Social Housing, Toronto, Canada

Field Test by The Atmospheric Fund of air source absorption heat pumps on an existing social housing complex in Toronto.

Key facts

Building
Location Toronto, Canada
Construction 2015
Heat distribution in building
Heated area m² living
Level of insulation ….

Heat pump and source
Number of heat pumps 2
Installed capacity 72 kW
Operation mode: Gas condensing boiler as back up for peak demand
Heat source Air source
Brand and type ROBUR GAHP-A
Refrigerant Lithium/bromide
Sound level 57 dB

Heating system
Heat demand
Heating temperature °C

Domestic hot water
Type of system see overview
Max. Temperature 54°C
Circulation system: Central with substations
Legionella measures thermal
Storage size 12,112 litres
Number of storage tanks 4
Storage losses
Temperature control

Lessons learned
Technology Assessment and Field Test Findings by TAF

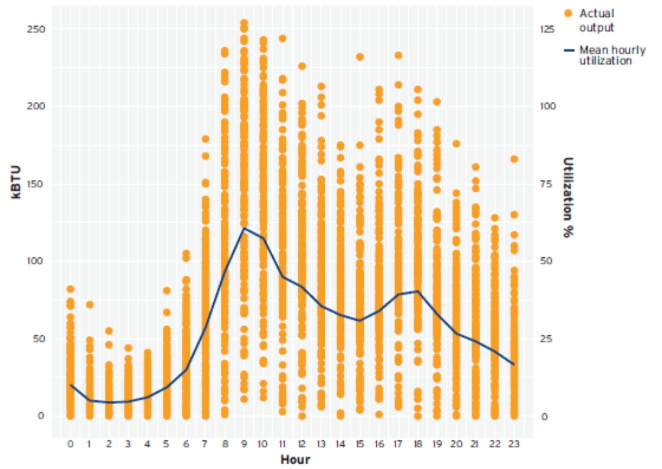
Considering that gas is the primary fuel used for heating and domestic hot water (DHW) systems in Canada, alternative heating technologies that enable buildings to consume natural gas more efficiently are a key priority for improving energy efficiency and reducing carbon emissions.

The Gas Absorption Heat Pump (GAHP) is one such technology. GAHP technology promises efficiencies significantly exceeding 100 per cent, while still using low-cost natural gas as the primary fuel source. To determine if GAHPs are a technology that can provide efficient heating and reduce carbon emissions in a cold climate, The Atmospheric Fund (TAF) installed two units as part of a DHW system in a large multi-unit residential complex.

The site selected was a social housing complex in Toronto, Ontario consisting of two buildings with a combined 372 apartments for seniors, and a gross floor area of 16,258 m2. The buildings were constructed in 1972 and both are four-story concrete structures with original brick cladding and single-pane, aluminum-framed windows.

Prior to the project retrofits, two oversized gas boilers located in a basement boiler room provided space heating and DHW for both buildings. The boilers are each rated at 1,290 kW and ran at an average efficiency of approximately 54 per cent based on TAF's pre-retrofit monitoring. The boilers heated a 12,112 litres DHW storage tank (which remains post-retrofit) that is the source of hot water for both buildings.

After an evaluation of the few available GAHP systems sold in the Canadian market, the project team selected Robur's model GAHP-A, which is a non-reversible hydronic heat-only system with a heating capacity of 36 kW and a maximum outlet temperature of 60°C. Ecosystem, TAF's engineering partner on the project, modelled various DHW system scenarios and determined that two Robur units could provide 58 per cent of the site's overall DHW capacity and 100 per cent of its daily non-peak capacity. The heat pumps provide heat to the DHW system via a brazed plate, double walled heat exchanger. Any additional heating required to meet the DHW setpoint of 54°C is provided by a pair of Viessmann 200 CM2-246 condensing boilers, which provide both space heating and supplemental DHW. Modelled efficiency of the combined DHW system is 110 per cent.



Domestic hot water use at the site — with peaks and valleys in demand — results in fluctuating utilization of the GAHPs over the course of a day, with output peaking between 8-10 a.m. and a secondary peak occurring between 4-6 p.m. The figure shows actual hourly output for the two GAHP units, along with average hourly capacity utilization, which was estimated using the manufacturer's ambient temperature performance curve. Capacity utilization during the day (7 a.m. through 7 p.m.) averages 40 per cent and peaks at 61 per cent at 9 a.m. While fluctuating utilization can be expected in a DHW implementation, hourly GAHP output is well below pre-installation modelling.

