Gas Absorption Heat Pumps Best Practices Guide

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Commissioned by:
FORTIS BC™

Developed by:
CLEAResult® Canada

Foreword

FortisBC proudly delivers natural gas and electricity to more than 1.3 million British Columbians. As a critical energy provider, we are committed to providing customers with safe, affordable and reliable energy that our customers need. As a part of this commitment, we continue to explore and support innovative technologies that help organizations take steps to lower their energy use, operational costs, and associated emissions.
Gas absorption heat pumps provide building owners and operators with a practical solution to help support their goals while maintaining comfort and reliability. CLEAResult has been instrumental in educating the market about installation best practices, case studies, and unit maintenance through webinars, in-person workshops, and with this guide. This guide provides information and resources for those looking to implement this technology and contribute to a lower carbon energy future for our communities. *Cameron Lee, FortisBC.*

CLEAResult Canada is the nation's leading consultant of energy efficiency, energy transition, and energy sustainability programs. We deliver tailored solutions to address today's energy supply and demand challenges and help our clients build a more energy resilient future. This Best Practices Guide is the outcome of a multi-year collaboration with FortisBC and Building Energy Solutions, who shared invaluable practical insights and project delivery expertise about GAHP technology. The guide is designed to provide clear, actionable answers to key questions about GAHP technology, empowering stakeholders to make informed decisions. *Ali Abbas, CLEAResult Canada Inc.*

This guideline has been written using the knowledge gained from the FortisBC Gas Absorption Heat Pump (GAHP) Pilot. It has been our privilege to be the measurement and verification implementation consultant for the pilot program, which has provided extremely useful insights into this emerging technology. We are excited to be part of the continuing story in the advancement of the installation of this equipment with the goal of reducing greenhouse gas emissions. *Steven Arnold, BES-Building Energy Solutions Ltd.*

Disclaimer

The information in this Gas Absorption Heat Pumps Best Practices Guide is provided solely for educational and informational purposes to help readers understand this technology. It is not intended to offer project-specific advice and should not be relied upon as such. No actions or decisions should be taken without conducting independent due diligence and obtaining professional guidance in compliance with applicable codes and regulations.

This guide is not a substitute for formal engineering analysis. Neither the authors (CLEAResult Canada Inc. and BES-Building Energy Solutions Ltd.) nor the commissioner of this guide (FortisBC Energy Inc.) make any representations or warrant the accuracy or completeness of information related to equipment supplied by different manufacturers. Furthermore, the authors and commissioner accept no liability for any loss or damage arising from inaccuracies, errors, or omissions in this document.

Version History

Version No.	Date	Author	Description of the change
1	16-May-23	CLEAResult Canada Inc. and BES-Building Energy Solutions Ltd.	Version 1 of the Best Practices Guide for Gas Absorption Heat Pumps
2	02-Oct-23	CLEAResult Canada Inc. and BES-Building Energy Solutions Ltd.	Update on BC carbon tax rate for 2023, Minor updates on Figures 7, 8 and 9.
3	16-Dec-25	CLEAResult Canada Inc. and BES-Building Energy Solutions Ltd.	Additional guidance on refrigerant safety, updates to design best practices, changes to different schematics, minor updates to manufacturer's specifications and maintenance section, addition of photos from project sites in BC, addition of case studies, and summary of key findings from FortisBC's Deep Energy Retrofit projects.

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Executive Summary

FortisBC is British Columbia's largest energy provider, with more than 100 years of knowledge and experience in delivering energy to its customers. They deliver safe, reliable, and cost-effective natural gas, electricity and propane and continue to acquire renewable and lower carbon energy, including natural gas designated as Renewable Natural Gas (RNG) to its customers across the province. FortisBC has more than 2,700 employees who proudly serve approximately 1.3 million customers across British Columbia (BC), including 135 cities and towns and 58 Indigenous communities across 150 Traditional Territories.

In 2018, FortisBC released its "Clean Growth Pathway to 2050" [1], which presents their pathway to align with the provincial government's goal to significantly reduce greenhouse gas emissions (GHG) while supporting economic growth and maintaining affordability and customer choice. FortisBC's proposed pathway highlights four pillars requiring significant energy system transformation to meet the growing demand for clean energy[2]. One of these areas highlights the need for increasing the investment in energy efficiency within the built environment and developing innovative technologies in this space in BC. Building market awareness of Gas Absorption Heat Pump (GAHP) technology is one of the many strategies FortisBC employs to achieve this goal.

In 2019, FortisBC's Innovative Technologies team, as part of the Conservation and Energy Management (C&EM) department, initiated a pilot program to verify the operational performance of commercial GAHPs and installed 14 Robur-A units at seven commercial sites across BC, serving domestic hot water. The program was designed to demonstrate the energy savings potential, address any issues associated with the installation and operation, and test the compatibility of commercial GAHPs with local climate zones in commercial (Part 3) buildings. The pilot served as an opportunity to learn about the customer experience and market readiness of GAHP technology. These projects helped FortisBC verify the manufacturers' published performance data for GAHP units and apply it at a system level. Commercial Air-to-water GAHP units were installed in Multi-Unit Residential Buildings (MURBs) and school facilities in the Lower Mainland climate zone (i.e., Climate Zone 4) under live conditions. This guide relies heavily on the learning acquired from GAHP pilots projects led by FortisBC.

GAHPs offer a resilient space and hot water heating option for facilities that are connected to the natural gas or propane fuel supply. The technology is also compatible with renewable and low-carbon fuels, such as RNG and hydrogen blend of up to 20% with natural gas.

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[1] "Clean growth pathway to 2050" FortisBC - 2018

[2] The four pillars are as follows: Liquified natural gas (LNG) for marine fueling & global markets; zero & low-carbon transportation; renewable gas and, energy efficiency.

GAHPs operate on a heat-activated absorption cycle. The cycle relies on the absorption of refrigerant (ammonia[3]) by a transport medium (water). The circulation of water-ammonia (diluted) solution is limited to the refrigeration loop inside the outdoor unit. The heat is transferred from a GAHP unit to end-use through water that is running in a separate piping loop. Since most of the GAHP units come pre-charged and sealed with ammonia-water solution, it is less likely that operations, maintenance, or installation personnel will come into contact with the refrigerant. With proper guidance from the manufacturers during the field demonstrations, FortisBC was able to mitigate concerns about the use of ammonia.

In July 2021, FortisBC launched a limited-time "GAHP early adopter offer" to support a select commercial early adopters in implementing this technology at their facilities. 15 facilities from the province signed up to participate in the offer. These facilities represented a range of sectors, including healthcare, higher education, recreation centers, emergency services, and multi-unit residential buildings (MURBs) as well as schools.

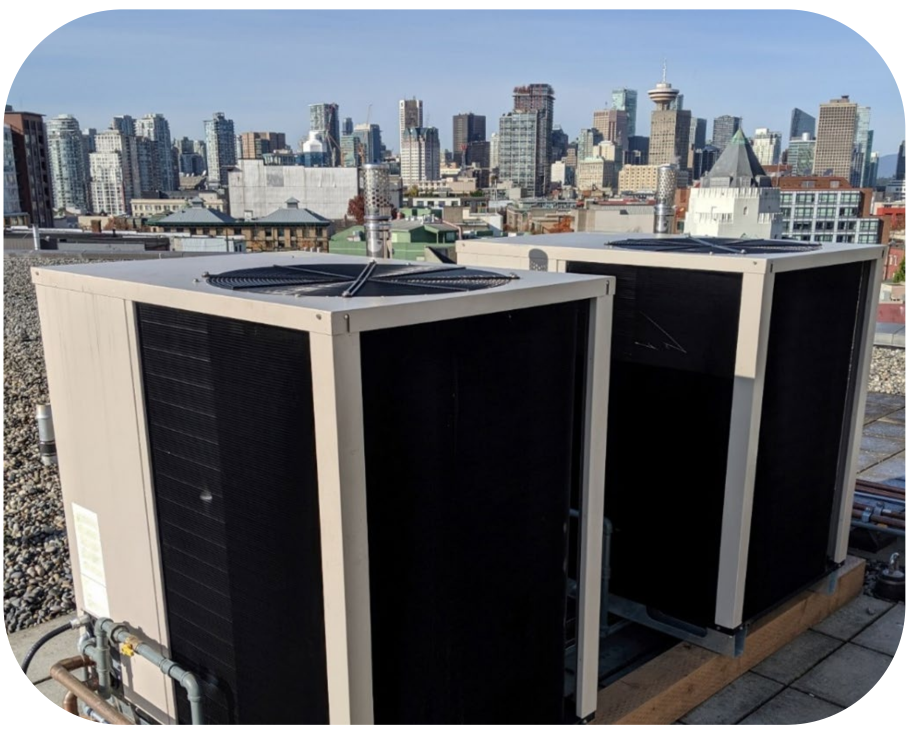

Figure 1: GAHP units being commissioned at a facility for a FortisBC pilot project in Vancouver, BC.

[3] Refer to the Refrigerant Safety section and Table-1 for more details on ammonia.

In June 2022, FortisBC became the first utility in Canada to introduce gas absorption heat pump prescriptive rebates for its commercial customers. The rebate offer also provides support for customers with costs associated with a detailed engineering feasibility study, to ensure customers are able to do their own due diligence with peace of mind. GAHPs range in price, and the units alone can cost between $20,000 and $30,000[4]. Project-specific factors such as the number of units, controls, integration with existing equipment, installation requirements, piping and insulation can impact the overall total project cost.

The objective of this Best Practices Guide is to provide a comprehensive and informative resource for individuals and organizations interested in adopting gas absorption technology. The guide is designed to introduce the technology in a clear and concise manner, while also addressing critical questions that may arise during the adoption and implementation process. The guide covers important aspects of gas absorption technology, including the principles behind the process, the equipment and materials required, and the best practices for implementing the technology. It also addresses common challenges that may arise during the adoption process and how to optimize the process conditions for maximum efficiency.

Overall, this guide is a valuable resource for those interested in gas absorption technology, with the aim of promoting broader market adoption and helping to increase efficiency, profitability, and sustainability across a wide range of facilities.

CLEAResult Canada Inc. has developed this guide in collaboration with Building Energy Solutions Ltd. for FortisBC.

[4] "What are gas heat pumps and how can they save money and energy?". Article posted on FortisBC webpage on June 21, 2022.

Overview

Climate change mitigation is one of the most pressing challenges faced by today's consumers, businesses, and policymakers. Market-ready technologies and solutions are available today to help customers meet their greenhouse gas (GHG) emissions reduction targets. Deployment of energy-efficient equipment has been a proven strategy to support climate action. GAHP is a promising technology that can help consumers and energy providers reduce GHG emissions at low costs.

Although GAHPs have been commercially available for many years, they have not been used to their fullest advantage for several reasons. One of the reasons is the market availability of other lower cost and code-compliant equipment, (albeit with lower efficiency), such as condensing boilers. GAHP systems can perform at levels that exceed the traditional efficiency barrier for gas-fired equipment and offer a pathway to substantially reduce GHG emissions associated with energy consumption for residential and commercial applications.

Figure 2: GAHP units in operation in BC's lower mainland.

GAHPs have been successfully deployed across Europe, Asia, and the United States for several years because of their energy-saving potential. In recent years, several North American utilities, such as FortisBC have also conducted field tests and pilot projects to assess the energy conservation potential of this technology. FortisBC, through its GAHP rebate offer, is at the forefront of the advancement of GAHP technology adoption and promotion in Canada. This best practice guide aims to answer critical questions about the workings and application of GAHPs, establish practical and realistic expectations and share insights to help with the adoption of GAHPs in the province. The document offers support to decision-makers, designers and installers considering efficient building heating, hot water and ventilation systems that may benefit from implementation of GAHPs systems.

This guide draws upon third-party measurement and verification results from the three-year-long pilot projects FortisBC ran from 2019 to 2021 for domestic water heating as well as subsequent phases conducted for additional end-uses. These pilot projects were installed at a number of MURBs and commercial facilities in BC's lower mainland. The pilot units were exposed to actual climate conditions and end-use loads in several different configurations. Through these projects, FortisBC verified the merits and addressed any challenges in adopting this technology in BC.

Introduction to the Gas Absorption Heat Pump (GAHP) Technology

Heat pumps have been around for decades and are proven to support heating operations with very high efficiency. Most common heat pump applications are powered by electricity. In contrast, thermally driven heat pumps can run on natural gas, hydrogen, or renewable and low-carbon fuels, such as RNG[5] to make complex heating systems more efficient by replacing legacy boiler systems for space heating and hot water applications. In particular, facilities located in electric grid-constrained areas that are dealing with electrical capacity issues and have access to gas supply networks may consider thermal heat pumps to lower operating costs and reduce their emissions over conventional natural gas equipment.

Background and History

The absorption heat pump technology has been available globally to end users for the past two decades. It was introduced in Europe much earlier than in North America and has experienced growth of the technology in some Asian markets within the last decade. Unlike traditional heat pumps that operate on a vapour compression cycle, GAHP units work on an absorption cycle. The working principle of ammonia-water based absorption was originally patented in 1859 and has since been widely used in refrigeration systems. One of the earliest pilot projects for GAHPs was run in Germany during the mid-1980s for residential applications[6].

More recently, California's Energy Commission Natural Gas Research & Development Program also funded the demonstration and assessment of GAHP technologies between 2017 and 2021. GAHP units were installed at two full-service restaurants and residential sites in Los Angeles. This pilot confirmed the possibility of quick paybacks in less complicated retrofits, with gas savings up to 45%[7].

In Canada, Toronto Metropolitan University[8] ran a GAHP technology review project. The university collaborated with The Atmospheric Fund, Toronto and Region Conservation Authority (TRCA) and Enbridge Gas[9]. The project tested Robur's 36 kW GAHP units across different water and space heating

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[5] Renewable Natural Gas is produced in a different manner than conventional natural gas. It is derived from biogas, which is produced from decomposing organic waste from landfills, agricultural waste, and wastewater from treatment facilities. The biogas is captured and cleaned to create carbon-neutral Renewable Natural Gas (also called biomethane). Visit fortisbc.com/RNG for more information.
[6] European commission report – "20 SMALL GAS-FIRED ABSORPTION HEAT PUMPS."
[7] Results from Gas-Fired Heat Pump Demonstrations and Research-California.
[8] Formerly known as Ryerson University.
[9] Evaluation of a Gas Absorption Heat Pump - Toronto and Region Conservation Authority.

configurations in cold ambient conditions and confirmed its viability in decarbonizing the conventional boiler-based systems. This project identified the best applications and locations for GAHP technology, which can be deployed in engineering design. The study concluded that Domestic Hot Water (DHW) applications have strong potential for notable operational cost and carbon reductions. Annual cost savings of $1500 for residential DHW preheating were estimated.

In 2019, FortisBC started a pilot program to test Robur's 36 kW GAHP-A units in MURBs and school facilities under live conditions in the Lower Mainland (Climate Zone 4). These projects helped FortisBC verify the manufacturers' published performance data for GAHP units and apply it at a system level. The project has since expanded to test the GAHP application with different end-uses. The results from the pilot program are discussed in the later sections.

Other prominent groups that have either successfully tested the technology or are contemplating the launch of GAHP pilots include National Energy Action (NEA) UK, Northwest Energy Efficiency Alliance (NEEA), Gas Technology Institute (GTI Energy), Energy Solutions Center, Southern California Gas and SEMCO Energy Gas in Michigan, USA.

