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GEOTHERMICA Initiative & CETPartnership TRI4
Workshop in Dublin 10/10/2023

Low-medium Temperature Geothermal for Campuses – University of Calgary, Canada

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EUROPEAN PARTNERSHIP

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Agenda

- Introduction
- University of Calgary District Heating System
- Proposed Geothermal System
- System Design
- Performance Results

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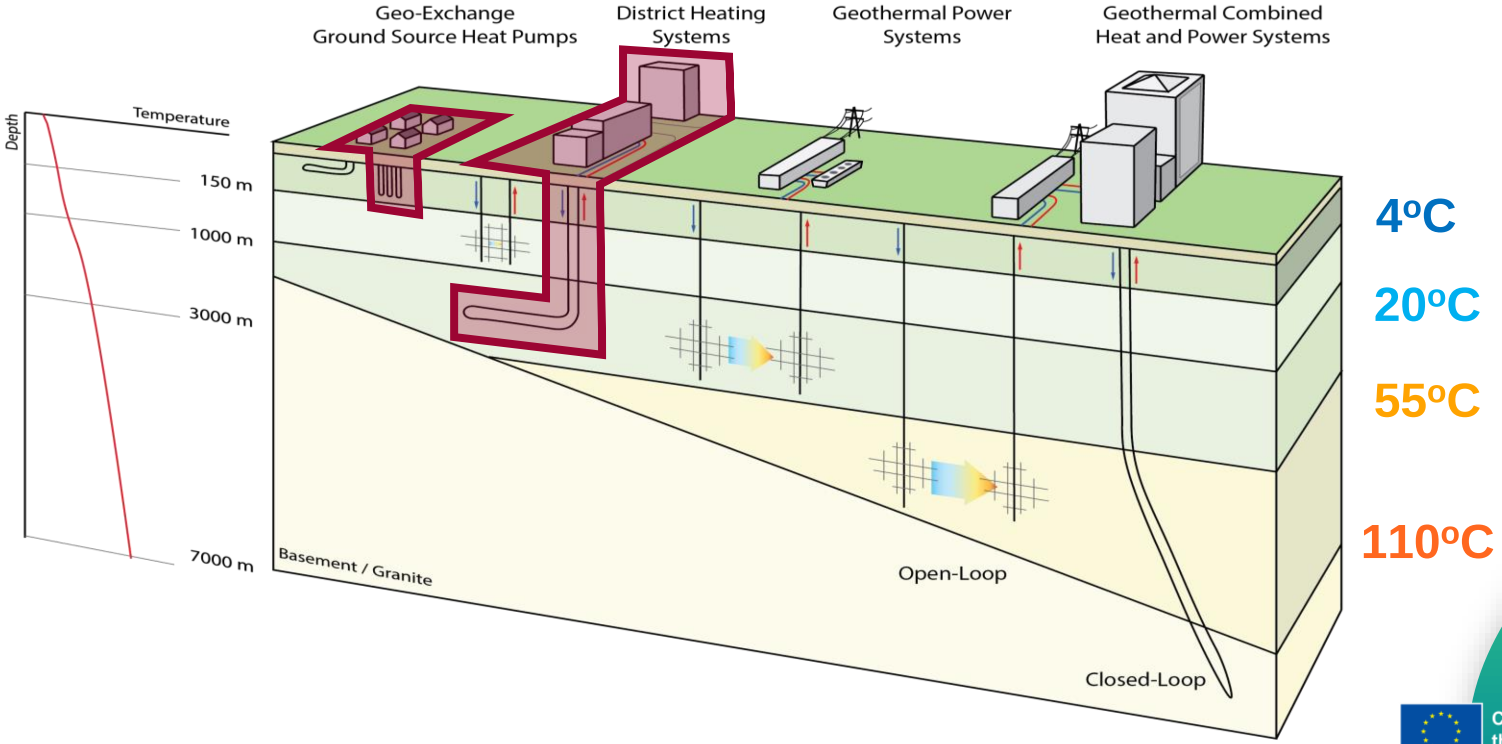
Introduction



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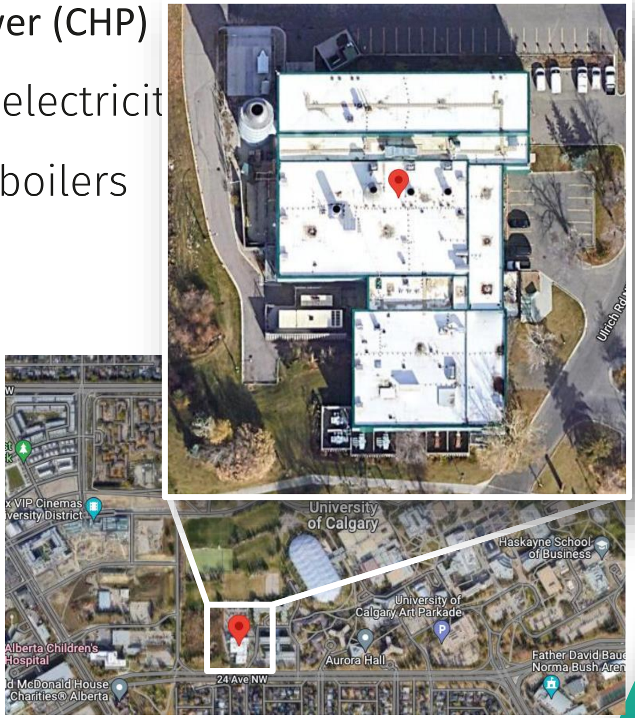
University of Calgary System

- Cogeneration system for combined heat and power (CHP)
  - 14 MW natural gas turbine – 70% of the electricit
  - Heat recovery system + supplementary boilers
  - District heating system
- Energy demand (annual)
  - Power: 85 GWhe/year
  - Heat: 147 GWht/year
- Emissions (annual)
  - 72,000 tonnes CO2-eq.



