NET-ZERO INDOOR OVERWINTERING FACILITY DESIGN FOR THE ALBERTA COMMERCIAL BEEKEEPING INDUSTRY

NOVEMBER 8, 2019

PREPARED FOR:

ALBERTA BEEKEEPERS COMMISSION

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1. Executive Summary

The purpose of this report is to present a design concept and economic feasibility of building a commercial net-zero indoor overwintering beekeeping facility, including energy efficiency and renewable energy technology, for the Alberta commercial beekeeping industry. The overall objective of this design is to reduce the carbon footprint and improve environmental sustainability of future builds of indoor overwintering beekeeper farm facilities in Alberta.

The net-zero facility design scope included all of the energy requirements (heating and electrical) at the facility without burning fossil fuels at the site. The net-zero design for the facility excludes vehicles such as trucks and forklifts, although battery-electric vehicle options are expected to be available and economical in Canada in the years ahead.

Nine beekeeper facilities were selected as a sample set of farms to represent the typical conventional commercial beekeeping facility in Alberta, and three of those farms had indoor overwintering rooms. Dandelion Renewables completed energy efficiency measurements, assessments, and recommendations for energy cost savings at each farm.

Additional research was conducted based on beekeeping operations outside AB, where indoor overwintering is more common. For example, the percentage of Alberta hives overwintered indoors is 12% (2018 survey), compared to 50% in Manitoba and 73% in Quebec. [1]

The net-zero facility was sized to 9,240 hives with 2,772 (30%) of hives overwintered indoors.

The net-zero facility consumes $91/year (0.8%, $0.010/year/hive) more in energy costs than a conventional facility (first year) due to the net-zero heating system using electricity (heat-pumps) instead of a natural gas (boiler). With grid-tied solar photovoltaic (PV) power generation onsite, the net-zero operation is expected to generate a net annual energy savings of $10,990/year (first year), compared to a conventional facility without renewable energy.

The indoor overwintering hive losses with the net-zero design are expected to be 2% lower than a conventional indoor overwintering facility, due to more control and uniformity of the air quality throughout the hives in the room. The 2% reduction in hive losses is expected to save $16,632/year.

The net-zero facility design concept showed that it is feasible to build a net-zero facility instead of a conventional facility. Based on an investment cost of $222,796 to build a net-zero facility instead of a conventional facility, the additional investment has a 13.6% IRR (internal rate of return on investment) over a 30-year economic life, and 9-years payback.

The net-zero facility is expected to eliminate 74.08 tCO2e (0.008 tCO2e per hive) of GHG from the atmosphere that a conventional facility would otherwise produce.

The economic results are sensitive to different rates of indoor hive-loss improvement. The IRR varied from 3.1% to 18.8%, and payback varied from 22 years to 7 years, for hive loss reduction in the range of 0% to 3%.

2. Introduction

The Alberta Beekeepers Commission, with support from the Canadian Agricultural Partnership, engaged Dandelion Renewables to conduct a project to research and also identify opportunities for energy efficiency improvements for farms to save on energy costs, increase sustainability, and reduce the carbon footprint of commercial beekeeper farm operations in Alberta. The project included research about current technologies and energy consumption of the commercial beekeeping facilities, and the evaluation of opportunities to integrate renewable energy technologies with beekeeping facilities including a conceptual design of a net-zero overwintering facility.

A report was produced by Dandelion Renewables, which summarized the current technologies and the findings and recommendations for energy efficiency opportunities for the Alberta Commercial Beekeeping Industry ("Current Technology and Energy Efficiency Opportunities for Alberta Commercial Beekeeping Industry" – Oct 3, 2019).

This report covers the integration of renewable energy technologies and a net-zero design of a commercial indoor overwintering beekeeping facility. A "net-zero" facility generates as much renewable energy as it consumes from any energy sources, on an annual basis. The net-zero facility design scope included meeting the energy requirements for heating and equipment operation at the facility without burning fossil fuels at the site. The net-zero design for the facility excludes vehicles such as trucks and forklifts.

The following sections of the report describe the technologies included in the net-zero facility design, in comparison to a conventional indoor overwintering facility.

3. Conventional Versus Net-Zero Facility Design

The conventional indoor overwintering beekeeping facility design reflects the technologies and energy costs observed at the nine sample farms visited in Alberta. That conventional facility energy consumption, not including vehicles (e.g. trucks and forklifts) consisted of electricity, diesel and gasoline. Three of the nine farms were operating indoor overwintering rooms, without the use of refrigeration systems for cooling. However, a conventional overwintering room is expected to include a refrigeration system, based on HVAC modeling for indoor overwintering in Alberta (historical weather data used for Blackie, AB), and also based on current design guidelines for indoor overwintering in Quebec where more studies have been done around indoor overwintering. [2]

The technologies used in the conventional facility, and comparison to the technologies used in the net-zero facility, are briefly described in the following table. More detailed description of the conventional technologies can be found in the report "Current Technology and Energy Efficiency Opportunities for Alberta Commercial Beekeeping Industry" – Oct 3, 2019.

Table 1: Technology Comparison Conventional Facility vs. Net-Zero Facility Design

Technology Function	Conventional Facility	Net-Zero Facility
Space Heating	Natural gas boiler with hydronic in-floor heating.	Heat-pump system including air-to-water, geothermal water-to-water, and high temp water-to-water.
Lighting	Average of sample farm energy consumption, using T5, Incandescent, HPS/MH, LED, T12, T8, and CFL.	100% LED.
Honey Heating	Electric/Oil honey heat exchanger.	Heat-pump hydronic hot water, plate heat exchanger to honey heat exchanger.
Indoor Overwintering (OW) Refrigeration	Heat is transferred from indoor air to outdoor air. Evaporators absorb heat directly from OW room air.	Heat-pump system absorbs heat from OW air inside a recirculation air-mixing plenum.
Indoor Overwintering Fans	AC fans. Recirc fan. Wall exhaust fans with variable speed stage-1 exhaust, and on/off additional fan stages.	Variable-speed EC fans for recirc and stage-1 wall exhaust. AC wall fans for additional fan stages.
Pressure Washer	Portable, diesel-heated, electric pump.	Portable, heat-pump hot water supply (60-71degC / 140-160degF), electric high-temperature pump.
Oxalic Acid Vaporizer (Varroa Mite Treatment)	Portable power station with gasoline generator for electric air compressor and electric-heated vaporizer cannons/guns.	Portable power station with off-grid 120/240VAC inverter-charger and reconditioned 48VDC forklift battery.
Wax Melters	Water-jacketed electric-heated tanks.	Conventional.
Extracting motors and air compressor	Variable-speed 3-phase pump motors and spin-float motor, with VFD.	Conventional.
Circulators	Hydronic zone circulators, PSC motors.	Hydronic main circulators, EC motors. Power-open-close zone valves.
Tools & Other Electrical Devices	Grinders, welders, woodworking tools, office computers.	Conventional.
Appliances	Clothes washer, clothes dryer, lunchroom small appliances.	Conventional.
Dehumidifier	Used certain years to dehumidify honey in the hot room.	Conventional.
Circulation Fans	Hot room ceiling fans.	Conventional.
Well Pump and Water Treatment System	Conventional.	Conventional.
Renewable Energy Power Generation	None.	Solar photovoltaic (PV) system.

Heat-Pump System – Space Heating

Heat-pump systems use electricity to run a compressor, which circulates refrigerant between an evaporator (absorbing heat into the refrigerant) and a condenser (releasing the heat from the refrigerant). The heat-pump system selected for the net-zero facility is available from Maritime Geothermal. The system includes three air-to-water heat pumps (ATW-75, see image to the right) that will cool the air from the indoor overwintering room and transfer the absorbed heat into water that will be used for hydronic in-floor heating and domestic hot water in the other heated buildings at the site through the winter.

Figure 1: ATW-75 Evaporator

Figure 2: ATW-75 Condenser

The system also includes a geothermal water-to-water heat-pump (W-75) with a vertical ground loop (see example image to the right) that circulates water through loops 250 feet (76m) underground to absorb heat energy from the soil. The heat-pump then cools that ground loop water, and transfers the absorbed heat into the hydronic in-floor heating system. The main purpose for including this geothermal heat-pump is for an extra heat source (backup/boost heating capacity) for the heated building during extreme cold periods in winter, when the heat from the bees may be insufficient for heating the building, and outdoor air is below -25 degC, which reduces the heating capacity of the air-to-water ATW-75 heat-pump units. The heat-pump system also includes two high-temperature water-to-water (WH-55) heat-pump units to raise the hydronic water temperature above 120degF (49degC) as high as 160degF (71degC). Those water temperatures are required for the in-floor heating of the Hot Room in the summer months and to heat the pressure washer.

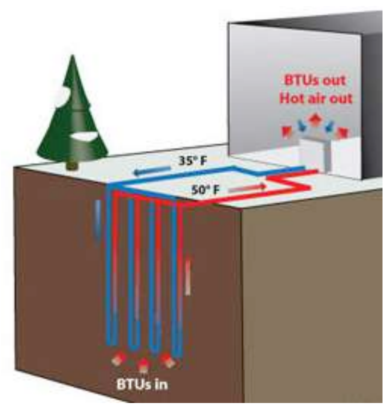

Figure 3: Vertical Ground Loop for Geothermal (Geo-exchange)

Lighting

The conventional beekeeping facilities visited were using different types of lighting, some with lower energy efficiency than others. The types of lighting observed, broken down by the attributed lighting energy costs is shown in the following figure.

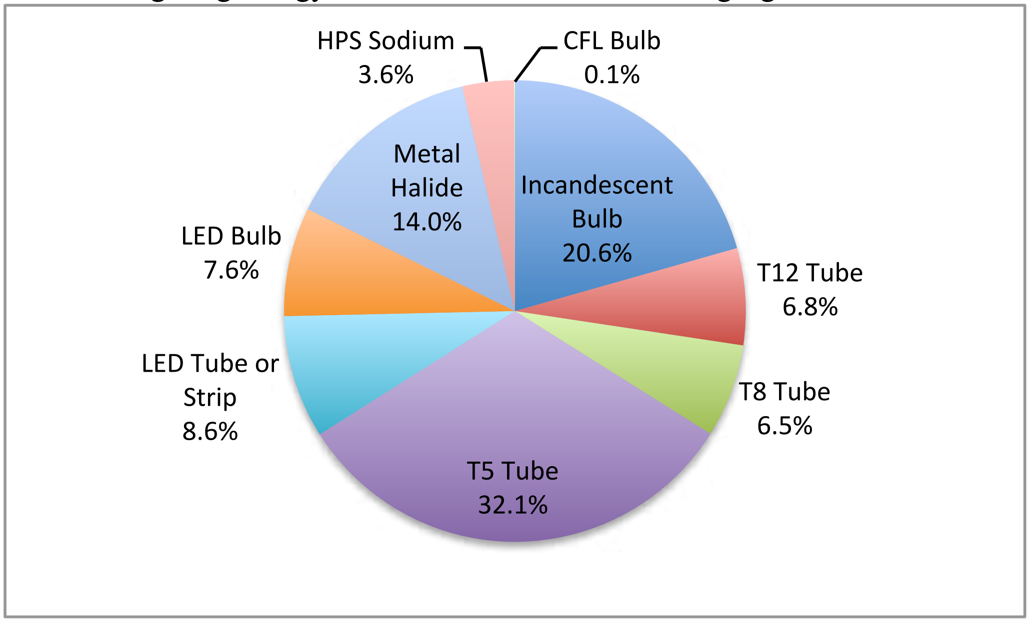

Figure 4: Lighting technology energy consumption observed at sample farms (conventional facilities)

LED lighting uses the least amount of energy to provide the lighting required, when compared the rest of the lighting types observed. Each type of lighting is described in more detail in the report "Current Technology and Energy Efficiency Opportunities for Alberta Commercial Beekeeping Industry" – Oct 3, 2019

The net-zero facility will use only LED lighting.

Honey Heat Exchanger

The conventional facility design uses a honey heat exchanger that heats the honey after extraction for the purpose of achieving the best honey clarification or separation in the spin float separator [3]. The conventional honey heat exchanger (see example in the figure to the right) has electric heating elements that heat a circulated oil loop, which exchanges heat into the honey to reach a honey temperature of 35C to 41C (95F-105F).

Figure 5: Honey Heater (Heat Exchanger) (cooknbeals.com)

The net-zero facility will not use the electric heating elements in the honey heat exchanger. Instead a plate heat exchanger will be used to transfer heat from the heat-pump hydronic hot water to the oil/water circulating through the honey heat exchanger. In the summer, when this heating is required, the outdoor air temperatures are relatively warm, which increases the energy efficiency of the air-to-water heat pump. The efficiency of the heat-pump is measured as COPh (coefficient of performance for heating). The COPh is amount of heat (e.g. Watts) supplied by the heat-pump to the hydronic water, compared to the electrical energy consumed by the heat-pump equipment (e.g. Watts). The COPh of the heat-pump when supplying the honey heat exchanger water is expected to be 3.85 W/W. This means the heat-pump will use 74% less electricity to heat the honey than the conventional electric elements.

Indoor Overwintering Refrigeration – Heat-Pump System ATW-75

The indoor overwintering (OW) room refrigeration cooling in the conventional facility design uses evaporators ("indoor units", see example figure to the right) mounted near the ceiling in the overwintering room, to cool the air and transfer that heat outdoors through condensers ("outdoor units"). One downside of this conventional approach is that the heat energy moved by the system is expelled outdoors, where it could be used to meet heating requirements for adjacent buildings. The other disadvantage of this conventional system is that the evaporators introduce undesirable air currents, air speeds, and noise inside the overwintering room, all of which can contribute to higher stress on the bees.

Figure 6: KLV Evaporator (Conventional)

The net-zero indoor OW room refrigeration system recirculates air out of the hive space near the floor level, through an air conditioning/mixing plenum where the evaporators cool the air (see example photo to the right), and then recirculation fans distribute the cooled air back to the room through a plenum and ducting network across the ceiling. The reason the recirculation system distributes the air across the ceiling and pulls the air from the room near the floor level is to encourage the most uniform and thorough airflow through all the hives in the room. The air-to-water system will transfer the heat absorbed from the OW room into water that will be used for hydronic heating requirements in the heated building spaces through the winter.

Figure 7: ATW-75 Evaporator (Net-Zero Facility)

See the Appendix for a floor plan of the indoor overwintering facility, showing the refrigeration heat-pump system (3x air-to-water TW-75 evaporators and condensers).

Indoor Overwintering Fans – Net-Zero EC Fans vs Conventional AC Fans

Conventional indoor OW room ventilation includes recirculation fans and wall exhaust fans. The fan technology is referred to as AC, meaning an alternating current motor. The conventional variable speed control for these fans is a triac speed controller. It is the lowest cost speed control for AC fans, but it doesn't produce as much energy savings at lower speeds, compared to the more costly VFD (variable frequency drive) or EC (electronically commutated) speed control technologies.

The following figure shows that at a high-airflow fan speed:

- three-phase VFD uses 89% more power than ECM.
- single-phase VFD uses 127% more power than ECM.
- triac uses 14% more power than ECM.

The following figure also shows that at low-airflow fan speed:

- three-phase VFD uses 63% more power than ECM.
- single-phase VFD uses 175% more power than ECM.
- triac uses 350% more power than ECM.

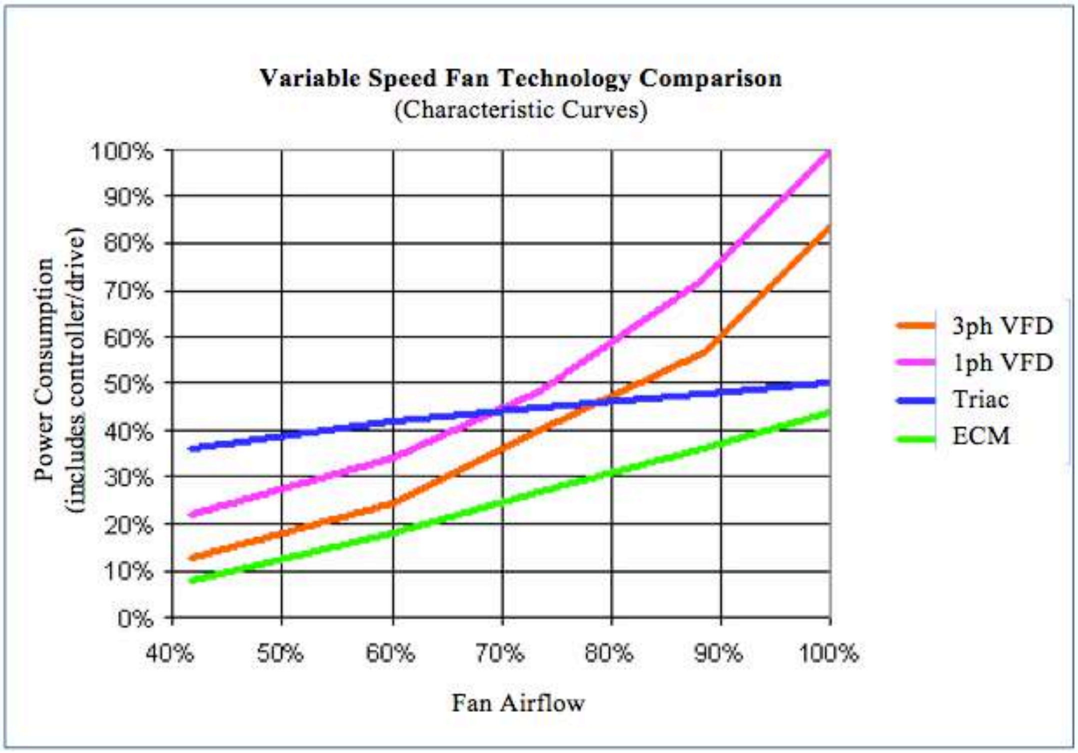

Figure 8: Variable Speed Fan Technology Comparison (study data from Control Resources Inc.)

The conventional OW room uses five AC fans, consisting of two recirculation fans, one variable speed stage-1 wall exhaust fan, and two single-speed staged wall exhaust fans. The net-zero design uses controlled dampers to allow the recirculation fans to contribute to the exhaust capacity when maximum exhaust is required, which allows the net-zero design to use fewer fans than the conventional facility. The net-zero OW room uses three fans, consisting of two EC recirculation fans and one single-speed AC fan. The EC recirculation fans combined with controlled exhaust dampers allow the EC fans to provide a recirculation and exhaust simultaneously or to contribute fully to exhaust or fully to recirculation. For the EC fans to contribute to exhaust, a controlled damper is opened in the OW room outdoor wall, and the recirc air supply to the EC fans closes, and the fresh air supply to the EC fans opens. This creates a positive pressure in the OW room, which causes OW air to be pushed out through the outdoor exhaust wall damper, while maintaining the airflow pattern of the room. The AC wall exhaust fan is not expected to run many hours per year, except where bees generate more than the estimated 10 W/hive, or when the refrigeration or damper system requires downtime.

Both the conventional and the net-zero designs have a ventilation capacity of 14,622 cfm exhaust (5.3 cuft/hive), and 9,748 cfm recirculation (3.5 cuft/hive).

Pressure Washer (Portable)


Figure 9: Portable Pressure Washer, Diesel-Heated (Hotsy)

The conventional facility uses an electric water pump that pumps cold water through a diesel-fired water heater (e.g. Hotsy, see example image to the right) and out through the pressure washing nozzle. The net-zero facility design uses a hot water supply from the domestic hot water tank, heated by the heat-pump system, and a similar portable electric pumping unit without needing a portable heater. The conventional pressure washer pump head however, is not designed to pump hot water and hot water would quickly shorten the life of a conventional pumping head, so the net-zero design uses a high-temperature water pumping head. Despite the additional cost for the high-temperature pumping head, the elimination of the portable diesel-fired water heater is expected to reduce the overall cost of the portable pressure washing unit.