Figure 3: Single GAHP unit installation in BC's lower mainland.

Working Principle of GAHP Technology

GAHPs operate on a heat-activated absorption cycle. The cycle relies on the absorption of refrigerant (ammonia[10]) by a transport medium (water). GAHPs need three energy inputs to run the absorption cycle, which transfers the heat from the heat source to the heat sink.

1. Renewable heat source in the environment: All heat pumps require a source of heat to operate. This heat can be extracted from the surrounding air, water, or under the ground.[11]
2. Combustion heat: The generator carries the ammonia-water solution that is separated into water and ammonia by introduction of thermal energy. This energy is primarily provided through the combustion of natural gas, propane or RNG. According to some manufacturers, GAHP units can also operate on a blend of natural gas containing 20% hydrogen[12].
   In addition to extracting heat from the environment, GAHPs can also capture supplemental heat from the combustion process. This improves the overall system efficiency and makes GAHPs operation effective in colder climates.
3. Electricity: The absorption cycle does not require work input for compressors like most vapour-compression refrigeration cycles. Instead of a compressor, the refrigerant is cycled between the evaporator and condenser using an absorber, a pump, and a generator. Since liquid is pumped instead of vapour, the electrical work required for pumping in the absorption systems is minimal. A condenser fan on the external unit and control systems also consume small amounts of electricity.

The following schematic explains the operating heating cycle at a high level. In cooling mode, the cycle is reversed.

[10] Refer to the Refrigerant Safety section and Table-1 for more details on ammonia.
[11] Most of the discussion in this document is limited to air-to-water gas absorption heat pumps.
[12] Based on conversations with Robur and Homy Building Solutions (on behalf of Vicot).

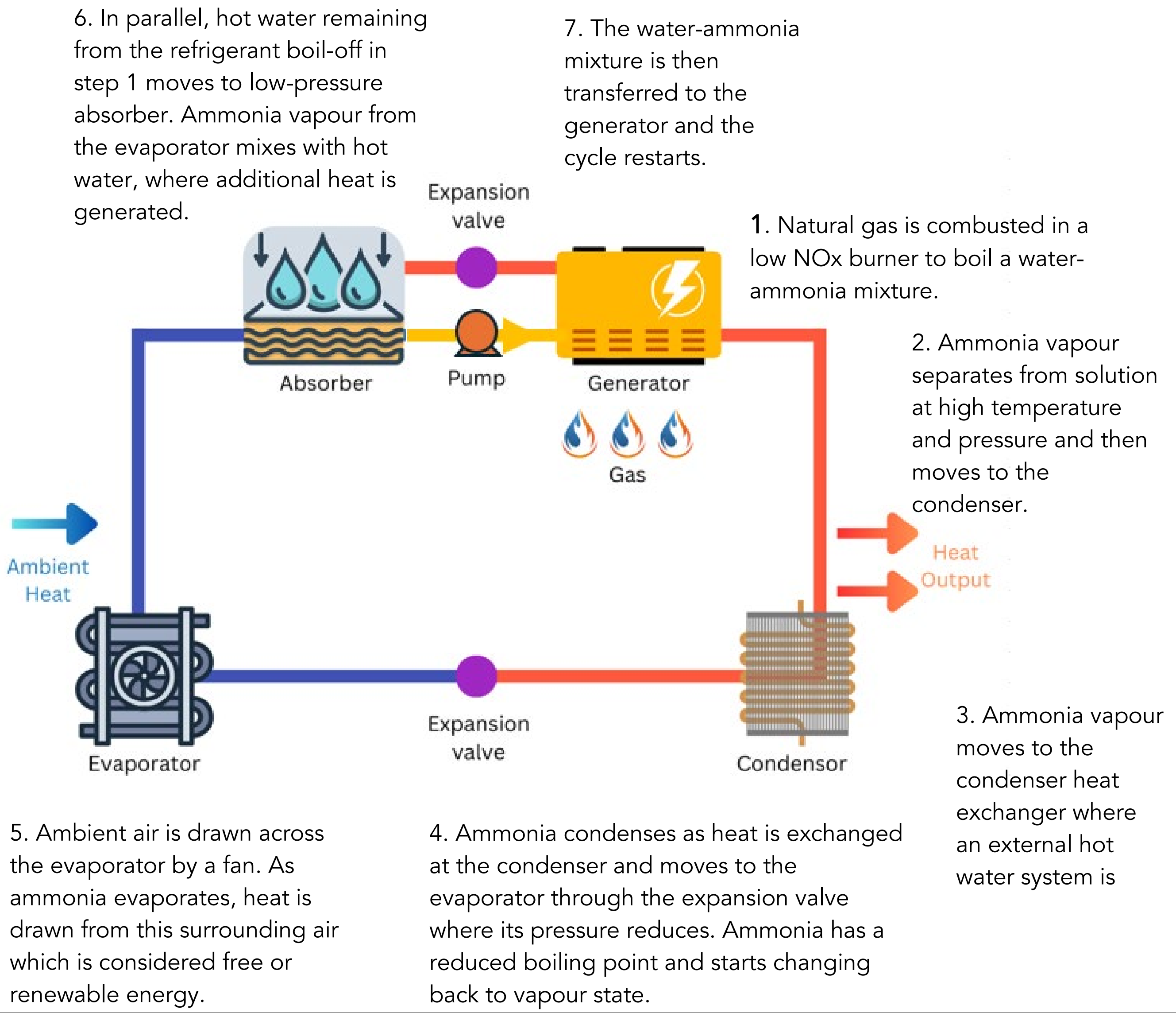

Figure 4: A simplified schematic of the GAHP operating in heating mode

A more detailed schematic of this process is included in Appendix-B.

Application End Uses

GAHP units perform at their peak when these are supporting systems that require continuous heating loads. GAHPs are best suited to support any hydronic hot water heating systems that are alternatively served by conventional or condensing boilers. Closed loop hydronic systems (non-potable water) are particularly more compatible with GAHP technology with an operating set point between 40-60°C (104-140°F). GAHPs have also demonstrated promising results when hot water coils are connected with make-up air units.

Moreover, GAHPs have also been deployed in hybrid configurations for high temperature (greater than 60°C or 140°F) applications where GAHP units pre-heat the water and high-efficiency boilers provide the additional heating to raise the temperatures to desired levels. Some manufacturers also offer hybrid systems where GAHPs and condensing boilers are built into a single package. Another example of hybrid configuration involves connecting GAHP units with solar water heaters. [13]

The following are some of the examples where GAHPs can be successfully applied [14].

- Multi-unit residential buildings
- Assisted living facilities (Healthcare)
- Education facilities, schools
- Recreation centers with swimming pools
- Hotels
- Office buildings
- Laundromats
- Restaurants
- Process heat

Most of the GAHPs available in the market only offer heating as output. However, some manufacturers also offer GAHPs with dual capability of heating and cooling. In those cases, chilled water can also be used for space cooling applications.

[13] Demonstration of Gas Heat Pump with Scalable Solar Thermal Array in Multi-Family Central Water Heating – Emerging Technologies Coordinating Council webinar. Note: At the moment, this solution has not been tested in BC.

[14] Depending on the continuous loading of GAHPs and the annual run hours, the project economics of installing GAHPs may be more favourable in certain applications than others.

Equipment Manufacturers

GAHPs are manufactured by many leading Heating, Ventilation and Air Conditioning (HVAC) brands, which include:

- Robur (Italy)
- Vicot (China)
- Anesi – SMTI (USA)
- Remeha (UK)
- Lochinvar (UK)
- Worcester Bosch (UK)
- Energy Concepts (USA)

Well-established brands, Robur, Vicot and Anesi are commercially available for installation in Canada. Robur is represented by JSA Sales Inc., based in Coquitlam, BC and retailed through major retailers such as Emco, Andrew Sheret, Noble Supplies to name a few. Vicot Group is represented by Homy Building Solutions in Toronto, ON, while Anesi is represented in BC by Canadian Aqualine based in Delta, BC.

Figure 5: GAHP Units installed at Logan Lake, BC.

GAHP Performance

Coefficient of Performance (COP) is the main parameter for comparing different types of heat pumps. COP is a ratio of useful heating or cooling produced, and the energy input provided to the heat pump.

$$\text{COP}_{\;Heating} = \frac{\text{Useful heating produced}}{\text{Total energy input}}$$

and

$$\text{COP}_{\;Cooling} = \frac{\text{Useful cooling produced}}{\text{Total energy input}}$$

GAHPs units perform at a COP greater than 1 under most ambient temperatures i.e., more heating is produced than the energy input. While the overall performance depends on variables such as ambient conditions, the flowrate, and the temperature difference of water flowing through the GAHP units, most models are rated to deliver a COP of above 1.2 for heating.

For example, the following figure demonstrates the performance of a heating-only unit at different ambient air and water output temperatures.[15] At different water output temperatures, the unit performs at a COP of higher than 1 until the dry bulb temperature drops to -7°C (19°F). In temperatures above 0°C (32°F), the unit performance improves considerably.

[15] Equipment specifications can sometimes use coefficient of performance (COP) and gas utilization efficiency (GUE) interchangeably. For consistency in measuring performance of different projects, it is recommended to use the following definitions:
GUE = thermal output / natural gas input.
COP = thermal output / (natural gas input + electricity input)

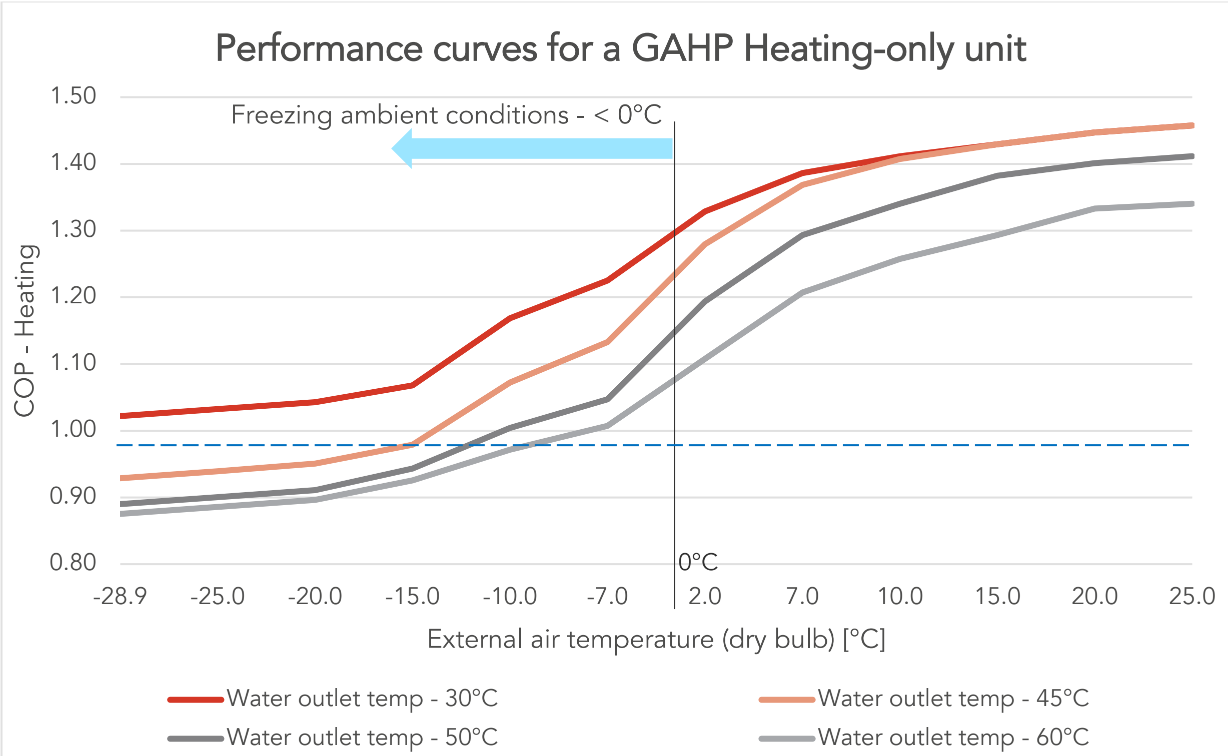

Figure 6: Example of GAHP heating performance relative to ambient air and hot water supply temperatures. [16]

When comparing different heat pumps, care must be taken to consider the COPs at relevant operating conditions. As demonstrated in the figure above, the COP of the unit operating at a given ambient condition varies due to difference in the water output temperature. As a general principle, the lower the difference between the heat source and the output, the higher the COP of the heat pump.

In cases where the GAHPs are deployed to replace legacy mid-efficiency boiler systems (such as having efficiencies up to 85%), the system-level performance improvement can be more than 30%. For applications where GAHPs are compared with high-efficiency boilers and rooftop units (> 92% efficiency), the seasonal system-level efficiency can be improved by 20%. This improvement is possible as a result of operating at a high system efficiency in shoulder seasons where there is no need for a supplementary boiler system to boost the GAHP output.

[16] Based on manufacturer published performance data for Robur's GAHP-A air-to-water unit.

According to some manufacturers, the GAHP units have been tested to operate between -30°C (-22°F) and +45°C (113°F) dry bulb temperature between elevations of 0 – 12,000 ft (3,656 m)[17]. In heating mode, the units can provide hot water at 60°C (140°F) or above[18].

For units capable of cooling, the COP is typically 0.6 in cooling mode[19].

In all air-to-water type GAHP systems, the units must be located outside a facility, usually on a concrete pad at ground level or on structural supports on the roof. In most Canadian climate zones, the units will be exposed to sub-zero temperatures in winter; therefore, glycol antifreeze (ethylene or propylene) is needed to prevent the system water from freezing. Depending upon the concentration of the antifreeze and the design minimum temperature, the heat output capacity of GAHPs drops and so does the performance.

Noise Levels

Since the air-to-water GAHPs are installed outdoors, there is an inherent increase in noise levels compared to boilers that are usually installed indoors in mechanical rooms. For outdoor applications, compliance with local municipal noise bylaws is imperative to successful installation and customer acceptance. A number of GAHPs have been in operation at several municipalities in BC as part of the FortisBC's pilots and the rebate program. No noise complaints were reported from any of the pilot installations.

According to manufacturers, Vicot GAHPs have a sound level of 40 dB(A) and 54 dB(A) at 5-meter distance for its 20 kW and 65 kW units, respectively.[20] Robur's 36 kW GAHP units have sound level ranging from 46 dB(A) to 56 dB(A) at 5 meters.[21]

Refrigerant Safety

The GAHP units rely on a solution of water and ammonia as a refrigerant to operate. Ammonia is considered a natural refrigerant with high thermodynamic efficiency and minimal environmental impact[22].

In GAHP applications, the circulation of water-ammonia solution is limited to the refrigeration loop inside the outdoor unit. The heat is transferred through water running in a separate piping loop. Manufacturers

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[17] Operating range for different elevations taken from Robur.
[18] According to Robur, its upcoming GAHP-A+ units are expected to deliver water at 65°C
[19] Robur's GAHP-AR unit can operate in cooling mode to produce chilled water.
[20] Based on Vicot GAHP technical information for V20 and V65 units.
[21] Based on information shared by Robur.
[22] ASHRAE – position documents on refrigerants version 2020 and 2006.

pre-charge all the units. For the GAHP units that are manufactured with a sealed ammonia- water solution from the factory, it is less likely that any personnel in operation and/or maintenance including the installing technician be exposed to ammonia.

