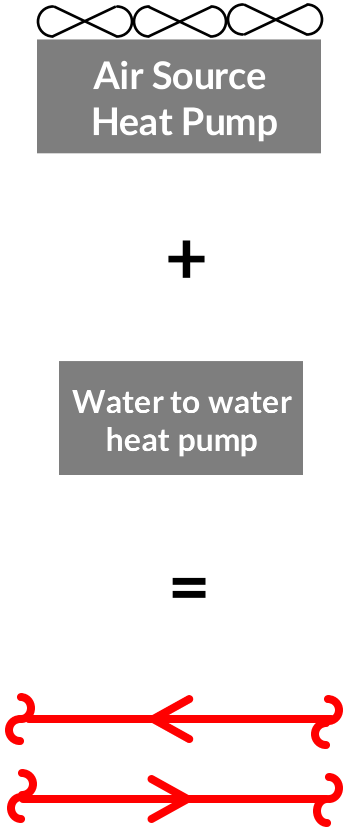


CoP of 4.24



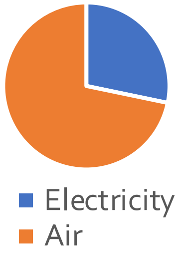
Net CoP of 1.79

$$4.24 / (1 + 3.24/2.36)$$

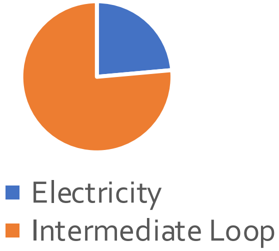


at +15°C

CoP of 4.35

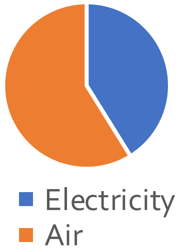


CoP of 4.24



