CITY OF VANCOUVER | GREENEST CITY

Phased Heat Pump retrofit as part of City's long term capital planning to achieve zero emissions in all buildings

Vancouver has the goal to derive 100% of its energy from renewable sources by mid-century. As part of this strategy, the City of Vancouver is committed to show leadership and green its own operations and facilities. Accordingly, the City plans to achieve 100% renewable energy and zero emissions in its own facilities by 2040.

Address	453 West 12th, Vancouver
Ownership	City of Vancouver self-managed
Type of building	Institutional
Year of construction	1936
Number of floors	12
Height	323 ft (98 m)
Floor area	152,000 sq ft

CASE STUDY - VANCOUVER

VANCOUVER CITY HALL

RETROFIT MOTIVATIONS

The City plans to achieve 100% renewable energy and zero emissions in its own facilities by 2040. The chosen approach focuses on 3 pillars:

1. build new City-owned facilities to zero emission standards from 2018 onwards
2. upgrade existing facilities to make them more energy efficient and converting natural gas to high-efficiency electric heating
3. connect close-by civic facilities to low carbon Neighbourhood Renewable Energy systems

The City Hall campus is in need of development and expansion due to seismic safety issues and growing service requirements.

The East Wing demolition catalyzed the replacement of the old chiller and cooling tower system with an Air Source Heat Pump. Retrofit projects can sometimes take multiple years. This is also the case here since the City is working on a long-term plan to redevelop a large part of the City Hall grounds.

Aeriel view of the East Wing that was demolished.

PHASED RETROFIT OVERVIEW

Phase	Description	Purpose	Timeline
1	• Planning for East Wing demolition. • Choice of heating & cooling equipment. • Demolition East Wing & construction work. • Heat Pump installation & high-level commissioning. The Heat Pump currently heats the entire building but only in the shoulder season. It was turned off during the winter months.	• High risk of East Wing collapsing in an earthquake. • Existing chiller plant housed in East Wing had to be relocated and replaced. • Opportunity to convert to zero emissions equipment.	2014 – 2017 (completed)
2	• Finish commissioning and adjust temperature set points throughout 2018. • Modify the building piping system on the first four floors to redirect the lower temperature heat from the heat pump to existing low temperature fan coils.	• City Hall building has some high-temperature hydronic distribution equipment that the heat pump cannot supply in very cold weather. • Modify so that heat pump can provide space heating to the lower building part all winter. • Take advantage of full heat pump capacity & further reduce GHG emissions.	2018 – 2019 (planned and budgeted)
3	• Complement the heat pump heating and cooling system with a ventilation strategy customized for each building section. • Install Dedicated Outdoor Air Systems throughout the building. • Install additional heat pump supply and distribution systems in the upper portions of the building.	• By separating ventilation from heating and cooling, ventilation can be optimally controlled and energy use reduced. • Improve temperature and humidity control, enhance comfort. • Maximise energy & GHG emissions savings.	By 2030

PHASE 1 | PROJECT PROCESS

1. 2014-15

The larger East Wing demolition project necessitated building studies, as well as funds from the capital plan and approval from senior management and Council.

Two services, the heating and chilled water systems, were interconnected between the East Wing Annex and the main City Hall Building. The Annex housed a 270 ton chiller plant in the basement and cooling towers on the roof that provided chilled water to both building fan coils. The existing chiller plant was over 13 years old and near the end of its lifecycle and had to be either relocated or replaced in a new location.

2. 2015

Heating & Cooling system option evaluation:

- A helical rotary chiller with a fluid based cooling tower (a like-for-like replacement)
- An air cooled chiller
- An air cooled chiller with a desuperheater
- A heat recovery air source heat pump (ASHP)

3. 2016

The opportunity was identified to take advantage of equipment replacements and renovation for converting to zero emissions equipment. The ASHP option had the same incremental capital cost as adding a desuperheater. Rather than replacing the cooling system with a similar system that would provide cooling only, the decision was made to move to a more energy efficient solution.

4. 2016 – 2017

Demolition of the East Wing building was accomplished at the end of 2016. Construction of a new public plaza and City Hall mechanical room took place in 2017.

5. Fall 2017

Phase 1 of the phased retrofit project was finalized with the installation of the new ASHP equipment. The new heating & cooling ASHP system recycles the waste heat that is generated from cooling, or extracts the heat from the air directly, using it to heat the building and hot water instead of gas boilers.

PHASE 1 | PROJECT STAKEHOLDERS

The collaboration between multiple stakeholders during the consultation, design, and implementation of the first project phase was essential.