Oxalic Acid Vaporizer Portable Power Station (e.g. Varroa Cannon)


Figure 10: Inverter -Charger (120/240VAC, 4400W, 48VDC)

The conventional facility uses an electric-heated oxalic acid vaporizer (e.g. Varroa Cannon, see image to the right) with an electric air compressor for spraying the oxalic acid vapor into the hives. To supply electricity to the equipment in the field, the conventional practice is to use a gasoline generator.


Figure 11: Inverter - Charger (120/240VAC, 4400W, 48VDC)

The net-zero facility design uses a 120/240VAC off-grid inverter-charger (see image to the right) and a reconditioned 48VDC forklift battery (see image to the right) for the portable AC power supply instead of the gasoline generator. The reconditioned forklift battery is well suited to the task as there are only 20 to 40 days of oxalic acid mite treatments per year, based on 3 treatments per year and 800 hives per day per portable power station, with 2 cannons. This would translate to 20 to 40 battery cycles per year (charge and discharge), which would give the battery more longevity (e.g. 10-15 years) than typical forklift usage.


Figure 12: 625Ah 48VDC Forklift Battery (Reconditioned)

The maintenance costs for the flooded lead acid (FLA) battery (e.g. water top-up) are expected to be similar to the gasoline generator maintenance costs.

An alternative battery technology that would require little or no maintenance is a lithium-ion battery. This would also be a much more compact and lightweight solution. Based on the higher estimated costs of the lithium battery compared to the FLA battery, the payback would be longer (9 years with li-ion vs 6 years with FLA). However the li-ion battery would allow a much higher power draw and battery cycling life (recharges) than the FLA, which could be useful for other mobile power applications around the farm such as powering electric sugar pumps instead of the conventional gasoline sugar pumps.

There is also a potential opportunity to further reduce the cost of the battery-power station by sourcing or customizing the vaporizer and air compressor to use 48VDC instead of AC power.

Hydronic Water Circulator Pumps

The conventional facility design uses circulators to supply hydronic hot water space heating from a natural gas boiler to different areas or zones of the building. The conventional circulators observed at the sample farms were single-speed, or manual three-speed (see example figure to the right), with PSC (permanent split capacitor motors).

Figure 13: 3-speed circulator PSC (single/multi-speed)

An example of an intrinsically controlled ECM circulator is the Grundfos Magna3 (see example figure to the right). The variable speed circulator monitors water pressure and water temperature and adjusts the circulator speed to slow down and save power when hot water is not required (intrinsic control). Even at full speed the ECM technology uses less energy than a circulator with a PSC motor.

Figure 14: Grundfos Magna3 variable speed circulator ECM

The typical energy savings associated with changing from a single-speed circulator to an ECM variable speed circulator such as Grundfos Magna3 is estimated as 40-75% savings [4].

The net-zero facility design will use high-efficiency variable-speed pumps with ECM (electronically commutated motors). ECM pumps are more energy efficient than PSC pumps, but PSC pumps cost less to purchase than ECM pumps. The net-zero facility will require more water circulation than the conventional facility, as the multiple heat-pumps each require circulation of water for heat transfer from the heat-pump refrigerant. With ECM circulators improving the energy efficiency of hydronic water circulation, the net-zero facility is still expected to consume double the annual circulator energy as the conventional facility.

Solar Photovoltaic (PV) Power Generation System – Renewable Energy

The net-zero facility design includes a grid-tied solar PV system, with a roof-mounted PV array of 128 solar modules and wall-awning-mounted array of 112 solar modules. The total capacity of 87.6kW (DC) is expected to produce 100% of the total annual electrical demand of 105MWh/year. The system is estimated to cost $$159,105 installed, with no applicable solar PV rebates currently available in Alberta.

The following figure shows the mounting layout plan for the roof and wall awning arrays on the building.

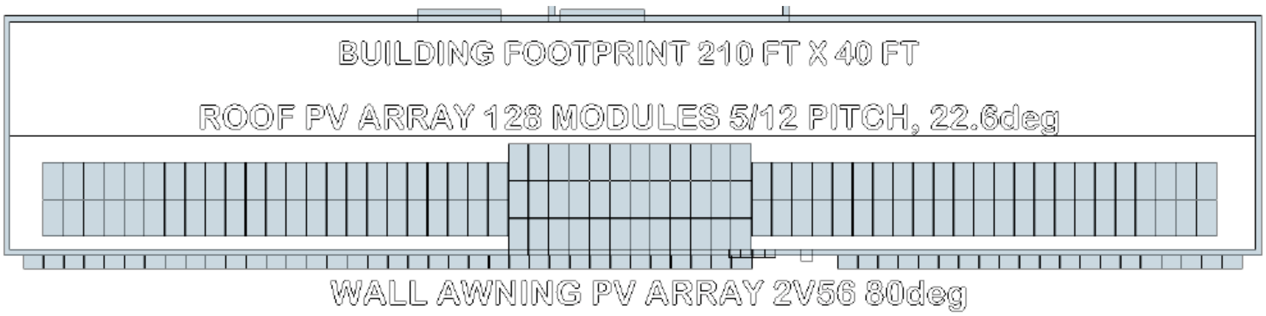

Figure 15: Solar PV Array Mounting Layout Plan

The selection of roof-mounting and wall-awning mounting locations for the net-zero facility was based on targeting higher generation during the winter months with the steeper tilt of the wall awning array. In the winter months, the sun doesn't rise as high in the sky so the steeper tilt of the wall awning array captures more energy from the sun than the roof array, and the steeper tilt helps to prevent snow from building up on the solar modules for more consistent power generation through snowy winter periods.

The net-zero facility design has an expected electrical consumption of 105 MWh/year, which the solar PV system is expected to generate. This achieves the maximum allowable solar power production under the micro-generation regulation in Alberta. The resulting net annual energy consumption of the facility is zero ("net-zero") and the net GHG emissions from the facility operation are zero, as the solar power generation is expected to offset 67.86 tonnes of GHG per year from the power grid.

Solar PV is a low-risk renewable energy technology, with a performance track record and long manufacturer warranty periods available. Alberta has over 60 MW of total solar PV (photovoltaic) capacity installed, combining over 3509 solar PV systems, producing over 69GWh/year. [5]

A solar photovoltaic power generation system (PV system) converts light from the sun into useable electrical power. This is different from "concentrated solar" or "solar thermal" systems that capture energy from the sun's heat, rather than converting sunlight into electrical power.

Electrically, two main applications of solar PV technology are available, which include:

1. Grid-tied, where any generated solar power that the farm doesn't need immediately can be fed back to the power grid. This is the best option for most AB farms, because the farms are already connected to the power grid.
2. Off-grid, where the solar power generated can be used or stored on site, but not fed to the grid. Off-grid PV systems typically include significant additional costs to store power in batteries to use later at night, or at other times when the sun isn't shining.

The following figure shows the major components of a typical grid-tied PV system for a farm.

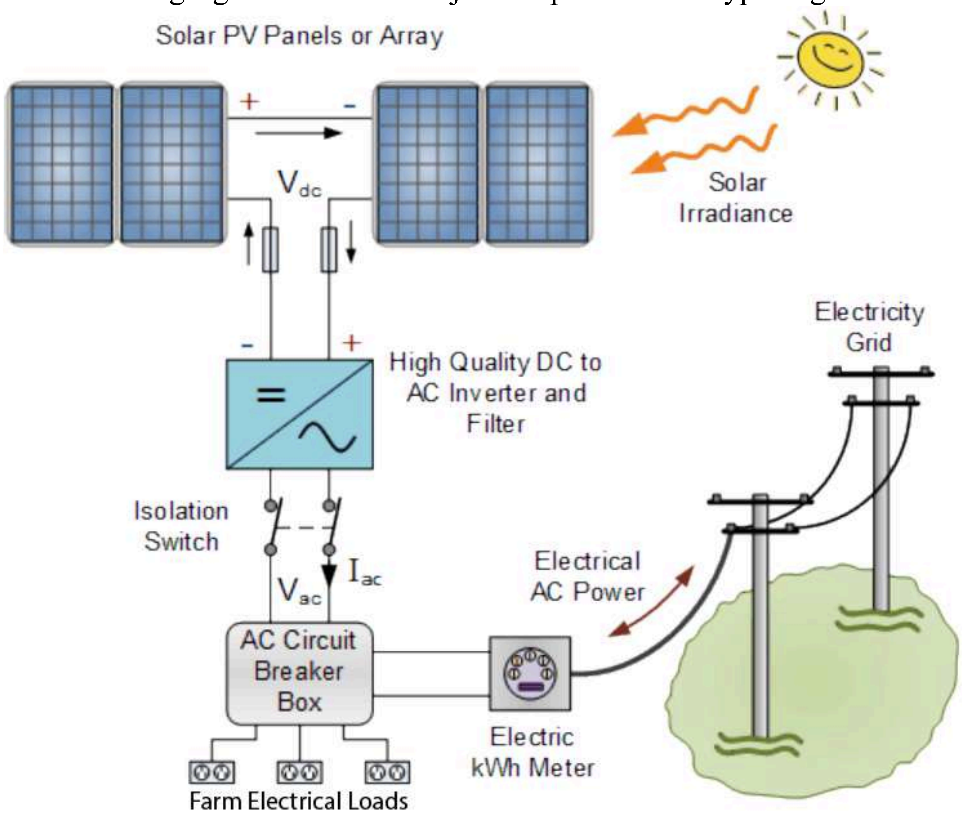

Figure 16: Typical grid-tied PV system electrical connection concept [6]

Solar PV modules generate DC power, which is fed into DC-AC inverters to change the power from DC to AC. The generated AC power from inverters is fed into AC electrical panels to provide power to electrical loads on site and to feed back to the grid through a bi-directional meter.

Solar PV Generation Potential

A solar PV system produces the most power when the solar modules are not subjected to shading from trees, equipment, buildings, or dust buildup. The amount of sun at the location of the solar PV system also affects the power generated by the system.

The following figure shows the solar PV power generating potential for different locations in Canada, based on the amount of sun in the area. The PV potential is shown as kWh/year per kW of PV module capacity.

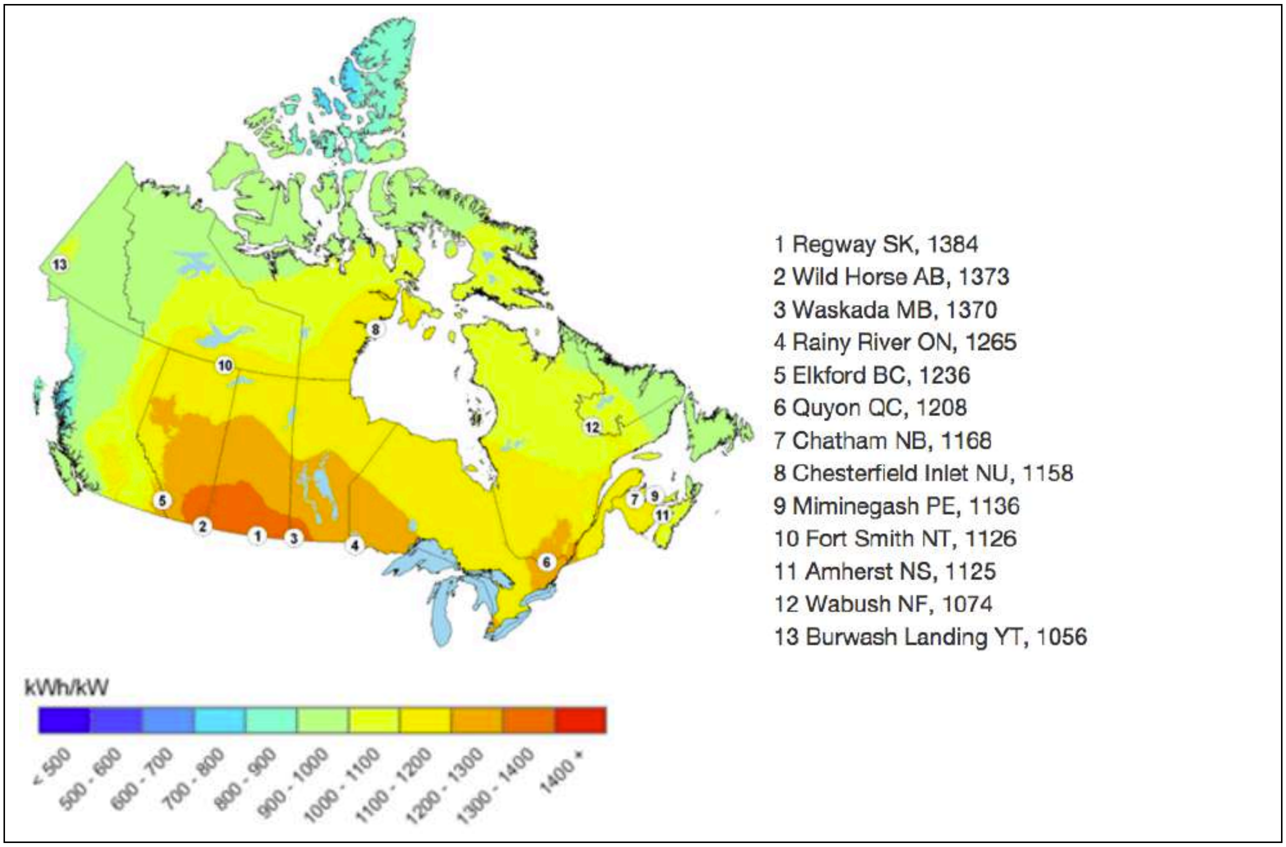

Figure 17: Solar PV potential in Canada, as kWh/year per kW PV [7]

Figure 18: 365W Mono-Crystalline Solar PV Module

A high-efficiency (18.8%), solar PV module was selected for the net-zero facility (see image to the right). The higher module efficiency translates to higher power output for the size of module, which means that fewer modules are required in order to produce the farm's annual power requirement. Also, fewer modules means lower racking costs and lower installation costs. The efficiency of a PV module refers to the percentage of sunlight that the module can convert to electricity.

Figure 19: 120/240VAC Transformerless Inverter (1000VDC)

Each solar module has a PV output capacity of 365W (DC). The modules would be connected to each other in strings that would connect to the inverters. A high-efficiency, transformerless inverter was selected (see image to the right), with system monitoring technology included. The array was planned with 16 modules per string, to increase voltage for better energy flow efficiency in the DC wiring. The 240 solar modules will divide evenly across the 5 inverters planned, with 48 solar modules per inverter. Each inverter will be connected to 3 strings of 16 modules. The inverter has 3 MPPT inputs (maximum power point tracking). For each MPPT input, the inverter will adjust the load (power consumption) on the PV strings to achieve the maximum power production from each string. This separate tracking by string also prevents one string from affecting the power generation of another, if for example one string is covered in snow, the other strings connected to the inverter will not be affected by the reduced power production of the snow-covered string.

Solar Thermal (Solar Hot Water) Consideration

Evacuated tube collector (ETC) solar thermal technology was considered but not selected for the net-zero facility design. The cost to produce heat from the solar thermal collector system is higher than the cost of producing the heat from the planned heat-pump system at the farm. The installed cost of a 240-tube ETC system estimated to be $28,200 with the potential to generate 18.4MWh/year of heat energy. Based on grid-electricity costs to produce heat at $0.116/kWh, this could generate up to $2134/year in electric heating cost savings. However, the heating requirements at the facility are not steady throughout the year, so a significant portion of the potential solar thermal heat generation would be lost. Also, the heat-pump system is able to produce heat with at a cost of less than $0.0387/kWh based on a COPh of 3.0 W/W. At this heating cost savings rate for solar thermal, the 18.4MWh/year of heat generation would translate to a maximum of $711/year. This would not be sufficient savings to justify the $28,200 investment in solar thermal.

Solar thermal panels use energy from the sun to heat a liquid (i.e. water with additives to prevent freezing). The heated water from the solar thermal panels can be circulated through a heat exchanger (i.e. indirect hot water tank) to make use of the solar heat energy for hydronic heating or for domestic hot water. There are three basic types of solar thermal panels: unglazed collectors, flat panel collectors (FPCs) and evacuated tube collectors (ETCs). Each type of panel has their advantages and disadvantages. Only the second two are evaluated in this report because the thermal losses associated with unglazed collectors make them inoperable in cold climates [8]. FPCs are effective to heat water in the 30-50°C range, they are more affordable than ETCs but they have higher heat losses. ETCs have minimal heat losses and are more effective than FPCs when heating water in the range of 60-80°C [8].

Flat panel collectors, or glazed collectors, have a full frame with insulating backing and glass cover enclosing copper pipes which wind back and forth through the collector. The absorber plate is painted black and the copper tubes are sometimes fixed to it to increase heat absorption. The glazing is the glass plate whose main function is to prevent heat loss.

The following figure shows the basic components of a solar thermal glazed flat plate collector unit (FPC).

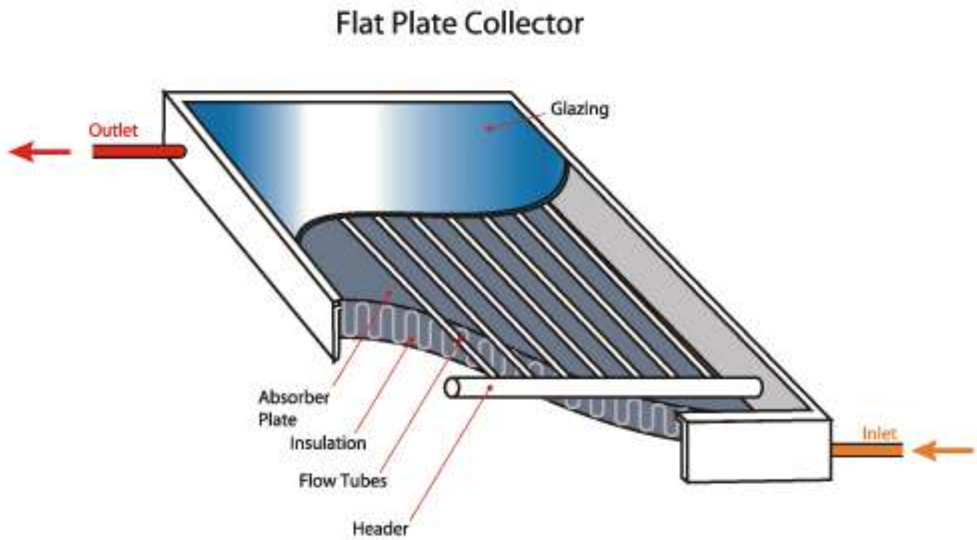

Figure 20: Glazed Solar Thermal Flat Plate Collector (FPC)

Glazed FPCs heat water to medium temperature of (up to 50°C) and can be operated year-round if proper freeze protection such as glycol or a drain-back design is in place.

Evacuated tube collectors (ETC) use a different technology than FPCs to harvest the sun's energy. Instead of heating the water directly, ETCs use a fluid (alcohol or purified water with additives) as a working fluid that gets vaporized within an enclosed heat pipe. The vaporization occurs as the working fluid absorbs heat from the sun, under the low-pressure vacuum inside the tube. The vapor naturally rises to the top of the heat pipe where a heat exchanger transfers the heat to water (reaching 60-80°C) and the fluid within the heat pipe is condensed back to a liquid, draining down to the bottom of the heat pipe to absorb more heat from the sun. The vacuum also helps to reduce conductive and convective heat losses. The image to the right shows an example of an ETC on a tilted rack.

Figure 21: Solar Thermal Evacuated Tube Collector

The following figure shows the heat absorption process of an ETC.