While high concentrations of pure ammonia can cause injury, it is easy to detect a potential ammonia leakage due to its pungent and irritating odour. The ammonia-water solution is only harmful if directly contacted, inhaled, or ingested. Table 1 provides information on how much ammonia and water is contained in different GAHP units.

Table 1: Weight of Ammonia and Water in GAHP Units

Manufacturer	Unit Size kW	Amount of Ammonia kg (lbs.)	Amount of Water kg (lbs.)
Robur[23]	36	6.7 (15)	10 (22)
Anesi	23	5.5 (12)	7 (15)
Vicot[24]	20	5.5 (12)	7 (15)
Vicot[21]	140	20 (44)	24 (53)

In the unlikely event of a leakage in the refrigerant loop of a GAHP unit, ammonia being lighter than air, is expected to evaporate into the environment before causing any harm to human health. Manufacturers' guidance must always be followed, and the outdoor units should be installed at recommended clearances and safe distances from the air intakes of a facility, in line with applicable Building Codes and/or ASHRAE Standards. In addition, it is not recommended to install the outdoor units underneath or adjacent to an operable window.

Since the ammonia-water solution is housed in the outdoor unit, no special risk assessments were required for FortisBC's pilot projects or subsequent installations.

Several safety measures are also embedded into the outdoor units focusing on the sealed refrigerant system. These include corrosion proof system components, where materials resistant to ammonia exposure are used to eliminate concerns about corrosion and system degradation. A pressure relief valve is also installed whereby if the internal system pressure reaches a predefined threshold, the pressure relief valve will automatically open to reduce the pressure.

[23] Robur – GAHP Installation, use and maintenance manual.
[24] Based on data shared by Homy building solutions.

Through field demonstrations, FortisBC was able to mitigate concerns with the use of ammonia for school districts through proper education led by the manufacturer. The GAHP manufacturer, Robur, claims to have never received a liability claim due to refrigerant leakage in the last twenty years.

According to the Safety Standards Act, S.B.C., the installation of a GAHP generally does not require a refrigeration permit if the unit is listed/certified and incorporates a prime mover with a nameplate rating of up to 5 kW. CSA B52 compliance should also be considered. Furthermore, a refrigeration mechanic may, without an installation permit: Replace valves, controls, piping, refrigerant, or relief devices on the GAHP, provided the replacement components are of a similar type and approved by a provincial safety manager.

Specific municipal refrigeration permits may be required, such as the City of Vancouver Mechanical Permit for installing any type of heat pumps.

Figure 7: GAHP units installed in BC's lower mainland during FortisBC's pilot stage.

Licenses and Certifications

All responsible manufacturers test their equipment through rigorous testing and compliance with applicable standards. The requirements outlined in the standards are intended to ensure minimum performance levels and to protect people, property, and the environment. Project designers are recommended to review the required certifications for respective jurisdictions when specifying GAHPs for a project. Some of the relevant standards for GAHP certifications include:

- ANSI Z21.40.1 – CGA 2.91 – Gas-Fired, Heat Activated Air Conditioning and Heat Pump Appliances: This is the standard for safe operation, substantial and durable construction, and acceptable performance of gas-fired, heat-activated air conditioning and heat pump appliances.
- ANSI Z21.40.4 – CGA 2.94 – Performance Testing and Rating of Gas-Fired, Air Conditioning and Heat Pump Appliances: This standard refers to performance tests to cover a wide range of unitary gas-fired technologies, such as absorption, adsorption, and engine-driven equipment cycles. The test results are used to generate performance curves, estimate efficiency (seasonal COP), and electric power consumption.

Comparing GAHPs with Competing Technologies

Like other energy efficient technologies, GAHPs can also offer a decarbonization pathway for facilities that were designed to operate with conventional HVAC systems. However, based on the existing design configuration of a facility, the rationale for installing GAHPs may differ. For example, depending upon the existing electric load profiles and location of a facility, switching space and water heating loads from natural gas to electricity results in a need for electric service upgrades. The timing and costs of these upgrades vary from one facility to another. Every facility must compare the timing and costs of service upgrades and the incremental electricity charges versus the cost of operating GAHPs on natural gas, RNG or if applicable, propane.

We reviewed different technologies for domestic hot water heating, space heating and cooling that may be compared with GAHPs when considering a project. These include condensing and non-condensing boilers, air conditioners, and electric heat pumps (EHPs). An effort was made to compare the market-ready options based on technical information published by manufacturers. Tables 2 and 3 present high-level features of different technologies.

Table 2: Comparison of GAHP with other technologies

Parameter	Technology				
	Non-condensing boiler	Condensing boiler	GAHP	EHP	Air Conditioner
Operating Technology	Combustion	Combustion	Thermal absorption cycle	Vapour compression cycle	Vapour compression cycle
Energy Source	Natural gas, RNG, Propane, diesel, fuel oil	Natural gas, RNG, Propane, diesel, fuel oil	Natural gas, RNG, propane + ambient heat from air, water, or ground	Electricity + ambient heat from air or ground	Electricity
Energy Sink	Water	Water	Water	Water or Air	Air
Space Heating	Yes	Yes	Yes	Yes	n/a
Hydronic Space Heating	Yes	Yes	Yes	Yes	No
DHW Heating	Yes	Yes	Yes	Yes	No
Thermal Efficiency	up to 80%	up to 98%	n/a	n/a	n/a
COP – Heating	n/a	n/a	~ 1.3 [a]	~ 3.4 [b]	n/a
COP – Cooling	n/a	n/a	~0.6 [c]	~3.22 [d]	~3.5 [e]
Estimated Useful Life	25 [f]	18 [g]	20 [h]	15-20 [i]	15 [f]

Notes:

a: Assessed at 6.7°C ambient air (dry bulb) and 45°C water output.

b: Assessed at 8.3°C ambient air (dry bulb) and 47°C air supply.

c: Assessed at 35°C ambient air (dry bulb) and 7°C water output.

d: Assessed at 35°C ambient air.

e: Assessed at 35°C ambient air.

f: Illinois Technical Reference Manual (TRM) – Version 11.

g: Ontario energy board TRM for natural gas demand side management – Version 5.

h: Based on conversations with manufacturers and 2018 whitepaper by The Atmospheric Fund

i: NRCan publication "Heating and Cooling with a Heat Pump" – 2022.

Table 3: Comparison of GAHP with other technologies - continued

Parameter	Technology				
	Non-condensing boiler	Condensing boiler	GAHP	EHP	Air Conditioner
Installation Location for Main Components	Mechanical room	Mechanical room	Outdoor	Outdoor	Outdoor
Is Antifreeze Protection Required?	No [j]	No [j]	Yes [k]	Yes – Air to water systems only.	No
Is Back-Up Heat Required?	No	No	Not required for most space heating applications. Back-up may be required for high-temperature hydronic heating systems, DHW systems or for installations in very cold climate zones.	May be required for installations in very cold climate zones.	n/a
Is the Equipment Available in BC?	Yes	Yes	Yes	Yes	Yes
Rebate Availability [l]	Yes	Yes	Yes	Yes	No
Is 12% PST Applicable? [m]	Yes	Yes	No	No	No
Refrigerant Type	n/a	n/a	Ammonia-water solution	R454B	R454B [n]
Refrigerant Charge [o]	n/a	n/a	~6.8 kg (15 lbs.)	~5.0 kg (11 lbs.)	~2.3 kg (5.1 lbs.)
Is Refrigerant Handling Required? [p]	n/a	n/a	No	Yes	Yes
Environmental Impact	Emissions are associated with the consumption of natural gas. These emissions can be significantly lowered with low-carbon fuels, such as RNG. New units are equipped with Low NOx burners.			Emissions may be associated with a non-electric back-up heating system or in the case of a refrigerant leak. Emissions associated with electricity consumption in BC are minimal due to low emission intensity of the electricity grid.	

<u>Notes:</u>

j: Assuming that piping is not exposed to outside conditions.

K: Specific to climate zones in BC.

l: Different rebates are available for different technologies. These may include funding for new equipment, equipment upgrades, and feasibility studies.

m: BC provincial sales tax (PST) notice effective April 1, 2022. Revision July 2022.

n: Some air conditioner models may operate with other refrigerants, such as R22.

o: Specific to the models specified in Table 4.

p: Refrigerant handling required at commissioning or during operations and maintenance.

The following table provides a list of makes and models that were considered for this analysis where model-specific data was required.

Table 4: Make/Model used for Comparison of GAHP with other technologies

Technology	Make / Model
Non-condensing boiler	Fulton – ICW6
Condensing boiler	Rheem – GHE80SU/SS-130(A)
Absorption heat pump (GAHP)	Robur[25] – GAHP-A and GAHP-AR
Electric heat pump (EHP)	Trane – WSK072A3S0C
Air Conditioner	Lennox – LCM074U5E

While Tables 2 and 3 offer a non-exhaustive list of potential comparison points for these technologies, facility owners may also compare other factors such as, global warming potential and ozone depletion potential of refrigerants, project lifetime costs and the overall decarbonization potential.

Decarbonization Potential

The decarbonization potential of different refrigerant-based technologies can be classified under direct and indirect impacts[26].

- The direct impact can be achieved through the type of refrigerant that is exposed to the atmosphere in the event of a leak, accident, handling, or disposal. The ammonia-water solution used as the refrigerant in GAHPs has zero global warming potential and zero ozone depletion potential.
- The indirect impact is delivered through the savings in energy consumption in operating the technology over a complete season. Compared to conventional water and space heating equipment

[25] Robur's new GAHP Plus units have a rated GUE of 138% with maximum water output temperature of 65°C (149°F).

[26] ASHRAE Position Document on Refrigerants and Their Responsible Use - Jun 2020

running on natural gas, GAHPs can deliver the same output with a COP higher than 1, through most of the year. This reduction in natural gas consumption helps reduce the GHG emissions intensity associated with traditional heating systems. Moreover, most of the manufacturers offer low-NOx burners on GAHP units.

According to some manufacturers, GAHP units are compliant to operate on a blend of natural gas or RNG with up to 20% hydrogen. FortisBC customers can further reduce their GHG emissions today by signing up to receive various blends of renewable and low-carbon fuels, such as RNG up to 100 percent. At the time of publishing this guide, the manufacturers are researching the development of a burner that can operate on 100% hydrogen. The compatibility of GAHPs to operate on higher blends of hydrogen or pure hydrogen in the future can add to the decarbonization benefits of GAHP technology.

Operating and Unit Costs

Lifetime operating costs mainly consist of energy costs, maintenance costs, and potential decommissioning costs. Switching to high-efficiency equipment such as GAHP, can not only allow facilities to reduce the carbon footprint of their operations but also help save on operating fuel costs over the equipment's lifetime.

GAHPs range in price, and the units alone can cost between $20,000 and $30,000[27]. Project-specific factors such as the number of units, controls, integration with existing equipment, installation requirements, piping and insulation can impact the overall project costs. GAHP prices are expected to decrease with more commercialization and market adoption of the technology.

Compliance with BC's Current Climate and Energy Policies

BC is ranked among the leading jurisdictions in North America when it comes to climate action and policies to support climate change mitigation and adaptation. The province is a net exporter of electricity, more than 90% of which is generated through renewable resources, such as hydropower[28]. While electrification, among other measures, is considered one of the strategies for deep decarbonization, most facilities across the province rely on natural gas for their heating needs. Moreover, with ever-increasing demand for electric vehicles, the electrification of space and water heating systems can lead to rapid increases in electrical peak demand in buildings[29]. Tackling the peak demand issue requires additional dispatchable electrical power and substation upgrades that can be expensive. The

[27] "What are gas heat pumps and how can they save money and energy?". Article posted on FortisBC webpage on June 21, 2022.

[28] Canada energy regulator – Provincial and Territorial energy profile of British Columbia

[29] "Cost and capacity requirements of electrification or renewable gas transition options that decarbonize building heating in Metro Vancouver, British Columbia" by Palmer-Wilson et.al. in Energy Strategy Reviews, vol 42, 2022

expected near-term growth in electrical demand due to switching heating loads to electricity requires a carefully thought-out strategy.

While some municipalities are accelerating their electrification journey, others are considering alternative solutions to this complex problem, which indeed includes some level of electrification. In 2018, FortisBC released the "Clean Growth Pathway to 2050"[30] report to demonstrate its commitment to climate change solutions. FortisBC's proposed pathway highlighted four areas requiring significant energy system shifts to meet the growing demand for clean energy. These include continued investment in energy efficiency in the built environment and developing innovative energy projects in BC's communities.

This approach is consistent with CleanBC's 2030 roadmap that highlights the need for all new space and water heating equipment sold and installed in BC after 2030 to be at least 100% efficient. GAHPs align with this approach because these units have a COP of greater than 1. Gas absorption heat pump technology is also identified as an eligible solution in the recently published independent review of CleanBC[31].

In 2022, the province also introduced an additional provincial sales tax (PST) on the purchase or lease price of all fossil fuel combustion equipment. While the conventional combustion systems are subject to 12% PST (previously 7%), gas heat pumps were excluded from PST altogether. This positions GAHP technology as an accepted pathway for decarbonization by the province.

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[30] Clean growth pathway to 2050" FortisBC - 2018

[31] "Final report of the CleanBC Independent Review Panel – November 2025". Under recommendation 2-c-ii, it is proposed to develop a Highest Efficiency Equipment Standard (HEES) to require all new space and water heating equipment sold and installed in BC to be at least 100% efficient by the early 2030's. GAHPs are identified as an eligible technology.

FortisBC's Pilot Program Experience

In line with the Federal Pan Canadian Framework and FortisBC's Clean growth pathway to 2050, FortisBC's Innovative Technologies team in the Conservation and Energy Management (C&EM) department initiated a pilot program to verify the performance of GAHPs. The program was designed to demonstrate the energy savings potential, address any issues associated with the installation and operation, and test the compatibility of GAHPs within Climate Zone 4. The program offered great insights into the customer experience and market readiness of GAHP technology.

For the commercial sector, GAHP installations under the pilot program were completed in 2019 and Measurement and Verification (M&V) were conducted in 2020. A total of seven facilities (5 MURBs and 2 Schools) located in the lower mainland were selected to participate in the program. The initial focus of the pilots was to support the DHW systems using a hybrid approach. Each facility was retrofitted with two Robur GAHP-A (air-to-water type, heating-only) units. While the GAHP units were installed outside the buildings, a buffer tank (80 gallons), a double-walled heat exchanger, and circulation pumps were installed inside the utility rooms.

Figure 8: Left: Robur units installed on a rooftop. Right: Pump skid with a buffer tank and glycol feeder.

The projects were designed to cover up to 70% of the DHW load capacity for each facility and rely on the existing boiler systems to meet the remaining load. The baseline systems were non-condensing boilers with up to 80% efficiency.

Upon successful commissioning of the units, the projects were evaluated in line with Retrofit Isolation Key Parameter (Option A) as per the International Performance Measurement and Verification Protocol (IPMVP)[32]. Figure 9 shows a typical data measurement strategy applied during the pilot program.

