WHOLE HOME HEATING WITH AIR TO WATER HEAT PUMPS
FINAL REPORT

PREPARED FOR

City of Vancouver
Planning Urban Design & Sustainability
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INTRODUCTION

Heat pumps will play a significant role in helping the City of Vancouver achieve its goal of reducing greenhouse gas emissions and drawing 100% of its energy from renewable sources by 2025 for new buildings and 2050 for existing buildings.

For retrofits in existing houses, and installations in new construction and renovations, air to air heat pumps can scale up to meet the regulatory demand-side changes without significant adjustment to the current market. However this is only true for homes where forced-air is the heating and cooling delivery mechanism. Forced-air represents only a small number of new home systems.

Some existing homes utilize hydronic heating with radiant floors or radiators. New construction in Vancouver heated by radiant in-floor heating has been growing for the past twenty years and we see no change in this trend. It is in these larger homes with hydronic systems where major challenges exist within the regulatory environment of Vancouver's Renewable City Action Plan.

Air to water heat pumps currently don't have the same market structure enjoyed by their air to air counterparts. Some of the issues are:

- A modest number of installed systems exist to serve as examples.
- Trades need to be trained and qualified to install these systems.
- Lack of awareness of air to water heat pumps throughout the industry including design professionals, builders, trades, and homeowners.
- Capital cost when compared to alternative natural gas boilers.

GLOSSARY OF TERMS

AIR TO AIR HEAT PUMP (ATA HP): A Heat Pump that transfers heat from outside air to inside air. Reverses for cooling in the summer.

AIR TO WATER HEAT PUMP (ATW HP): A Heat Pump that transfers heat from outside air to inside water. Reverses for cooling in the summer.

COEFFICIENT OF PERFORMANCE (COP): The COP is the energy output of the heat pump divided by the amount of electricity needed to run the unit. The higher the COP, the more efficient the heat pump.

HEAT PUMP (HP): A device that transfers heat energy from a heat source (air, ground, water) to a destination. For example, in winter it will transfer heat from outside air, a pond, or from the ground, to inside the house – then reverse the process in the summer.

GROUND SOURCE (GEOTHERMAL) HEAT PUMP (GS HP): A Heat Pump that transfers heat from vertical or horizontal piping in the ground, or a body of water, to inside air, water or both. Reverses for cooling in the summer.

REVERSIBLE: A Heat Pump capable of reversing its refrigerant cycle to provide heating in the winter and cooling in the summer.

AIR TO WATER SYSTEMS

Air to water heat pump products span a variety of system types, but essentially operate on the same premise of capturing heat and moving it through a refrigerant cycle from one space to another.

Source: www.easyairconditioning.com

In the winter, heat is extracted from the ambient air outside and transferred to water inside.

With some products, the cycle is reversed and heat is extracted from inside the home and transferred through the refrigerant to be discharged to outside.

Similar to air to air they are most often split systems. Unlike air to air, they can provide heat for radiant in-floor, hydronic radiators, hydronic fan coils for heating and cooling and in some cases domestic hot water.

AIR TO WATER PRODUCTS

Available to the British Columbia market, and specifically Vancouver:

Aermec — ANK

- Reversible split system.
- Manufactured in Italy with global distribution including BC.
- Available in 3 capacity sizes from 37,670 BTU/h to 57,598 BTU/h (nominal).
- Provides a variety of compatible fan coil units.
- At Vancouver winter design conditions can deliver up to 27,340 BTU/h at an efficiency of 1.97 C.O.P.
- Will provide Domestic Hot Water without auxiliary boiler.

Ecologix — A2W Series

- Reversible split system.
- Manufactured in Ontario with distribution from Ontario.
- Available in 2 capacity sizes from 58,000 - 68,000 BTU/h (nominal).
- Currently revising their 3rd party controls to provide in-house controls by 1st quarter 2019.
- At Vancouver winter design conditions can deliver up to 32,000 BTU/h at an efficiency of 2.0 C.O.P.
- Will provide Domestic Hot Water preheat only, auxiliary boiler required.

ForestAir — Versati II

- Reversible split system.
- Manufactured in China by Gree, one of the world's largest manufacturer's of HVAC equipment, with global distribution including BC.
- Available in 1 capacity size 52,888 BTU/h (nominal).
- At Vancouver winter design conditions can deliver up to 24,874 BTU/h at an efficiency of 1.67 C.O.P.
- Will provide Domestic Hot Water preheat only, auxiliary boiler required.