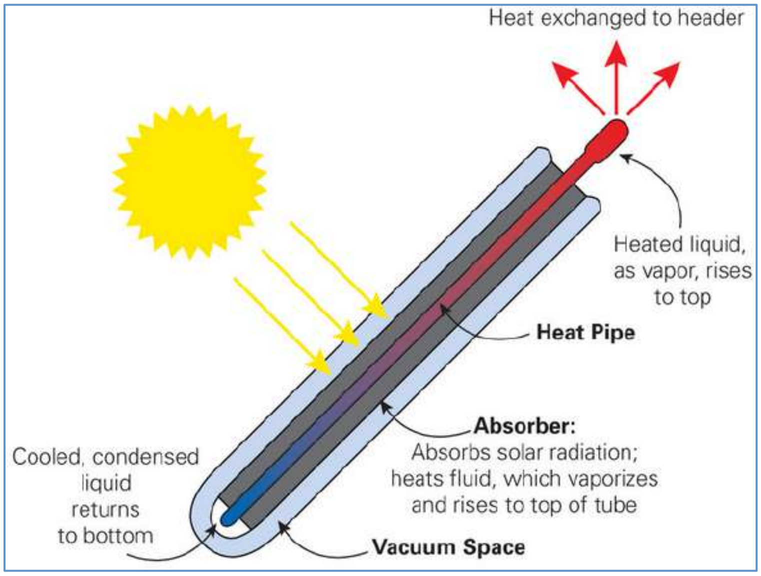

Figure 22: Solar Thermal Evacuated Tube Collector (ETC)

Wind Power Consideration


Figure 23: 60KW Wind Turbine

A grid-tied wind turbine to generate electricity was considered for the net-zero facility but not selected due to no payback expected within the 20-year design life of a wind turbine, based on an installed cost of a $339,521 for a 60kW wind turbine to produce the electricity required for the net-zero facility of 105 MWh/year. Wind turbines are also a higher risk technology with weather events or improper routine maintenance potentially causing large downtime periods and repair costs.

Wind turbines are not currently economical in Alberta at small scale (e.g. smaller than 100kW turbine, grid-tied). The tall mounting structure required to access good wind speed is too costly, compared to the power generation from the wind turbine. Also, the power generation from a wind turbine is proportional to the cube of the wind speed. This means that a turbine exposed to 5m/s wind speed would generate almost twice as much power compared to 4m/s wind speed.

The following figure shows an example of how elevation above the ground relates to wind speeds, which is the reason a tall mounting structure is typically required.

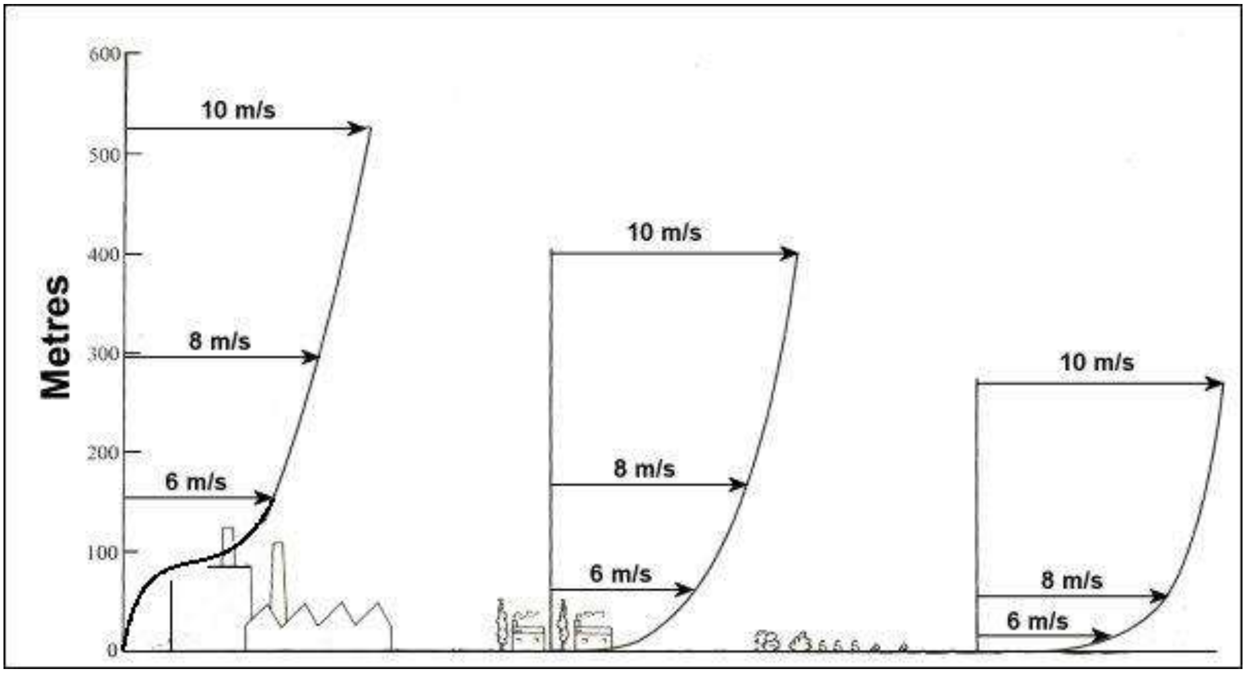

Figure 24: Wind speeds in relation to elevation above the ground and different surface terrain

Solar Air Heating (e.g. Solar Wall)

Solar wall is a technology that typically consists of a perforated black metal colored cladding enclosing an air plenum space that is ducted into a space that benefits from the heated air. The black perforated surface absorbs the heat from direct sunlight and air is drawn through the perforated material with ventilation fans, transferring heat from the perforated cladding to the incoming air. A specialized solar wall installation is not recommended due to the relatively low air changes required for the heated building spaces in the summer (e.g. no exhaust air running for the Hot Room). However, we do recommend the addition of ducting to use the solar-heated air from under the rooftop PV array.

During the summer it is common for air to become heated under the solar PV array on the roof and that heat can reduce the power generation potential of solar PV modules. The net-zero facility uses ducting between the rooftop array and the fresh air plenum of the heat-pump system to allow circulation of air from under the solar array to enter the air-to-water heat-pump fresh air plenum. The cooling effect on the solar modules could increase the power generation of the PV system, while also increase the energy efficiency (COPh) of the heat-pump system, allowing the heat-pump system to generate the heat for the Hot Room using less electricity.

Based on a budgetary cost of $1500 to install the ducting to direct airflow from under the PV array into the heat-pump fresh air plenum, and a resulting air temperature increase in the plenum from 13degC to 18degC, the COPh of the heat-pump would increase from 3.85 to 4.47 W/W (16.1% efficiency improvement). Based on an estimated 11 MWh/year of heat-pump power consumption for the summer heating hours when the pre-heated air is available, the pre-heated air would result in a heat-pump power savings of 1525 kWh/year. Assuming a 0.5% PV generation increase for summer months could generate an extra 132 KWh/year from the solar PV array. The total savings would be 1657 kWh/year or $192/year, and a simple payback in 8 years.

Heat Recovery Ventilation (HRV) Consideration

An HRV unit was considered for the net-zero facility but not selected. The rate of air changes in the heated building space through the winter is not expected to be high enough to produce a positive return on investment for an HRV unit. For heated building spaces with exhaust ventilation, HRV units use an air-to-air heat exchanger to absorb some of the heat from air just before it gets exhausted from the building and transfer that heat into the fresh air coming in from outdoors. HRV units can also be used to pre-cool the fresh air coming into the building, if there is value in cooling the air.

4. Conventional versus Net-Zero Facility Energy Consumption and Costs

Net-Zero Facility Energy Simulation Model

Using historical weather data for central Alberta (Blackie, AB weather station data), an hourly simulation model was created to estimate the performance of the climate control and heat-pump system designed to maintain the indoor overwintering room climate within acceptable ranges of temperature, CO2, and humidity.

The following inputs and assumptions were used in the HVAC simulation model.

Table 2: Input and Assumptions for Indoor Overwintering Room HVAC Simulation Model

Input Value	Description of Input of Assumption
1.8 umol/hr	CO2 release rate per bee at 5degC ambient air temperature
30,000 bees/hive	Bees per hive in November, starting the indoor overwintering period
10,000 bees/hive	Bees per hive in April, ending the indoor overwintering period
5 degC	Target OW room air temperature
2772 hives	Number of hives indoor overwintered (7 pallets high, 4 hives per pallet)
10 Watts/hive	Heat generation rate released by each bee hive into the air in the room [9]
109,500 btu/hr	Heat-pump system cooling capacity at OW operating conditions
159,078 btu/hr	Heat-pump system heating capacity at OW operating conditions

The overwintering (OW) room air temperature was maintained at 5degC throughout the period. The concentration in the air (ppm, parts per million) was targeted for 2000ppm based on suggestions from beekeepers in Alberta, operating indoor overwintering rooms. The simulated CO2 concentration was allowed to rise as high as 6000-7000ppm during warm outdoor temperatures, to reduce the amount of warm outdoor air adding heat to the bee room. A concentration of 7000ppm is expected to be safe for short-term human exposure (15-minute exposure ceiling limit 30,000ppm [10]), and there has been research published that supports the expectation that higher CO2 concentrations could be an effective natural treatment for Varro mite. [11]

The following figure shows a portion of the simulated indoor overwintering climate control system, from January through April.

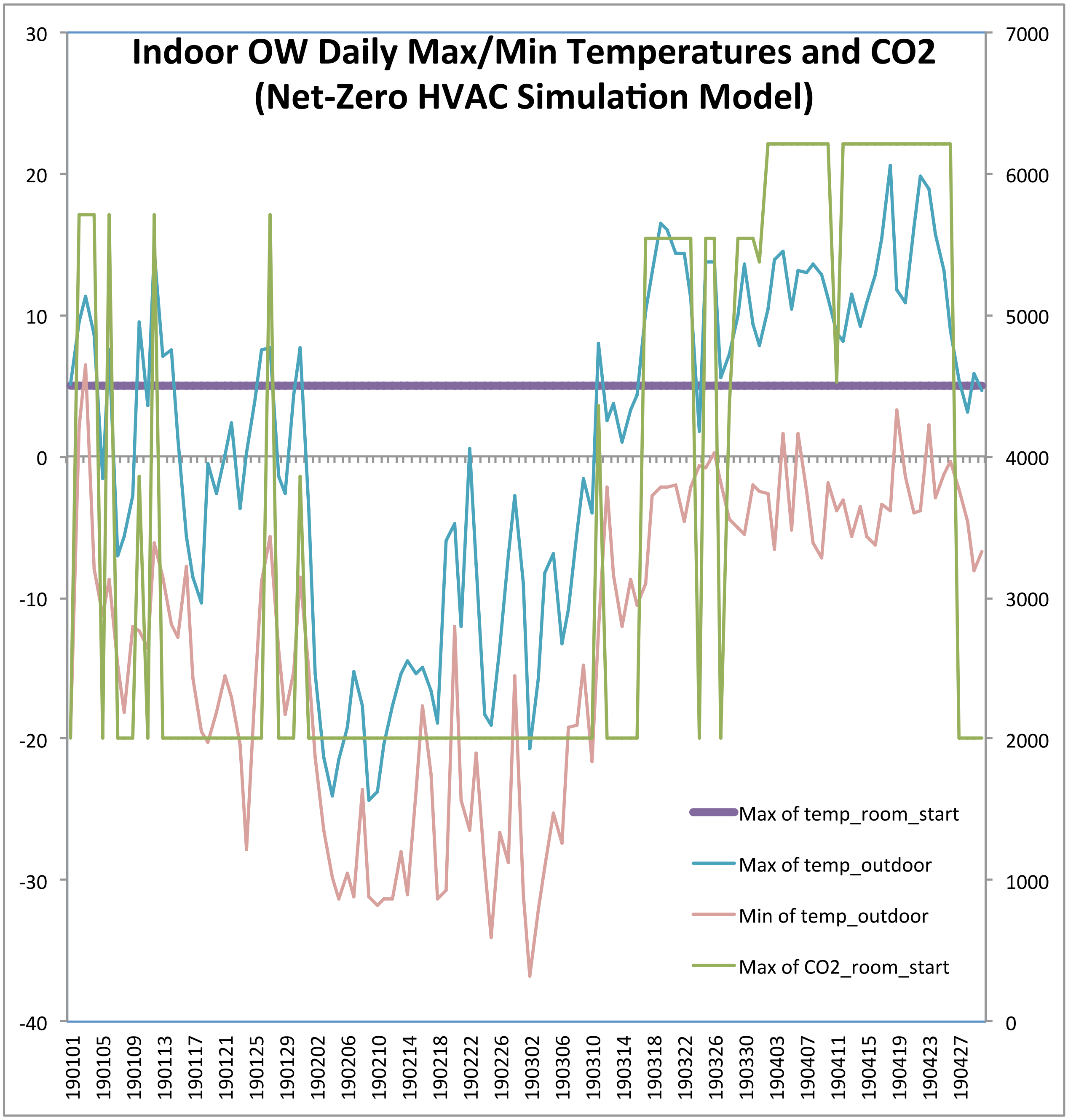

Figure 25: HVAC Simulation for Indoor Overwintering Room Air Temperature and CO2 Control.

Sensitivity of Indoor Overwintering Max Refrigeration Load to Heat Generation Per Hive

Bees colonies (hives) generate excess heat during the winter. The rate of heat generation is typically between 8W to 34W per hive [12]. The net-zero overwintering facility assumes 10W/hive of heat generation, as a conservative estimate for the heating capacity to be available for heating the adjacent building. Energy modeling of the room with 10W/hive resulted in a maximum refrigeration load of 109,500 btu/hr, which is 95% of the expected cooling capacity of the specified equipment for the conceptual net-zero facility design.

Higher heat generation per hive results in more heat required to be removed from the overwintering room to maintain the target room temperature of 5degC, either through outdoor fresh air cooling (if available) or refrigeration cooling. If the heat generation per hive exceeds the assumed 10W/hive, the refrigeration capacity would be reached and could lead to the room temperature climbing up to a maximum equal to the outdoor air temperature.

Sensitivity analysis was performed on the maximum refrigeration load due to variations in the heat generation rate per hive. For hive heat generation of 8W/hive to 32W/hive, the resulting max refrigeration load (after outdoor cooling capacity) varied from 89,542 btu/hr to 344,759 btu/hr.

The following figure shows the sensitivity of the maximum refrigeration-cooling load (after outdoor air cooling) to variations in the heat generation per hive.

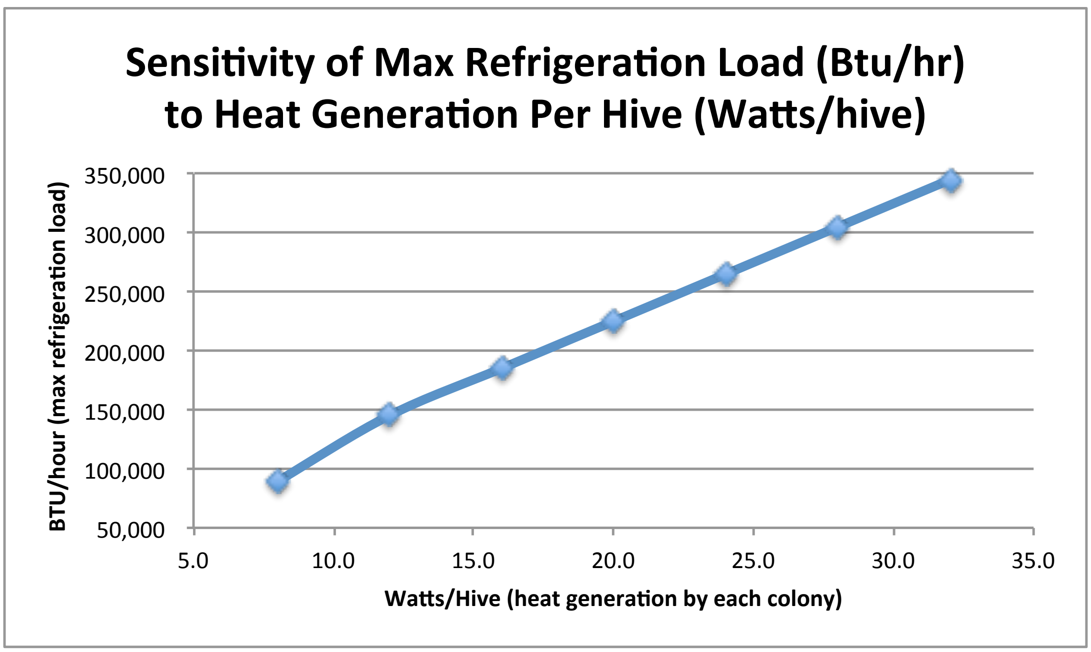

Figure 26: Sensitivity of maximum required refrigeration load to variations in the heat generation per hive

Energy Consumption Comparison – Conventional vs Net-Zero Facility

Based on the technology differences designed for the net-zero facility compared to the conventional facility, the associated differences in expected energy consumption between the conventional facility and the net-zero facility are shown in the following set of tables. The tables show annual energy consumption and costs, by energy source, with annual "facility totals", and "per hive" totals.

Table 3: Annual Energy Consumption, Facility Totals, Conventional vs Net-Zero Design

	Annual Energy Consumption				
	Conventional Facility				Net-Zero Facility
	GJ NatGas	L Diesel	L Gasoline	kWh Electricity	kWh Electricity
Space Heating	457				44461
Lighting				10875	7058
Hny Heating				5744	1492
Indoor OW Refrigeration				2717	701
Indoor OW Fans				13875	5655
Pressure Washer		300			450
Oxalic Acid Vaporizer			610		853
Wax Melting				10396	10396
Extracting Motors/Air				8340	8340
Circulators				4293	8586
Pressure Wash Pump				916	916
Tools & Other Electric				1069	1069
Appliances				3152	3152
Dehumidifier				7223	7223
Circulation Fans				1372	1372
Well Pump & Treatment				2782	2782
Total	457	300	610	72755	104506

The following table shows that various fossil fuels used by the conventional facility are to be replaced with electricity as the energy source for the net-zero facility.

Table 4: Annual Energy Consumption, "Per-Hive", Conventional vs Net-Zero Design

	Annual Energy Consumption Per Hive				
	Conventional Facility				Net-Zero Facility
	GJ NatGas	L Diesel	L Gasoline	kWh Electricity	kWh Electricity
Space Heating	0.050				4.812
Lighting				1.177	0.764
Hny Heating				0.622	0.161
Indoor OW Refrigeration				0.294	0.076
Indoor OW Fans				1.502	0.612
Pressure Washer		0.032			0.049
Oxalic Acid Vaporizer			0.066		0.092
Wax Melting				1.125	1.125
Extracting Motors/Air				0.903	0.903
Circulators				0.465	0.929
Pressure Wash Pump				0.099	0.099
Tools & Other Electric				0.116	0.116
Appliances				0.341	0.341
Dehumidifier				0.782	0.782
Circulation Fans				0.149	0.149
Well Pump & Treatment				0.301	0.301
Total	0.050	0.032	0.066	3.594	6.566

Energy Costs and GHG Emissions Comparison – Conventional vs Net-Zero Facility

Energy prices were estimated based on the average historical energy prices observed at nine sample farms. The average prices are shown in the following table.

Table 5: Energy Prices

Price $	Energy Unit
$0.066/kWh	Energy cost of electricity
$0.050/kWh	Variable non-energy cost of electricity
$0.116/kWh	Effective variable cost of electricity
$5.804/GJ	Effective variable cost of natural gas
$1.030/L	Cost of diesel or gasoline

The following table shows that the net-zero facility is expected to have a $91/year higher energy consumption cost ($12,123/year) than the conventional facility ($12,032/year).