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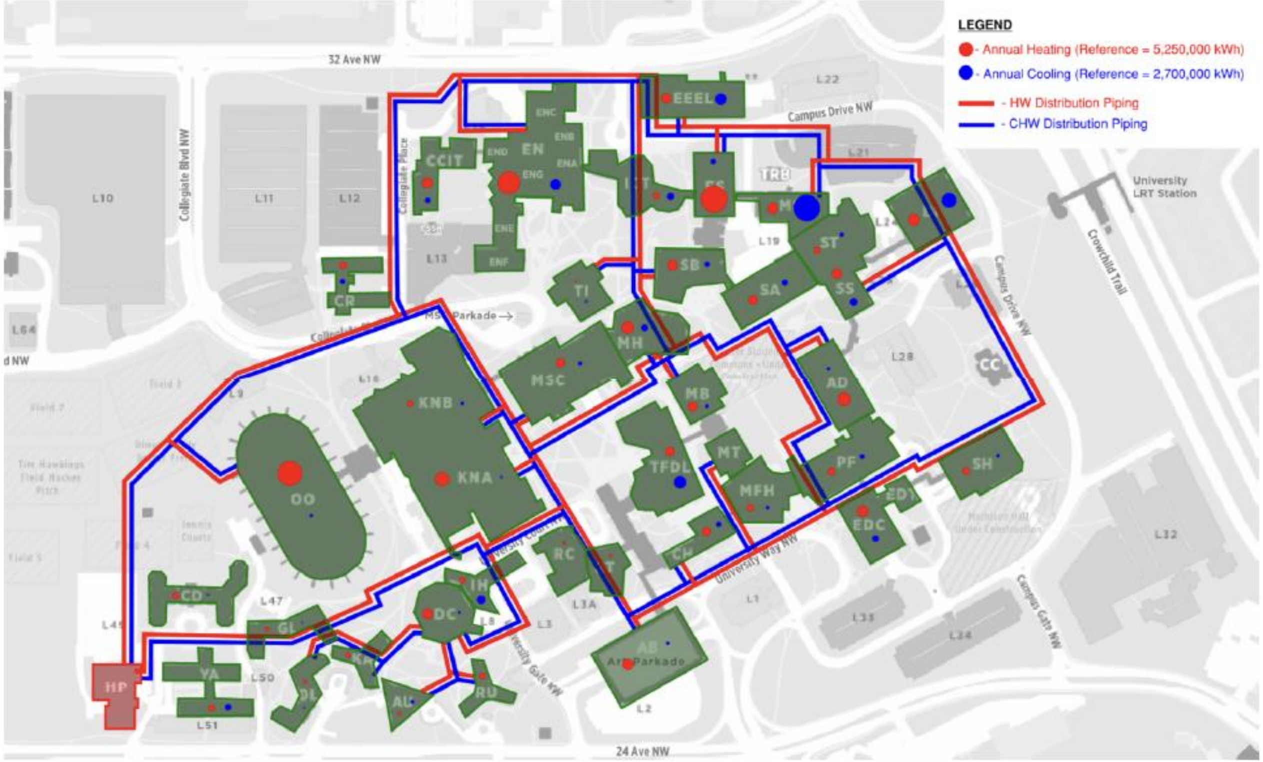
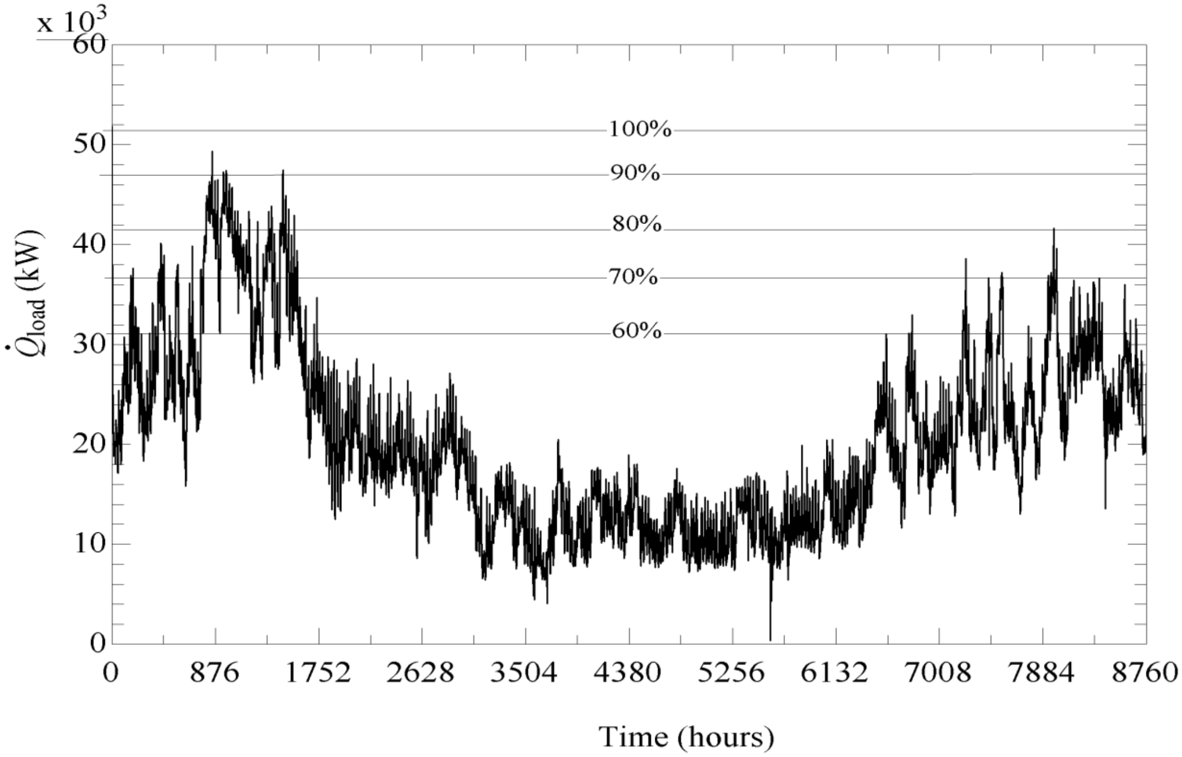
University of Calgary System