Role	Who	Description
Project Manager	City staff	Project oversight; hired and coordinated the consultants and general contractor.
Architect	DA Architects & Planners	Architectural design and co-ordination of other professionals.
Structural Consultant	RJC	Structural design and construction consulting services.
Mechanical Consultant	AME Group	Mechanical design and construction consulting services.
Mechanical Contractor	Alpha Mechanical	Mechanical construction.
General Contractor	Heatherbrae Builders	Project construction and co-ordination of sub trades.
Electrical Consultant	AES Electrical Engineering	Electrical design and construction consulting services.
Commissioning Agent	Western Mechanical Services	Commissioning of mechanical systems.
City Energy Manager	City staff	Set objectives for the project in terms of energy efficiency and GHG reductions; review design to ensure that objectives and budget are met; identify financial sources to cover the incremental cost of the ASHP.
City Facility Mechanical Supervisor	City staff	Design review and commissioning assistance to ensure that systems are easy to maintain.

TECHNICAL DETAILS

The Air Source Heat Recovery unit was chosen for multiple reasons:

1. Thanks to its heat recovery, the high efficiency that the unit provides is even greater compared to a traditional HP. The Total Efficiency Ratio (TER) – the ratio between the total capacity produced simultaneously (heating and cooling) and the electrical power input to the unit – is a maximum of 6.3.

2. The NRP multipurpose unit offers flexibility: It satisfies simultaneously and independently requirements for cooling, heating, and domestic hot water (DHW). It is available in several models with different noise and temperature ratings.

3. The Italian equipment had been successfully implemented in other buildings in the Lower Mainland. The City's energy management team was keen to test the chosen model with a building that they have good control over before implementing it in other City-owned facilities.

Technology	Air Source Heat Pump (ASHP)
Make & Model	Aermec, Model NRP Air Source Heat Recovery Unit
Service provided	Medium temperature space heating & cooling; DHW preheat
Installation Date	October 2017
Refrigerant	Two R410A refrigerant circuits
Operating Limit: max. leaving water temperature	55°C
Operating Limit: external air temperature	-10°C to 42°C
Total Efficiency Ratio (TER)	6.3
Available models	4 pipe system (simultaneous demands for heating & cooling)
	2 pipe system (simultaneous cooling & DHW production)

SYSTEM DESIGN

The unit chosen for the Vancouver City Hall is the four pipe system for simultaneous heating and cooling. The equipment has four different operating modes: it pulls heat from the air or from the cooling loop and sends heat to either the space heating or DHW system; excess heat can be rejected to the air. A DHW preheat tank was installed as part of the retrofit to use waste heat for DHW preheating.

The limitation of the current system design is that the City Hall building has some high-temperature hydronic distribution equipment. During very cold weather, the supply water temperature delivered by the ASHP is too low for the building's high temperature hot water distribution system and gas boilers need to provide back-up heat. This means that the ASHP can currently only provide heating to the building during shoulder season, when temperatures are above freezing.

Aermec ASHP installed at City Hall

ANNUAL SAVINGS (PHASE 1 & 2)

45% GAS

34% GREENHOUSE GASES

PHASE 1 | PROJECT IMPLEMENTATION & INSTALLATION CONSIDERATIONS

Integrating the ASHP with the rest of the building's older mechanical systems was a challenge and careful commissioning was crucial. The commissioning consultant, with the assistance of City facility operations staff, was successful in right-sizing the pumps and commissioning the flow rates to match the design of the existing building. Having the right stakeholders work together effectively was paramount for successfully integrating the new energy efficient system with the existing building.

The ASHP commissioning started in late October 2017. This only allowed a few weeks of operation before the weather turned cold and the boilers had to be started. Commissioning will continue in the spring of 2018 and temperature set points will be adjusted throughout the year as the building systems are modified in the second phase of the project to use the ASHP for heating throughout all seasons.


ASHP installation outside City Hall

ECONOMIC ANALYSIS

Total Installation Costs	**$534,000**
Including additional costs for ASHP (vs. like-for-like replacement)	$138,000
Estimated Annual Savings (Phase I & II)	
$	$20,000*
Gas (GJ)	2,000
Electricity (kWh)	(110,000)
Phase 1 GHG (t CO_2e)	25
Phase 2 GHG (t CO_2e)	75
Phase 3 GHG (t CO_2e)	210
Estimated Annual Savings (Phase I & II)	
Gas (%)	45%
Electricity (%)	(-6%)
GHG (%)	34%

The tender price for the installation of an air cooled chiller, which would have constituted a regular like-for-like replacement, was $396K. An additional $138K was paid for the ASHP equipment and installation, adding DHW preheat, piping, and controls. The equipment's service life is expected to be 15 to 20 years. Maintenance and operating costs are insignificant because the manufacturer will perform important equipment maintenance during the first years. Other routine maintenance will be carried out by City staff.

The first and second phases of the project are estimated to reduce City Hall's annual natural gas consumption by 45% (2,000 GJ). Electricity use is expected to slightly increase by 6% (110,000 kWh).

Combined, this leads to annual energy cost savings of $20,000*. Important drivers of the project were the GHG emission reductions: they are expected to drop by 34% (75t CO_2e annually) after the second phase of the project with much higher reductions being achieved after the final project phase is completed.


