Assessment of ambient loop-coupled GSHP and WWHP systems in a cold-climate institutional/residential development

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Podium/tower development

- 44-storey residential tower
- 15-storey podium: 1 mechanical floor, 14 floors of academic/commercial space (retail, café, science gallery, study rooms, classrooms, laboratories)
- 62,297 m^2 (702,850 ft^2) floor area
- Downtown core location on campus of **Toronto Metropolitan University** in Ontario, Canada
- Energy modelling performed in **eQuest** by consultants employed by the University

Regulatory and economic context

- Residential and commercial buildings account for almost **30% of secondary (end-user) energy use** in Canada [1]
- 81% of residential energy consumption goes towards space and water heating [1]
- Canada aims to reduce GHG emissions 40% below 2005 levels by 2030; net-zero by 2050
- Carbon pricing set to increase to $170/tonne CO_2eq by 2030
- Generation intensity of Ontario grid is 25 g CO_2e/kWh (compare Illinois at 314 g CO_2/kWh) [2] [3]

Systems modelled

- Base case (natural gas boilers and water-cooled chiller)
- Conventional ambient loop (ambient loop coupled with open-loop cooling tower and natural gas boilers)
- Ambient loop-coupled **wastewater heat pump**
- Hybrid wastewater heat pump/conventional ambient loop
- Ambient loop-coupled **ground-source heat pump**
- Hybrid ground-source heat pump/conventional ambient loop

Systems modelled (cont.)

Ambient loops

- Ambient or near-ambient temperatures (8-25°C)
- Possibility of simultaneous heating and cooling

WWHP

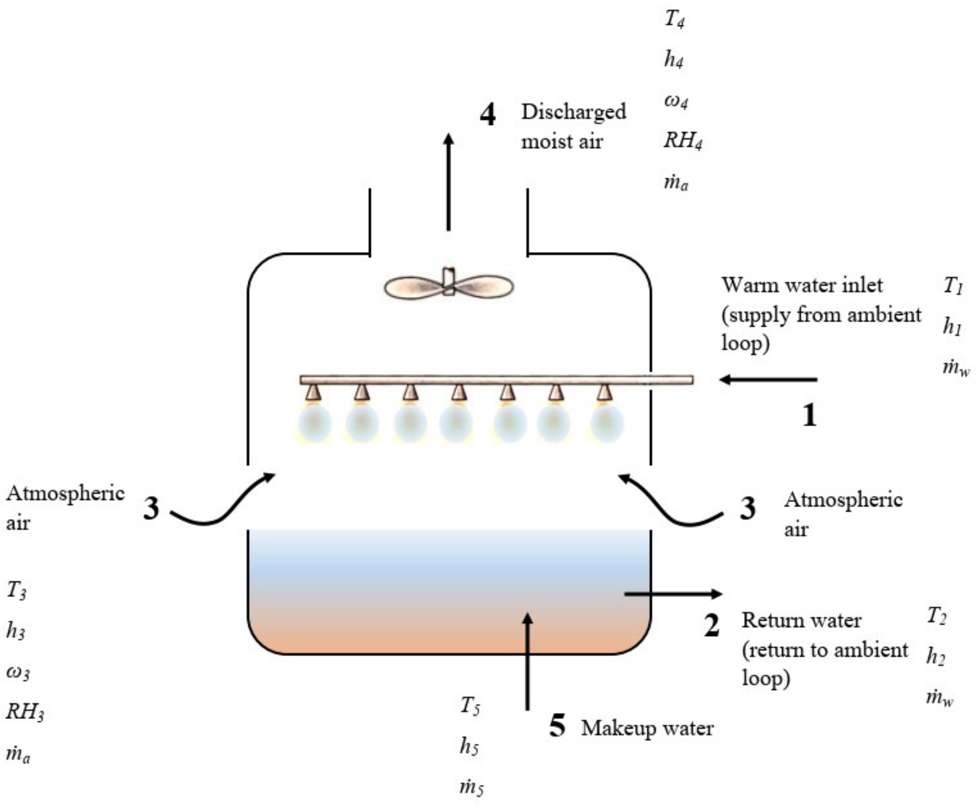
- Urban sewers have high flows, ambient or near-ambient temperatures

GSHP

- Soil used as heat source/sink
- Average ground temperatures of 5-15°C

Modelling methodology

- Base, conventional AL, and both WWHP systems modelled in **Microsoft Excel** using **XSteam** and **Psych** plugins
  - Water-cooled chiller data acquired from manufacturer
  - TRNSYS water-to-air heat pump performance data used
  - Open-loop cooling tower model created
  - Available energy for WWHP estimated using flow data provided by Toronto Water (non-adjacent sewer), sewer temperature correlation



Modelling methodology (cont.)

- GSHP systems modelled in Hybrid Ground-Coupled Heat Pump (“**HyGCHP**”) software (TRNSYS-based software package)

Ground temperature	13.9°C	**Ambient loop fluid**	Propylene glycol
Drilling depth	91.4 m	**Minimum fluid temperature**	-7.78°C
Bore spacing	6.10 m	**Pump power per 100 tons of peak block load**	7,457 W
Header depth	1.80 m	**Fraction of pressure drop attributable to GHX**	0.55
Center-to-center half distance	3.80 cm	**COP heating**	3.42
Borehole radius	5.70 cm	**EER cooling**	15.6 MBH/kW
Ground thermal diffusivity	0.10 m	**Fan operation**	Continuous
Ground thermal conductivity	5.68 W/m^2-K	**Performance curves**	Default
U-tube size	25 mm	**Heating EAT**	21°C
Grout thermal conductivity	4.54 W/m^2-K	**Cooling EAT**	24°C

Results

System	Energy use *(MWh)*	GHG emissions *(tonnes)*	Cost *($ CAD, 2019)*	Cost *($ CAD, 2030)*
Base	13,193	2,118	$630,450	$987,149
Conventional AL	9,566	1,236	$689,332	$897,107
WWHP	5,711	171	$866,423	$894,409
WWHP-Conventional	6,007	589	$582,861	$681,656
GSHP	**3,261**	**97**	**$494,646**	**$510,623**
GSHP-Conventional	**3,218**	**96**	**$488,123**	**$503,889**

Conclusions

- GSHP systems (hybrid and non-hybrid) outperform all other systems in **energy use, GHG emissions, and cost** (2019 and 2030 energy costs)
- By 2030, the base case has higher energy costs than any of the other five systems – result of scheduled Canadian carbon pricing increase
- Economics favour increasing adoption of heat pump systems

Limitations of present study, future work

- Asymmetry in modelling of different systems; GSHP-specific software packages tend to **overestimate the long-term performance of GSHP** systems
- Limited space for GSHP systems in dense urban areas
- Flow data from adjacent sewers required to accurately estimate available wastewater energy
- Capital cost comparison needed to fully assess economic feasibility of all systems under consideration

Works cited

1. Natural Resources Canada, *Energy Fact Book 2021-2022*, 2021.
2. Environment and Climate Change Canada, *National Inventory Report 1990-2020: Greenhouse Gas Sources and Sinks in Canada*, 2022.
3. U.S. Energy Information Administration, "Illinois Electricity Profile, 2021." [Online.] Available: https://www.eia.gov/electricity/state/illinois/ [Accessed 2023-05-03]

Thank you!

Questions?

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