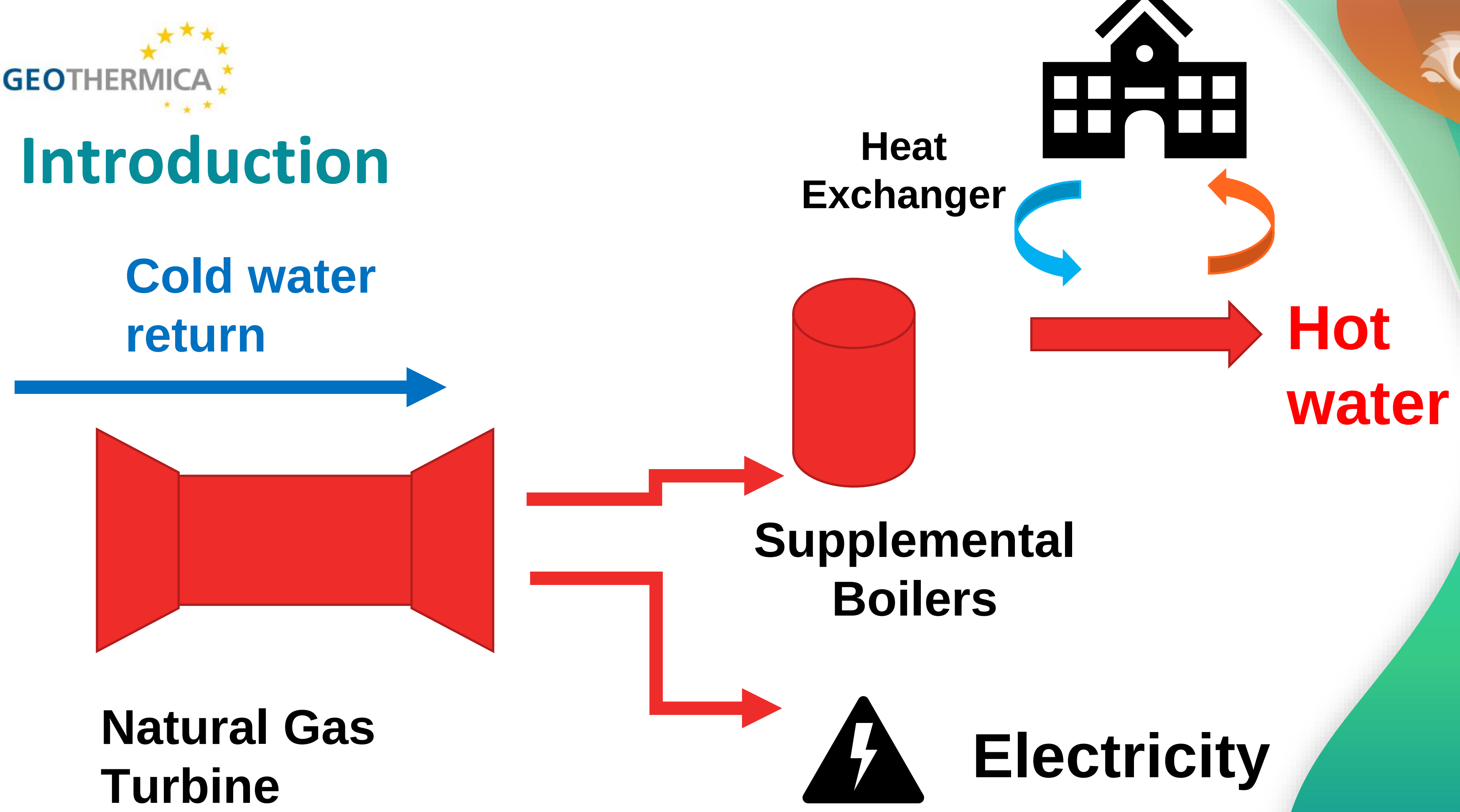


Heating load profie

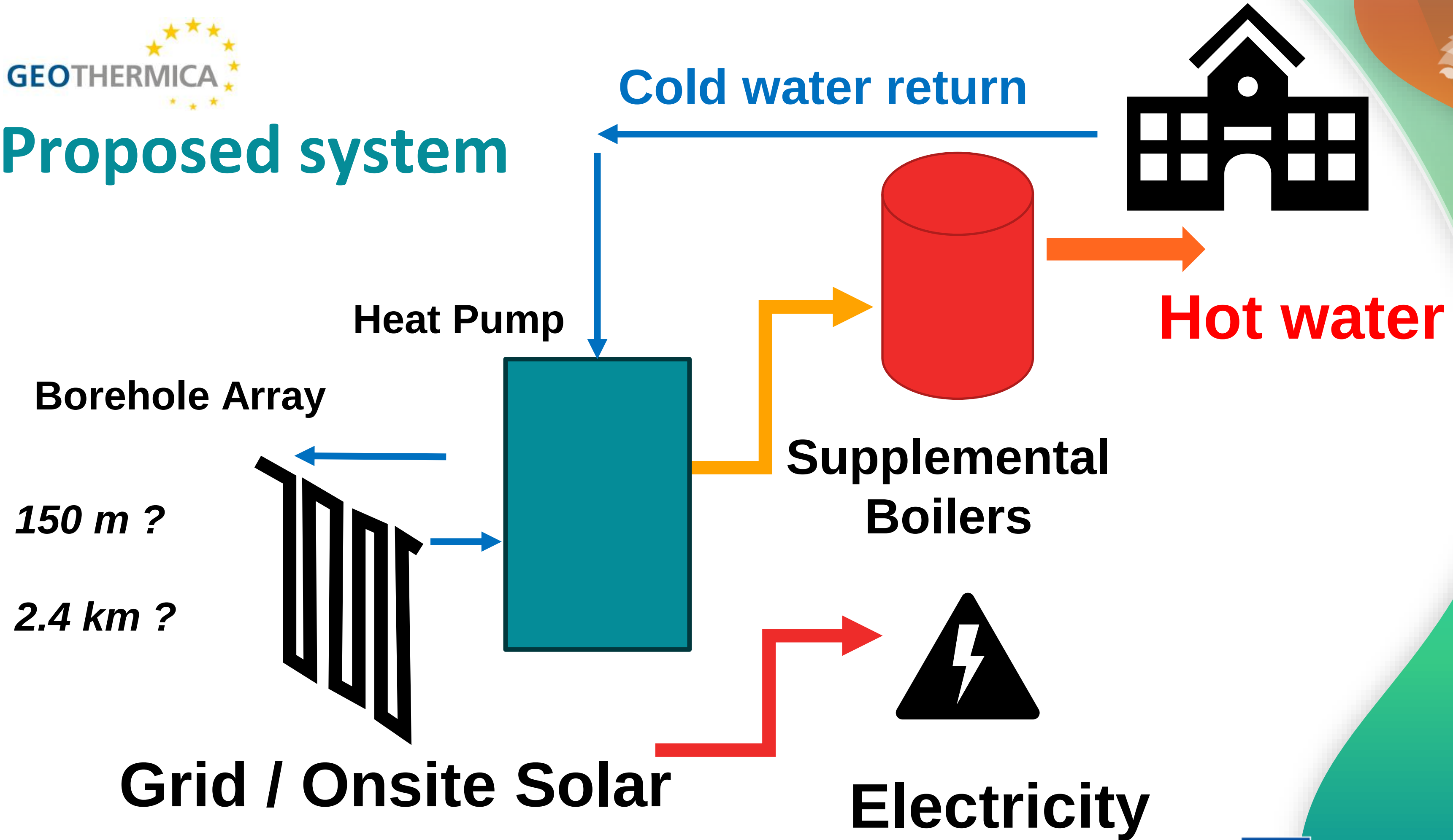


Winter **Spring** **Summer** **Fall**

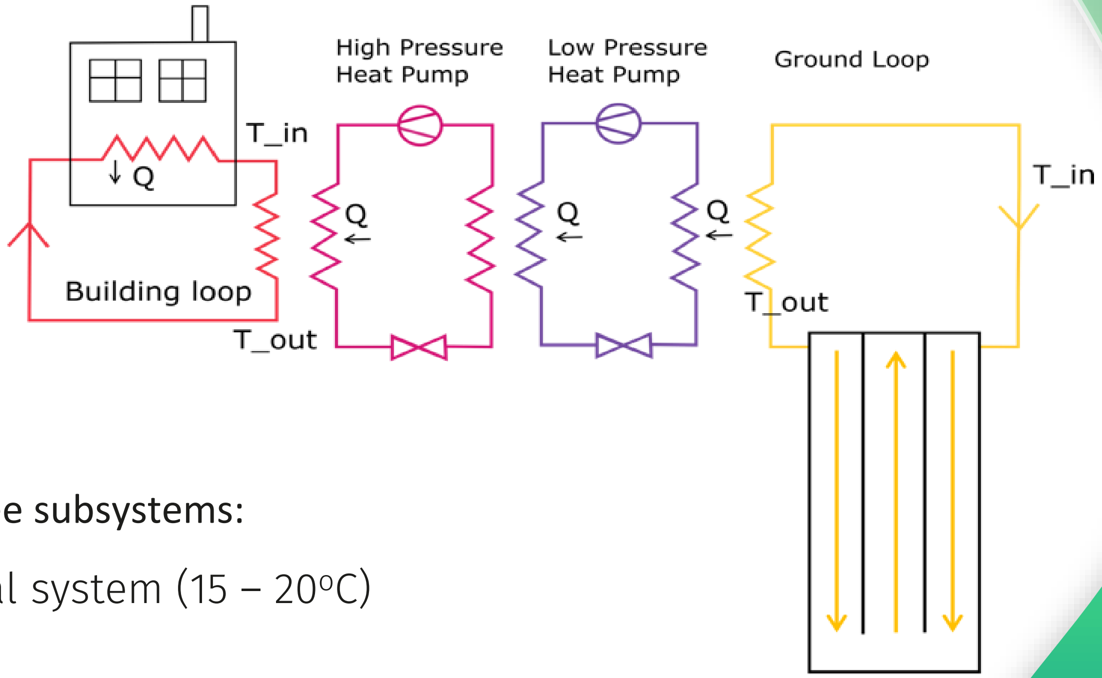
Introduction



Proposed system



System design



- Overall system integrates three subsystems:
  - Subsurface geothermal system (15 – 20°C)
  - Heat pump
  - Building heat loop (90-77°C)

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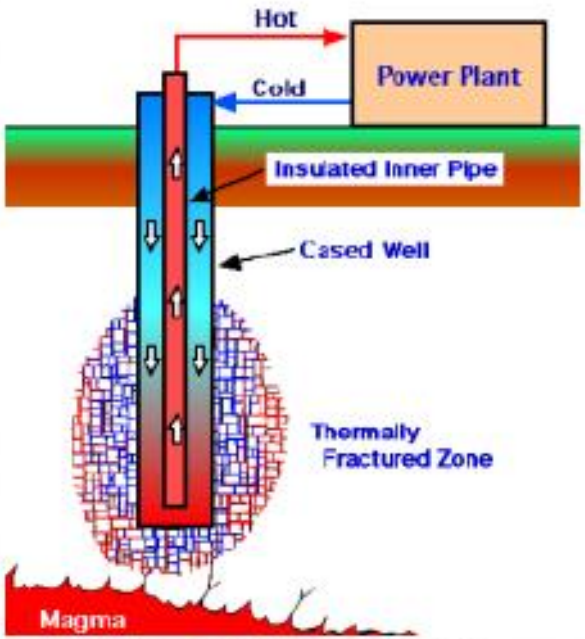
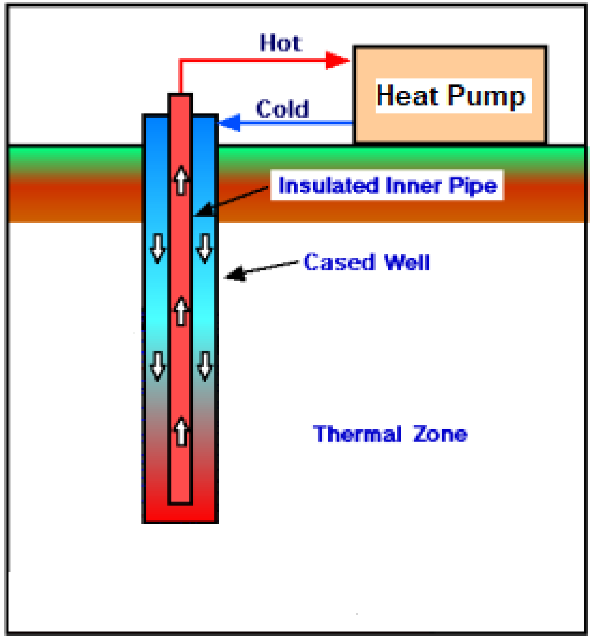
System design

- Co-axial closed loop
- Reservoir:
  - Permeable water-saturated sedimentary
  - T_{res} = 60°C @ 2000m
- Piping:
  - 11” ID Casing, 3” ID / 3.5” OD
- Operation:
  - T_{in} = 15°C



Source: Morita et. al., 2005

Sub-surface system design



Parameter	Value
Porosity (fraction)	0.01
$k_x = k_y = k_z$ (mD)	0.1
Thermal conductivity (geothermal reservoir) (J/mdayC)	274,000
Thermal conductivity (overburden) (J/mdayC)	210,000
Heat capacity (geothermal reservoir) (J/m^3C)	2.6×10^6
Heat capacity (overburden) (J/m^3C)	2×10^6
Tubing insulation thickness (in)	0.5
Tubing ID (in)	3
Tubing OD (in)	3.5
Casing ID (in)	11
Casing OD (in)	13.8
Hole diameter (in)	13.8 (no cement)
P at 2000 m (kPa)	20,000
T at 0 m (°C)	15
T at 2000 m (°C)	60

Sub-surface simulation results

Injection Rate (m³/d)	Produced water temperature at surface (°C)			Thermal Output (kW)		
	1 year	5 years	10 years	1 year	5 years	10 years
100	30	28.6	28.1	73	66	63
500	19.4	18.9	18.7	106	94	90
1000	17.3	17	16.9	111	97	92
5000	15.4	15.4	15.4	97	97	97

- Results (without the seasonal thermal energy storage) show an evident decline of working fluid's return temperature → indicating depletion of thermal reservoir with time!