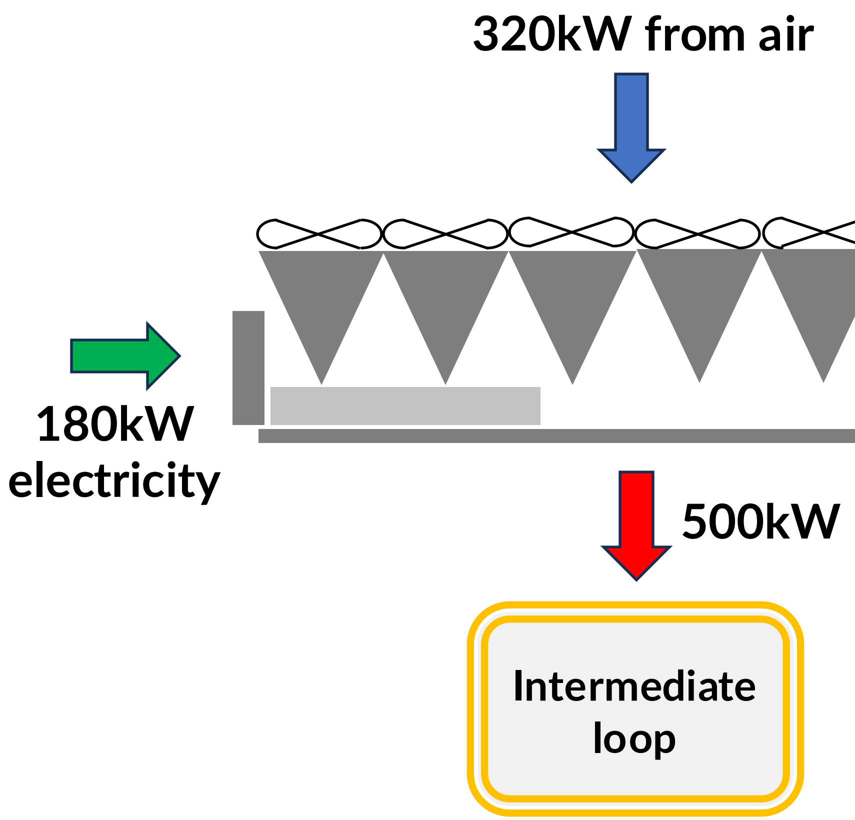
Net CoP of 2.43

$$4.24 / (1 + 3.24/4.35)$$

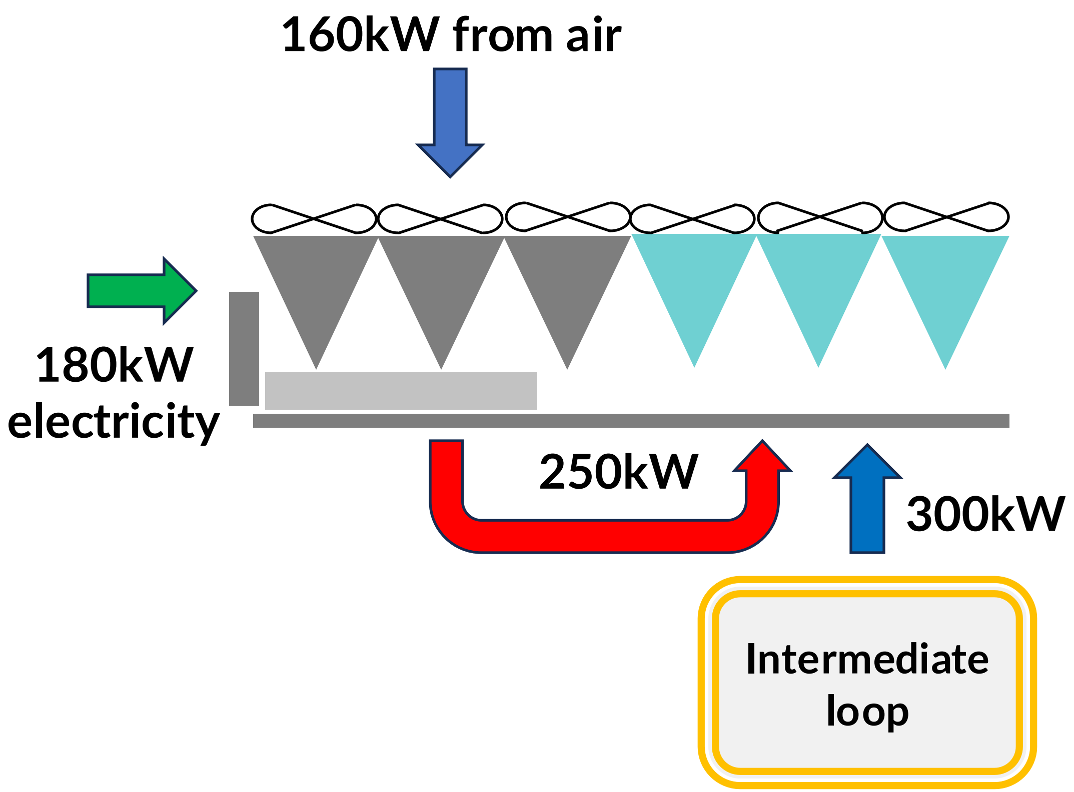


Defrost

Normal operation



Defrost mode

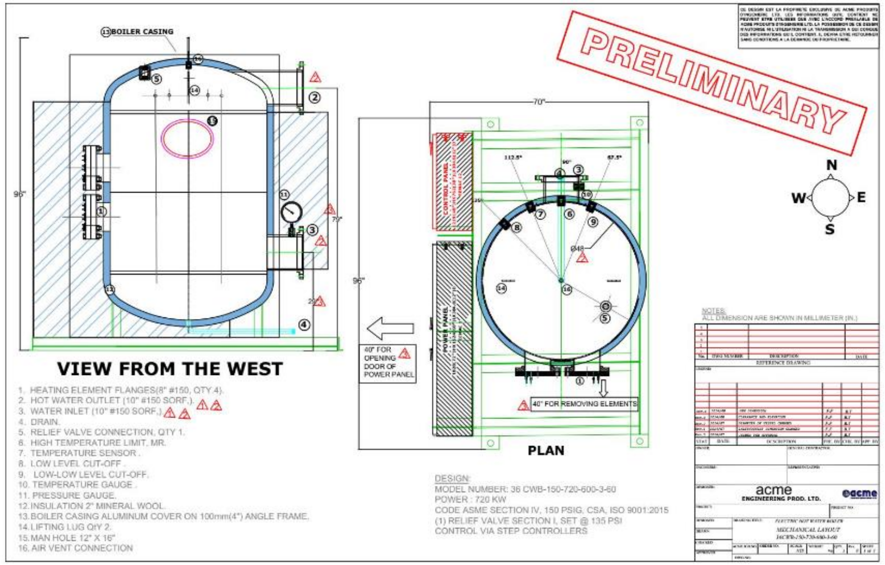


Role of Buffer Tank / Electric Boiler