Table 6: Annual Energy Costs, Facility Totals, Conventional vs Net-Zero Design

	Annual Energy Costs (Effective Variable Costs)					
	Conventional Facility					Net-Zero Facility
	NatGas	Diesel	Gasoline	Electricity	Total	Electricity
Space Heating	$ 2,655				$ 2,655	$ 5,158
Lighting				$ 1,262	$ 1,262	$ 819
Hny Heating				$ 666	$ 666	$ 173
Indoor OW Refrigeration				$ 315	$ 315	$ 81
Indoor OW Fans				$ 1,610	$ 1,610	$ 656
Pressure Washer		$ 309			$ 309	$ 52
Oxalic Acid Vaporizer			$ 628		$ 628	$ 99
Wax Melting				$ 1,206	$ 1,206	$ 1,206
Extracting Motors/Air				$ 967	$ 967	$ 967
Circulators				$ 498	$ 498	$ 996
Pressure Wash Pump				$ 106	$ 106	$ 106
Tools & Other Electric				$ 124	$ 124	$ 124
Appliances				$ 366	$ 366	$ 366
Dehumidifier				$ 838	$ 838	$ 838
Circulation Fans				$ 159	$ 159	$ 159
Well Pump & Treatment				$ 323	$ 323	$ 323
Total	$ 2,655	$ 309	$ 628	$ 8,440	$ 12,032	$ 12,123

The following table shows the energy costs on a "per hive" basis, for potential comparison to farms planned with a different number of hives.

Table 7: Annual Energy Costs, "Per Hive", Conventional vs Net-Zero Design

	Annual Energy Costs Per Hive (Effective Variable Costs)					
	Conventional Facility					Net-Zero Facility
	NatGas	Diesel	Gasoline	Electricity	Total	Electricity
Space Heating	$ 0.287				$ 0.287	$ 0.558
Lighting				$ 0.137	$ 0.137	$ 0.089
Hny Heating				$ 0.072	$ 0.072	$ 0.019
Indoor OW Refrigeration				$ 0.034	$ 0.034	$ 0.009
Indoor OW Fans				$ 0.174	$ 0.174	$ 0.071
Pressure Washer		$ 0.033			$ 0.033	$ 0.006
Oxalic Acid Vaporizer			$ 0.068		$ 0.068	$ 0.011
Wax Melting				$ 0.131	$ 0.131	$ 0.131
Extracting Motors/Air				$ 0.105	$ 0.105	$ 0.105
Circulators				$ 0.054	$ 0.054	$ 0.108
Pressure Wash Pump				$ 0.012	$ 0.012	$ 0.012
Tools & Other Electric				$ 0.013	$ 0.013	$ 0.013
Appliances				$ 0.040	$ 0.040	$ 0.040
Dehumidifier				$ 0.091	$ 0.091	$ 0.091
Circulation Fans				$ 0.017	$ 0.017	$ 0.017
Well Pump & Treatment				$ 0.035	$ 0.035	$ 0.035
Total	$ 0.287	$ 0.033	$ 0.068	$ 0.913	$ 1.302	$ 1.312

The following figure shows the expected conventional vs net-zero energy costs per year, by equipment function. The additional Space Heating cost is significantly higher with the net-zero facility by avoiding the low cost natural gas as a heating source. Improvements in energy costs with other equipment functions help to offset additional Space Heating costs.

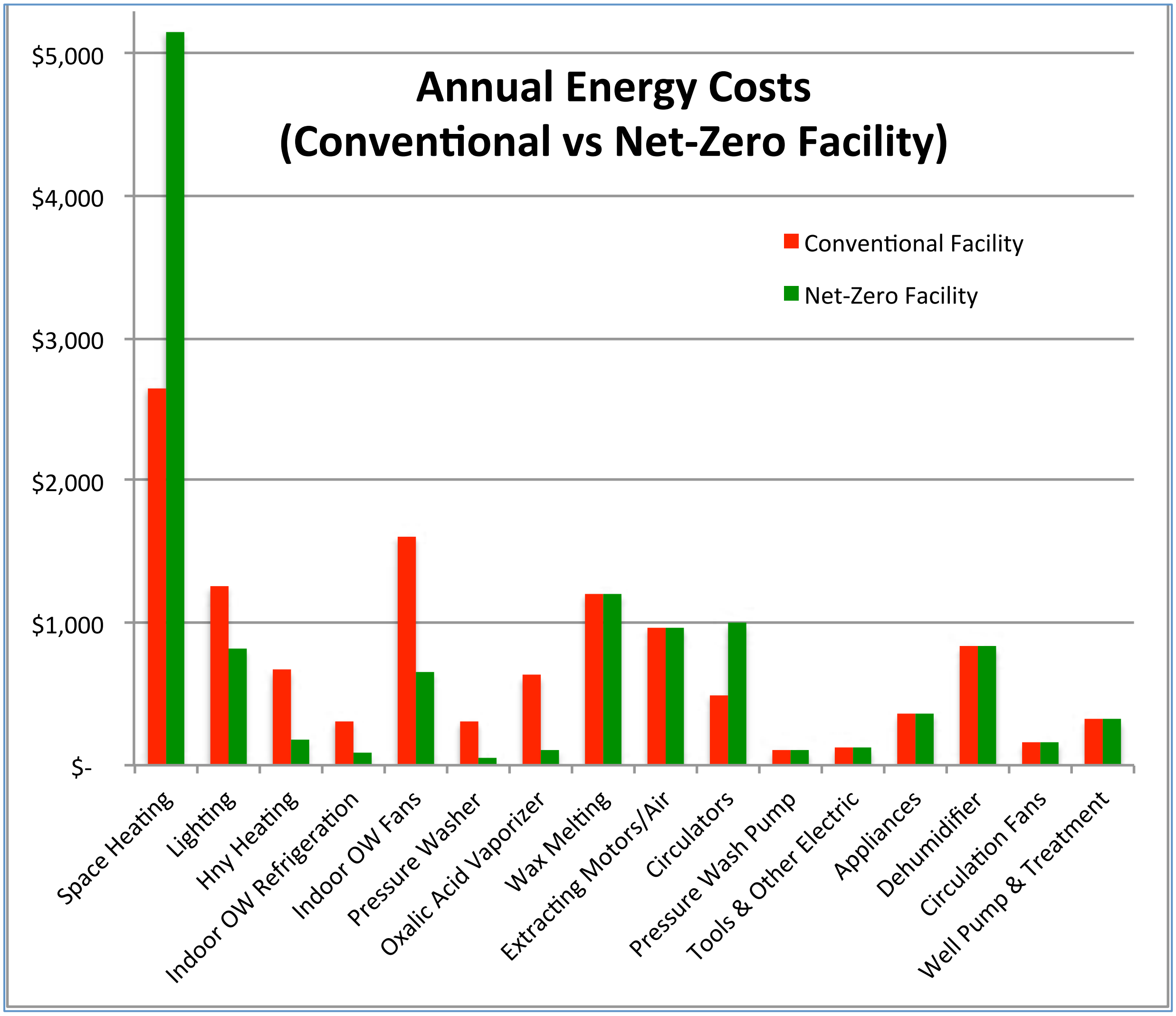

Figure 27: Annual Energy Costs Comparison Conventional vs Net-Zero Facility Design

The following figure shows the sources of GHG (greenhouse gas) emissions into the atmosphere associated with the energy consumption at the facility. GHG emissions are measured as tCO2e (tonnes of CO2 equivalent), which represents the tonnes of multiple types of greenhouse gases combined as an equivalent amount of CO2. The totals show that the conventional facility creates 74.08 tCO2e/year and the net-zero facility creates 0 tCO2e/year (net) after the renewable energy generation of the solar PV system.

Table 8: Annual GHG Emissions by Equipment and Energy Source, Conventional vs Net-Zero Design

	Annual GHG Emmissions (tCO2e, tons of CO2 equivalent greenhouse gases)					
	Conventional Facility					Net-Zero Facility
	NatGas	Diesel	Gasoline	Electricity	Total	Electricity
Space Heating	25.19				25.19	28.46
Lighting				6.96	6.96	4.52
Hny Heating				3.68	3.68	0.95
Indoor OW Refrigeration				1.74	1.74	0.45
Indoor OW Fans				8.88	8.88	3.62
Pressure Washer		0.84			0.84	0.29
Oxalic Acid Vaporizer			1.49		1.49	0.55
Wax Melting				6.65	6.65	6.65
Extracting Motors/Air				5.34	5.34	5.34
Circulators				2.75	2.75	5.50
Pressure Wash Pump				0.59	0.59	0.59
Tools & Other Electric				0.68	0.68	0.68
Appliances				2.02	2.02	2.02
Dehumidifier				4.62	4.62	4.62
Circulation Fans				0.88	0.88	0.88
Well Pump & Treatment				1.78	1.78	1.78
Solar PV Generation						-66.88
Total	25.19	0.84	1.49	46.56	74.08	0.00

Facility Construction Cost Comparison – Conventional vs Net-Zero Design

The following table shows the breakdown of the estimated cost differences between the net-zero facility construction costs and the conventional facility, which is a total of $222,796 higher cost to build the net-zero facility instead of the conventional facility. Negative values in the table indicate a cost savings with the net-zero facility when compared to the conventional facility.

Table 9: Net-Zero Facility Construction Cost Differences vs Conventional

	Cost "Differences" Only		
	Materials	**Labor/Install**	**Total**
Building Heat			
Hydronic heat system extra engineering & controls	$ 2,000	$ 5,000	$ 7,000
Heat pump system instead of NG boiler and dedicated OW refrigeration	$ 29,791	$ 4,500	$ 34,291
Hot solar-heated roof air ducting, dampers, and PV array air sealing	$ 1,000	$ 500	$ 1,500
Lighting			
LED lighting instead of T5/T8/T12/MH/HPS/CFL	$ 1,000	-$ 200	$ 800
Overwintering Room			
Additional air distribution ducts	$ 5,500	$ 4,500	$ 10,000
EC fans & controller upgrade from AC for recirc and stage 1 exhaust	$ 3,200	$ 600	$ 3,800
Oxalic Acid Vaporizer Portable Power System			
FLA battery (recond.) w inverter-charger instead of gasoline generator	$ 6,200		$ 6,200
Honey Heat Exchanger			
Plate heat exchanger from heat pump with circulator	$ 1,500	$ 600	$ 2,100
Pressure Washer			
High temp portable elec pump instead of diesel-fired heater w elec pump	-$ 2,000		-$ 2,000
Solar PV			
87.6kW Wall Awning and Rooftop Solar PV System	$ 159,105		$ 159,105
Total	$ 207,296	$ 15,500	$ 222,796

Economics of the Net-Zero Indoor Overwintering Beekeeping Facility

Based on escalating energy prices by 3% per year, and 2% reduction of indoor overwintering hive losses, the additional cost to build a net-zero facility instead of a conventional facility would be $222,796 including the installed cost of the solar PV system for $159,105 (without any rebates). The IRR would be 13.6% over a 30-year economic life, with a 9-year payback.

The first 5 years of cash flows for the economic calculation are shown in the following table.

Table 10: Net-Zero Facility Cash Flow First 5 Years (Cash Flow Difference vs Conventional)

Year	1	2	3	4	5
Net-Zero Construction & Equip Cost Difference	-$ 222,796				
Energy Consumption Costs	-$ 91	-$ 94	-$ 97	-$ 100	-$ 103
Solar PV Operating Cashflow	$ 10,286	$ 10,561	$ 10,843	$ 11,132	$ 11,429
Mechanical Maintenance	-$ 800	-$ 800	-$ 800	-$ 800	-$ 800
Overwintering Hive Loss Reduction	$ 16,632	$ 16,632	$ 16,632	$ 16,632	$ 16,632
Yearly Cost	-$ 196,770	$ 26,299	$ 26,579	$ 26,865	$ 27,158
Cumulative Cost	-$ 196,770	-$ 170,470	-$ 143,892	-$ 117,027	-$ 89,869
IRR, Net-Zero vs Conventional Facility	13.6%	IRR, 30-Years			
Payback =	9	years			

Economic Sensitivity Analysis – Overwintering Hive Loss Improvement

Sensitivity analysis was performed on the economic results for variations of the expected improvement to **indoor overwintered hive losses**. For hive loss improvements of 0% to 3%, the IRR ranged from 3.1% to 18.8% respectively, and payback varied from 22 years to 7 years.

The following figure shows the sensitivity of IRR and payback period, to variations in the improvement of indoor overwintering hive loss percentage.

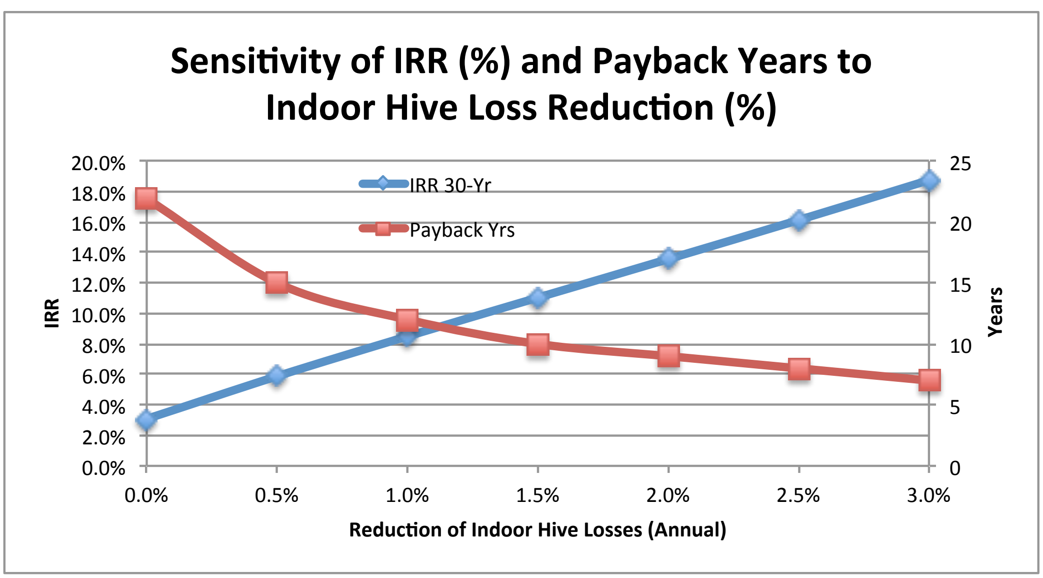

Figure 28: Sensitivity of IRR and Payback Years to variation in Indoor Hive Loss Reduction Percentage

The estimate of 2% for the improvement of indoor overwintered hive losses, compared to a conventional indoor overwintering room, is based on expected performance improvements of the net-zero design to improve on the following factors affecting hive losses:

1. Air speed near hive entrances affects the health of the bees because if air speeds are too low, the ventilation in the hives is reduced, which can cause humidity levels, temperatures, and CO2 levels to rise inside the hive above healthy overwintering levels for the bees. Also, if air speeds near hive entrances are too high, this can over-ventilate and over-cool the hives. Over-cooling of the hives can cause the colony to cluster more tightly, which increases the risk of the cluster losing their reach or accessibility to the food sources inside the hive.
2. Ideal humidity levels for overwintering bees can target a range of 30% to 75% relative humidity (RH). It is generally thought that "low" humidity increases the potential for feed granulation and can result in starvation of bees or that it can impair brood rearing, whereas "high" humidity is thought to cause problems with mold growth, cause water to condense inside the hives and drip on the winter cluster. [12]
3. The net-zero design includes CO2 sensors and a climate control system that can allow targeting CO2 levels in the room. Higher CO2 levels can be achieved by reducing the amount of fresh outdoor air added to the room while cooling the room using the refrigeration system. The use of the heat generated by the refrigeration system as heating for the adjacent buildings allows the net-zero design to more economically rely on refrigeration cooling instead of outdoor fresh air, which allows the net-zero design more control over CO2 levels than the conventional overwintering room. Research has shown results that support the theory that higher CO2 concentrations can be used as a treatment of Varroa mites. [11]
4. Fumigation treatments for hives inside the wintering room (e.g. oxalic acid vapor for Varroa mite treatment) could be more feasible [13] and effective with the increased air uniformity of the net-zero design, the space for fumigation equipment inside the walk-in air plenum corridor, and the increased capacity of air recirculation with the reduced reliance on outdoor fresh air for cooling.

Economic Sensitivity Analysis – Utility Grid Electricity Prices

Sensitivity analysis was also performed on the economic results for variations in **electricity prices**. For power price variations from $0.05/kWh to $0.27/kWh, the IRR ranged from 15.1% to 9.7% with paybacks ranging from 8 to 11 years.

The following figure shows the sensitivity of IRR and payback period, to variations in power prices.

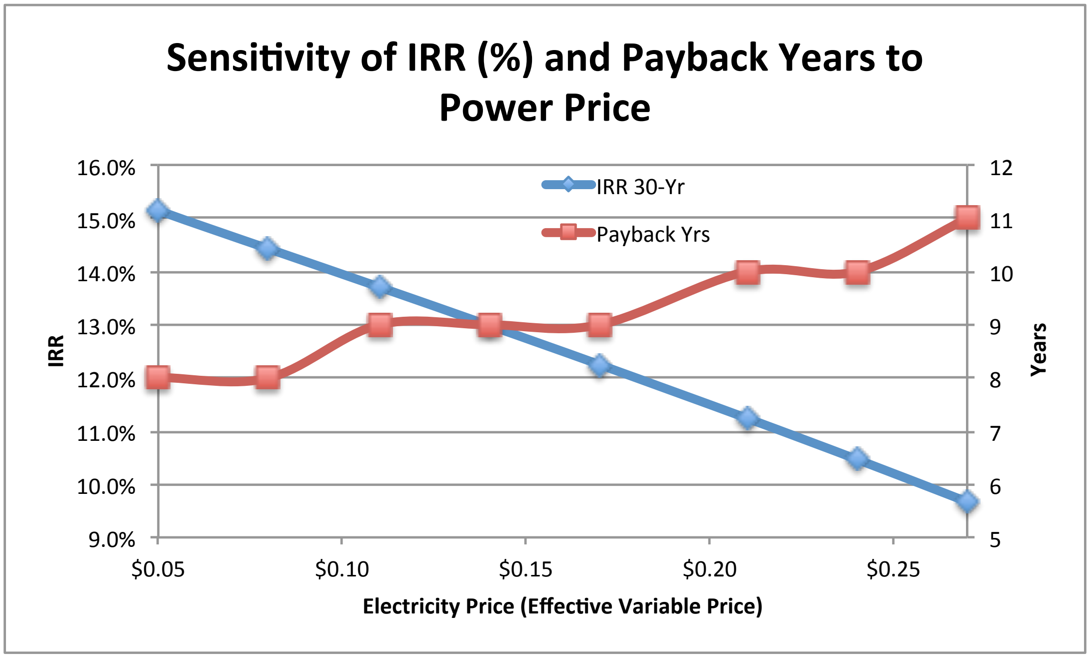

Figure 29: Sensitivity of IRR and Payback Years to variation in Power Price

5. Conclusions

The design of a net-zero commercial indoor overwintering beekeeping facility showed that the additional investment to build a net-zero facility instead of a conventional facility has a positive 13.6% IRR over a 30-year economic life, with a 9-year payback.

The net-zero facility is expected to eliminate 74.08 tCO2e (0.008 tCO2e per hive) of GHG from the atmosphere that a conventional facility would otherwise produce.

The sensitivity analysis showed that the return on investment is highly sensitive to the additional reduction in indoor overwintering hive losses that can be achieved with the design of the overwintering room proposed in this report.

To better measure and predict the outcome how much improvement to hive losses can be achieved with the net-zero indoor overwintering room design, two adjacent indoor overwintering rooms could be operated with on of the rooms implementing the net-zero design and the other operating conventionally.