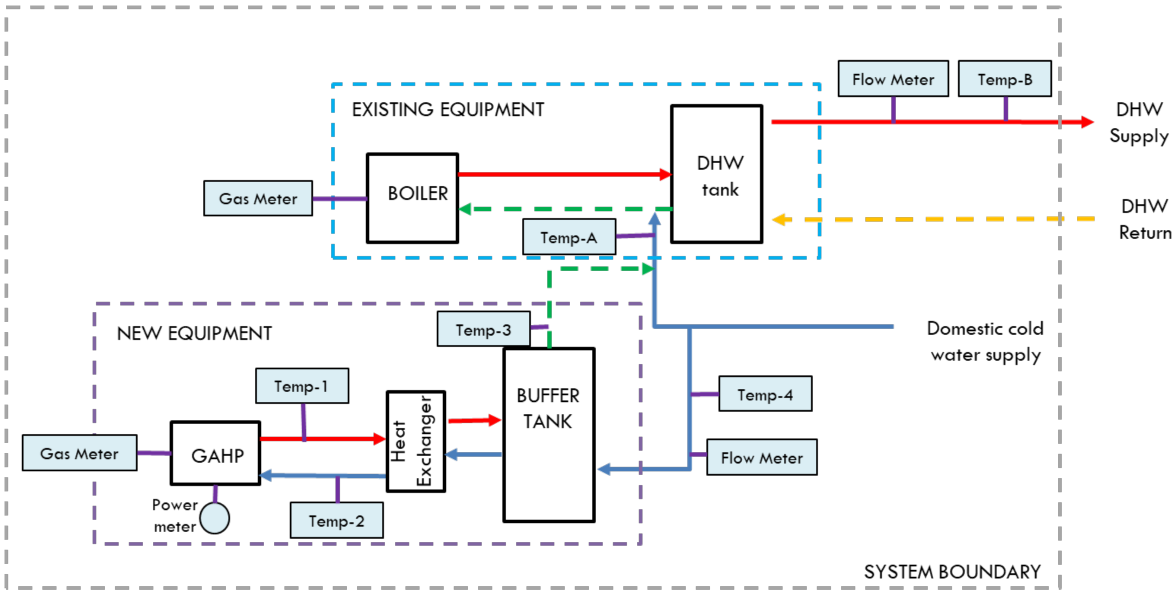


Figure 9: Example of a measurement strategy for savings calculations for GAHPs supporting DHW systems.

The quality of collected data was reviewed to establish confidence in the results. To reduce uncertainty in the data from one of the facilities, Whole Facility IPMVP Option C was also considered since most of the natural gas consumption was attributed to DHW use at the location.

The overall efficiency of a hybrid system was calculated by dividing the useful work done by the GAHP and boiler system in raising the water temperature by the energy input to the system (natural gas and electricity).

For consistency with other gas equipment, the gas utilization efficiency (GUE) of the hybrid systems in the pilot projects was calculated by dividing the system output by the natural gas consumption of the existing boiler and GAHP units.

$$\text{GUE} = \frac{\text{Heat produced by the system}}{\text{Gas energy consumed by the system}}$$

[32] IPMVP is owned by Efficiency Valuation Organization (EVO®) and serves as a measurement and verification framework.

The useful work done by this system is proportional to the water flow rate through the system and the temperature rise of the water. During the pilots, the heating outlet temperature of the GAHPs was generally in the region of 55-58°C (131-136°F).

The GAHPs rejected heat to the buffer tank through a double-walled heat exchanger. Glycol or another anti-freeze agent was required in the GAHP primary loop where the GAHP was subject to freezing temperatures. During the pilots, thermal losses of approximately 6% were experienced across this heat exchanger using glycol in the lower mainland, and up to 12% can be expected in other geographical areas of the province.

To achieve a GUE greater than 1.0, the pilot results revealed the importance of maintaining a differential temperature across the GAHP of greater than 5°C. At a differential temperature greater than 6°C to 7°C, the units achieved a GUE of 1.2 to 1.4. Figure 10 demonstrates this from the data recorded during the pilot projects. Hydronic systems with constant flow or constant demand are therefore preferred systems where this condition can be easily achieved.

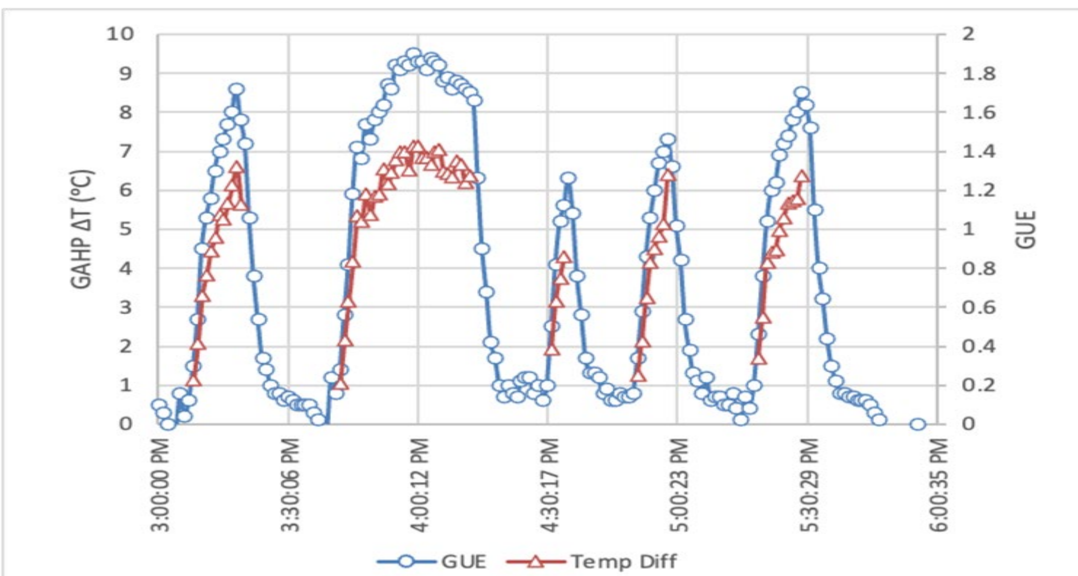


Figure 10: The effect of GAHP differential temperature on GUE.

Enhancements Made During the Pilot Program

Based on learnings from the initial phases of the pilot program, enhancements were made to the GAHP configurations to improve the system-level performance. Some of the key improvements made during the pilot are discussed here.

1. Even though all pilot sites installed two GAHP units each, it was discovered that right sizing of the units was essential. The sizing of the GAHP system affects the energy output, response time and

temperature differential across the heat pumps. The intermittent nature of DHW loads can provide undesirable conditions for the heat pump performance due to constant cycling based on the temperature differential. Subsequently, some of the facilities were changed to operate on a single GAHP unit at a higher loading and the performance improved.
2. It was noted that the existing boiler systems often performed inefficiently as the GAHPs met most of the heating load. Each test site had standard efficiency boilers varying in age. These older boiler systems have a poor turndown ratio and do not operate efficiently when cycled at part load. When the GAHPs were operating, the existing boiler fired to top up the DHW temperature to 60°C (140°F). As the GAHP system took the load off the boiler, the short cycling effect was exaggerated, causing a further drop in boiler efficiency and thus reducing the system efficiency. Therefore, subsequent pilot tests were conducted by adding a high efficiency condensing boiler to back up the GAHPs. Due to the high turn-down ratios of these boilers, the system could perform at a much higher COP.
3. The initial tests also highlighted the need for an advanced control system capable of integrating the GAHPs and the existing boiler system. The controls improved GAHP and system efficiency through superior flow sequencing and temperature differential management.

Following figure demonstrates the performance improvements due to different enhancements to the pilot configurations.

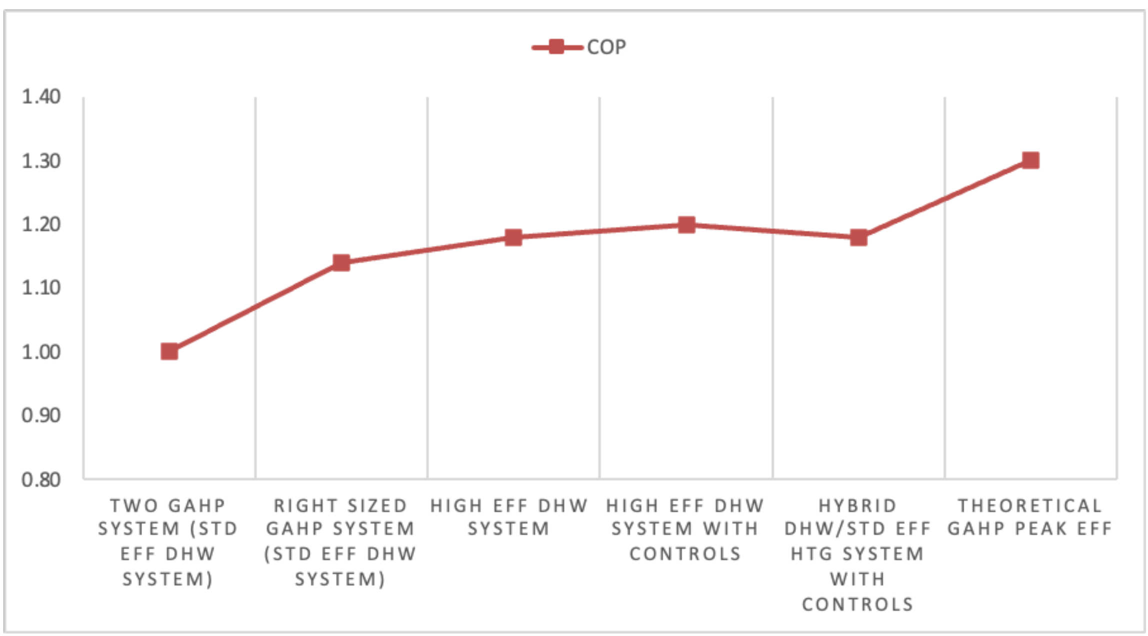


Figure 11: GAHP COPs measured at different phases of the pilot program.[33]

[33] System COPs were calculated by accounting for natural gas and electric power inputs.

Building upon the confidence in GAHP's performance for DWH systems, the pilot was later extended to test space heating configurations. GAHP technology was tested with a direct connection to a 100% outdoor make-up air unit as well as for supplemental cooling.

For make-up air heating, a dual-purpose hydronic coil was sized and selected to provide 75% heating load to the make-up air unit when connected to right sized GAHPs. GAHP-AR[34] outdoor units were selected as they offer a reversible cycle and provide cooling as well as hot water heating. In this regard the dual-purpose hydronic coils have the ability to provide first stage hot water heating and supplementary cooling.

First stage cooling was provided by the existing electrical driven direct expansion cooling system. GAHP-ARs were chosen for this phase of the pilot because the existing cooling system was unable to meet the cooling setpoint. The building chosen also had no spare electrical capacity to add more electrical driven cooling systems. The hydronic coil was carefully chosen to ensure the hot/chilled water flow rate and entering/leaving water temperatures were conducive to GAHP specifications.

Monitoring, measurement and verification of this new system confirmed that the new systems proved highly successful. Not only was the thermal comfort adequately maintained in both heating and cooling operation modes, but the increased natural gas usage in summer, to provide supplementary cooling, was also greatly offset by the natural gas savings in heating operation.

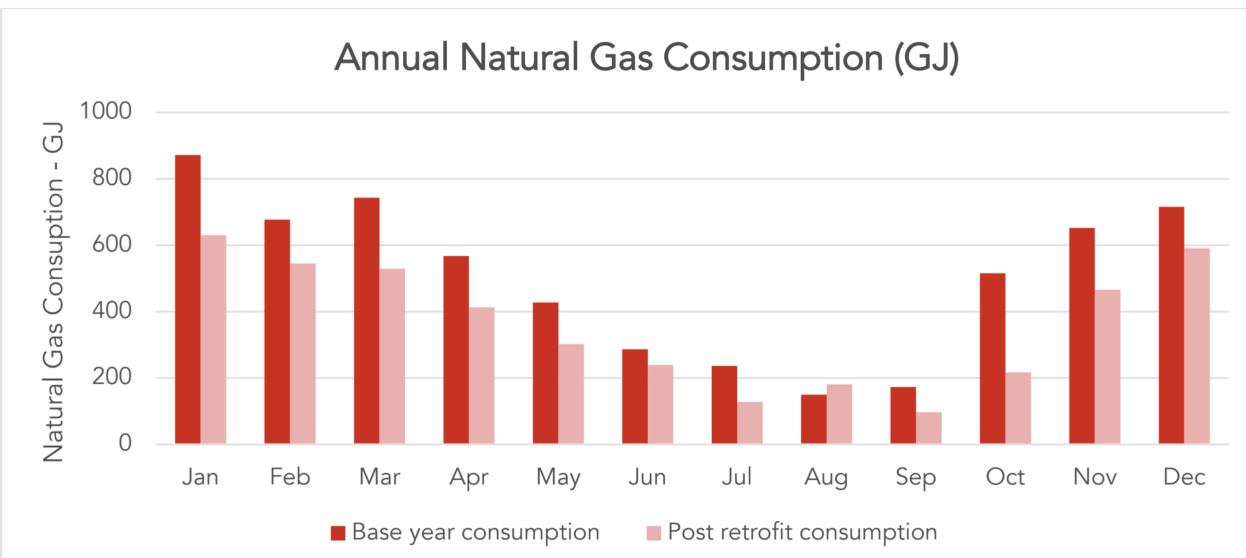


Figure 12: GAHP-AR Natural Gas Consumption for Heating and Cooling.

The system demonstrated consistent heating COP of greater than 1.3. The peak heating COP was determined as 1.4. The COP for supplementary cooling was calculated as 0.55. This configuration was found to be the most cost-effective application of the GAHPs tested in the pilot program.

[34] GAHP-AR is Robur's air-to-water gas absorption heat pump capable of heating and cooling output.

The system recorded a 34% natural gas reduction over the measurement period for providing makeup air unit heating, compared to the pre-existing hot water heating system that consisted of high efficiency boilers. The overall natural gas savings were reduced by 14% due to the increase in natural gas consumption in summer due to the supplementary cooling. Overall, the pilot recorded an annual natural gas saving of over 22% during the measurement period.

Figure 13: GAHP-AR units installed on a rooftop for a space heating and supplementary cooling pilot in BC's lower mainland.

Design Best Practices

This section builds upon the hands-on experience of designers and installers of GAHP units in BC. Most of this knowledge was acquired during FortisBC's multi-year pilot programs and refined over the years through the projects that were funded by FortisBC's early adopter offer[35] and FortisBC's GAHP rebate offer.

Note that this information is presented for guidance to help the readers learn about the design considerations of this technology. This information is not intended to provide project-specific advice and should not be relied on as such. Designers should follow recommendations from manufacturers, conduct due diligence and comply with the applicable codes and regulations. The information is also not intended to replace the need for engineering analysis.

Integrating GAHPs with Other Systems

While GAHPs can be installed to operate independently in small systems, most of the larger applications will require integration with other space and/or hot water heating systems. The following should be kept in mind while designing integrated or hybrid GAHP systems.