Nordic — ATW Series & ATF Series

- Reversible split system. ATF Series is a combo air to water/air to air unit.
- Manufactured in New Brunswick with global distribution including BC.
- Available in 4 capacity sizes from 33,600 - 58,600 BTU/h (nominal).
- At Vancouver winter design conditions can deliver up to 38,400 BTU/h at an efficiency of 2.3 C.O.P.
- Will provide Domestic Hot Water preheat only, auxiliary boiler required.

Noraire

- Indoor unit only. Outdoor unit installers choice of brand.
- Manufactured in Minnesota with distribution through plumbing wholesalers in BC.
- Available in 3 capacity sizes from 33,000 - 55,000 BTU/h (nominal).
- At Vancouver winter design conditions can deliver up to 33,000 BTU/h at an efficiency dependent on choice of outdoor unit.
- Will provide Domestic Hot Water preheat only, auxiliary electric boost internal.

electromn.com

Sanden — SAANCO2

- Non-Reversible split system.
- Manufactured in Japan with global distribution including BC.
- Primarily Domestic Hot Water but can be used for space heating with limited capacity in very high performance homes (e.g. Passive House).
- Sanden is developing a larger capacity heat pump better suited for space heating sometime in 2019.
- Uniquely utilizes CO2 as refrigerant.
- Single heat pump capacity of 15,400 BTU/h.
- At Vancouver winter design conditions can deliver up to 15,400 BTU/h at an efficiency of 2.75 C.O.P.
- Will provide Domestic Hot Water.

SpacePAK — Solstice Series

- Reversible split system.
- Manufactured in North Carolina with distribution in BC.
- Available in 2 capacity sizes from 36,840 - 52,200 BTU/h (nominal).
- At Vancouver winter design conditions can deliver up to 28,500 BTU/h at an efficiency of 1.59 C.O.P.
- Will provide Domestic Hot Water preheat only, auxiliary boiler required.

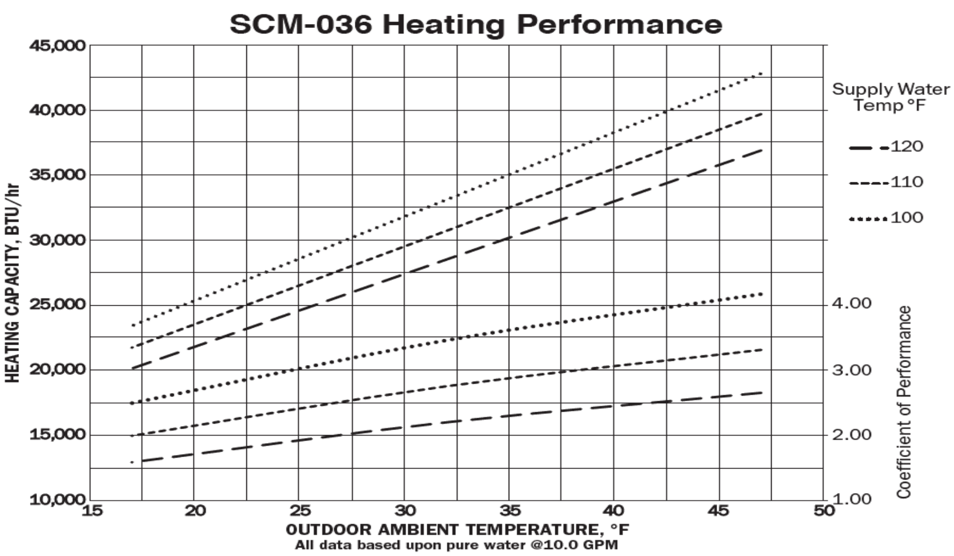
DESIGN CONSIDERATIONS

HEAT LOSS/GAIN CALCULATIONS

As with any heating or cooling design, it is critical and required by BC Building Code to perform proper room-by-room load calculations using CSA F280-12 compatible software.

CHOOSE EQUIPMENT BASED ON EFFECTIVE CAPACITY

Heat pump models are typically identified by their nominal capacity at 47°F. It is important to dig into the product technical literature to discover its rated capacity at design conditions.