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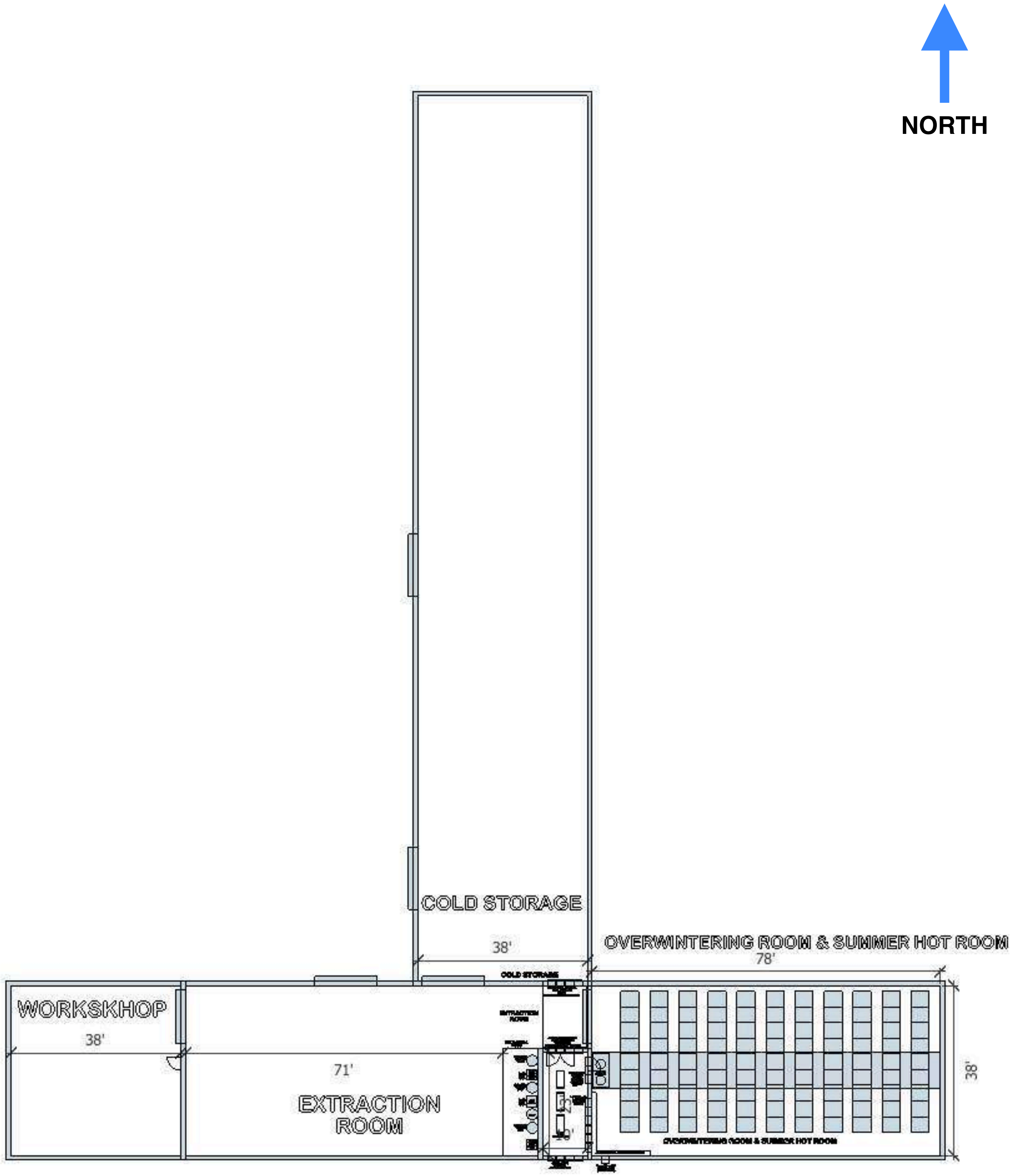
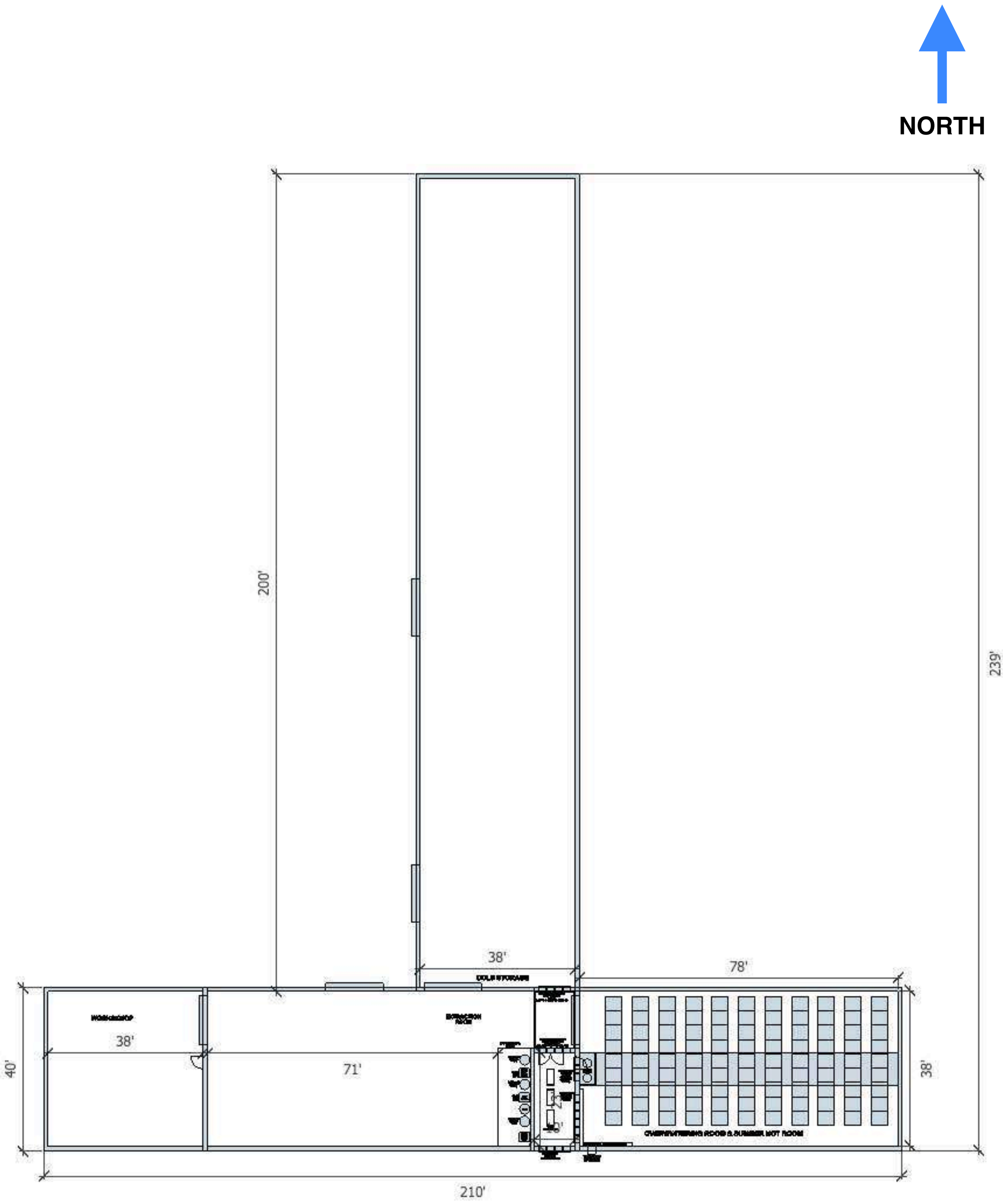
APPENDIX

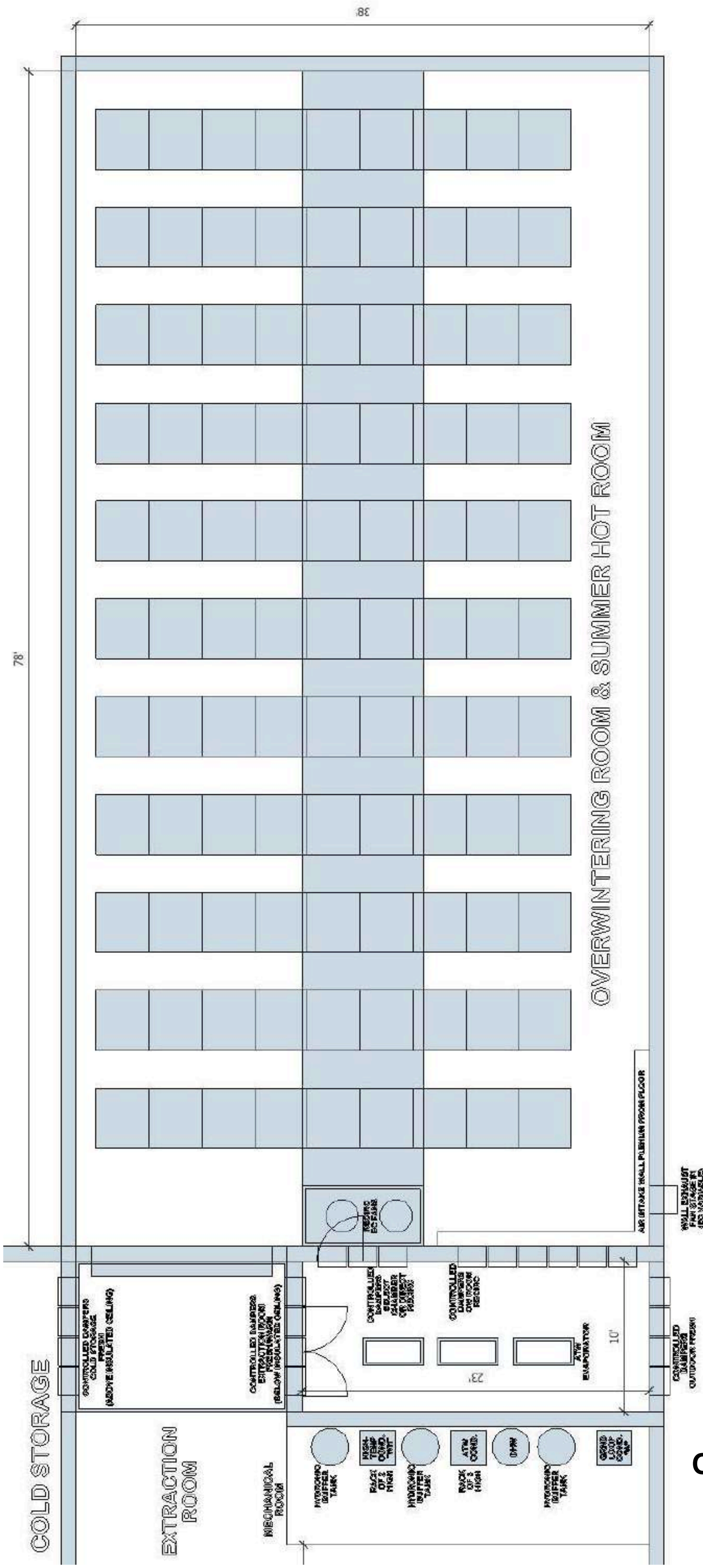
1. NET-ZERO FACILITY FLOOR LAYOUT PLAN
2. NET-ZERO FACILITY SOLAR PV ARRAY LAYOUT PLAN
3. SOLAR PV MODULES DATASHEET
4. SOLAR INVERTER DATASHEET
5. HEAT-PUMP EQUIPMENT SPECIFICATIONS (ATW-75, W-75, WH-55)



NET-ZERO FACILITY FLOOR LAYOUT PLAN

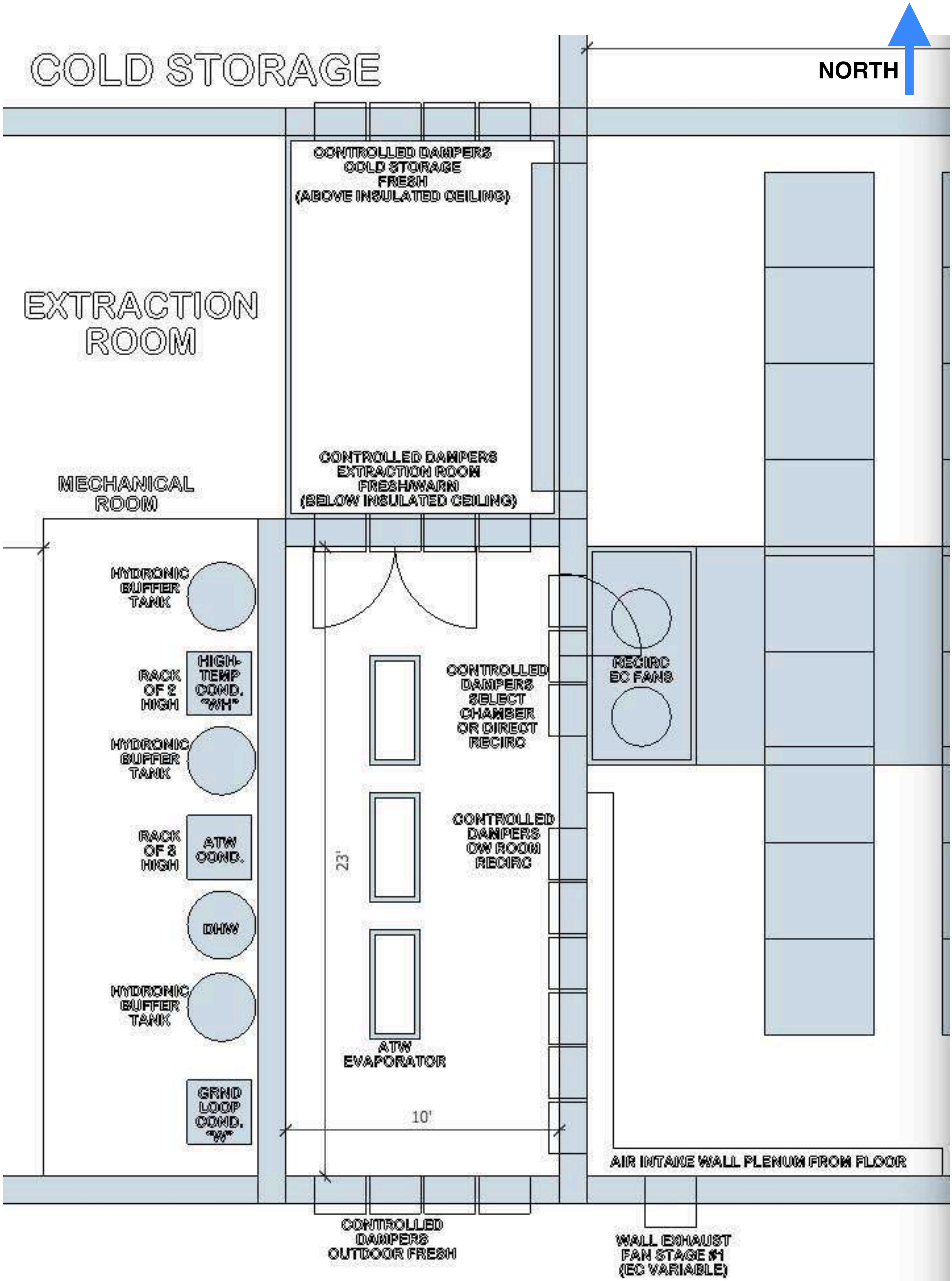


NET-ZERO FACILITY FLOOR LAYOUT PLAN

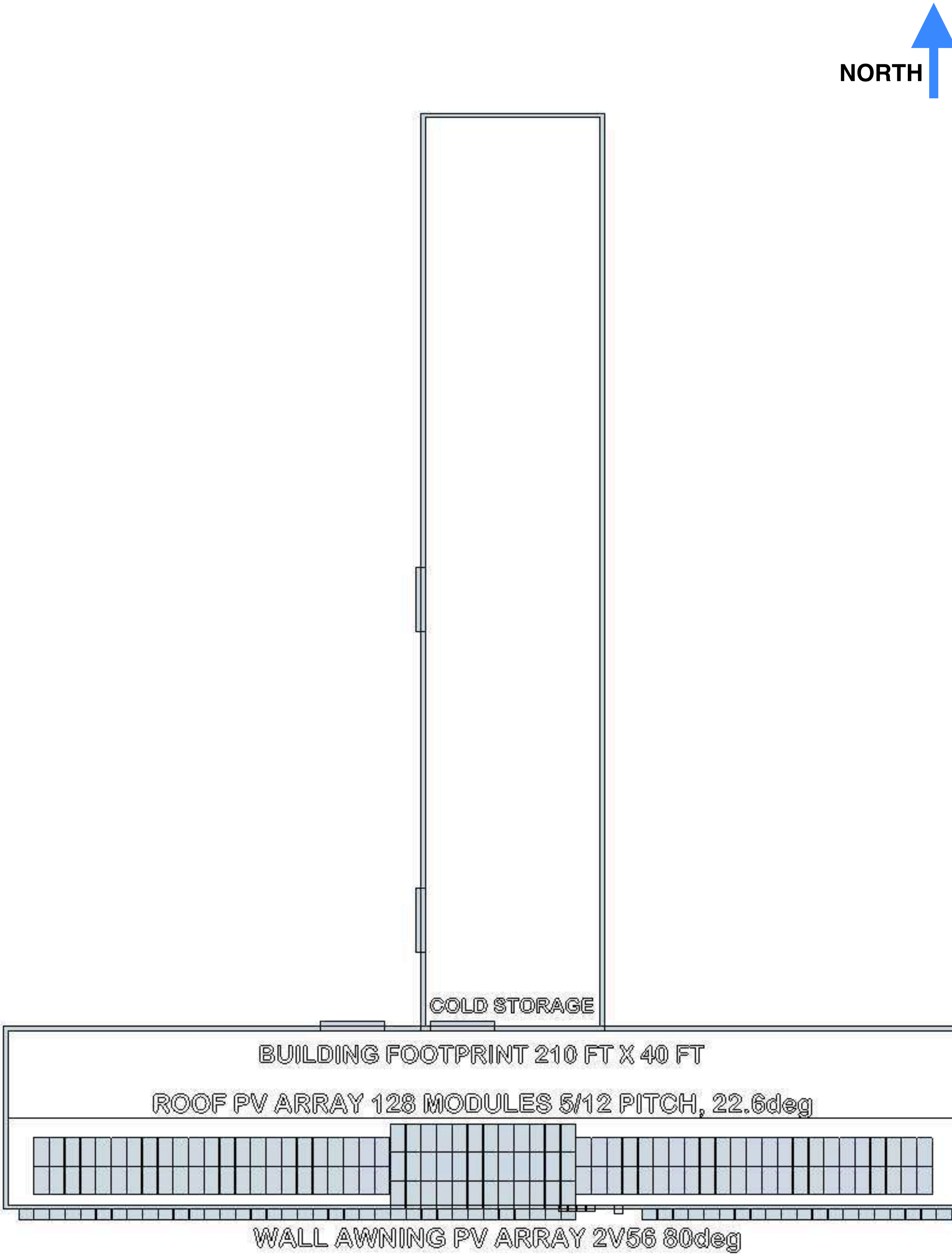


NORTH

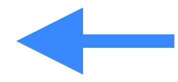
INDOOR OVERWINTERING ROOM LAYOUT PLAN

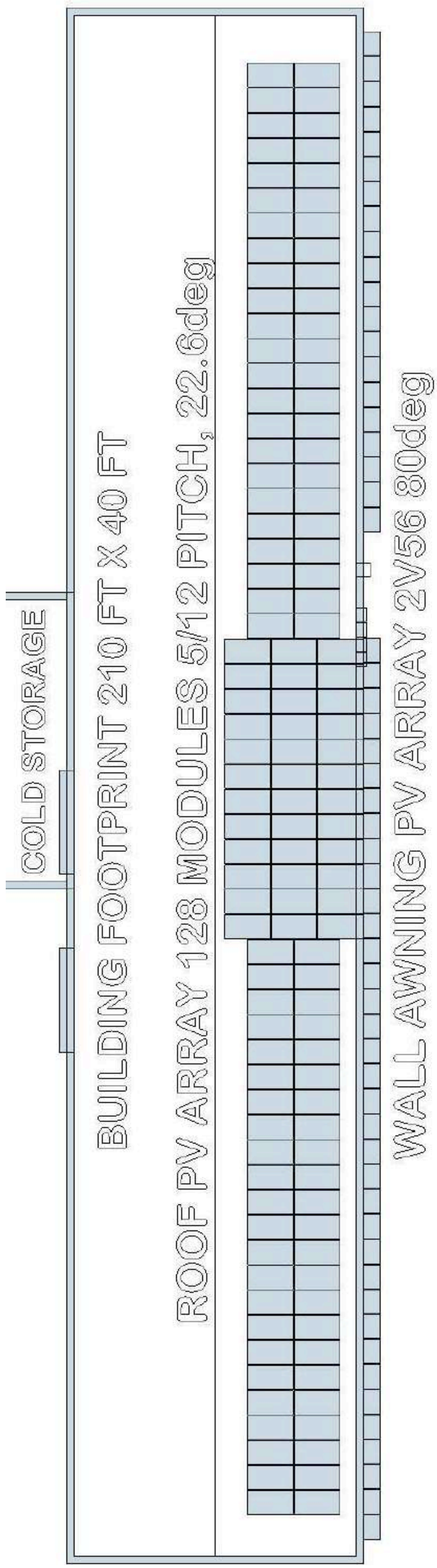


INDOOR OVERWINTERING RECIRC AIR PLENUM AND MECHNICAL ROOM LAYOUT PLAN



SOLAR PV WALL AWNING AND ROOFTOP ARRAY LAYOUT PLAN





SOLAR PV WALL AWNING AND ROOFTOP ARRAY LAYOUT PLAN

powered by Q.ANTUM

Q.PEAK L-G4.2 365-370

Q.ANTUM SOLAR MODULE

The new solar module Q.PEAK L-G4.2 with power classes up to 370 Wp is the strongest module of its type on the market globally. Powered by 72 Q.ANTUM solar cells Q.PEAK L-G4.2 was specially designed for large solar power plants to reduce BOS costs. Only Q CELLS offers German engineering quality with our unique Q CELLS Yield Security.