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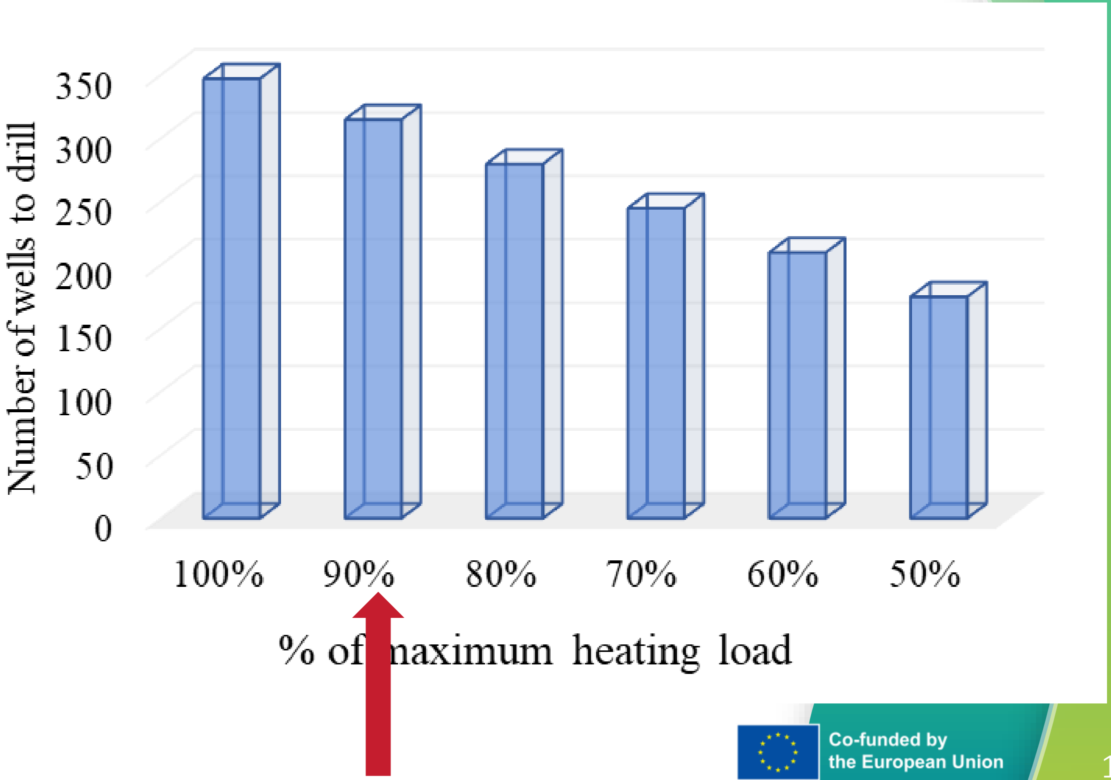
Sub-surface system design

- Optimal flow rate of 500 m^3/d, results in the temperature gain of 4° C.

- To meet 90% of the peak heating load, about **300** vertical wellbores need to be drilled.

Number of vertical well bores required at 500 m^3/d



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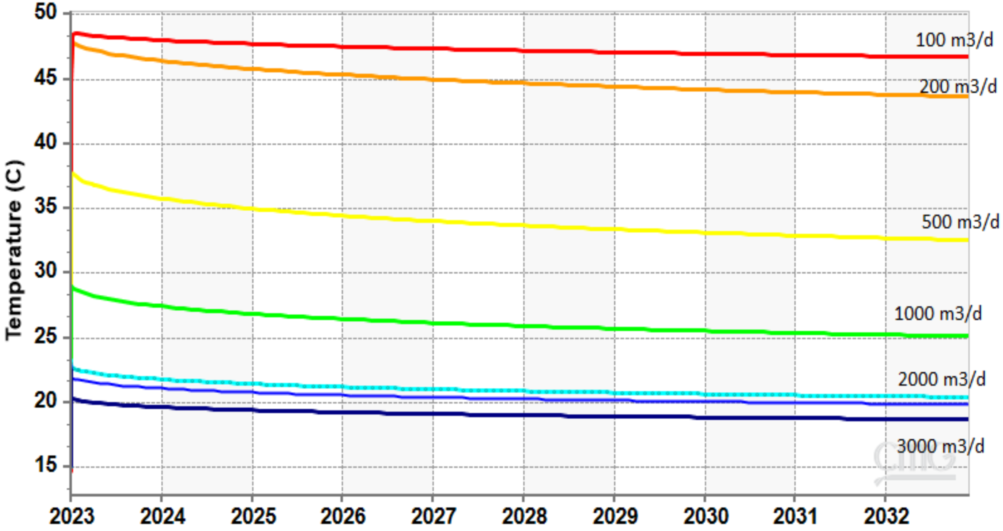
Sub-surface system design



Flow rate (m^3/day)	Produced temperature (°C)	Thermal output (kW)
100	46.7	153
200	43.7	278
500	32.6	426
1000	25.2	493
2000	20.4	523
2250	19.9	533
3000	18.7	537

- Drilled to 2 km depth and then extended laterally for another 2 km.