TYPICAL PERFORMANCE CHART

Source: Spacepak Specifications & Ratings Document

ESTABLISH CLIENT EXPECTATIONS

The range in function, efficiency and costs of air to water heat pumps varies greatly. Therefore, it is imperative to explore with client the range of options to find the best fit, establish performance targets, and thereby manage their expectations.

A few of the points to discuss with the client are:

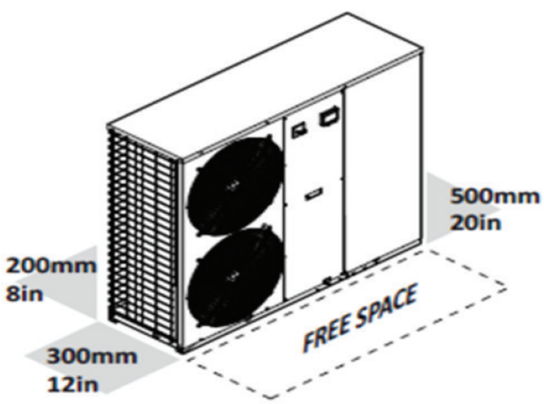
- If cooling is desired ensure a reversible heat pump is chosen.
- Provide clarity about the operating cost as many clients have unrealistic expectations of heating bill savings.
- Ensure the electrical panel will have enough capacity to incorporate the extra load, especially if an auxiliary boiler is required.
- Establish a suitable and acceptable location for the outdoor unit and how the lines will penetrate the building. Remember side yard placements may not be permitted in Vancouver (ask the city, especially on larger lots).
- Use equipment data to identify the sound decibel level.

ELECTRICAL LOAD

Heat pumps require large breakers to run the compressors. Where an electric back-up or auxiliary boiler is required, combined with the heat pump, the electrical panel may need as much as 100 amps to accommodate the load demand of the system. Ensure the electrical panel will have enough capacity to incorporate the extra load, especially if an auxiliary boiler is required.

OUTDOOR UNIT PLACEMENT

Heat pumps are not always permitted in side yards in Vancouver.



TYPICAL CLEARANCE C157:K158 IN INSTALLATION MANUAL
Source: Aermex Installation Manual

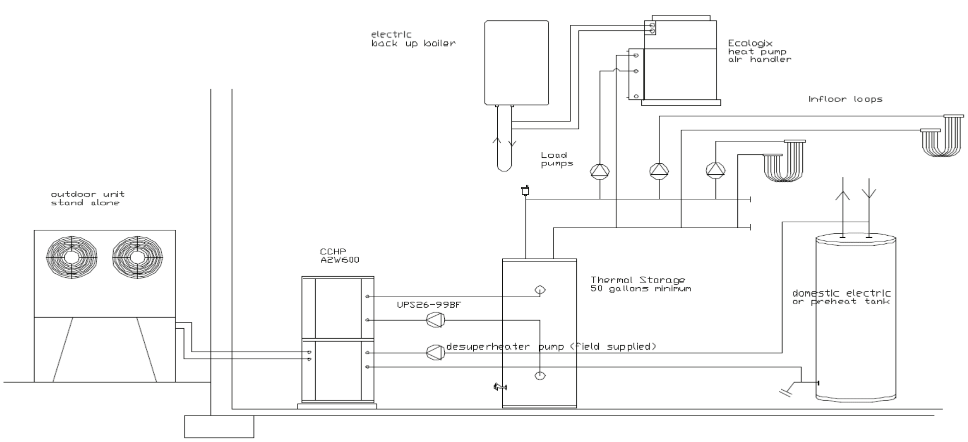
Some air to water heat pumps have refrigerant lines that run from the outdoor unit to inside, while others will have water lines instead. In either case it is important to review the product installation manual to determine maximum line lengths allowed, insulation requirements and other physical and thermal protections such as glycol.

In addition to compliance with manufacturers clearance requirements, it is also prudent to place the unit away from overhangs with potential for rain water or snow impact, and excessive needle accumulation from trees.

Sound ratings will sometimes be a factor in choice of equipment. Regardless of the rated sound level, it is always best to avoid placement directly under an opening window.

HYDRONIC PIPING

As previously stated, air to water heat pumps come in a variety of configurations, therefore it is essential to consult with the installation manual to verify any unique manufacturers requirements.



TYPICAL HYDRONIC SCHEMATIC INTEGRATING DOMESTIC WATER, RADIANT HEAT, AND FORCED-AIR HEATING/COOLING
Source: Ecologix Installation & Maintenance Manual

Whether it is a refrigerant circuit or a water circuit entering the building on the source side, load side distribution requires standard hydronic design practices to apply appropriate pipe sizing, pumping, motorized valves, and controls. Load calculations, pressure drops and flow will be customized for each application.