Helen Gutteridge Plaza (former East Wing) in front of ASHP

*The City has been purchasing Renewable Natural Gas (RNG) for the City Hall building. Energy cost savings are based on RNG prices. GHG savings are based on natural gas since RNG purchases will be transferred to other City-owned buildings where they will displace natural gas.

NEXT PROJECT PHASES

The end goal of the project is for ASHPs to provide space heating and DHW preheat for the entire building all year long. Only then will the equipment's full GHG emissions reduction potential be reached. Accordingly, two more project phases are planned.

Phase 2: Modify the building piping systems to redirect the lower temperature heat from the ASHP to existing low temperature fan coils so that the equipment can provide heating throughout the winter. The lower four floors of the building will be targeted in this phase. The ASHP's capacity should be able to serve this area. The second phase is expected to be implemented in 2018 – 2019.

Phase 3: Complement the ASHP heating and cooling strategy with a ventilation strategy for the City Hall building, customized for each building section. The building was originally designed for cross-flow ventilation and operable windows but over the years interior walls were put up and spaces subdivided. A mismatch of ventilation and cooling systems were installed which now need to be redesigned.


Outside the new building that houses the ASHP.

The third phase will involve installing Dedicated Outdoor Air Systems (DOAS) throughout the entire building using high-efficiency heat recovery ventilators (HRVs), which will separate the ventilation from the heating system. New ASHP supply and distribution systems will be installed in the upper portions of the building that are not already served by the work completed in the second phase. Either additional ASHPs or variable refrigerant flow systems will be chosen. This phase will require the building to be vacated and for the staff to move to a different location. It will therefore likely only be completed by 2030 during implementation of the broader City Hall campus redevelopment. Final GHG emission reductions are expected to reach 91% (210t CO_2e annually).

USER EXPERIENCE & RECOMMENDATIONS

It is too early for the City's energy and maintenance departments to confirm the equipment's performance until phase II work is completed. The City of Vancouver is leading this project as a pilot for testing the technology before implementing it more widely.

Since the HP retrofit project was part of a larger City Hall demolition and construction project, the energy aspect was not a priority at the beginning. Once the City's energy management department became involved, the opportunity for energy and GHG savings was identified and it became an energy retrofit project.

> **"It is really important for organisations to make sustainability objectives a priority; otherwise you will never step out of the like-for-like replacement cycles. The more efficient option will usually involve higher capital costs and be more complicated to implement. But projects like this will pay off financially in the long run, and help the City achieve its aggressive GHG reduction targets."**
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> –Craig Edwards, City Energy Manager

APPLICABILITY

- Systems like the Aermec NRP multipurpose ASHP can be a good choice for applications that have simultaneous and independent requirements for heating and cooling. Many buildings in the commercial, hotel, and health care sectors have heating and cooling demands not directly linked with seasonal variations. This creates the need to provide simultaneous and independent chilled water for space cooling and dehumidification and hot water for space heating and/or for the production of DHW.

- ASHPs can be widely applied to different building types to provide space heating and cooling. At 10°C, the Total Efficiency Ratio (TER) of the Aermec NRP series is a maximum of 6.3. This means that 6.3 kilowatt hours (kWh) of heat and cooling are transferred for every kWh of electricity supplied to the heat pump. The TER decreases with temperature because it is more difficult to extract heat from cooler air. The local mild climate makes the Lower Mainland an ideal geographic area for ASHP application.

LIMITATIONS

This type of equipment has a number of limitations that need to be considered depending on site and building specificities:

- Sufficient outdoor space is required which can sometimes be difficult in retrofit applications. In particular, ASHPs require outside air to operate and should not be completely enclosed.
- The colder it gets outside the less efficient ASHPs get, declining rapidly from 1°C. ASHP technologies differ in minimum outdoor air temperatures at which they can operate, but generally fall in the range of -10°C to -20°C, so specific equipment selection is important. Depending on building envelope and HVAC equipment design, partial or full backup heating systems may be required for the coldest days of the year.
- Equipment and installation costs for ASHPs are higher than for natural gas boilers. Due to current low gas prices and comparably higher electricity prices, paybacks can be long, especially in comparison to gas-fired chillers or boilers. To mitigate this, heat pump retrofits should be planned when the existing heating equipment has reached the end of its lifetime and needs replacement, so that only incremental costs need to be taken into consideration.
- In buildings that do not have cooling systems prior to the retrofit, the introduction of summer cooling loads will reduce energy savings, but can be a highly desirable co-benefit for occupants – and in some cases could be the primary motivation for installing an ASHP.
- Although today's ASHPs are significantly quieter than previous generations, the noise generated by the fans can still be an issue and the placement of the heat pump therefore needs to be carefully considered.

FOR MORE INFORMATION, PLEASE CONTACT:

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