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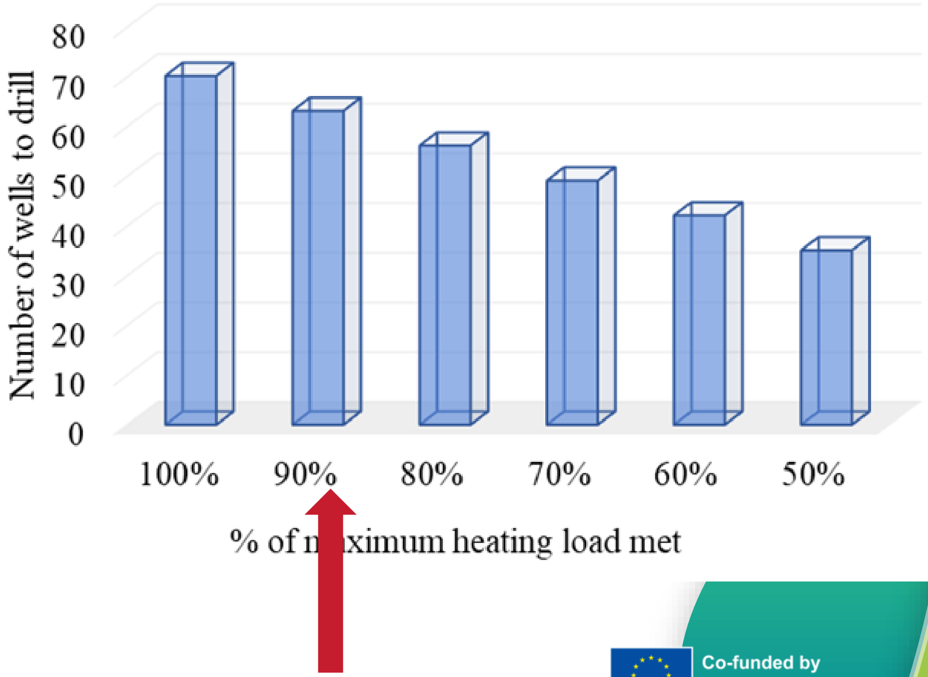
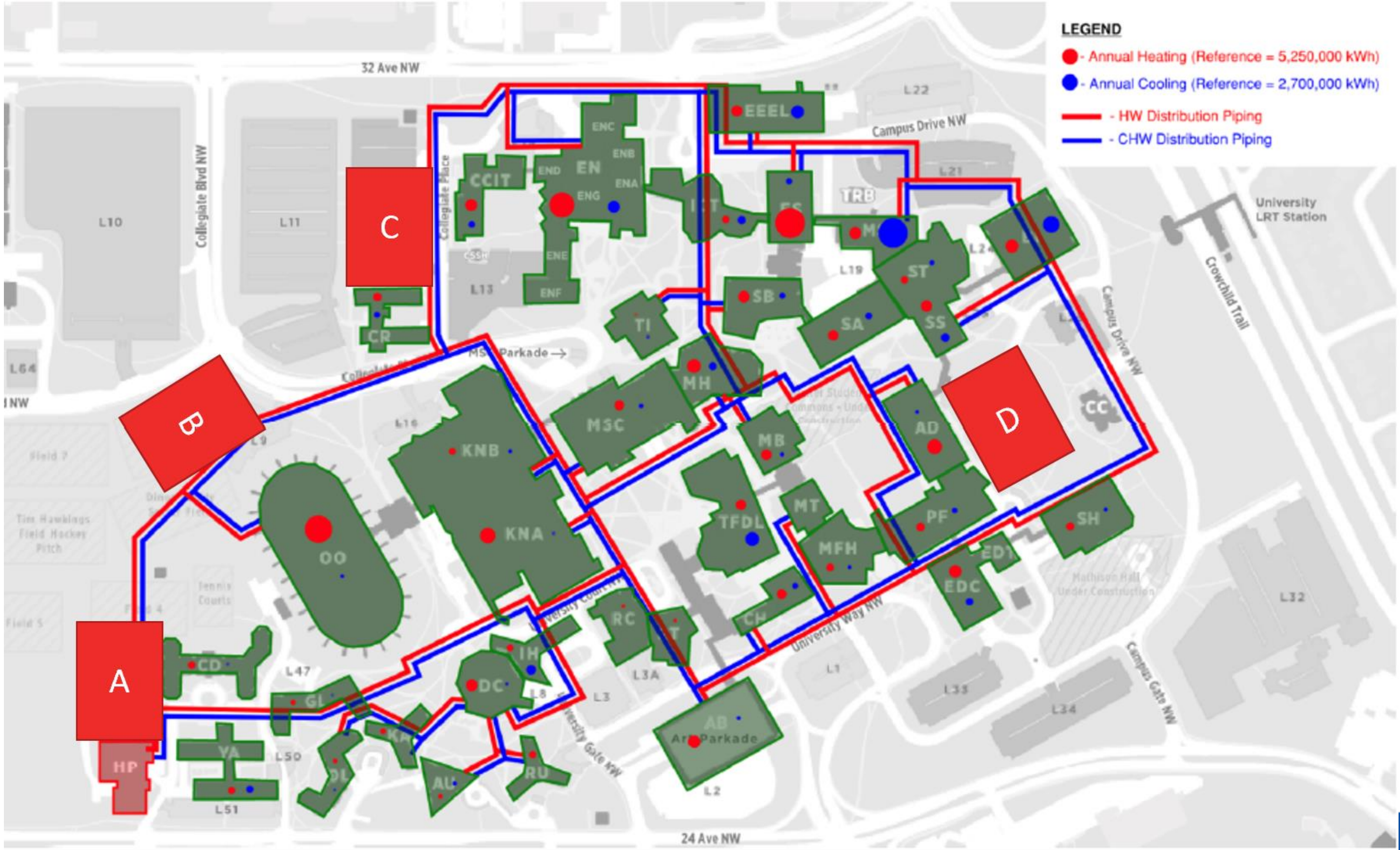
Sub-surface system design

- The case of 1000 m^3/d is favourable, as it yields a ΔT of 9° C.
- To meet 90% of the peak heating load, about **60** horizontal wellbores need to be drilled.

Number of horizontal well bores required at 1000 m^3/d



Potential drilling sites



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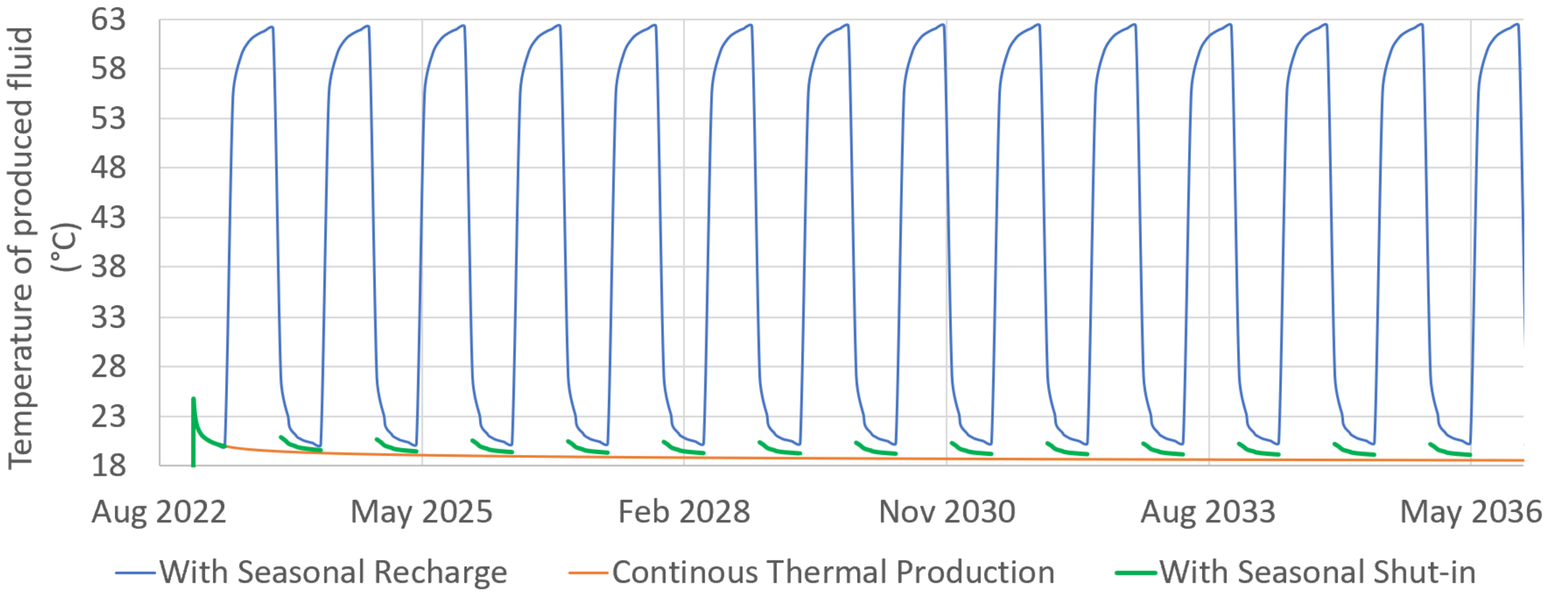
Sub-surface system design