AUXILIARY HEAT

In Vancouver's climate, auxiliary heat is not required on all heat pumps if the load at design condition can be met. However, it is good practice to provide back-up heat in any case — if the budget allows. Obviously if the equipment cannot meet the required load of space and domestic water heating, a booster or auxiliary boiler becomes necessary.

Considering Vancouver's Renewable City Action Plan, we must assume the auxiliary boiler will be electric. It does not need to be sized to 'take over' the load, instead it would suffice to size the boiler as a booster or assist heating. For example, some heat pumps cannot bring domestic water to the required temperature and would instead act as a preheater with the boiler boosting the temperature the last 5°C or 10°C. Depending on the thermal performance of the home, this may only require a 3 - 5 kilowatt boiler.

Likewise, space heating can be supplemented by an auxiliary boiler. If the heat pump cannot meet the space heating load at design conditions, a boiler can assist the heat pump, or boost its heat output to make up the difference as a second stage. This by no means requires the boiler be sized to the total capacity requirement of the system.

Only if the intent is to provide 100% capacity as a back-up heating source in case of heat pump failure would the boiler be sized for the full load. This would not be typical and would likely require upsizing of the electrical panel.

START -UP & COMMISSIONING

All mechanical systems should be commissioned with professional diligence. Air to water heat pumps tend to be more complex and consequently have a unique set of start-up procedures. Each manufacturer will have their own check list.

Unit & System Checklist

Item	Description	Done
1	Ensure Voltage is within an acceptable range for the unit and wiring and fuses/breakers are properly sized. Check low voltage wiring is complete	☐
2	Ensure transformer has properly selected control voltage tap. 208-230V units are factory wired for 230V operation unless specified otherwise.	☐
3	Check internet connection at unit to confirm gateway communication is working. If all lights are not on, please contact Ecologix for help troubleshooting connection.	☐
4	Verify inlet and outlet water temperatures on **load** side heat exchanger are recorded for each heat pump upon startup. This check can eliminate nuisance trip outs and high velocity water flows that can erode heat exchangers.	☐
5	Test thermostat to ensure each call is functioning as expected. If multi-zone system, test each thermostat separately and with all zones calling.	☐
6	Water used in the system must be potable quality initially and clean of dirt, piping slag, and strong chemical cleaning agents. Verify all air is purged from the system. Air in the system can cause poor operation or system corrosion.	☐
7	Test indoor and outdoor unit sensors are functioning by reading sensors at controller display, comparing to hand held thermometer. Test defrost control is working by triggering defrost cycle in heating mode. (see **Defrost**, above)	☐
8	Check filters are in place for attached forced air systems	☐

Startup Record Sheet—ATW-Series Two-Stage R410a

Installation Site		Startup Date	Installer	
City			Company	
Province		Check boxes unless asked to record data. Circle data units.	Model	
Country			Serial #	
Homeowner Name		Homeowner Phone #		

PRE-START INSPECTION

Outdoor Unit	System is pressure tested, vacuumed and extra charge added		(extra charge only if needed)
	Access valves are open and caps securely fastened		
	Unit is securely mounted at least 12" from building		
	All inter-connect piping is insulated and properly supported		
	Wiring is neat and securely fastened		
	Fan outlet is clear of obstructions		
Indoor Loop (Hydronic)	All shut-off valves are open (full flow available)		
	Loop is full and purged of air		
	Antifreeze type		
	Antifreeze concentration		% Volume % Weight
	Loop static pressure		PSI kPa
Domestic Hot Water	All shut-off valves are open		
	Lines are full and purged		
	Desuperheater pump wire is disconnected		
Electrical	High voltage connections are correct and securely fastened		
	Circuit breaker (or fuse) size and wire gauge for heat pump		A Ga.
	Circulator pump voltages (Indoor 1, Indoor 2)		V V V
	Low voltage connections are correct and securely fastened		

TYPICAL MANUFACTURER CHECKLIST / START-UP SHEET

Source: Ecologix Start-Up Sheet & Nordic Start-Up Guide

In addition to performing start-up procedures as specified by the manufacturer, it is good practice to provide a binder or an equivalent means of compiling and storing all documents related to the installation. This would include any design drawings, technical manuals, specifications submittal sheets, start-up check list, maintenance schedule, warranty paper work, and homeowners instructions.