1. Right sizing of the GAHP system is critical to maintain a reasonable temperature difference and to prevent short cycling of the units.
2. Controls are essential for high system efficiency by maintaining the ideal temperature differential.
3. Glycol is required to prevent the freezing of any outdoor piping and equipment.
4. It is recommended that thermal insulation be installed on all piping and that the distance between the GAHP and the existing system is kept to a minimum to reduce the loss of hot water temperature in the loop connecting the GAHP.
5. A backup or peaking boiler may be required to ensure peak loads are met. If so, consideration should be given to utilizing a high efficiency boiler (such as, a condensing boiler or a tankless water heater for domestic hot water application) with a good turndown ratio to prevent short cycling and system inefficiencies. If an existing cast iron boiler is used, there may be a requirement to protect the boiler from 'cold' inlet temperatures. It should also be noted that if a high temperature (> 60°C/140°F) boiler is used for peak load, the GAHPs will not operate at those temperatures. Therefore, the boiler needs to be capable of providing 100% heating load.

[35] In 2021-22, FortisBC introduced an early adopter offer to more than 15 facilities for their GAHP installation projects.

Designers should also pay attention to system balance points[36] when integrating GAHPs with other systems that provide peak load or backup options.

Considerations for Integration with Air Handling Systems

When GAHPs are combined with air-handling units (AHU), the following additional considerations should be kept in mind:

1. GAHPs are expected to meet most of the heating loads in this configuration. Therefore, a backup or peaking boiler may or may not be required to ensure peak load is met.
2. The hot water coils must be sized correctly to maintain the desired temperature difference and flow rate across the GAHP unit(s).
3. Due to constant heating load and low project costs due to the relative simplicity of these systems (GAHP+AHU) compared to domestic hot water systems, some projects in this configuration may experience short payback periods.

Figures 14 and 15 present a sample schematic for integrating GAHPs into air handling systems.

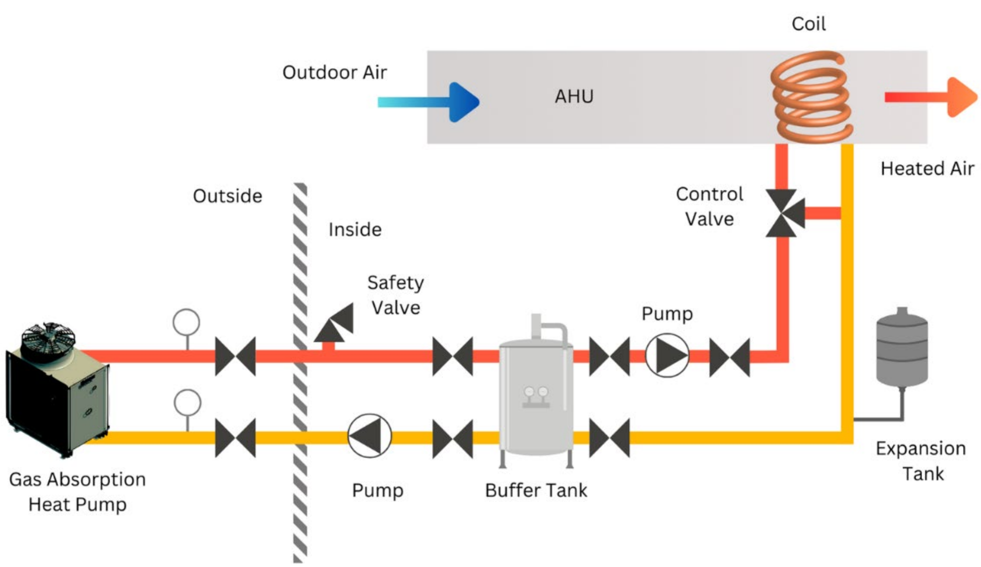


Figure 14: Sample schematic for GAHP heating application with an air handling system.

[36] Balance point refers to the temperature at which a backup system is designed to take over the system load.

GAHP units capable of cooling can also be connected with air handling units to provide cooling.

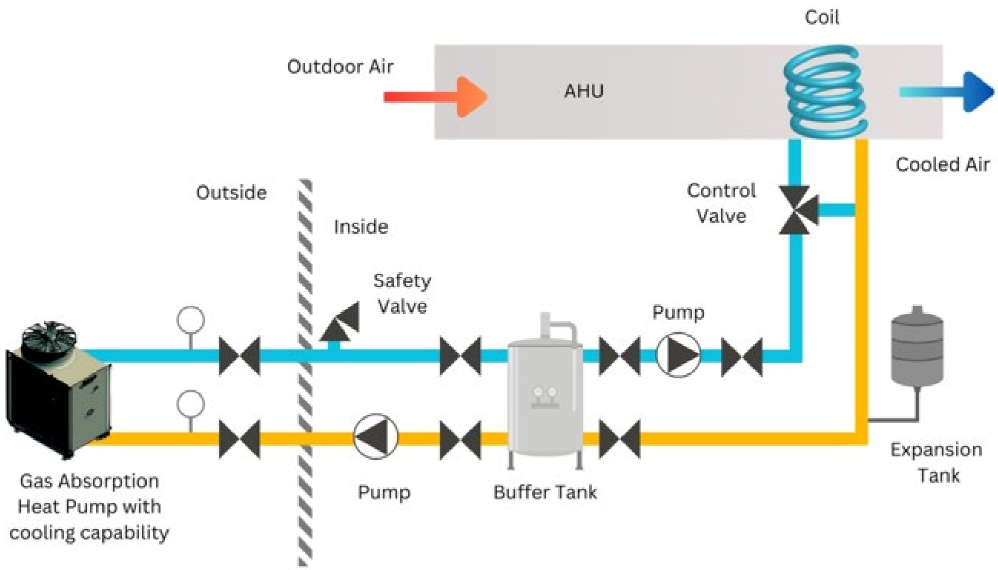


Figure 15: Sample schematic for GAHP cooling application with an air handling system.

Considerations for Integration with Domestic Hot Water (DHW) Systems

When GAHPs are combined with the domestic hot water system, the following additional considerations should be kept in mind:

1. A double wall heat exchanger between the non-potable and potable water systems may be required by local codes.
2. A suitably sized DHW Preheat tank is the preferred methodology for integration of a GAHP into an existing DHW system. This preheat tank should be sized to maintain a reasonable temperature difference and to prevent short cycling of the GAHP.
3. Consideration should be given to the domestic water recirculation connection point to ensure the return water to the GAHP is lower than 48°C/120°F.

Figure 16 presents a sample schematic for the domestic hot water heating system application.

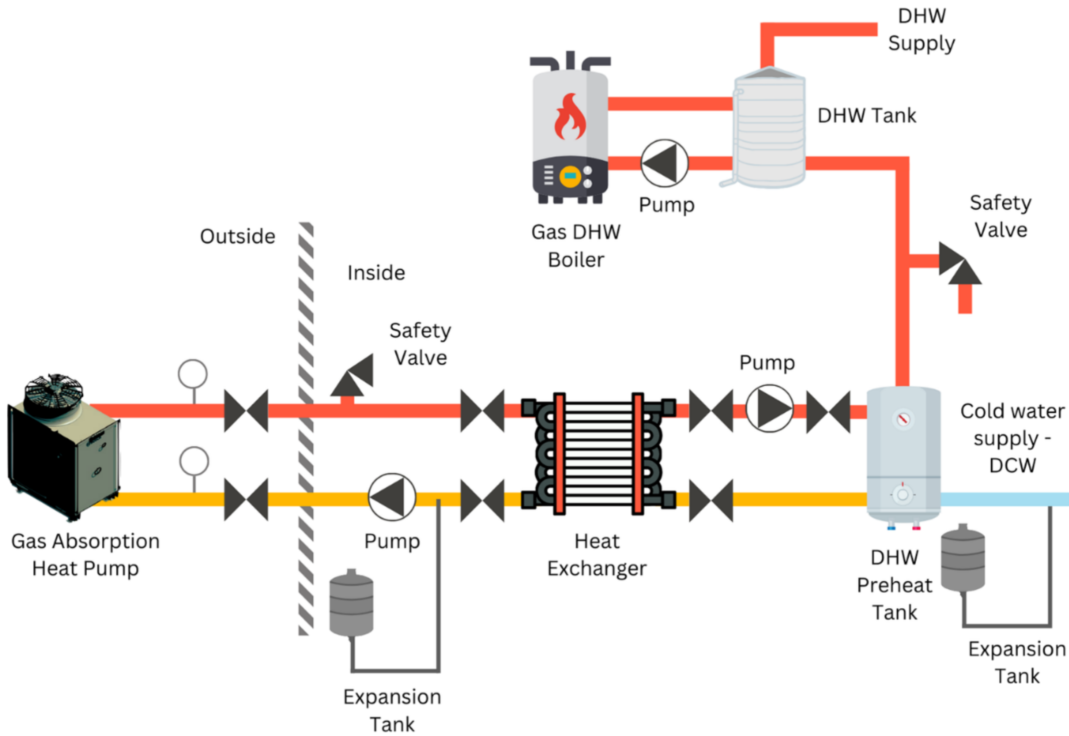


Figure 16: Sample schematic for GAHP application in a DHW system.

Considerations for Integration with Hot Water (Hydronic) Systems

When GAHPs are combined with hot water heating systems such as hydronic space heating, the following considerations should be kept in mind:

1. The maximum output temperature of several GAHPs is around 60°C (140°F). Some older buildings have hot water heating systems sized for above 80°C (176°F), which is only required for peak load heating or when the outdoor temperature falls below 0°C (32°F). Therefore, GAHPs can still be incorporated into older buildings without the need for a complete heating system retrofit, as long as "peak-load" boilers are installed. During those times when the peak load boilers operate, the GAHPs may not operate due to high return water temperatures. The maximum return temperature to a GAHP is 48°C (120°F).
2. The type of existing terminal unit should be reviewed to ensure heat requirements can be met at lower hot water temperatures supplied through GAHPs.
3. In multiple GAHP installations on a single site, control sequencing should be reviewed to prevent short cycling. In addition, the use of control isolation valves (back-end valves) should be considered to prevent standing losses across those GAHPs that are not operating due to low system loads. The back-end valves can be controlled directly from the GAHP.

Figure 17 presents a sample schematic for the hot water heating system application.

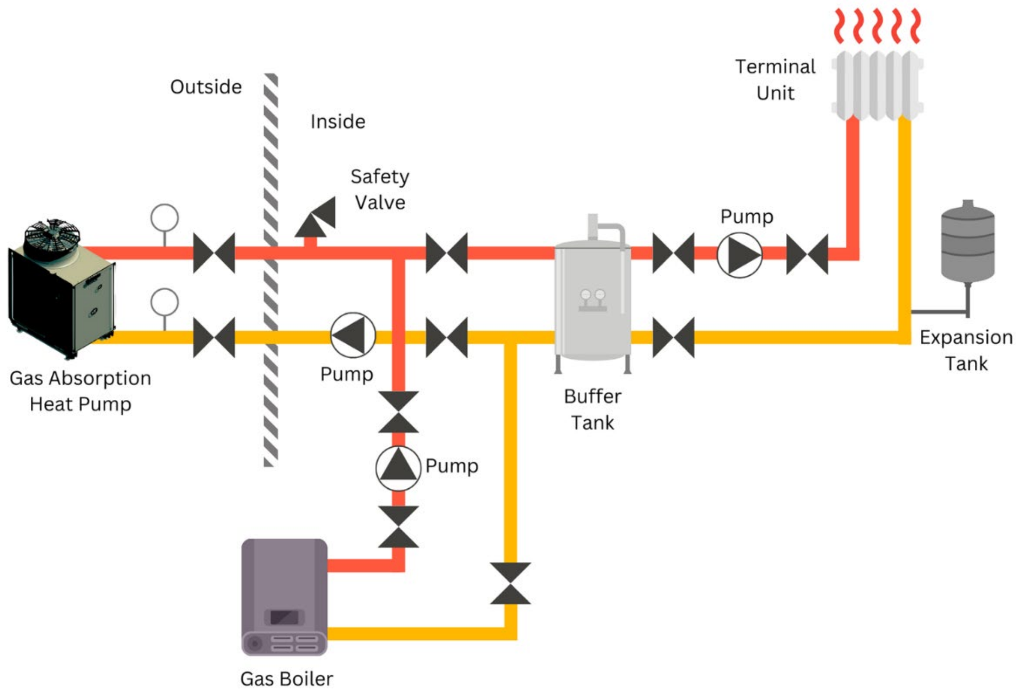


Figure 17: Sample schematic of a GAHP applied to a hot water system.

System Right Sizing

The right sizing (engineering) of the GAHPs is critical for optimum performance and resultant energy savings. It is necessary because the load profile of a facility considering GAHP installation can significantly differ from another, depending on a number of variables. Some of the variables specific to DHW and hydronic heating systems include but are not limited to the following:

1. Building age and type
2. End uses (domestic hot water, space heating, etc.)
3. Efficiency and condition of the existing equipment
4. Flowrates and temperature (delta T) requirements for integrating systems
5. Heating profile for ventilation systems or hydronic systems
6. Domestic hot water fixture specification (low flow fixtures)
7. Thermal losses of the DHW system (type of insulation/return piping size)

The figure below demonstrates the impact of right sizing on the possible effective range of GUE of GAHPs, as determined during the tests carried out at one of the FortisBC pilot facilities. GAHP units were operated in single and double-unit modes during similar operating conditions to substantiate the impact of right sizing.

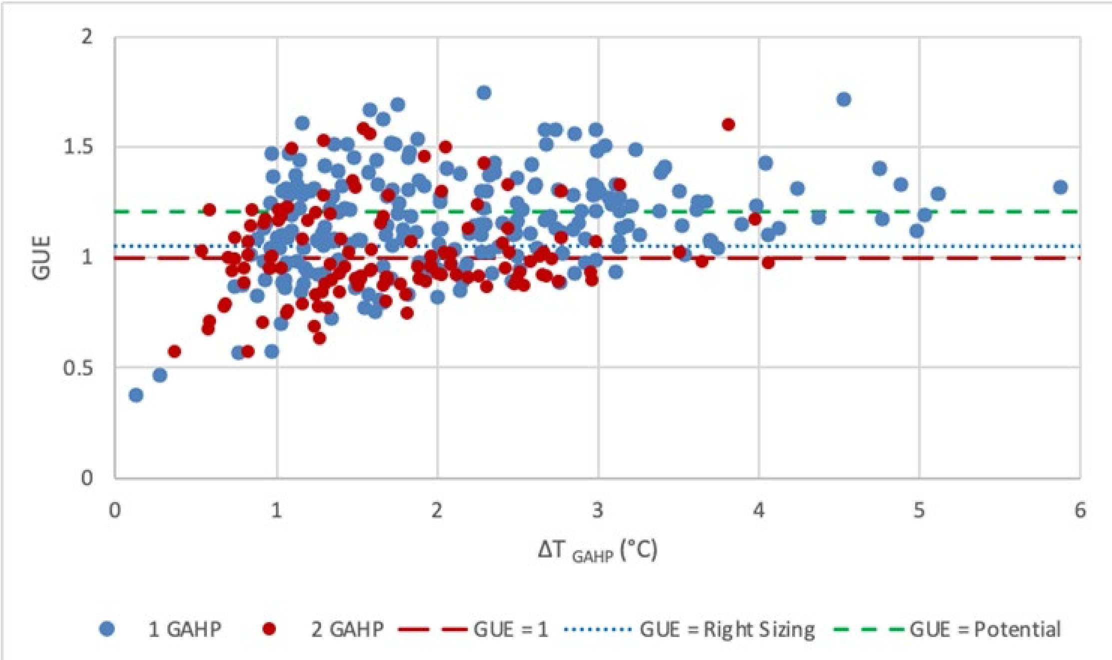


Figure 18: Effect of rightsizing on natural gas utilization efficiency of GAHPs for a DHW system.