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2016

Q CELLS
YIELD SECURITY
ANTI PID TECHNOLOGY (APT)
HOT-SPOT PROTECT (HSP)
TRACEABLE QUALITY (TRA.Q™)

Photon
Q CELLS
Best polycrystalline solar module 2014
Q.PRO-G2 235
174 modules tested

LOW ELECTRICITY GENERATION COSTS

Higher yield per surface area and lower BOS costs thanks to higher power classes and an efficiency rate of up to 18.8 %.

INNOVATIVE ALL-WEATHER TECHNOLOGY

Optimal yields, whatever the weather with excellent low-light and temperature behavior.

ENDURING HIGH PERFORMANCE

Long-term yield security with Anti PID Technology[1], Hot-Spot Protect and Traceable Quality Tra.Q™.

EXTREME WEATHER RATING

High-tech aluminum alloy frame, certified for high snow (5400 Pa) and wind loads (2400 Pa).

A RELIABLE INVESTMENT

Inclusive 12-year product warranty and 25-year linear performance guarantee[2].

THE IDEAL SOLUTION FOR:

Ground-mounted solar power plants

[1] APT test conditions: Cells at -1500 V against grounded, with conductive metal foil covered module surface, 25 °C, 168 h

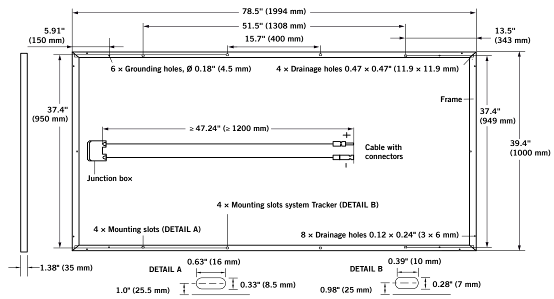
[2] See data sheet on rear for further information.

Engineered in **Germany**

Q CELLS

MECHANICAL SPECIFICATION

Format	78.5 in × 39.4 in × 1.38 in (including frame) (1994 mm × 1000 mm × 35 mm)
Weight	52.9 lbs (24 kg)
Front Cover	0.13 in (3.2 mm) thermally pre-stressed glass with anti-reflection technology
Back Cover	Composite film
Frame	Anodized aluminum
Cell	6 × 12 monocrystalline Q.ANTUM solar cells
Junction box	3.35-4.37 in × 2.36-3.15 in × 0.59-0.75 in (85-111 × 60-80 × 15-19 mm), Protection class IP67, with bypass diodes
Cable	4 mm² Solar cable; (+) ≥ 47.24 in (1200 mm), (-) ≥ 47.24 in (1200 mm)
Connector	Multi-Contact MC4-EVO 2, IP68

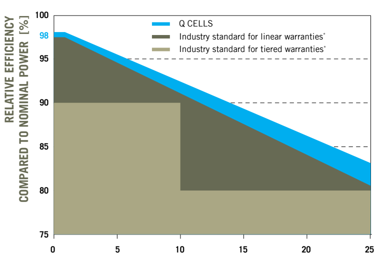


ELECTRICAL CHARACTERISTICS

POWER CLASS			365	370
MINIMUM PERFORMANCE AT STANDARD TEST CONDITIONS, STC[1] (POWER TOLERANCE +5 W / -0 W)				
Minimum — **Power at MPP[2]**	P_{MPP}	[W]	365	370
Short Circuit Current*	I_{SC}	[A]	9.83	9.89
Open Circuit Voltage*	V_{OC}	[V]	48.00	48.28
Current at MPP*	I_{MPP}	[A]	9.33	9.41
Voltage at MPP*	V_{MPP}	[V]	39.10	39.32
Efficiency[2]	η	[%]	≥18.3	≥18.6
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NOC[3]				
Minimum — **Power at MPP[2]**	P_{MPP}	[W]	270.1	273.8
Short Circuit Current*	I_{SC}	[A]	7.93	7.97
Open Circuit Voltage*	V_{OC}	[V]	44.90	45.17
Current at MPP*	I_{MPP}	[A]	7.34	7.40
Voltage at MPP*	V_{MPP}	[V]	36.81	36.98

[1] 1000 W/m², 25 °C, spectrum AM 1.5 G [2] Measurement tolerances STC ±3%; NOC ±5% [3] 800 W/m², NOCT, spectrum AM 1.5 G * typical values, actual values may differ

Q CELLS PERFORMANCE WARRANTY

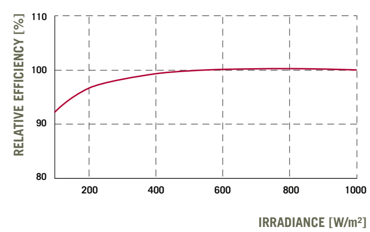


*Standard terms of guarantee for the 10 PV companies with the highest production capacity in 2014 (as at: September 2014)

At least 98 % of nominal power during first year. Thereafter max. 0.6 % degradation per year. At least 92.6 % of nominal power up to 10 years. At least 83.6 % of nominal power up to 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Q CELLS sales organization of your respective country.

PERFORMANCE AT LOW IRRADIANCE



Typical module performance under low irradiance conditions in comparison to STC conditions (25 °C, 1000 W/m²).

TEMPERATURE COEFFICIENTS

Temperature Coefficient of I_{SC}	α	[%/K]	+0.04	**Temperature Coefficient of V_{OC}**	β	[%/K]	−0.28
Temperature Coefficient of P_{MPP}	γ	[%/K]	−0.39	**Normal Operating Cell Temperature**	NOCT	[°F]	113 ± 5.4 (45 ± 3 °C)

PROPERTIES FOR SYSTEM DESIGN

Maximum System Voltage V_{SYS}	[V]	1500 (IEC) / 1500 (UL)	**Safety Class**	II
Maximum Series Fuse Rating	[A DC]	20	**Fire Rating**	C (IEC) / TYPE 1 (UL)
Design load, push (UL)[2]	[lbs/ft²]	75 (3600 Pa)	**Permitted module temperature on continuous duty**	-40 °F up to +185 °F (-40 °C up to +85 °C)
Design load, pull (UL)[2]	[lbs/ft²]	33 (1600 Pa)	[2] see installation manual	

QUALIFICATIONS AND CERTIFICATES

IEC 61215 (Ed. 2); IEC 61730 (Ed. 1), Application class A
This data sheet complies with DIN EN 50380.

C Certified UL 1703 (254141) US

PACKAGING INFORMATION

Number of Modules per Pallet	29
Number of Pallets per 40' Container	22
Number of Pallets per 53' Container	26
Pallet Dimensions (L × W × H)	81.3 × 45.3 × 46.9 in (2065 × 1150 × 1190 mm)
Pallet Weight	1671 lbs (758 kg)

NOTE: Installation instructions must be followed. See the installation and operating manual or contact our technical service department for further information on approved installation and use of this product.

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Engineered in **Germany**

/ Perfect Welding / Solar Energy / Perfect Charging

Fronius

SHIFTING THE LIMITS

FRONIUS PRIMO

/ SnapINverter mounting system

/ Wireless monitoring

/ Open data communication

/ Smart Grid Ready

/ Arc Fault Circuit Interruption

The transformerless Fronius Primo is the ideal compact single-phase inverter for residential and small-scale commercial applications with power categories from 3.8 to 8.2 kW. In accordance with ESA rules for residential applications, the Fronius Primo can operate efficiently at a maximum input voltage of 600 V. And for increased efficiency and additional cost savings for commercial applications, the Fronius Primo can operate at the maximum input voltage of 1,000 V. Industry-leading features now come standard with the Fronius Primo, including: dual maximum power point tracking, arc fault protection, integrated wireless monitoring and SunSpec Modbus interfaces for seamless monitoring and datalogging via Fronius' online and mobile platform, Fronius Solar.web.

TECHNICAL DATA FRONIUS PRIMO

GENERAL DATA	FRONIUS PRIMO 3.8 - 8.2	FRONIUS PRIMO 10.0-15.0
Dimensions (width x height x depth)	16.9 x 24.7 x 8.1 in. / 42.9 x 62.7 x 20.6 cm	20.1 x 28.5 x 8.9 in. / 51.1 x 72.4 x 20.6 cm
Weight	47.4 lb. / 21.5 kg	82.5 lbs. / 37.4 kg
Degree of protection	NEMA 4X	
Night time consumption	< 1 W	
Inverter topology	Transformerless	
Cooling	Controlled forced ventilation, variable speed fan	
Installation	Indoor and outdoor installation	
Ambient operating temperature range	-40 to 131 F / -40 to 55 C	-40 to 140 F / -40 to 60 C
Permitted humidity	0 - 100 %	
DC connection terminals	2x DC+1, 2x DC+2 and 4x DC- screw terminals for solid: copper and aluminium stranded / fine stranded: copper and aluminium	4x DC+1, 2x DC+2 and 6x DC- screw terminals for copper (solid / stranded / fine stranded) or aluminum (solid / stranded)
AC connection terminals	Screw terminals 12 - 6 AWG	
Revenue Grade Metering	Optional (ANSI C12.1 accuracy)	
Certificates and compliance with standards	UL 1741-2015, UL1998 (for functions: AFCI, RCMU and isolation monitoring), IEEE 1547-2003, IEEE 1547.1-2003, ANSI/IEEE C62.41, FCC Part 15 A & B, NEC 2014 Article 690, C22. 2 No. 107.1-01 (September 2001) , UL1699B Issue 2 -2013, CSA TIL M-07 Issue 1 -2013	UL 1741-2015, UL1998 (for functions: AFCI, RCMU and isolation monitoring), IEEE 1547-2003, IEEE 1547.1-2003, ANSI/IEEE C62.41, FCC Part 15 A & B, NEC Article 690-2014, C22. 2 No. 107.1-01 (September 2001) , UL1699B Issue 2 -2013, CSA TIL M-07 Issue 1 -2013

PROTECTIVE DEVICES	STANDARD WITH ALL PRIMO MODELS
AFCI	Yes
Ground Fault Protection with Isolation Monitor Interrupter	Yes
DC disconnect	Yes
DC reverse polarity protection	Yes

INTERFACES	AVAILABILITY	AVAILABLE WITH ALL FRONIUS PRIMO MODELS
USB (A socket)	Standard	Datalogging and inverter update via USB
2x RS422 (RJ45 socket)	Standard	Fronius Solar Net, interface protocol
Wi-Fi*/Ethernet/Serial/Datalogger and webserver	Optional	Wireless standard 802.11 b/g/n / Fronius Solar.web, SunSpec Modbus TCP, JSON / SunSpec Modbus RTU
6 inputs or 4 digital inputs/outputs	Optional	External relay controls

*The term Wi-Fi® is a registered trademark of the Wi-Fi Alliance.

TECHNICAL DATA FRONIUS PRIMO 3.8-1 TO 8.2-1

INPUT DATA	PRIMO 3.8-1	PRIMO 5.0-1	PRIMO 6.0-1	PRIMO 7.6-1	PRIMO 8.2-1
Max. permitted PV power (kWp)	5.7 kW	7.5 kW	9.0 kW	11.4 kW	12.3 kW
Max. usable input current (MPPT 1/MPPT 2)	18 A / 18 A	18 A / 18 A	18 A / 18 A	18 A / 18 A	18 A / 18 A
Total max. DC current	36 A				
Max. admissible input current (MPPT 1/MPPT 2)	27 A				
Operating voltage range	80 V - 1,000 V				
Max. input voltage	1,000 V				
Nominal input voltage	410 V	420 V	420 V	420 V	420 V
Admissible conductor size DC	AWG 14 - AWG 6				
MPP voltage range	200 - 800 V	240 - 800 V	240 - 800 V	250 - 800 V	270 - 800 V
Number of MPPT	2				

OUTPUT DATA		PRIMO 3.8-1	PRIMO 5.0-1	PRIMO 6.0-1	PRIMO 7.6-1	PRIMO 8.2-1
Max. output power	240 V	3,800 W	5,000 W	6,000 W	7,600 W	8,200 W
	208 V	3,800 W	5,000 W	6,000 W	7,600 W	7,900 W
Max. output fault current / Duration	240 V	584 A Peak / 154 ms	584 A Peak / 154 ms	584 A Peak / 154 ms	584 A Peak / 154 ms	584 A Peak / 154 ms
Max. continuous output current	240 V	15.8 A	20.8 A	25.0 A	31.7 A	34.2 A
	208 V	18.3 A	24.0 A	28.8 A	36.5 A	38.0 A
Recommended OCPD/AC breaker size	240 V	20 A	30 A	35 A	40 A	45 A
	208 V	25 A	30 A	40 A	50 A	50 A
Max. efficiency (Lite version)		97.9 %				
CEC efficiency (Lite version)	240 V	95.5 %	96.5 %	96.5 %	97.0 %	97.0 %
Admissible conductor size AC		AWG 14 - AWG 6				
Grid connection		208 / 240 V				
Frequency		60 Hz				
Total harmonic distortion		< 5.0 %				
Power factor (cos $\varphi_{ac,r}$)		0.85 - 1 ind./cap				

TECHNICAL DATA FRONIUS PRIMO 10.0-1 TO 15.0-1

INPUT DATA	PRIMO 10.0-1	PRIMO 11.4-1	PRIMO 12.5-1	PRIMO 15.0-1
Max. permitted PV power (kWp)	15.00 kW	17.10 kW	18.75 kW	22.50 kW
Max. usable input current (MPPT 1/MPPT 2)	33.0 A / 18.0 A			
Total max. DC current	51 A			
Max. admissible input current (MPPT 1/MPPT 2)	49.5 A / 27.0 A			
Operating voltage range	80 V - 1,000 V			
Max. input voltage	1,000 V			
Nominal input voltage	655 V	660 V	665 V	680 V
Admissible conductor size DC	AWG 14 - AWG 6 copper direct, AWG 6 aluminum direct, AWG 4 - AWG 2 copper or aluminum with optional input combiner			
MPP Voltage Range	220 - 800 V	240 - 800 V	260 - 800 V	320 - 800 V
Number of MPPT	2			

OUTPUT DATA		PRIMO 10.0-1	PRIMO 11.4-1	PRIMO 12.5-1	PRIMO 15.0-1
Max. output power	240 V	9,995 W	11,400 W	12,500 W	15,000 W
	208 V	9,995 W	11,400 W	12,500 W	13,750 W
Max. output fault current / Duration	240 V	916 A Peak / 6.46 ms	916 A Peak / 6.46 ms	916 A Peak / 6.46 ms	916 A Peak / 6.46 ms
Max. continuous output current	240 V	41.6 A	47.5 A	52.1 A	62.5 A
	208 V	48.1 A	54.8 A	60.1 A	66.1 A
Recommended OCPD/AC breaker size	240 V	60 A	60 A	70 A	80 A
	208 V	60 A	70 A	80 A	90 A
Max. efficiency (Lite version)		97.9 %			
CEC efficiency (Live version)	240 V	96.5 %	96.5 %	96.5 %	97.0 %
Admissible conductor size AC		AWG 10 - AWG 2 copper (solid / stranded / fine stranded) , AWG 6 - AWG 2 copper (solid / stranded)			
Grid connection		208 / 240 V			
Frequency		60 Hz			
Total harmonic distortion		< 2.5 %			
Power factor (cos $\varphi_{ac,r}$)		0-1 ind./cap.			

December 12, 2016

MARITIME GEOTHERMAL LTD.