- Volume of piping loop ~ 5,000 litres
- Volume of buffer tanks – 4,500 litres

With one ASHP in defrost mode intermediate loop temperature drops…

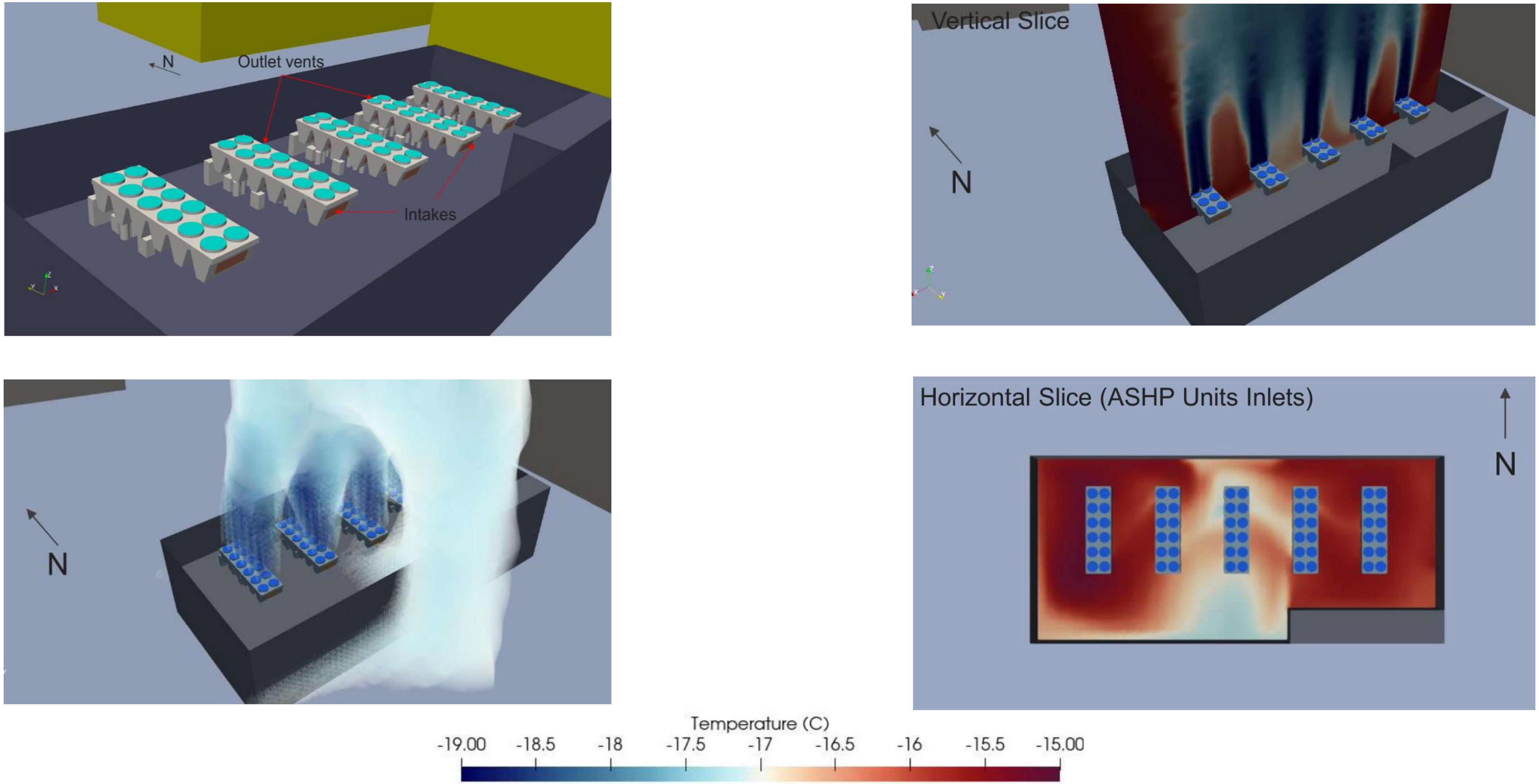
- 2.3°C per minute without buffer tanks
- 1.2 °C per minute with buffer tanks