Furthermore, no system commissioning is complete until a thorough walk-through with the homeowner has been performed.

COST CONSIDERATIONS

Air to water heat pumps are more expensive than their air to air counterparts but if infloor heat is desired they can be the best option. This is due in part to the fact that they are slightly more complex with the refrigerant to water exchange component. But this is also due in part to the scale of product in a small market.

Installation costs tend to cost more due to the extra components such as pumps, motorized valves, pipe and fittings, controls and sheer length of install time.

When compared to the alternative gas boiler the price difference is apparent. Up front costs for a gas boiler retrofit into an existing home built within the past twenty years will range $6,000 - $10,000. Whereas a heat pump in that same house will most likely start at $10,000.

Furthermore, operating costs at current energy prices will be higher than a condensing gas boiler.

If we model a modest newly built 4,000 square foot house in Vancouver built to Energy Step Code 3, we can expect a peak heat load of approximately 12.9 kilowatt.

Consider one hour during winter design conditions of heating costs:

TECHNOLOGY	EFFICIENCY	COST PER Kw HOUR
Electric Baseboard	C.O.P. = 1.0	**$1.63**
Heat Pump	C.O.P. = 1..5	**$1.08**
Heat Pump	C.O.P. = 2.0	**$0.81**
Heat Pump	C.O.P. = 3.5	**$0.46**
Natural Gas Boiler	92% Efficient	**$0.37**

***PLEASE NOTE**: A blended electricity rate of $0.126 per kWh is used. A natural gas rate of $7.36 per GJ is used.*

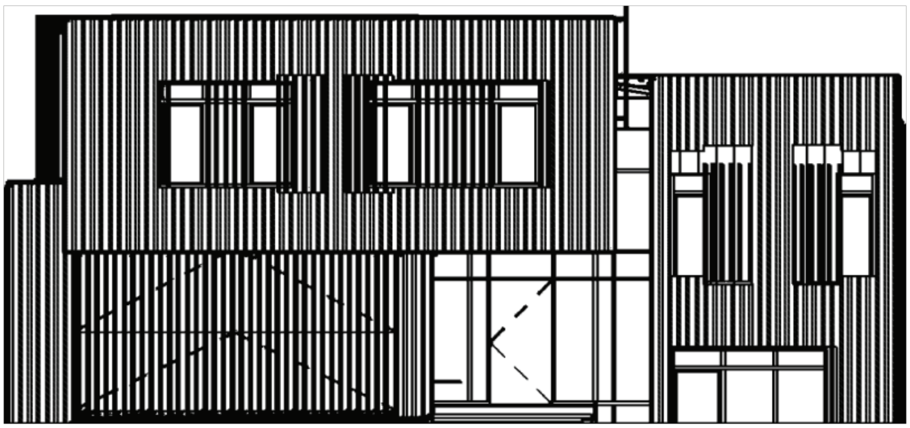
The table above demonstrates an operating cost difference between a standard condensing gas boiler and a heat pump operating within the winter efficiency range typical of most.

Even when the heat pump is operating within its peak performance range in the shoulder season, we still have a 40% higher cost per kilowatt of heat.

CASE STUDY

INSIGHTFUL HEALTHY HOMES, LIVING BUILDING CHALLENGE HOUSE

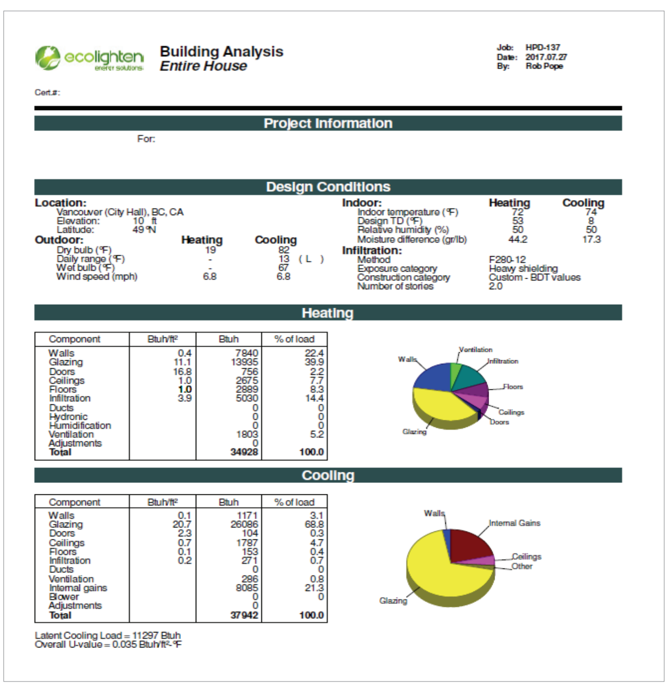
The Living Building Challenge is the most rigorous and comprehensive of all building rating systems. Net zero energy is among the many performance requirements.