Fig Hourly GAHP system output and capacity utilization (based on manufacturer's performance curve) for both units

The project team is addressing underutilization by prioritizing the GAHPs when the DHW system requires heat. Instead of calling for heat from the GAHPs and boilers simultaneously, the GAHPs will start first with the boilers firing up if demand cannot be met by the GAHPs alone. The team expects this to increase the GAHP utilization and output outside of the heating season. Increasing utilization during the winter and shoulder seasons presents a more difficult challenge, as the boilers are running and providing heat to the DHW system throughout the day. It is unlikely that heating-season utilization of the GAHPs can be increased significantly without physically reconfiguring the DHW system. The GAHPs will operate most efficiently with cool return temperatures (in this case below 50°C, but this may vary by manufacturer), and the system should be optimized with this in mind. In addition, cycle length should be maximized, while minimizing the downtime between cycles when heat built up by the units will dissipate (rapidly in cold outdoor temperatures). The project team made multiple changes to the DHW system to improve GAHP performance, and eventually settled on calling for GAHP heat in stages after the DHW storage tank temperature drops below the 54°C setpoint. A designated lead heat pump runs first, with the second unit starting up after 10 minutes if additional heat is needed; the units alternate as the lead each week in order to prevent wear and tear on a single GAHP. This configuration helped lower return temperatures, increased utilization, and led to better overall system performance. TAF recommends planning for and allocating time and resources for optimization once the system is operational.

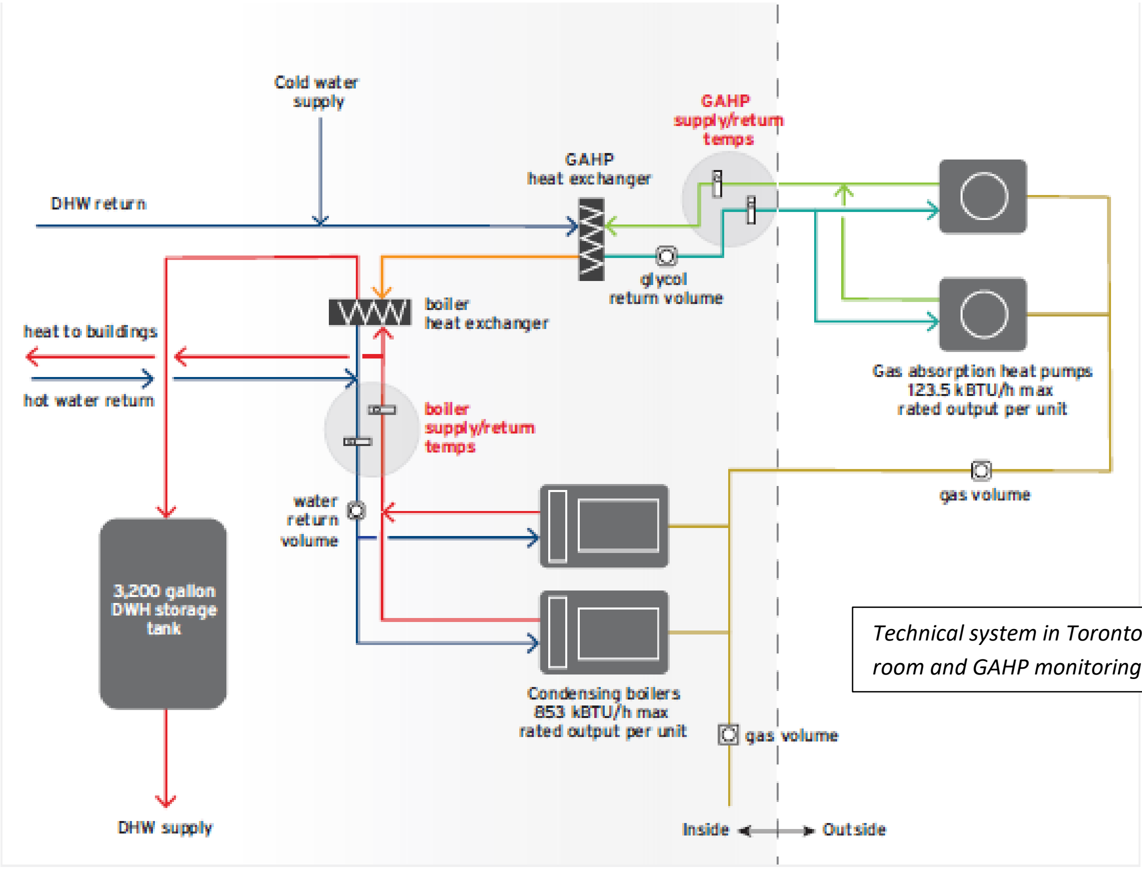
When displacing less efficient gas or oil-based systems, the use of GAHPs can result in GHG emission savings. However, in a region with low-carbon electricity (like Ontario), electric based systems are a superior choice from an emission standpoint; in these regions, the use of electric heat pumps results in fewer carbon emissions than GAHPs.[f] In regions with high-carbon electricity generation, GAHPs can offer significant emissions reductions compared to electric heat pumps; however, this can be expected to change over time as North American grids continue to decarbonize.