When heat pumps are primarily designed to deliver heating, the COP of potential units at low ambient conditions is an important factor in selection and right-sizing.

Designers are encouraged to review the right-sizing opportunities for their specific project and avoid oversizing the GAHP systems. Particularly, in cases where the project facility is undergoing building envelop upgrades or other changes that can alter the post-project heating load, the designers must consider right sizing the GAHPs in line with the expected future heating loads and not simply size the GAHP systems to replicate the exact output capacities of the baseline systems.

Integration with a Controls System

Integration of advanced dynamic controls for pilot projects presented excellent insights into the operation of the GAHP systems. A control system allows the staging of each GAHP unit depending on the thermal energy load. Two of the most critical control parameters of the GAHP equipment are the heating (temperature) setpoint and the dead band. A dead band (also known as a dead zone or a neutral zone) is a band of input values in the domain of a transfer function in a control system or signal processing system where the output is zero (the output is 'dead' - no action occurs). These parameters determine when the unit is operating or not. These advanced controls offer improved energy savings by automatically sequencing, scheduling, and changing setpoints of the GAHPs and interconnected systems.

For example, the control philosophy applied during the pilot projects required extensive system testing to identify the set points for optimum performance of GAHP units. The following control parameters were implemented during the pilot projects:

- Heating plant remote enable/disable
- Individual GAHP status
- Individual GAHP control
- Fluid inlet and outlet temperatures from each module
- GAHP gas meter digital input
- Pump Status and fan status/speed for each unit
- Plant hot water setpoint temperature
- Plant dead band temperature range
- Control (On/Off) of GAHP circulation pumps
- Plant temperature sensors[37]

Additional Considerations

As a general principle, manufacturers' recommendations should be adhered to for all additional considerations and situations not covered within this guide.

Noise and Vibration Control

The GAHP units may require vibration isolators. Using anti-vibration pads reduces noise, especially in rooftop applications. Based on the findings from the FortisBC pilot, no complaints were noted from the contractors or building owners. In addition, no noise complaints were recorded whether the equipment was installed at ground level 6m (20ft) from an apartment or on the roof of the building.

Careful consideration must be given to municipal noise bylaws when installing any outdoor equipment.

Electrical Connection

Most GAHP units do not require an upgrade of electrical service. Model specific guidance from manufacturers should be followed for every project. For reference, the GAHP-A (36 kW) manufactured by Robur requires a single power connection 208-230 V/1ph/60 Hz with 0.9 Minimum Circuit Amps (MCA) and Maximum Over-Current Protection (MOP) of 10.9 A. Vicot's V20 (20 kW)

[37] Refer to Figure 9 for an example of potential temperature measurement points.

unit requires a power supply of 220 V/1ph/60 Hz and V65 (65 kW) unit requires a supply of 240 V/3ph/60 Hz.

Buffer Tanks

GAHPs have been tested with and without buffer tanks. Typically, the system design should avoid low "delta T" situations because if the loop circulation time is too short, the condenser water does not have a chance to dispose of, exhaust, or transfer much heat. This can result in the GAHP short cycling and lead to potential nuisance trips.

For example, hydronic heating requires a lower flow rate than the effective flow rate of a GAHP unit. In such a situation, the GAHP may quickly heat the volume of liquid and then shut down if a buffer tank is not installed.

Piping Considerations

Piping for GAHP systems is very similar to boiler systems. From piping perspective, the simplest way to describe a GAHP is as an outdoor boiler capable of performing at a COP of greater than 1. Therefore, there is a hot water supply and return pipe and a gas pipe with associated valves. All of these items are typical of a gas-fired boiler.

Figure 19: Rooftop installation of GAHPs in Vancouver, BC.

Venting

Since the units must be located outside, the venting requirements are more straightforward than a boiler system. Caution must be exercised to maintain clearance from combustibles and air intakes surrounding the outdoor units.

Gas Pressure Requirement

GAHPs typically have a 5.0 to 14.0 inches of water column (in. WC) inlet natural gas pressure requirement (like most natural gas boilers). This may differ if a different fuel source is used. Manufacturers' installation guidance should always be adhered to.

Location Considerations

GAHP units must be located outside the buildings, on the ground or the roof. If located on the roof, a structural assessment by a professional engineer may be required to ensure that the roof can handle the weight of the GAHP units. In some cases, lifting equipment may be required to hoist the units into position, which can add to the project costs.

The GAHP units should be installed close to the mechanical room to minimize pipe lengths and resultant installation costs. While the GAHPs are installed outside, the pump(s), buffer tank and acid neutralizer need to be located inside and therefore, some mechanical room space is still required.

Freeze Protection

GAHPs are installed outside of the buildings, therefore these units require protection from freezing where ambient outdoor temperatures fall below freezing level. In most instances, propylene glycol is used for freeze protection in HVAC systems. Whenever a fluid other than 100% water is introduced into a hydronic system, consideration must be given to the resultant pump sizing as this may affect the pump selection. At 40% glycol concentration the drop in pressure across the GAHP system increases by approximately 50%.

Drainage

Drainage is required for all external units. For the non-condensing GAHPs, drainage is only needed during the defrost cycle, which is minimal in the lower mainland, even when tested with outdoor temperatures below -11°C (12°F). For condensing GAHPs, there is a requirement to provide a drain and acid neutralizer to the bottom of the combustion flue. Consideration is needed to heat trace this line to prevent freezing and to route this condensate pipe to a sanitary drain.

Figure 20: Multi-unit GAHP installation at a project site in Chilliwack, BC.

GAHP Installation, Operations and Maintenance

This section provides general guidance for installers and facility operators. The information is based on experience acquired during FortisBC's multi-year pilot and rebates program and conversations with the equipment manufacturers. The information is not intended to replace project-specific insights that experienced contractors have or override any applicable regulations and laws specific to the project jurisdiction.

Installation

Mechanical/plumbing contractors usually carry out the installation. These companies must have a competent class-B ticket gas fitter on their team. Guidance from manufacturers must always be adhered to.

Permitting

A gas and an electrical permit are typically required. Gas permits need to be coordinated with the local municipality. Typically for connected boiler loads greater than 399,000 BTUs/hour (117 kW), permitting is required with Technical Safety BC (TSBC).

A development permit/building permit may also be required, depending on where the equipment is located. Always refer to the local municipality bylaws to ensure permitting compliance.

Figure 21: GAHP in operation to support domestic hot water load in the BC's lower mainland.

Operations

Basic equipment training for facility operators is recommended during project commissioning. It is recommended to involve the manufacturers for their input into the controls set up during the commissioning stage. Operators should also refer to equipment manuals to learn about model/make specific instructions.

The operation of GAHP units is generally free of any intervention. A well-designed system with controls can maintain constant loads and prevent short cycling or issues related to output temperature. GAHPs were tested to maintain a consistent output temperature through peak winter and summer conditions during FortisBC's pilot projects in the lower mainland.

General housekeeping should always be maintained to ensure that finned coils are clean, and vents are not blocked.

Maintenance

GAHPs require no additional maintenance when compared to a traditional gas-fired boiler, an electric heat pump or any other vapour compression HVAC equipment. Maintenance is usually carried out by the installer or gas contractor, as is typically the case in a traditional boiler installation. According to the manufacturers' data, GAHPs have an effective useful life of about twenty years, proper maintenance is required

Manufacturers specify the exact preventive maintenance requirements for each model, but typical annual maintenance activities may include:

- Checking for any errors on the controller
- Inspecting coils of the GAHP for cleanliness, debris, leaks, blockages
- Inspecting hydraulic pump belts
- Checking condition & level of the oil in the hydraulic pump
- Checking condenser fan height
- Checking gas pressure
- Inspecting hydronic water circuit for leaks and levels of chemicals (inhibitor/glycol)
- Checking igniter and flame sensors
- Checking the water filter / strainer and cleaning it if necessary.
- Inspect water flow rate, operating pressure and antifreeze concentration

Additionally, facility managers:

- may consider replacing the belts on hydraulic pump, check burner, ignitor, flue gas passage and flame sensors and the generator every 12,000 hours.
- are recommended to replace the condenser, hydraulic pump, combustion blower, pump motor pulley, spark ignition module and pressure switch around 50,000 hours.

Note that above maintenance recommendations are provided for planning purposes only. Equipment-specific guidance must always be followed.

Equipment Availability and Project Support Services

In BC, JSA Sales is the manufacturer's representative for Robur. Homy Building Solutions, based in Toronto, ON, represents Vicot in North America. Canadian Aqualine based in Delta, BC. is the manufacturer's representative for Anesi Gas Heat Pumps (formerly known as SMTI).

Figure 22: A GAHP unit installed in Ontario.

While established manufacturers offer equipment warranties, technical support teams are locally available with their representatives. Engineering consultants registered with EGBC can provide engineering design for GAHP projects.

FortisBC's GAHP Rebate Program

In June 2022, FortisBC became the first utility in Canada to introduce GAHP prescriptive rebates for its commercial customers. The rebate program has been offered to commercial, MURBs and institutional buildings, from office buildings, hotels and schools to hospitals, recreation centers and care homes, to name a few.

Through an extensive pilot program, the utility gained deep insights into this promising technology that can be immediately deployed in the market to reduce GHG emissions. These pilot projects helped validate the performance of GAHP technology and gave a clear picture of the incremental costs, need for engineering evaluations, configuration specific control setups, installation requirements and overall market readiness.

FortisBC's rebate program also offers support for customers with the cost of conducting a detailed engineering feasibility study for their facilities. The study can help customers verify whether the installation of GAHP unit(s) will help achieve energy savings before committing to a project.

While GAHPs are available to recover heat from air, ground, or water, the rebate program is currently limited to air-source GAHP units. Through FortisBC's efforts in capacity building activities over the years, a number of consultants, contractors and facility owners have learnt about GAHP technology and installed dozens of GAHPs across the province.

For specific information about the FortisBC's GAHP prescriptive rebate offer, please contact FortisBC at businessrebates@fortisbc.com or visit the webpage at:
www.fortisbc.com/rebates/business/gas-absorption-heat-pump-rebates

Conclusion

Gas absorption heat pumps offer a highly effective and energy-efficient solution for space and water heating in buildings.

FortisBC's pilot initiatives and early adopter programs have validated the operational performance of commercial GAHP systems. These efforts have also provided valuable insights into customer experience and market readiness. FortisBC's introduction of the GAHP prescriptive rebate offer further underscores the utility's commitment to advancing GAHP adoption in the province. Some of the key considerations for facilities considering GAHP technology include the following:

- **Energy Efficiency and Operational Savings:** Verified projects in BC show that GAHPs consistently achieve high heating efficiencies (COP > 1), resulting in lower natural gas consumption and reduced utility costs compared to traditional boiler systems. GAHPs require minimal maintenance and achieve competitive payback periods when available rebates are considered.
- **Resilience and Flexibility:** GAHPs are well-suited for facilities with limited electrical capacity, enabling upgrades without major electrical infrastructure changes. Their compatibility with renewable natural gas (RNG) and hydrogen blends supports future proofing against evolving energy standards. Integrating GAHPs with existing mechanical systems adds flexibility by reducing operating hours on older equipment and extending service life.
- **Design and Integration Best Practices:** Successful GAHP projects highlight the importance of right-sizing equipment, advanced controls, and thoughtful system-wide design. Proper sizing should account for changing heating and cooling loads, such as those resulting from envelope upgrades. Effective control sequencing and integration with existing systems are essential to maximize performance and avoid common issues like short cycling.

This Best Practices Guide positions GAHP technology as a practical and one of the possible solutions for organizations seeking to transition to high-efficiency resilient energy systems. By applying the lessons captured in this document and leveraging the available market support through manufacturers, energy consultants and contractors who have commissioned GAHPs in BC, facility owners can confidently adopt GAHPs to achieve their operational goals and future-proof their facilities.

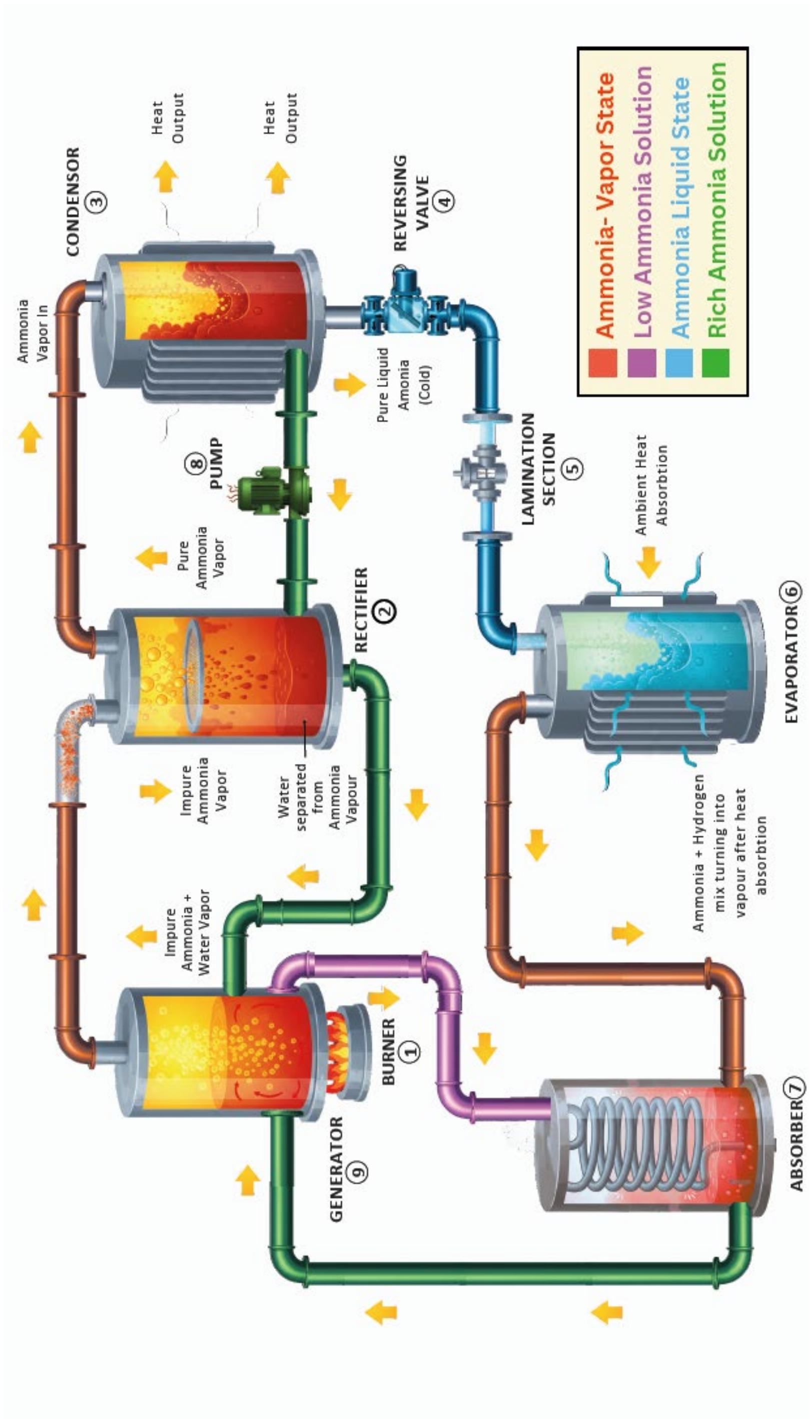
This Best Practices Guide is a comprehensive resource for individuals and organizations interested in gas absorption technology. It covers fundamental principles, required equipment and materials, best practices for implementation, and common challenges encountered during adoption.