FRONT ELEVATION VIEW
Source: Insightful Healthy Homes

When Insightful Homes began the design phase of this 5,600 square foot Vancouver custom home, the over-arching challenge was how to build a very high performing house without compromising the architectural features of the building such as the large amount of glazing.

As with all projects, the first step was to determine the heating and cooling loads using code compliant methodology — CSA F280-12.



Building Analysis
Entire House

Job: HPD-137
Date: 2017.07.27
By: Rob Pope

Cert.#:

Project Information

For:

Design Conditions

Location:
Vancouver (City Hall), BC, CA
Elevation: 10 ft
Latitude: 49 °N

Outdoor:	**Heating**	**Cooling**
Dry bulb (°F)	19	82
Daily range (°F)	-	13 (L)
Wet bulb (°F)	-	67
Wind speed (mph)	6.8	6.8

Indoor:	**Heating**	**Cooling**
Indoor temperature (°F)	72	74
Design TD (°F)	53	8
Relative humidity (%)	50	50
Moisture difference (gr/lb)	44.2	17.3

Infiltration:
Method: F280-12
Exposure category: Heavy shielding
Construction category: Custom - BDT values
Number of stories: 2.0

Heating

Component	Btuh/ft²	Btuh	% of load
Walls	0.4	7840	22.4
Glazing	11.1	13935	39.9
Doors	16.8	756	2.2
Ceilings	1.0	2675	7.7
Floors	**1.0**	2889	8.3
Infiltration	3.9	5030	14.4
Ducts		0	0
Hydronic		0	0
Humidification		0	0
Ventilation		1803	5.2
Adjustments		0	
Total		**34928**	**100.0**

Cooling

Component	Btuh/ft²	Btuh	% of load
Walls	0.1	1171	3.1
Glazing	20.7	26086	68.8
Doors	2.3	104	0.3
Ceilings	0.7	1787	4.7
Floors	0.1	153	0.4
Infiltration	0.2	271	0.7
Ducts		0	0
Ventilation		286	0.8
Internal gains		8085	21.3
Blower		0	0
Adjustments		0	
Total		**37942**	**100.0**

Latent Cooling Load = 11297 Btuh
Overall U-value = 0.035 Btuh/ft²-°F

In coordination with the design team, and after exploring various options for building assemblies, the resulting load at design conditions was an impressive 34,283 BTUh (10 kW) heat loss. However, due to the volume of glazing, this home had a 49,239 BTUh (14.4 kW) heat gain.

ONE SAMPLE PAGE OF THE LOAD CALCULATIONS
Source: Ecolighten Energy Solutions

The architectural and interior design features restricted the opportunities to route a full forced air system throughout the building. In order to meet the cooling load it was determined that a combination of radiant in-floor cooling and forced-air would provide the solution by reducing the sizing of ducting, while providing a comfort driven mechanical system for heating, cooling and ventilation. Therefore a heat pump that can provide chilled water became the best option, and — from a cost/benefit perspective, an air source heat pump was most suitable choice for this project.

After all considerations this home will meet the rigorous standards of the Living Building Challenge with an Air to Water Heat Pump as it's energy source, radiant floor heating and cooling, forced-air partial cooling and ventilation combined with an HRV.