As a side-by-side operational comparison of the GAHPs and equivalent electric ASHPs in a DHW scenario was not possible, ASHP emissions (and operational costs) are presented in ranges, based on theoretical COP values between 1.5 and 2.5, representing likely efficiencies of air to water ASHP systems running in cold climates.

The ASHP COP range of 1.5–2.5 is based on manufacturer specifications for air to water electric heat pumps available in Canada, multiple studies of cold-weather field and laboratory performance of ASHPs, and a case study done by Ecotope on an air to water electric heat pump system in a 194-unit multi-residential development in Washington state. The Ecotope project found COP values (2.7 in the winter and 3.3 in the summer) that exceed our upper threshold of 2.5, but the heat pumps were installed in an underground garage that provides a significant buffer to outdoor temperatures.

Estimates of ASHP emissions and costs for this analysis are theoretical and do not account for the real-world challenges associated with using ASHPs for water heating, such as the space required for installation of multiple units likely needed to meet demand, outdoor temperature operational limitations, and supply/return temperature constraints. These are all factors that need to be considered when evaluating the implementation of an ASHP DHW system in a multi-residential setting.

Social Housing, Toronto, Canada, Technical details

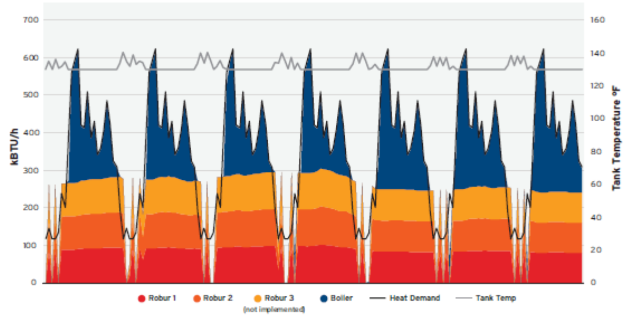


Technical system in Toronto pilot. Boiler room and GAHP monitoring flow

Description of the technical concept

Ecosystem also modelled installation of a third GAHP which when combined with the other two units would have covered 78 per cent of the buildings' DHW needs. However, the ideal location for this equipment (closest to mechanical room) had limited space in which to install three units. The project team settled on two units installed just outside the boiler room, which minimized the length of the exterior glycol piping and avoided any noise issues for occupants (maximum sound pressure at five meters is 57 dB, slightly higher than a modern window air conditioner).

Fig – GAHP and boiler modelling output for a week in January of 2015. Modelling done for TAF by Ecosystem with three GAHP units



Although the project team could have designed a system where the GAHP supplied 100 per cent of the site's DHW needs, this would have meant installing the equipment on the roof, which would have increased construction costs. This type of system would also have been overbuilt to handle peak demand hours; in essence running the last unit only a few times a day when hot water demand is highest. Combining the heat pumps with condensing boilers was the most cost effective solution given the GAHPs' maximum heating output and DHW demand at the site.