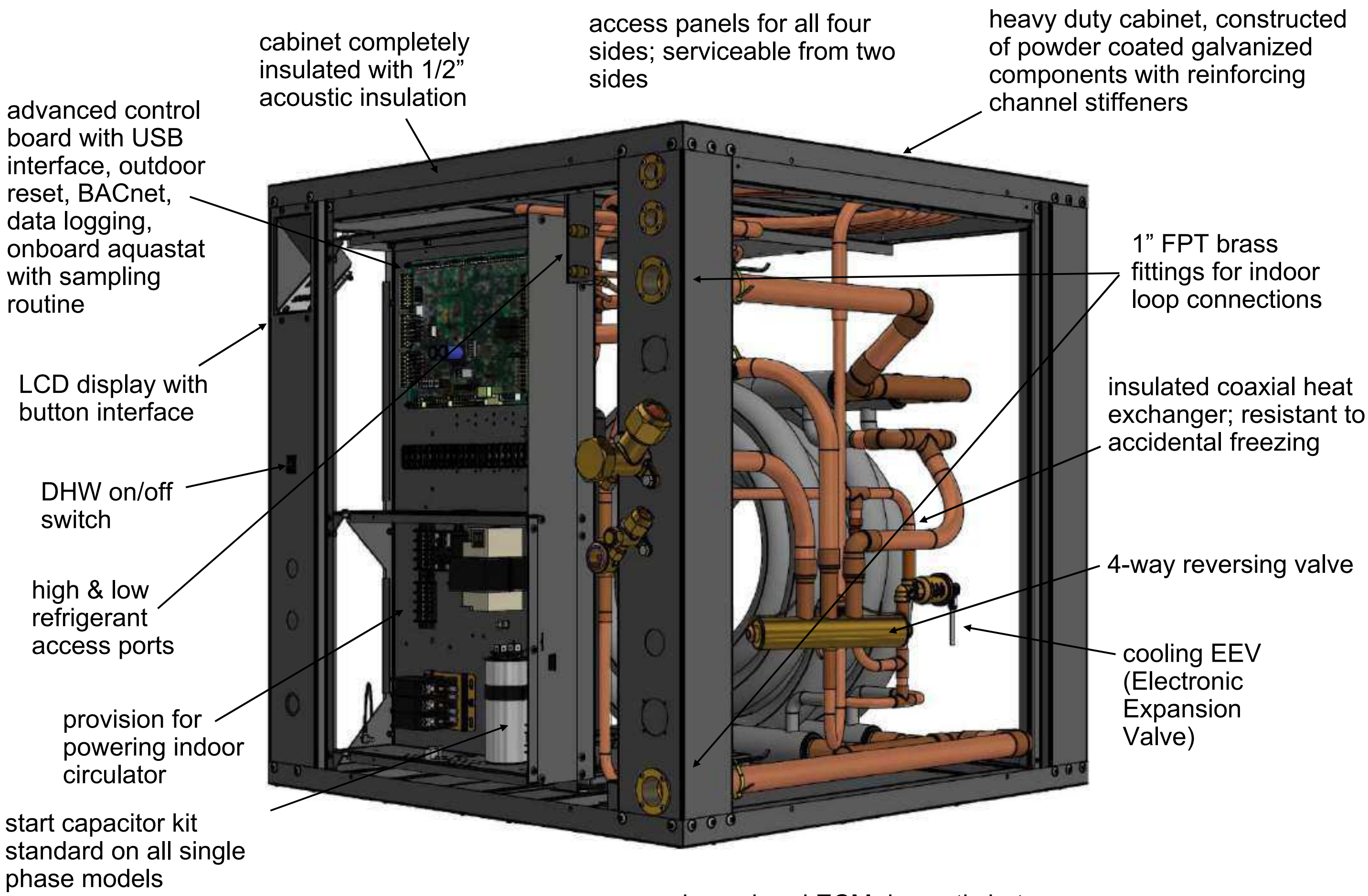
Engineering Specification

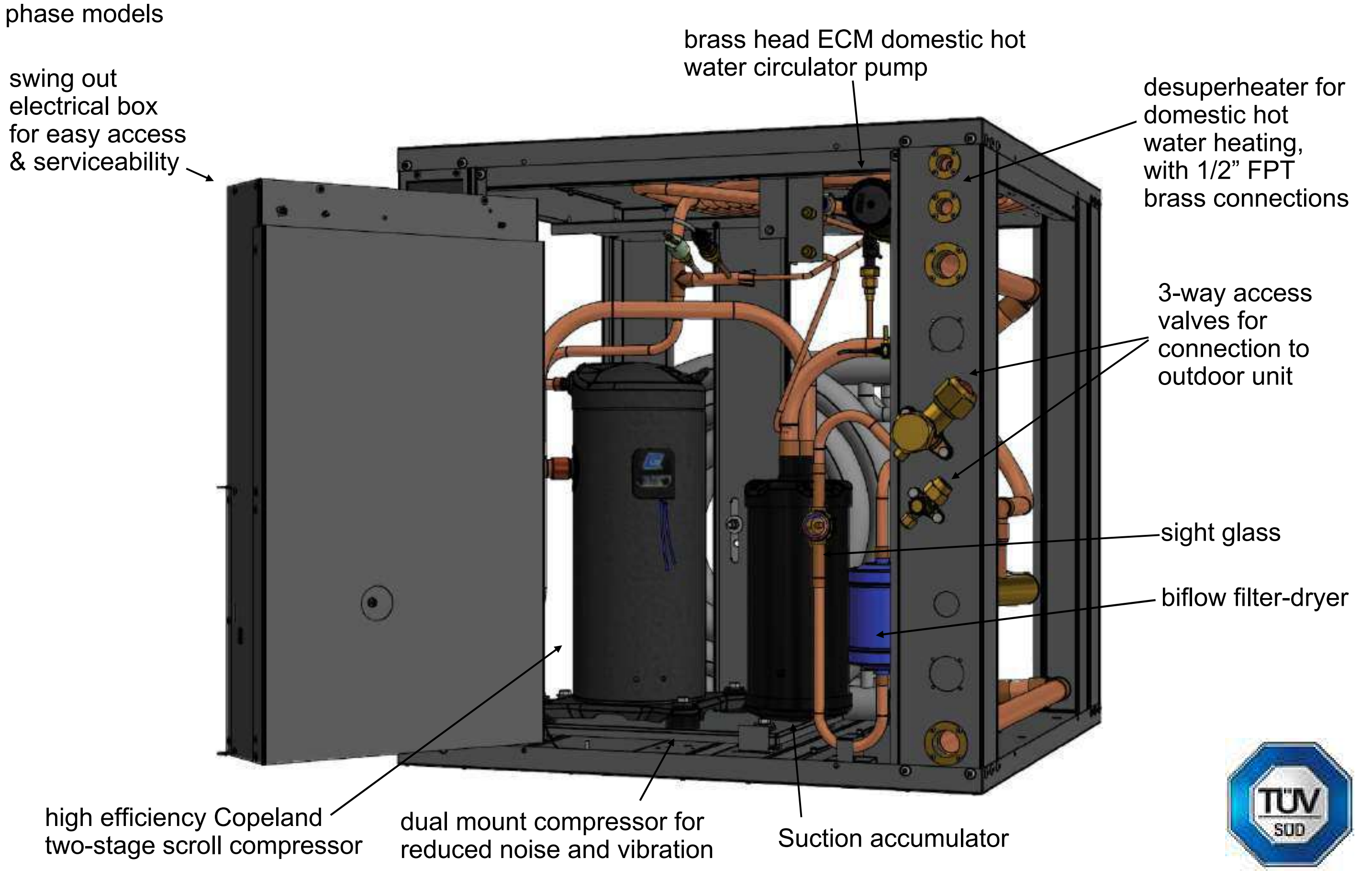
ATW-75-HACW-P-*T-*
Air to Water Heat Pump
60 Hz

Maritime Geothermal Ltd.
P.O. Box 2555, 170 Plantation Road
Petitcodiac, NB E4Z 6H4
(506) 756-8135

info@nordicghp.com
www.nordicghp.com
001851SPC-03

Design Features - Indoor Unit

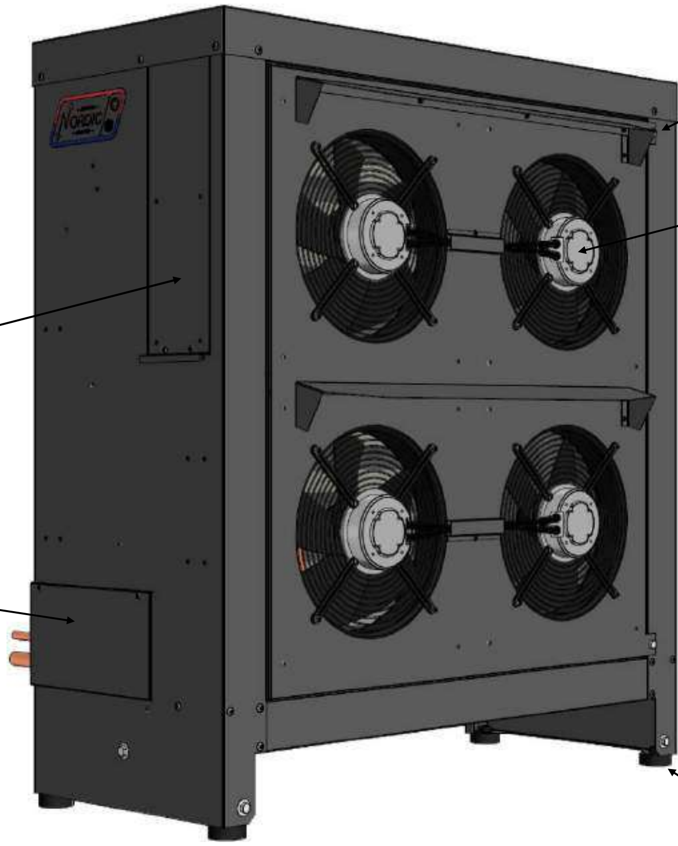




Design Features - Outdoor Unit

minimal components in outdoor unit, for maximum component life and ease of service

visors protect motors from water ingress and immobilization from freezing



EC (electronically commutated) fan hub motors, for full variable speed operation and maximum energy efficiency

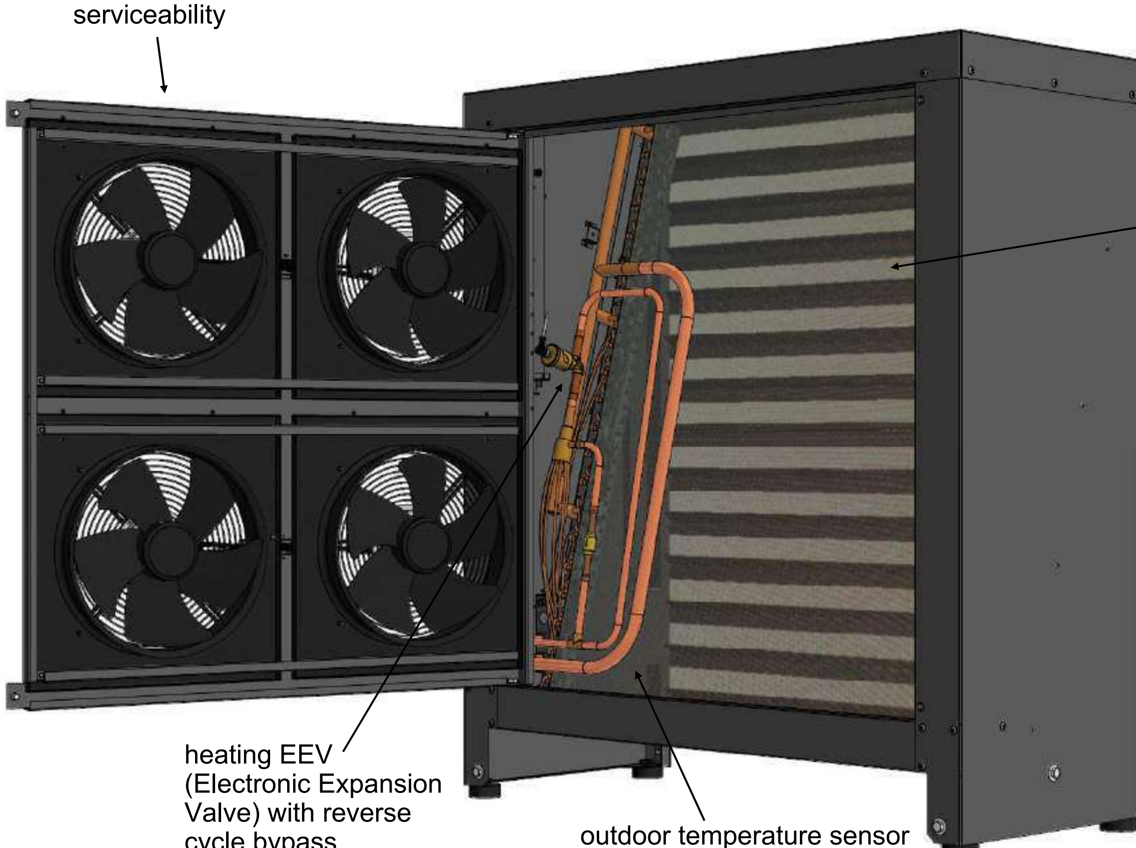
electrical box contains only connection terminal strips

heavy duty cabinet, constructed of powder coated galvanized components

side cover protects refrigerant pipes & wiring connection point

mounting grommets for vibration isolation

swing out fan panel for easy access & serviceability



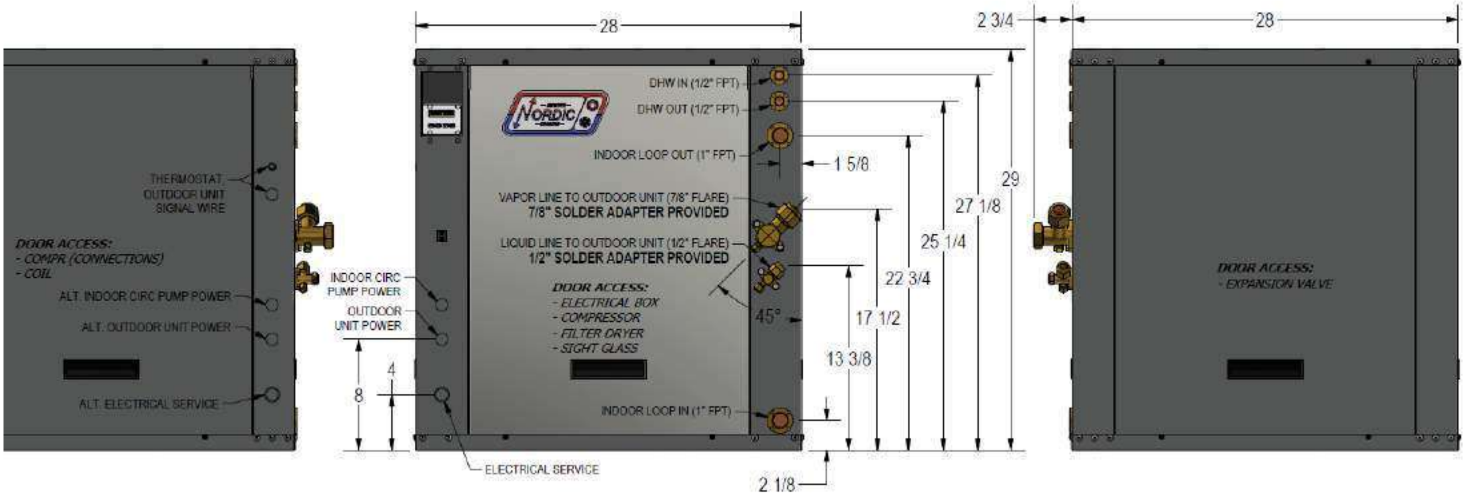
air coil with heavy duty fins, installed at slant for most effective condensate runoff and no drip tray where condensate could re-freeze

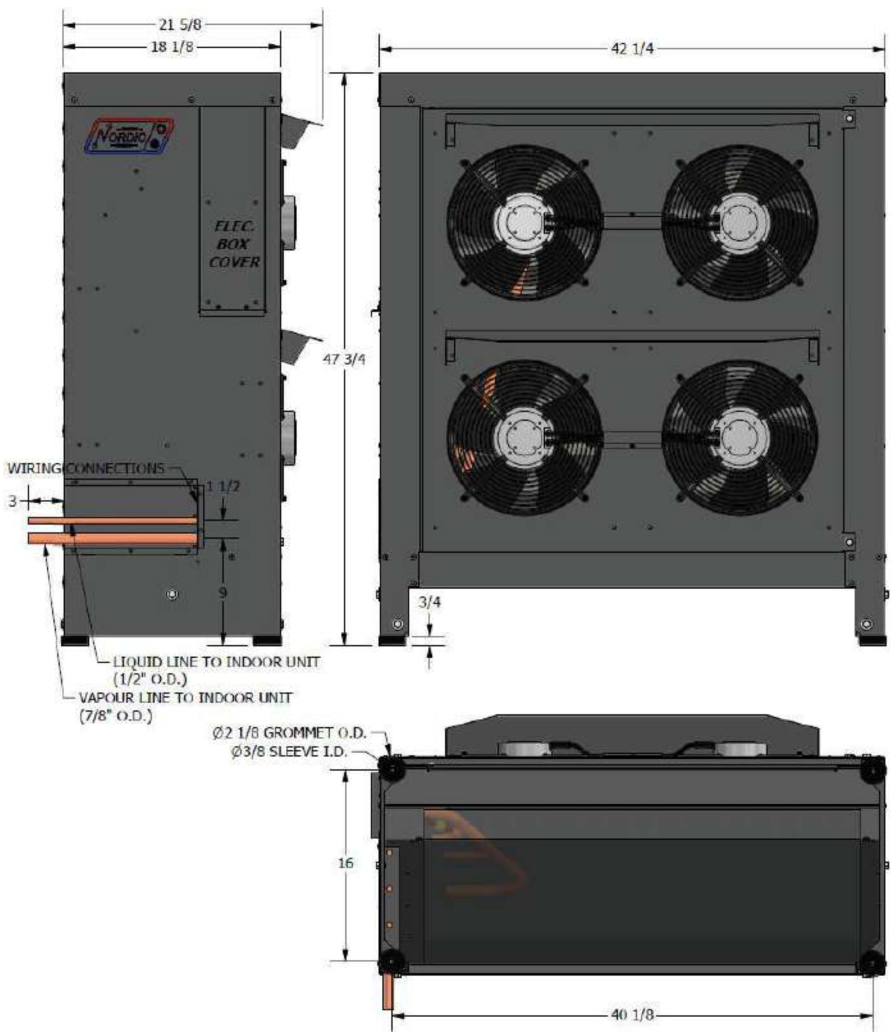
intelligent defrost logic eliminates unnecessary defrosts and ensures complete defrost each time

heating EEV (Electronic Expansion Valve) with reverse cycle bypass

outdoor temperature sensor reads out on indoor unit

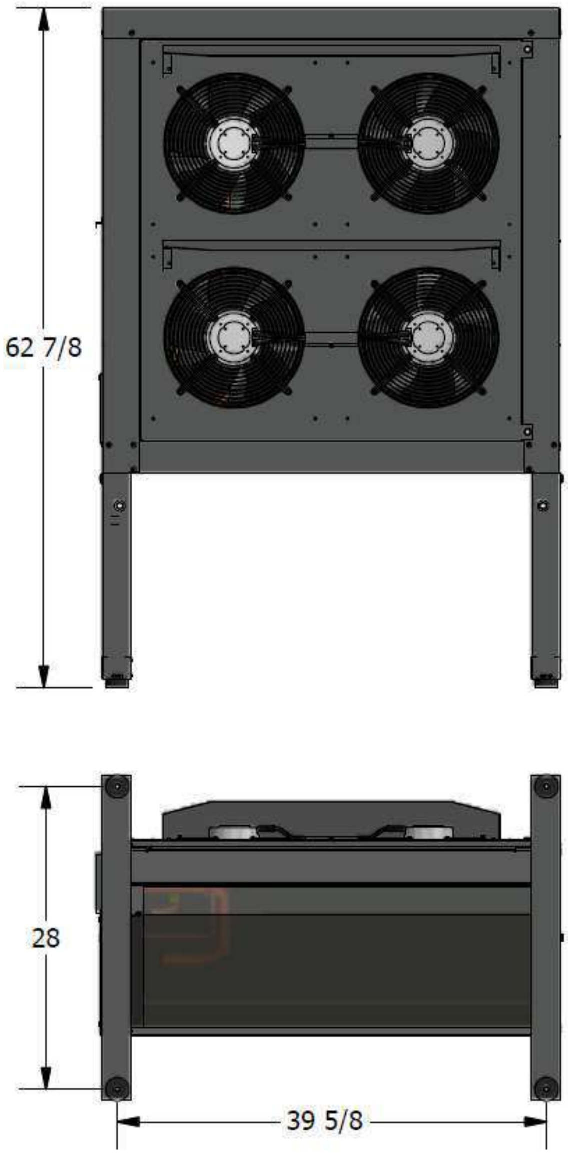
Dimensions


28
2 3/4
28
DHW IN (1/2" FPT)
DHW OUT (1/2" FPT)
INDOOR LOOP OUT (1" FPT)
1 5/8
29
27 1/8
25 1/4
22 3/4
17 1/2
13 3/8
45°
VAPOR LINE TO OUTDOOR UNIT (7/8" FLARE)
7/8" SOLDER ADAPTER PROVIDED
LIQUID LINE TO OUTDOOR UNIT (1/2" FLARE)
1/2" SOLDER ADAPTER PROVIDED
DOOR ACCESS:
- ELECTRICAL BOX
- COMPRESSOR
- FILTER DRYER
- SIGHT GLASS
INDOOR LOOP IN (1" FPT)
2 1/8
ELECTRICAL SERVICE
INDOOR CIRC PUMP POWER
OUTDOOR UNIT POWER
8
4
THERMOSTAT, OUTDOOR UNIT SIGNAL WIRE
DOOR ACCESS:
- COMPR. (CONNECTIONS)
- COIL
ALT. INDOOR CIRC PUMP POWER
ALT. OUTDOOR UNIT POWER
ALT. ELECTRICAL SERVICE
DOOR ACCESS:
- EXPANSION VALVE