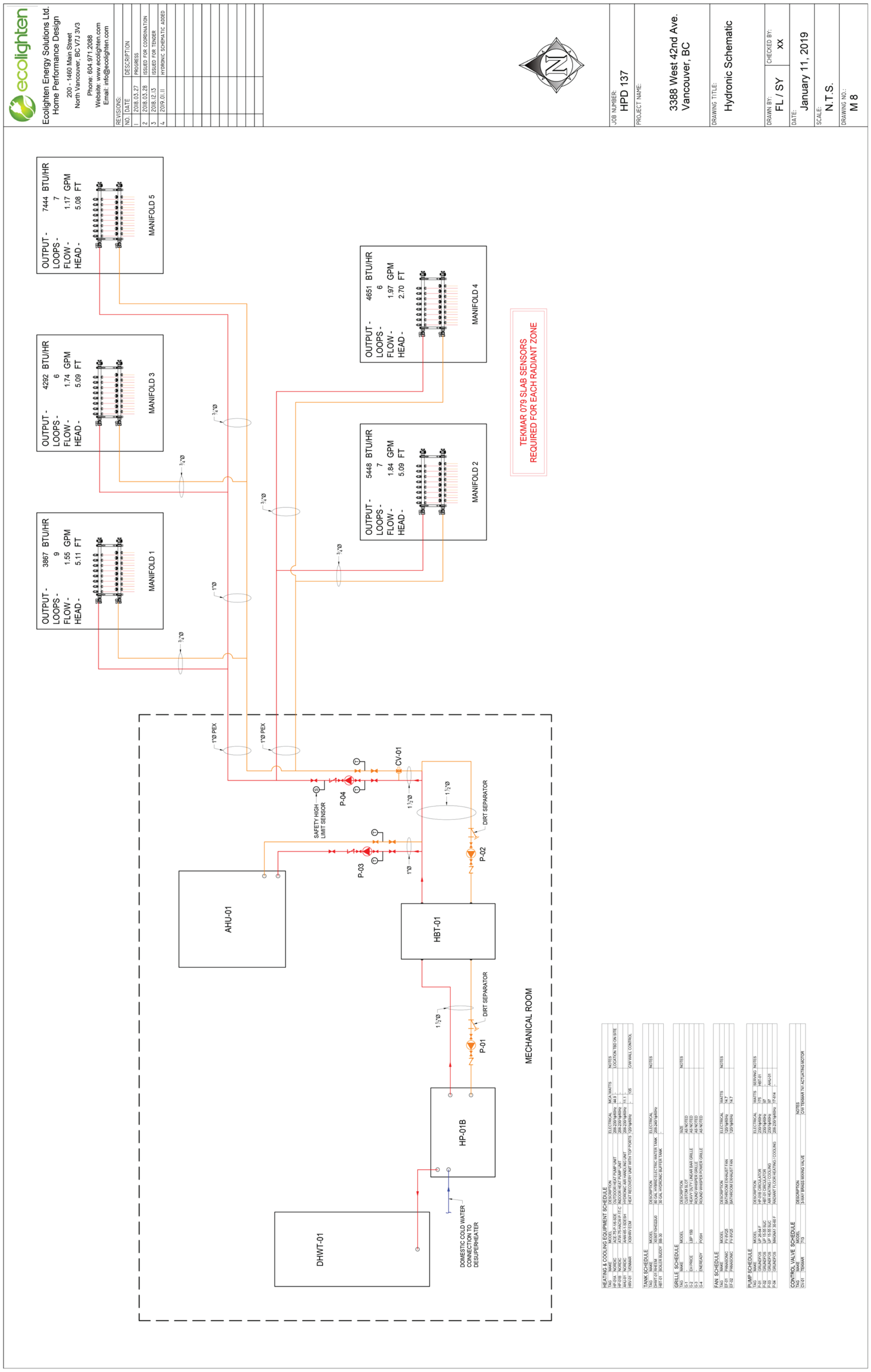
As with any air to water heat pump, careful attention to hydraulic distribution and system controls is required.

Manufacturers, through their representatives, tend to provide excellent technical support for their products in this market.