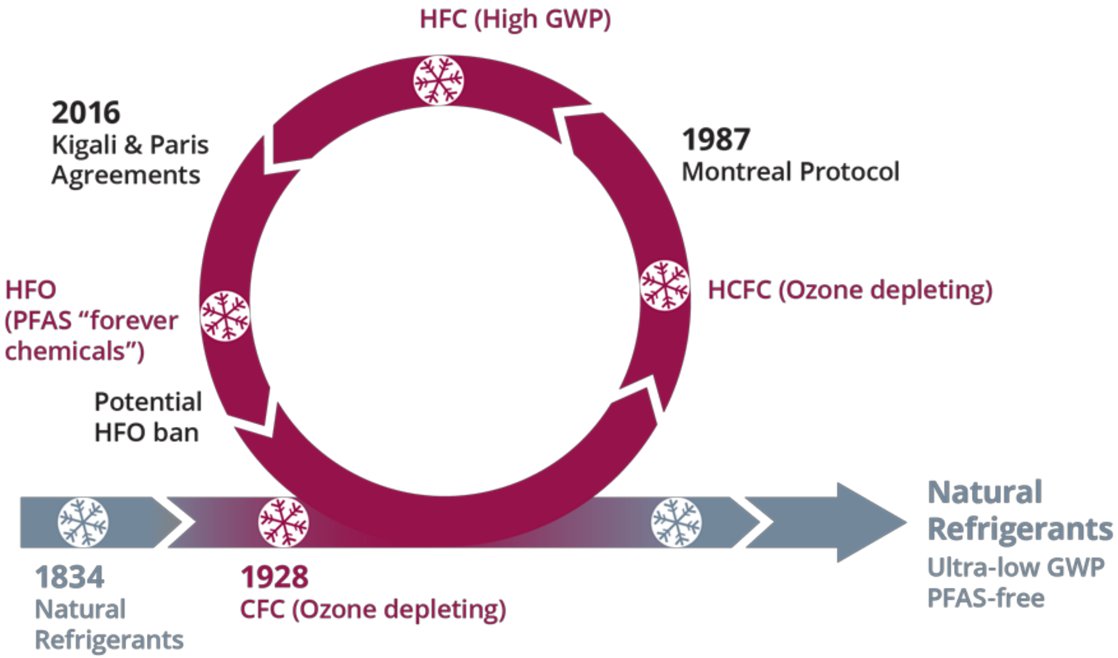
Benefits of electric boiler in intermediate loop:

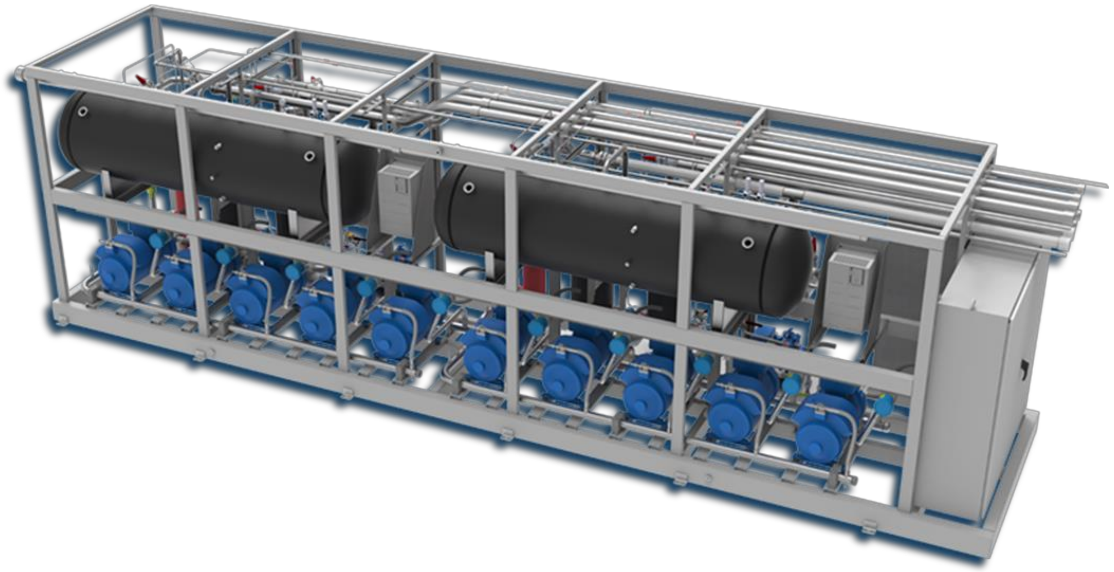
- Tops up when ASHPs cannot provide enough heat for the water to water heat pumps (below approximately -7°C)
- Below -18°C ASHPs turn off – electric boiler provides all heat to the water to water heat pumps
- Prevents ‘death spiral’ where intermediate loop temperature is too low for air source heat pumps to work

Computational Fluid Dynamic Modeling of Airflow



Future Developments – Natural Refrigerants





Summary

- Air source heat pumps can be a viable decarbonization strategy in cold climates
- Systems sized for only part of peak heating load can provide significant GHG reductions
- Consider noise mitigation and ensure adequate airflow when locating equipment
- Two stage systems can provide higher heating water temperatures
- Ensure freeze protection measures are in place
- Account for the impact of defrost cycles in system design
- Ensure air source heat pump loop temperature can be maintained in operating range
- Consider natural refrigerants for lower environmental impact and future proof systems