Seasonal Recharge



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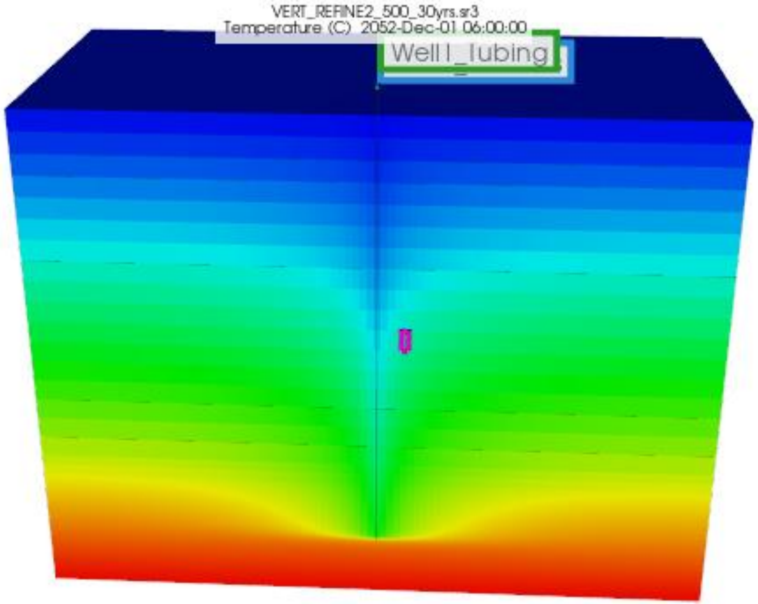
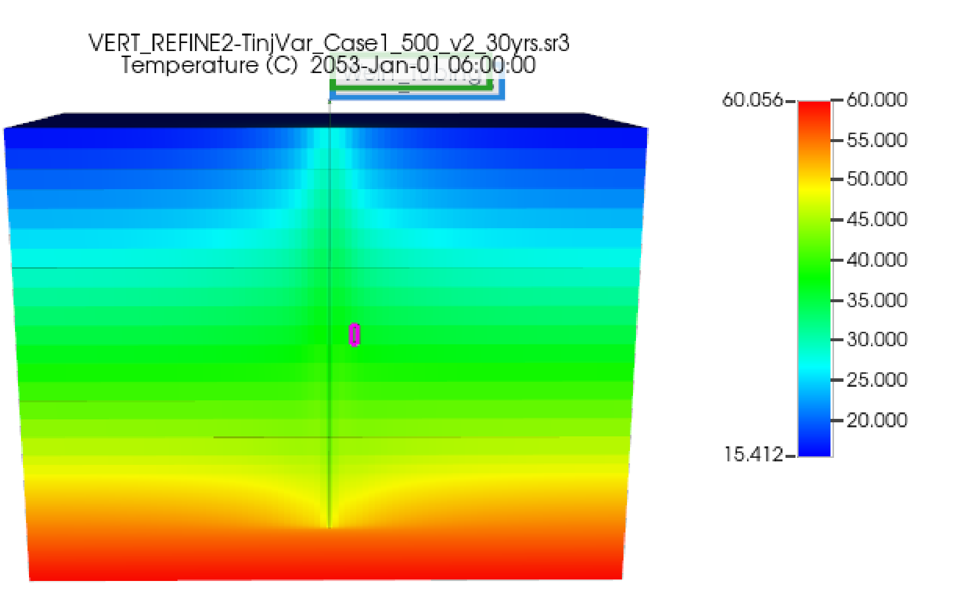
Sub-surface system design

Seasonal Recharge

Without Recharge



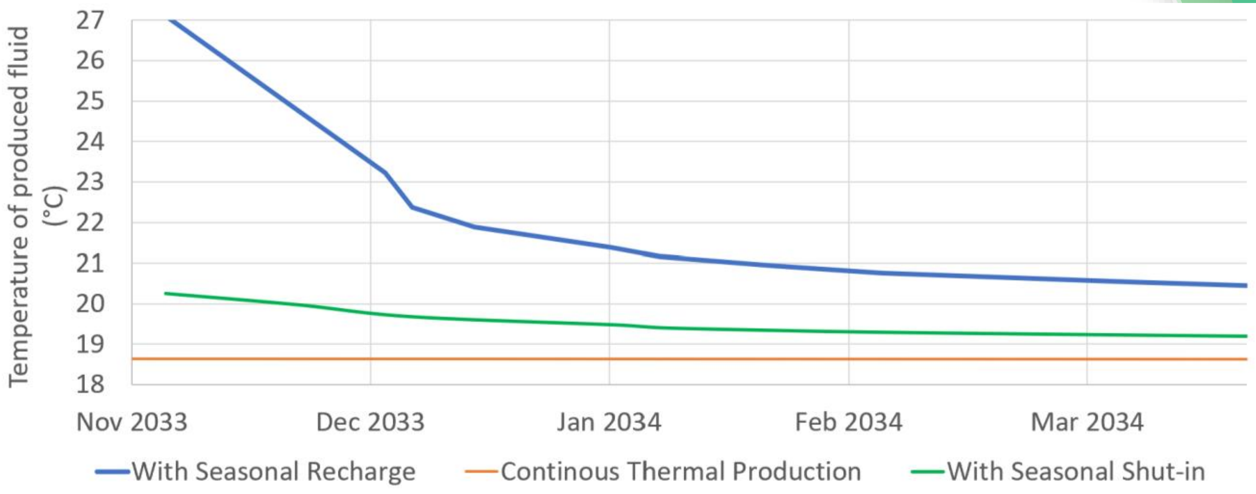
With Recharge



Sub-surface system design

Seasonal Recharge

T_{in} = 15ºC



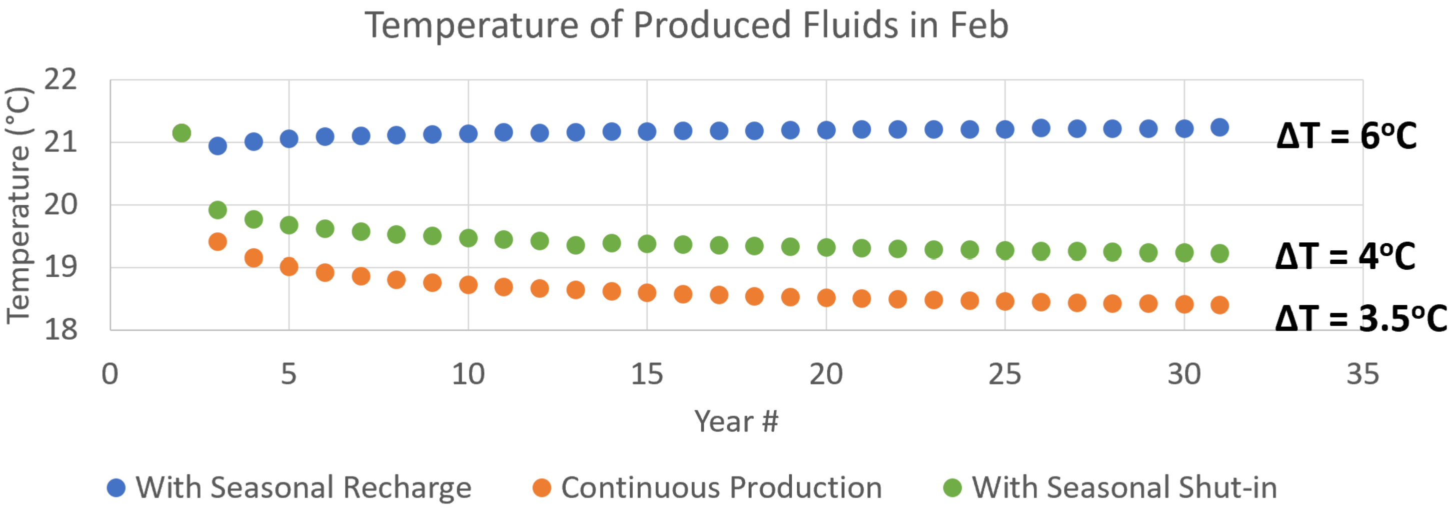
Winter Operation:
T_{in} = 15ºC
Q = 500 m^3/day (3145 BBL/day)