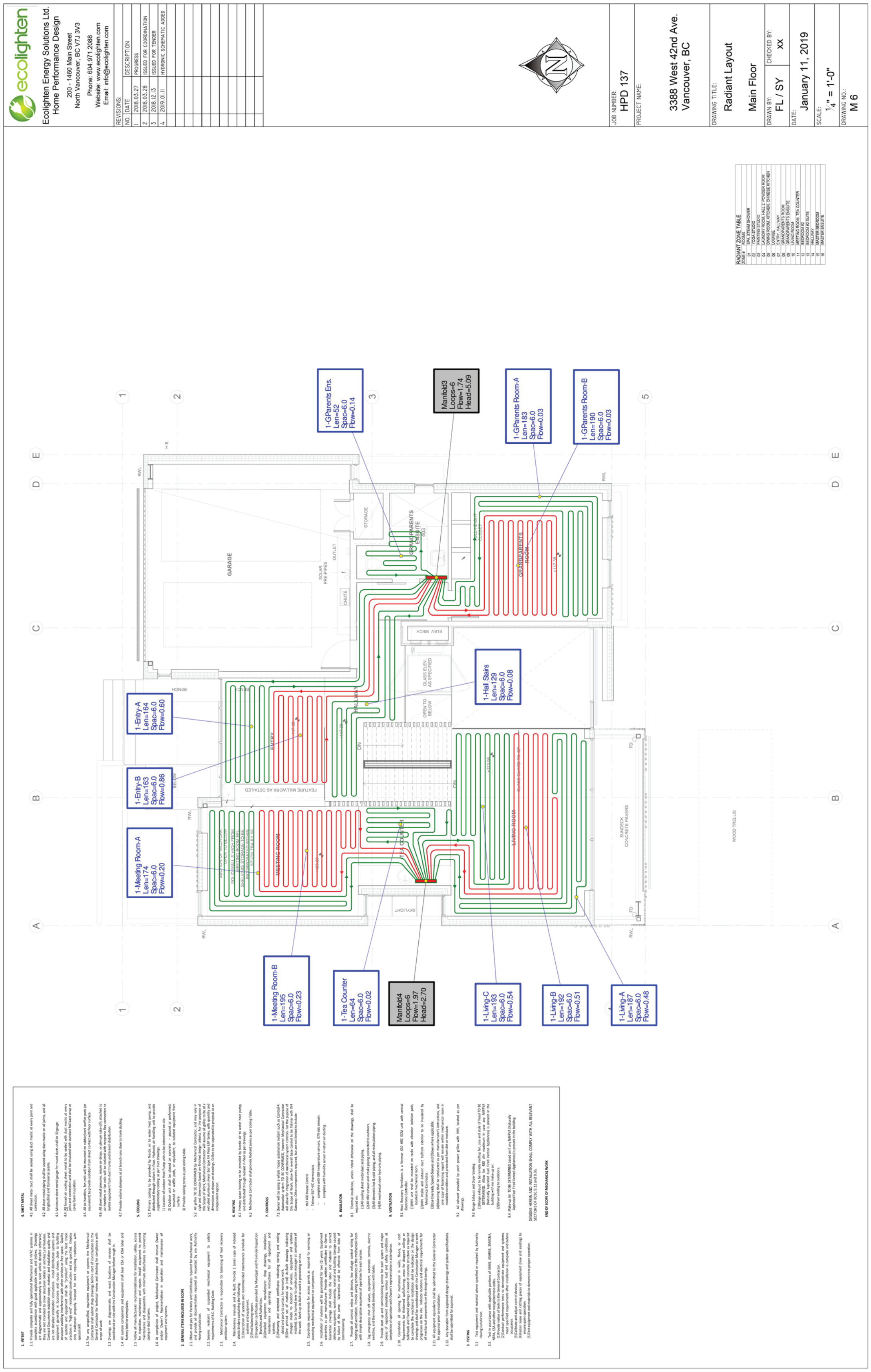
System equipment included:

- Nordic ACE-75 Outdoor Unit (heat pump)
- Nordic ATW -75 Indoor Unit (heat pump)
- Nordic AHW-65 Air Handling Unit
- Venmar X30 HRV with Eneready Posh system
- Tekmar Controls

HYDRONIC SCHEMATIC



HYDRONIC DESIGN



CONCLUSION

It is clear that air to water heat pumps can help projects achieve the greenhouse gas limit for large homes at a lower cost compared to geoexchange and at a lower operating cost than electric boilers. In hydronically heated homes it is the best option and can provide a greater degree of flexibility — in new construction particularly.

The challenges going forward are:

- Scaling the market for more product and responsive supply chain.
- Trades training and relationships with suppliers.
- Generating awareness in the industry and market.
- Making a case for air to water heat pumps in the face of upfront and operating costs.

All the representatives of the products listed in this report were contacted and engaged in lengthy discussions. All offered their support and willingness to help address the challenges they face as an emerging industry in BC. It is potentially an opportunity at this time to reach out to the manufacturers' reps and various stakeholders, and create a charrette to map out strategies to meet the challenges that this technology faces within the regulatory demand-side changes coming soon to Vancouver.

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