Appendix A: Glossary

AHU	Air Handling Unit
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BTU	British Thermal Units
COP	Coefficient of Performance
C&EM	Conservation and Energy Management (a department at FortisBC)
DHW	Domestic Hot Water
EGBC	Engineers and Geoscientists of British Columbia
EHP	Electric Heat Pump
GAHP	Gas Absorption Heat Pump
GHG	Greenhouse Gas
GJ	Gigajoule
GUE	Gas Utilization Efficiency
HVAC	Heating, Ventilation, and Air Conditioning
IPMVP	International Performance Measurement and Verification Protocol
kW	Kilowatt
LNG	Liquified Natural Gas
M&V	Measurement and Verification
MURB	Multi-Unit Residential Building
NRCan	Natural Resources Canada
PST	Provincial Sales Tax
RNG	Renewable Natural Gas
tCO_2e	Tonnes of Carbon Dioxide equivalent
TRM	Technical Reference Manual

Appendix B: Detailed Schematic Demonstrating GAHP Heating Process.

This schematic of the absorption cycle inside a GAHP unit was developed based on process descriptions by Robur corporation.



Appendix C: GAHP Case Studies

Case Study 1: GAHPs provide heating and cooling at a long-term care facility, preserving electric capacity for critical medical equipment.

Project Overview

Two long-term care facilities in the BC's lower mainland were successfully retrofitted with four gas absorption heat pumps (GAHPs). Two units were installed per building to support each building's ventilation system. This innovative solution addressed a critical infrastructure limitation of low spare electrical capacity. In the past electric capacity limitation had forced these facilities to turn away patients during the summer. The electric panels were overloaded because of the portable air conditioning units.

The Challenge

a) **Increasing Cooling Demand:** The facility's cooling loads were increasing. During recent summer seasons, the buildings relied on portable air conditioners, which impacted the energy availability for critical medical equipment.

b) **Heating Efficiency Goals:** The facility sought an approach that would not only enhance heating efficiency and reduce year-round operating costs but also provide cooling.

c) **Limited Electrical Capacity:** The buildings were operating at full electrical capacity, meaning traditional electrically driven cooling solutions were not viable without a major service upgrade.

Engineering Solution - GAHP

The facility engaged consultant (BES) to assess the facility and design a solution for the challenges. The consultant proposed using GAHPs, as a solution that did not require additional electrical power and aligned well with the facilities' infrastructure constraints. Two GAHPs were installed per makeup air unit in each building to handle the full heating and cooling load.

System Design & Installation

New Hydronic Hot Water Coils: Consultant designed and retrofitted a custom hot water coil into the main makeup air unit of each building. Each coil was engineered to match around 10,000 CFM airflow per unit and GAHP specific flow rates, pressures, and temperatures.

Buffer Tanks were not needed: Due to high and constant airflow and 100% outdoor air handling, buffer tanks were unnecessary, which reduced the complexity and capital costs.

Freeze protection: Glycol was added to the hot water loops to prevent freezing in winter conditions.

Project Outcome

After one year in operation:

- Supplementary cooling demand was fully met: Supplementary cooling was handled entirely by the GAHPs. (first stage cooling was achieved through original AC units)
- Heating efficiency surpassed expectations, with average equipment performance above a COP of 1.3 during heating mode.
- Existing boilers remained off when outdoor temperatures were above 10°C.

Project Performance

Even though GAHPs are not the most efficient cooling technology, the increased natural gas use for cooling in summer was offset by significant gas savings in winter heating operations. Following are measured and verified results after one year of project completion:

- Annual Energy Savings: 468 GJ
- Annual GHG Reduction: 23.2 tonnes CO_2e
- Estimated Annual Cost Savings: $5,304

- Total Installed Cost[38]: ~$250,000 (including GAHPs, coils, piping, electrical, cranage, structural)
- Net Cost to Client after FortisBC's GAHP Project Rebate: ~$62,500

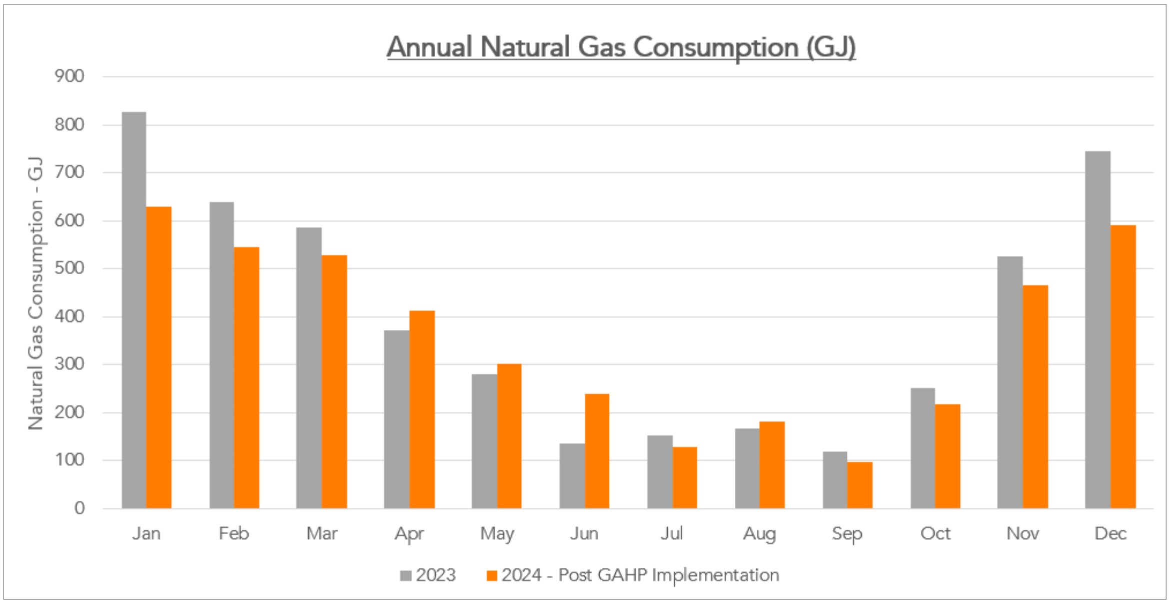


Figure 23: Comparison of Natural Gas Consumption Pre and Post GAHP Implementation

Conclusion

This project showcases how a customized GAHP solution can resolve the HVAC demand challenges in infrastructure-limited buildings. The facility received a cost-effective alternative solution to dealing with increasing heating and cooling loads, while also benefitting from reduction in operating costs. The project preserves the existing electrical capacity for the facility's core mission of delivering long-term healthcare.

[38] In comparison, the facility was quoted more than $250,000 for electrical upgrades, in addition to the cost of equipment and installation.

Case Study 2: GAHPs at a higher education center provide space heating, domestic hot water and space cooling.

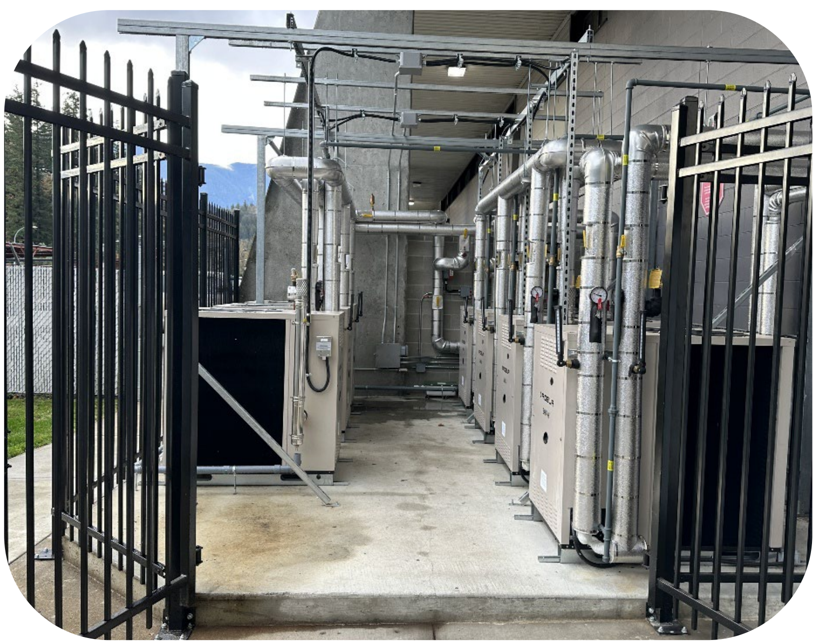
Project Overview

An educational facility was successful retrofitted in the Fraser Valley with seven GAHPs to support its hydronic heating, domestic hot water and supplementary cooling requirements. This innovative solution addressed the facility's aspirations and mandate to improve energy efficiency, reduce emissions, and enhance the overall system performance.

Project Challenges

a) **Complex system integration:** Special attention was required when connecting GAHPs to the existing non-condensing boilers and double-wall heat exchangers for DHW. Controls for all units had to be configured with existing build management systems.

b) **Location challenges:** Air intake management required special attention due to building overhangs. As the GAHPs were located right next to public walkways and roads, the equipment needed protection for safety and security risk mitigation. The project also involved dealing with hazardous materials.



c) **Permitting requirements:** Early engagement with the Technical Safety BC (TSBC) was essential, as GAHP systems were still relatively new in Canada. The project experienced slight delays due to technical documentation from the manufacturer that was originally carried written for European applications.

Engineering Solution – GAHP

In line with the facility's goals and the project constraints, the project consultant (BES) designed a solution involving seven GAHPs that were installed with three distinct functions:

- Hot water system integration for hydronic heating
- Domestic hot water (DHW) preheating
- Supplementary cooling (one GAHP dedicated)

The equipment proximity to public walkways and roads was mitigated with fencing and careful equipment placement.

System Design & Construction Approach

The project involved following considerations to balance the system performance and project costs:

- **Valve strategy:** Instead of six individual two-way back-end valves (that are expensive), two three-way valves were installed, each managing three GAHPs. This minimized standing losses and met the building's minimum BTU demand.
- **Buffer tanks:** Two buffer tanks were added in the mechanical room, one for heating integration and one for cooling integration. The tanks were sized at roughly 30 gallons per GAHP minus the system volume.
- **DDC controllers:** Two Robur DDC controllers were installed, one for heating and one for cooling. This allowed simultaneous sequencing for DHW and supplementary cooling.
- **Condensate management:** Although Robur GAHPs are non-condensing, minor acidic condensate can form in the outdoor stainless flue. An acid neutralizer with uninsulated drain lines was used, upsized, and routed close to the building to mitigate freezing.

Lessons Learned

- **Right sizing and system redundancy is key:** The facility's existing boiler system experienced a failure during the heating season. GAHPs took over the load without disruptions, demonstrating the value of backup and right-sizing.
- **Improved baseline equipment life:** Reduced runtime for existing cast iron boilers has extended the operating life of the aging heating equipment.
- **Cost Savings:** The efficiency gains have lowered the operating utility costs.

Project Performance

The project performance was continuously monitored through the heating and cooling seasons, with detailed data logging in line with IPMVP's Option-B methodology. The overall results were as follows:

- Energy savings for DHW: **34%**
- Energy savings for heating: **11%**
- DHW COP: **1.18**
- Heating COP: **1.07**
- Combined system COP: **1.1**

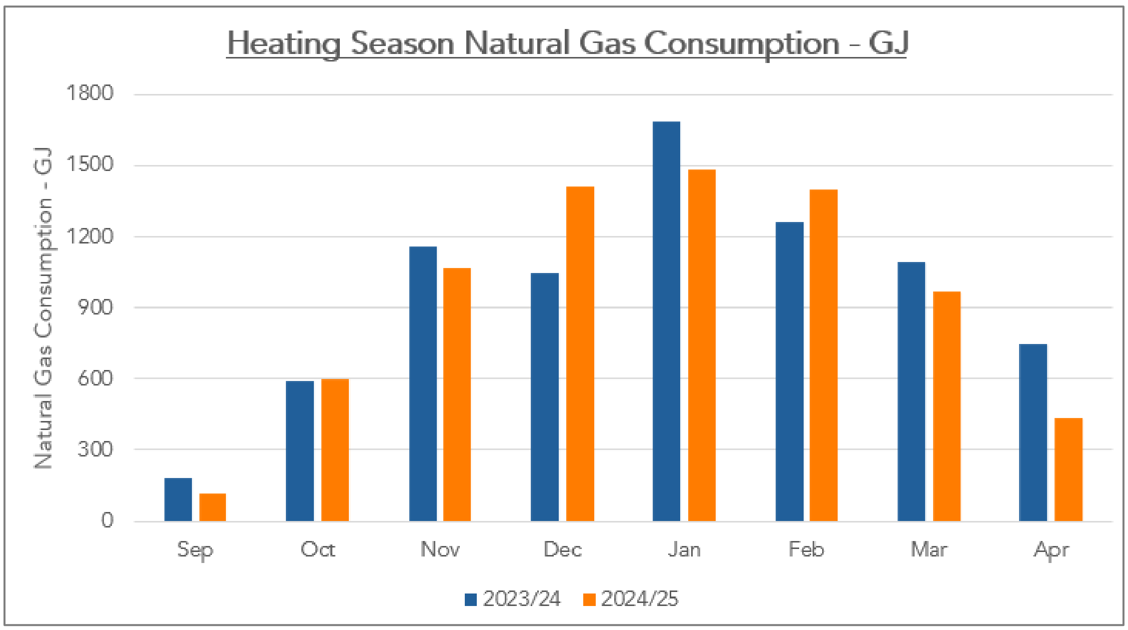


Figure 24: Natural Gas consumption comparison during heating season.

Conclusion

This retrofit demonstrates how GAHPs can be integrated with multiple existing HVAC and hot water systems at the same time. By leveraging GAHP technology, the facility is set up to record long-term performance improvements, add resilience to existing systems, reduce operational carbon footprint, and add service life to existing equipment. With support from FortisBC and the facility's leadership, this project is also set up to serve as a learning hub for students, engineers, and industry professionals exploring this technology.

Case Study 3: GAHP Technology Enhances Comfort and Energy Efficiency at an Animal Shelter.

Project Overview

An animal shelter facility in the BC's Okanagan region installed a GAHP unit to improve the space comfort for its occupants. In addition to providing animal care, the facility also houses an office where staff members perform general administration, and operation support duties.