Summer Operation:
Tin = 70ºC
Q = 500 m^3/day

Sub-surface system design

Seasonal Recharge

T_{in} = 15ºC



Small difference, **but 50-70% increase in thermal power**!

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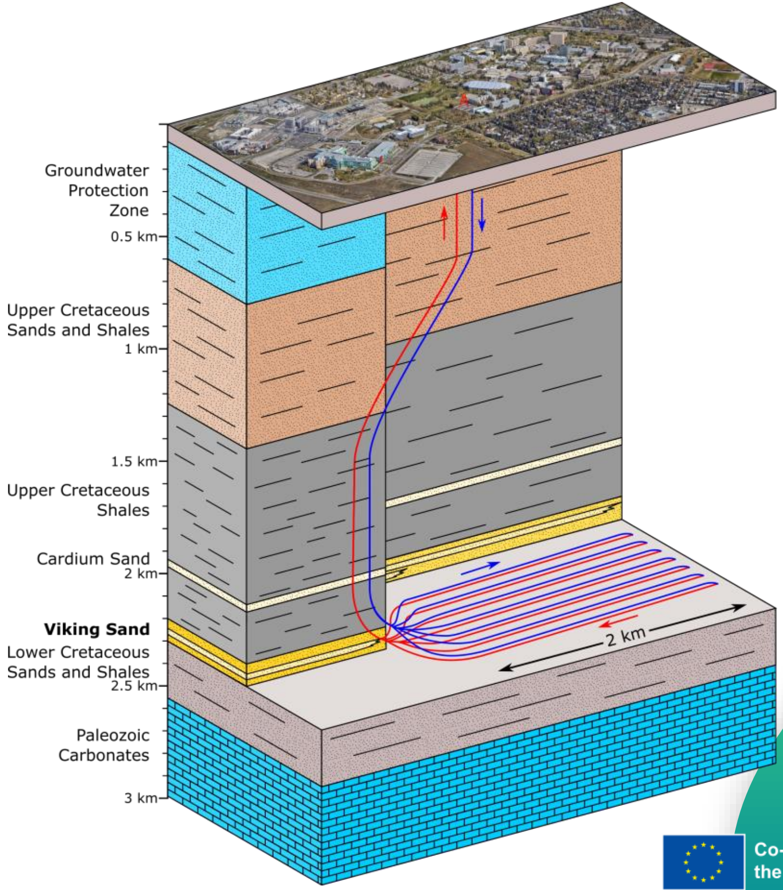
Sub-surface system design

Seasonal Recharge

Potential to offset **90%+** of heating load with 30 horizontal wells pairs in a **closed-loop** design.

Why closed-loop?

H_2S *… an Alberta problem*



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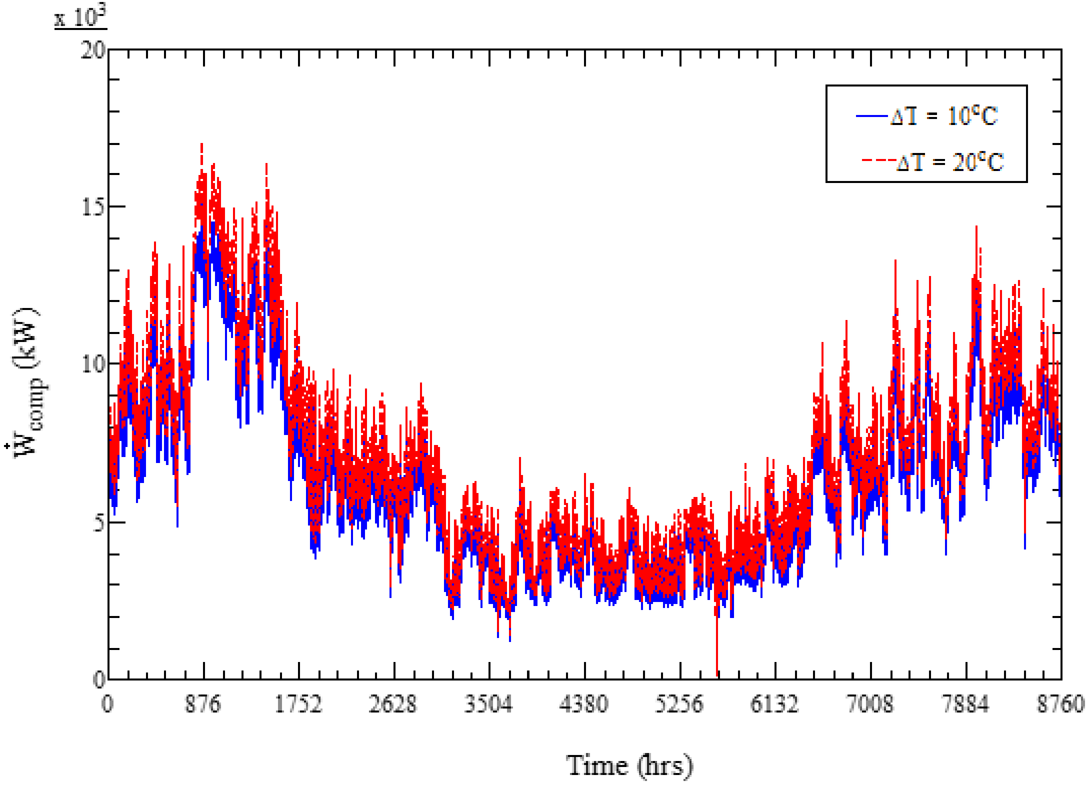
Heat pump performance



- Refrigerant: R1233zd(E)
- Supply Temperature: 95°C
- Return Temperature: 75°C
- COP: 3.068 average for the year.
- Power needed: 111 kW to 17 MW

Acknowledgements

Results in this presentation come from a study presented at the 2023 Geothermal Rising Conference. The contribution of each author is duly acknowledged.

Reservoir thermal storage as part of a middle-deep closed-loop geothermal system

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Thank you

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