The Challenge

a) Increased cooling demand: The region has been experiencing rising summer temperatures that put a constraint on facility's aging air-conditioning equipment. During a recent summer, the facility had to relocate all animals to a different location because the facility was difficult to keep cold under high outdoor temperatures.

b) Aging HVAC equipment: The facility had an air handling unit and a central air conditioner to meet its space heating and cooling needs. Both units were nearing the useful operating hours and require frequent maintenance calls. The facility often had to rely on portable electric heaters to keep the animals warm during extreme cold weather.

c) Difficult to maintain building envelop tightness: The facility did not have a high-end building envelope and incurred significant leakage of conditioned air due to frequent staff and animal movement in and out. In this situation, the old equipment had to work harder to maintain the heating and cooling needs.

d) Limited electrical capacity: The facility's existing electrical capacity was nearly fully utilized. The addition of electric space heating and cooling equipment would require a service upgrade.

Engineering Solution – GAHP

The facility engaged a consultant to conduct a FortisBC funded GAHP feasibility study and initial design. The project involved installing one air-to-water GAHP (Robur-AR) type unit that provides additional 120 MBH heat and nearly 4 tons of supplemental cooling capacity to the facility's existing HVAC systems.

The GAHP unit was integrated with the existing air handling unit through minor modifications. The unit generates hot and chilled water that is circulated through a coil located in the facility's existing ductwork. For operational safety, the GAHP circuit is also supported by a glycol anti-freeze system to prevent refrigerant freezing during the winter.

The project was funded through FortisBC's GAHP rebate of $110,000.

Project Outcome

After two years in operation, the facility has experienced several benefits through this project; including:

- Improved air quality, discontinuation of swamp cooler operation, no need for portable heaters or coolers to manage peak weather conditions.
- The added heating and cooling capacity has helped to reduce the run hours on the aging HVAC equipment and lower the maintenance costs.
- The added cooling capacity of 4 tons helped avoid any electric panel upgrade costs needed for new air conditioners or electric heat pumps and the need to shift animals to an alternate site in extremely hot conditions.
- Overall, the facility experienced a reduction in its natural gas consumption in winter and an increase in summer due to supplemental cooling. On annual basis, the increased natural gas usage in summer was offset by the savings in winter.
- The winter electricity usage slightly increased due to the additional power requirements for a glycol pump and GAHP auxiliaries. In summer, the electricity usage was calculated to be significantly lower than the potential electricity required to operate a heat pump or an air conditioner of similar capacity.

Project Performance[39]

- Natural gas savings for heating season: 13%
- Annual Nat. gas savings for heating and cooling: 3%
- Annual Electricity savings for heating and cooling: 5%[40]

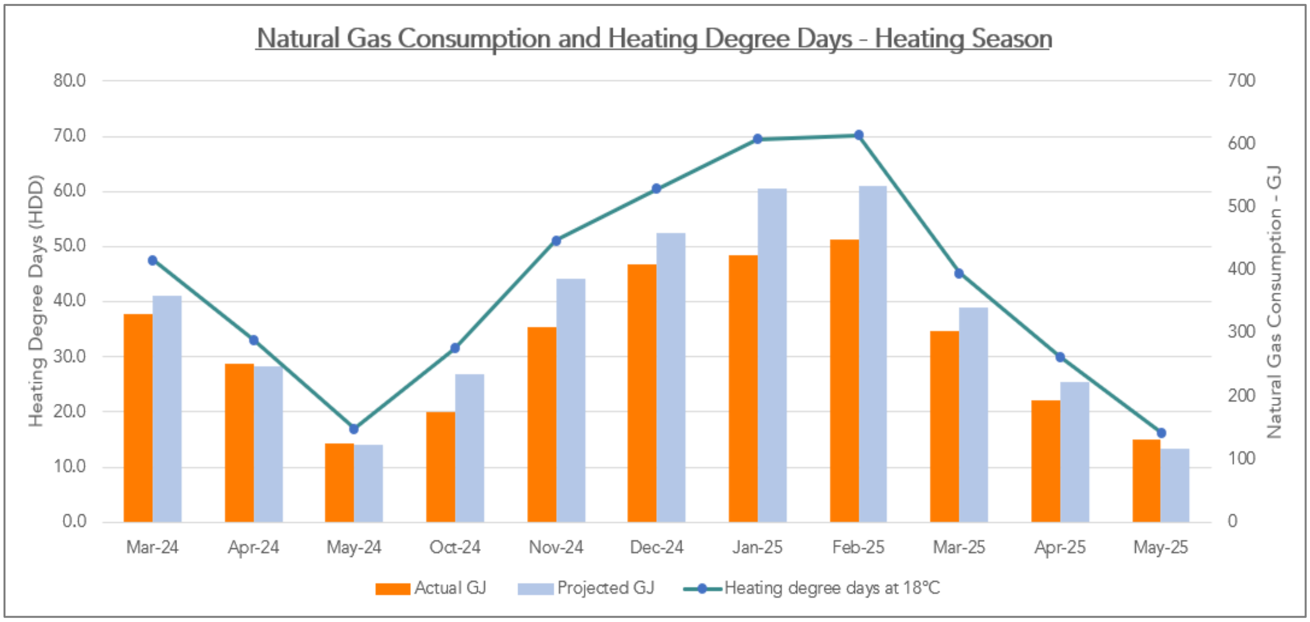


Figure 25: Comparison of Natural Gas Consumption and Heating Degree Days

Lessons Learned

- This project demonstrated how a single GAHP unit can be integrated into the existing HVAC systems of a small building with minimum modifications.
- While the energy savings are modest, the project proponents must also consider the non-energy benefits while making a business case. In this project, the facility owner appreciated the improved air quality, reduced maintenance costs, better occupant comfort, and not requiring an electric service upgrade.

[39] Savings for this project were calculated with IPMVP's Option C methodology.
[40] Electricity savings calculation assumes addition of a new 4-ton electric heat pump with an average cooling COP of 4.

Appendix D: Lessons Learned from GAHP Installations during FortisBC's Deep Energy Retrofit Project[41]

This appendix includes high-level minutes of the discussion that was held to share lessons learned from FortisBC's Deep Energy Retrofit Projects. This information is added here to provide insights gathered through experience of installing GAHPs in conjunction with other retrofits such as high efficiency boilers, gas engine driven heat pumps, electric heat pumps, energy recovery ventilators and building envelop upgrades to achieve deep energy retrofits.

[41] Additional information about FortisBC's deep energy retrofit pilot can be found here https://www.fortisbc.com/rebates-and-energy-savings/test-new-technologies-and-get-incentives/deep-energy-retrofit-pilot

REF#: 25-B413 reva

Meeting Minutes: Gas Absorption Heat Pump Workshop for Deep Energy Retrofits

Date: October 1st 2025
Facilitator: FortisBC
Presenter: BES – Steven Arnold

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1. Purpose

FortisBC recently completed four (4) deep energy retrofit projects aimed at significantly reducing greenhouse gas (GHG) emissions in existing multi-unit residential buildings (MURBs). A key component of these retrofit initiatives involved integrating Gas Absorption Heat Pumps (GAHPs) into the buildings' existing domestic hot water and heating systems to enhance overall energy efficiency and lower carbon intensity.

To support continuous improvement of this technology deployment, FortisBC convened a meeting with project stakeholders—including engineers, contractors, manufacturers, and project managers—who were directly involved in the design, installation, and commissioning of the GAHP systems. The purpose of this meeting was to collect feedback, document lessons learned, and identify opportunities for optimization based on real-world project experience.

Insights gathered in this session will be used to update and refine the **Gas Absorption Heat Pump Best Practices Guide**, ensuring it reflects current field knowledge and supports improved planning, installation, and performance outcomes for future GAHP retrofit projects across British Columbia.

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2. Key Discussion Points

a. Overview and Objectives

- Attendee's were introduced the workshop's focus: capturing experiences from design, implementation, and commissioning of GAHP systems.
- Emphasis to feedback from projects was requested (e.g., Forte, Manor House, Pendrellis and Viscount Villa) to improve future project execution and the Best Practices Guide.
- BES stressed the workshop would be conducted with interaction, non-judgemental discussion with the goal for honest feedback for the GAHP best practise guide.

- The presentation provided by BES was split into four categories to generate discussion and debate:
  - Design
  - Implementation
  - Commissioning
  - Integration into other systems

b. Participant Introductions

- Roundtable introductions from ~15 participants, including:
  - FortisBC program managers, engineers, contractors, CLEAResult representatives, BES engineers, and mechanical consultants.
  - Participants represented roles in design, M&V, installation, program management, and pilot operations.

c. Metering and Instrumentation

- Lessons learned included issues with BTU and flow meter specifications and the importance of correct sampling rates.
- Specification clarity needed for **sampling rates** (e.g., 30-sec sampling vs 15-min intervals). Peak flows or summarization over longer periods leads to inaccuracy in reporting COP/Efficiency/energy consumed or delivered.
- Contractor scope should include **instrument supplier verification** to prevent mis-installation.
  - **Common issues:** turbulent flow, incorrect meter orientation, tight spaces, glycol concentration mismatches.
- Importance of involving manufacturer reps during commissioning to ensure meter reading accuracy.
- Recommend **integrated design approach** involving M&V, design, and construction teams early.
  - Suggest establishing a **commissioning authority** for quality assurance.
  - 3D modeling of mechanical rooms could mitigate space and installation conflicts

d. Control System Challenges

- GAHP short cycling observed on multiple projects (Pendrellis, Forte, Viscount Villa).
- Emphasis on proper **load modeling**, **staging strategy**, and **collaboration with manufacturers**.
- Recognition that deep energy retrofits are **pushing boundaries** in system integration and performance optimization.

- Reported control issues with **Robur** systems — poor staging and cycling behavior causing comfort and performance issues. – refer to section 3 (Key Takeaway's)
- Discussion highlighted the need for **reliable control strategies**, avoidance of short cycling, and improved staging for efficiency.

e. Equipment Integration

- Recognition that deep energy retrofits are **pushing boundaries** in system integration and performance optimization can lead to integration challenges:
- Gas absorption systems often require **supplemental boilers** for domestic hot water (>60°C).
    - New units in development may meet higher temperature requirements.
- **Control sequencing and fine-tuning** identified as a critical gap.
    - Gas absorption Heat Pumps have a maximum output of 60°C -in reviewing of BMS sequencing, this has not always been factored into account, which results in excessive run time and energy consumption.
- Suggestion: include a **dedicated commissioning/fine-tuning phase** post-installation (e.g., 12-month period). This is typical on heat recovery heat pump systems where changing climate temperatures effect equipment performance
-
- Challenges with limited BACnet control interface.
- Suggested documenting control requirements in future designs.
- It was noted that **buffer storage** design is key to aiding stable operation; reducing short cycling tied to load reductions and envelope upgrades.
- SES proposed gas/electric **swing tanks for domestic hot water** as a cost-effective alternative to backup boilers.
- BES supported exploring **smaller, integrated gas/electric systems**, especially for retrofits in older buildings where mechanical space is limited.

f. Preventive Maintenance for GAHPs

- It was noted that preventive maintenance for GAHP units should be added to existing building maintenance contracts or integrated into in-house maintenance programs shortly after commissioning.
- Participants observed that some contractors may provide high maintenance quotes due to limited familiarity with GAHP technology.
- The group recommended that project proponents communicate the relative simplicity of GAHP design and construction to help ensure more accurate and reasonable maintenance pricing.

g. Building Integration

- Throughout the workshop, it was emphasized that building envelope improvements—particularly window replacements, Thermal insulation (cladding), air-sealing and envelope tightening—can significantly reduce heating loads.
    - Designers should consider these reduced loads when determining the number and capacity of GAHP units required, as oversizing can lead to operational issues such as short-cycling and reduced system efficiency.
- It was also noted a key challenge unique to older buildings: while tightening the envelope effectively decreases heating demand, it can inadvertently increase cooling loads during the summer months. Many legacy MURBs do not have mechanical cooling, and adding in-suite cooling solutions can be difficult due to cost constraints and limitations on existing electrical infrastructure.
- Designers should therefore address these potential cooling impacts early in the design phase and evaluate system options that can effectively support both heating and cooling without placing excessive burden on residents or building systems.
- When sizing equipment, it is important to design for the lowest anticipated heating loads while recognizing that the overall system efficiency will vary depending on how well the new GAHPs can modulate relative to existing baseline equipment. Older systems—such as cast-iron boilers with limited modulation capability—may require careful integration with newer high-modulation boilers serving as peaking units to maintain optimal performance across the full operating range.

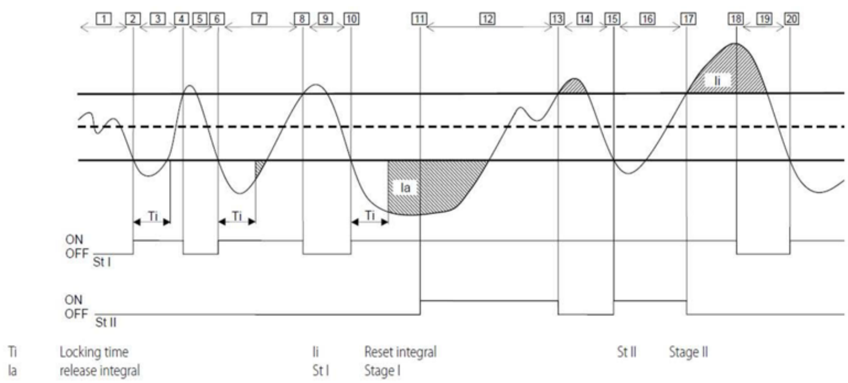
h. Reporting Clarification

A brief discussion was held regarding consistency in reporting. Mazzi Consulting clarified:

- GUE = thermal output / natural gas input
- COP = thermal output / (natural gas input + electricity input)
- always report using natural gas HHV (not LHV)
- use the same definition whether reporting short term performance (e.g. a 4 hour test) or long-term (e.g. seasonal)

3. Key Takeaways

- GAHPs require control strategies distinct from conventional boilers. The diagram below forms Robur GAHP-A operation, installation and commissioning manual. (other GAHP manufacturers may have differing diagrams)



GAHP PID diagram. Note:

- Integral setting can be different for above set point (reset integral, Ii) and for below set point (release integral, Ia).
- Dashed line is set point
- Band is +/- 1˚C

The above PID (proportional, integral, derivative) diagram represents the Robur DDC controller that controls multiple GAHPs serving the same system.

Default settings on the Robur DDC controller are provided below:

Table 4.2 *Default values for heating service control parameters (category 1)*

Parameter	Category 1 default	Recommended setting
"Unit Power"	35 kW	Not editable
"Turn On Priority"	6	Not editable
"Locking Time"	5 minutes	Use default values
"Min. Run Time"	7 minutes	Use default values
"Stages Number"	10	Use the maximum value allowed by the number of units
"Release Integr"	6 °C * minutes	Use the semi-automatic configuration (Paragraph 4.4.2.7.5 *p. 62*), which calculates the value of these parameters based on the other data set for all categories; the calculation is performed when you exit the configuration screen
"Reset Integral"	8 °C * minutes	

Based on multiple GAHP unit being installed on a single site, and in conjunction with Robur; a review, including modifications may be necessary to the PID controller (Robur DDC Controller) so that the controlled variable for the GAHPs is the inlet (return) temperature and not the outlet (supply) temperature. This is currently being reviewed on the Pendrellis building.

- Communication and feedback loops between engineers, contractors, and program managers are essential.
- Integration of metering, control, and equipment design must be better coordinated to enhance reliability, accuracy and client satisfaction.

End of Document