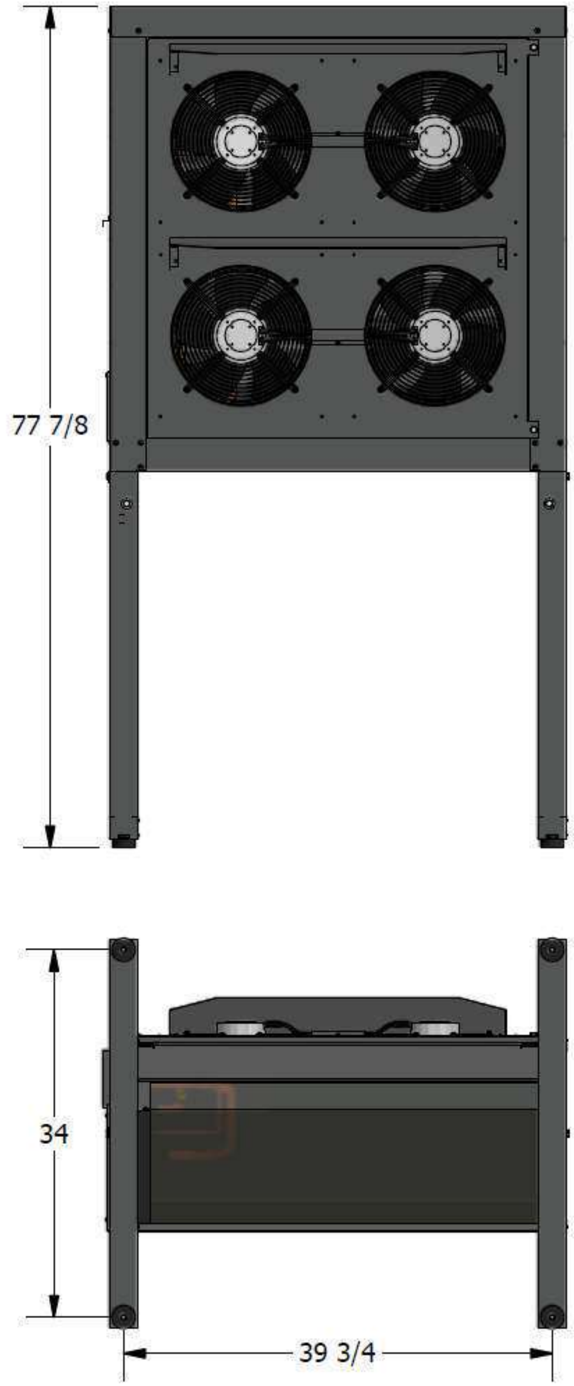

21 5/8
18 1/8
42 1/4
47 3/4
ELEC BOX COVER
WIRING CONNECTIONS
3
1 1/2
9
3/4
LIQUID LINE TO INDOOR UNIT (1/2" O.D.)
VAPOUR LINE TO INDOOR UNIT (7/8" O.D.)
Ø2 1/8 GROMMET O.D.
Ø3/8 SLEEVE I.D.
16
40 1/8

Dimensions

WITH LEG KIT



WITH TALL LEG KIT



Performance Tables ATW-75-HACW-P-1T *R410a, 60 Hz, ZPS60K5E-PFV*

	OUTDOOR			ELECTRICAL		INDOOR						
	Outdoor Air Temperature	Evaporating Temperature	Heat Absorbed (Btu/hr)	Compressor Current (A)	Input Power (W)	ELT	Condensing Temperature	Liquid Flow (gpm)	**LLT**	Delta T	**Heating (Btu/hr)**	**COP_H**
HEATING	**-5°F**	-16°F	7,910	23.1	5140	102°F	110°F	16	**105°F**	3°F	**25,100**	**1.43**
	5°F	-8°F	14,900	21.5	4820	101°F	109°F			4°F	**30,900**	**1.88**
	15°F	1°F	21,600	20.9	4690	100°F	109°F			5°F	**37,200**	**2.32**
	25°F	9°F	29,100	19.6	4440	100°F	109°F			5°F	**43,900**	**2.89**
	35°F	17°F	36,500	18.8	4270	99°F	109°F			6°F	**50,600**	**3.48**
	45°F	26°F	43,900	18.1	4120	98°F	108°F			7°F	**57,600**	**4.09**
	55°F	34°F	51,700	17.5	3980	97°F	108°F			8°F	**64,900**	**4.77**
	65°F	43°F	60,100	16.9	3820	96°F	108°F			9°F	**72,800**	**5.58**
	-5°F	-16°F	-	-	-	-	-	16	**120°F**	*LLT is limited to 105°F at these outdoor temperatures*		
	5°F	-8°F	-	-	-	-	-					
	15°F	1°F	19,100	24.3	5540	115°F	124°F			5°F	**37,100**	**1.99**
	25°F	9°F	25,900	22.9	5250	115°F	124°F			5°F	**43,400**	**2.42**
	35°F	17°F	32,500	22.0	5050	114°F	123°F			6°F	**49,400**	**2.86**
	45°F	26°F	39,300	21.2	4890	113°F	123°F			7°F	**55,600**	**3.33**
	55°F	34°F	46,400	20.6	4730	112°F	123°F			8°F	**62,100**	**3.85**
	65°F	43°F	54,100	19.8	4540	111°F	123°F			9°F	**69,300**	**4.47**

	Outdoor Air Temperature	Condensing Temperature	Heat Rejected (Btu/hr)	Compressor Current (A)	Input Power (W)	**ELT**	Evaporating Temperature	Liquid Flow (gpm)	LLT	Delta T	**Cooling (Btu/hr)**	**EER**	**COP_C**
COOLING	**50°F**	62°F	77,700	13.7	2840	**54°F**	39°F	16	45°F	9°F	**68,400**	**24.1**	**7.06**
	60°F	72°F	72,900	15.3	3220		39°F		46°F	8°F	**62,300**	**19.4**	**5.68**
	70°F	83°F	70,200	17.0	3640		40°F		47°F	7°F	**58,200**	**16.0**	**4.68**
	80°F	93°F	67,300	18.7	4030		40°F		47°F	7°F	**54,000**	**13.4**	**3.92**
	90°F	104°F	64,600	20.9	4520		40°F		48°F	6°F	**49,600**	**11.0**	**3.22**
	100°F	114°F	62,100	23.1	5030		40°F		48°F	6°F	**45,300**	**9.0**	**2.64**
	110°F	125°F	59,900	26.0	5680		40°F		49°F	5°F	**40,900**	**7.2**	**2.11**
	120°F	135°F	58,000	29.1	6380		41°F		50°F	5°F	**36,600**	**5.7**	**1.68**

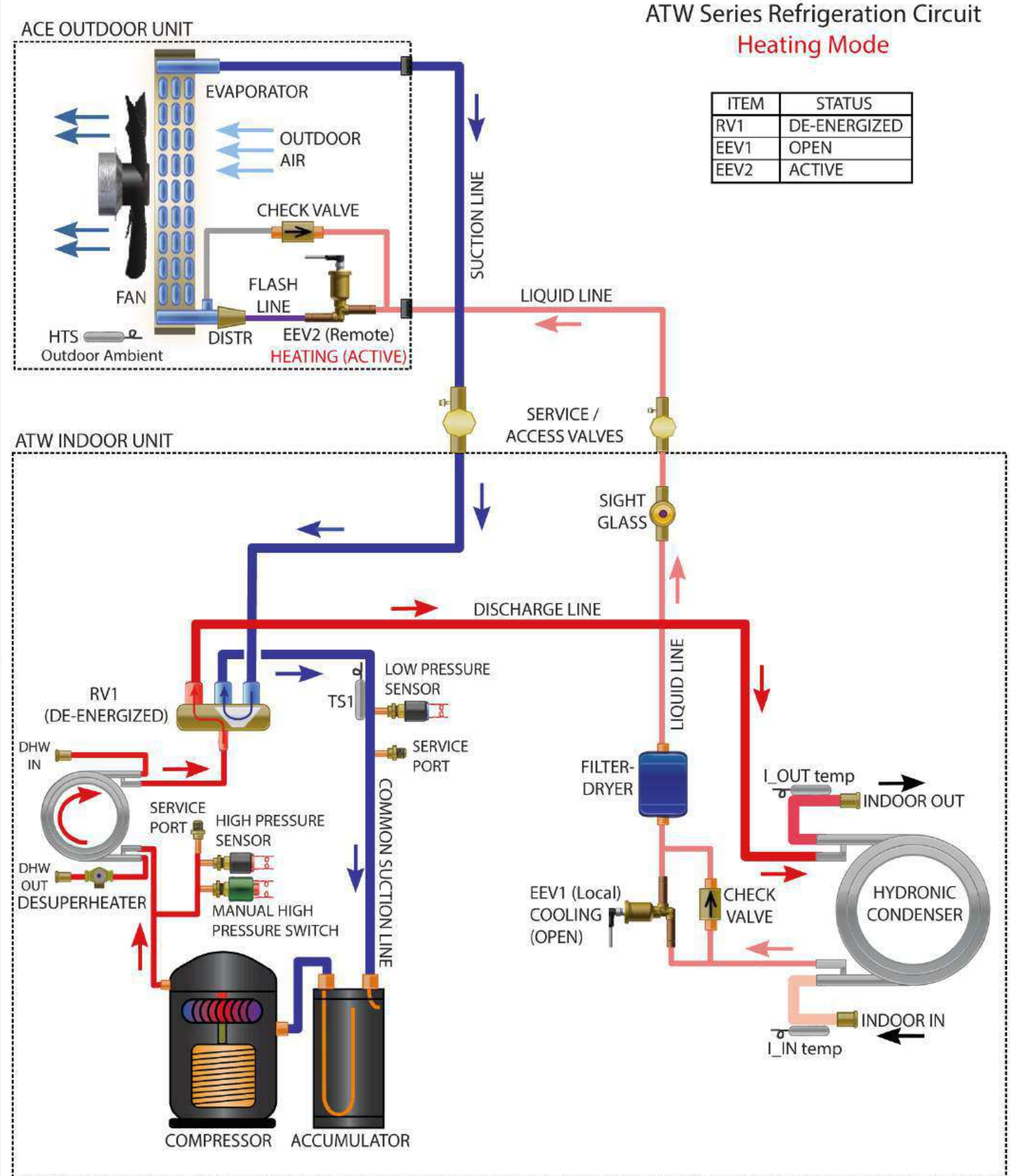
METRIC

	OUTDOOR			ELECTRICAL		INDOOR						
	Outdoor Air Temperature	Evaporating Temperature	Heat Absorbed (W)	Compressor Current (A)	Input Power (W)	ELT	Condensing Temperature	Liquid Flow (L/s)	**LLT**	Delta T	**Heating (W)**	**COP_H**
HEATING (METRIC)	**-21°C**	-27°C	2,320	23.1	5140	39°C	43°C	1.0	**40.5°C**	1.7°C	**7,350**	**1.43**
	-15°C	-22°C	4,360	21.5	4820	38°C	43°C			2.2°C	**9,070**	**1.88**
	-9°C	-18°C	6,320	20.9	4690	38°C	43°C			2.6°C	**10,900**	**2.32**
	-4°C	-13°C	8,520	19.6	4440	38°C	43°C			3.0°C	**12,900**	**2.89**
	2°C	-8°C	10,700	18.8	4270	37°C	43°C			3.5°C	**14,800**	**3.48**
	7°C	-4°C	12,900	18.1	4120	37°C	42°C			4.0°C	**16,900**	**4.09**
	13°C	1°C	15,100	17.5	3980	36°C	42°C			4.5°C	**19,000**	**4.77**
	18°C	6°C	17,600	16.9	3820	36°C	42°C			5.1°C	**21,300**	**5.58**
	-21°C	-27°C	-	-	-	-	-	1.0	**49°C**	*LLT is limited to 40.5°C at these outdoor temperatures*		
	-15°C	-22°C	-	-	-	-	-					
	-9°C	-18°C	5,590	24.3	5540	46°C	51°C			2.6°C	**10,900**	**1.99**
	-4°C	-13°C	7,580	22.9	5250	46°C	51°C			3.0°C	**12,700**	**2.42**
	2°C	-8°C	9,530	22.0	5050	45°C	51°C			3.4°C	**14,500**	**2.86**
	7°C	-4°C	11,500	21.2	4890	45°C	51°C			3.9°C	**16,300**	**3.33**
	13°C	1°C	13,600	20.6	4730	45°C	51°C			4.3°C	**18,200**	**3.85**
	18°C	6°C	15,900	19.8	4540	44°C	50°C			4.8°C	**20,300**	**4.47**

	Outdoor Air Temperature	Condensing Temperature	Heat Rejected (W)	Compressor Current (A)	Input Power (W)	**ELT**	Evaporating Temperature	Liquid Flow (L/s)	LLT	Delta T	**Cooling (W)**	**EER**	**COP_C**
COOLING (METRIC)	**10°C**	17°C	22,800	13.7	2840	**12°C**	4°C	1.0	8°C	4.8°C	**20,000**	**24.1**	**7.06**
	16°C	22°C	21,400	15.3	3220		4°C		8°C	4.3°C	**18,300**	**19.4**	**5.68**
	21°C	28°C	20,600	17.0	3640		4°C		8°C	4.0°C	**17,000**	**16.0**	**4.68**
	27°C	34°C	19,700	18.7	4030		4°C		9°C	3.8°C	**15,800**	**13.4**	**3.92**
	32°C	40°C	18,900	20.9	4520		4°C		9°C	3.4°C	**14,500**	**11.0**	**3.22**
	38°C	46°C	18,200	23.1	5030		5°C		9°C	3.1°C	**13,300**	**9.0**	**2.64**
	43°C	52°C	17,600	26.0	5680		5°C		9°C	2.8°C	**12,000**	**7.2**	**2.11**
	49°C	57°C	17,000	29.1	6380		5°C		10°C	2.5°C	**10,700**	**5.7**	**1.68**

ATW Series Refrigeration Circuit
Heating Mode

ITEM	STATUS
RV1	DE-ENERGIZED
EEV1	OPEN
EEV2	ACTIVE



REV	ECO#	IMPL BY	APVD BY	DATE
03	000270	D. RHEAULT	D. RHEAULT	12-FEB-2019
02	000253	D. RHEAULT	D. RHEAULT	01-JUL-2017
01	Initial Release	C. GEDDES	C. GEDDES	16-JUL-2014

Drawn By C.GEDDES	Date 16-JUL-2014
Checked By C.GEDDES	Date 16-JUL-2014
Eng. Approved By C.GEDDES	Date 16-JUL-2014
Mfg. Approved By	Date
Approved By	Date

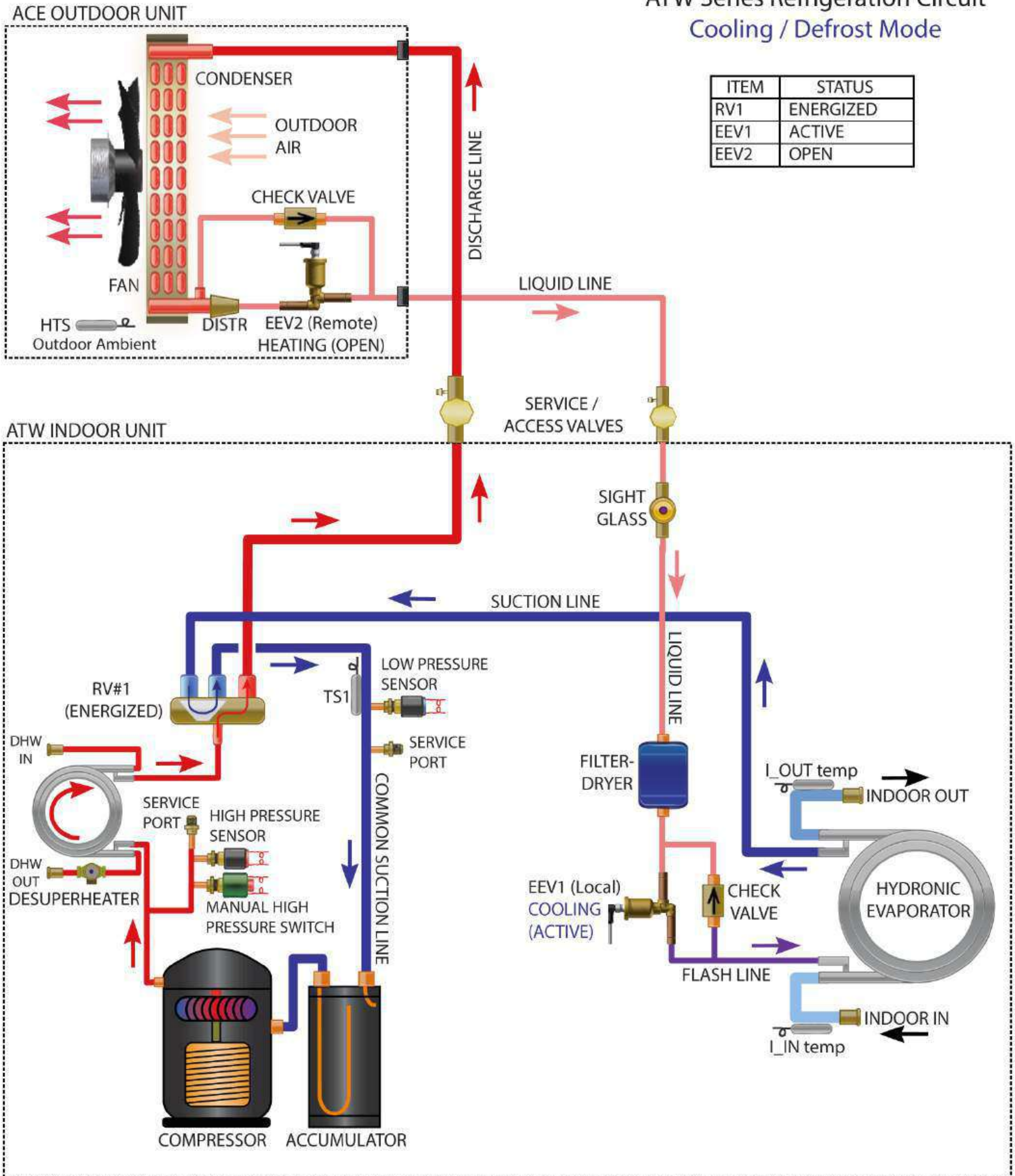
MARITIME GEOTHERMAL LTD. P.O. Box 2555 170 Plantation Rd. Petitcodiac, NB CANADA E4Z 6H4

Drawing Name
ATW-Series Refrigeration Circuit Heating Mode

Size	Drawing Number	Drawing Revision	Sheet
LET	001840RCD	03	1 / 1

ATW Series Refrigeration Circuit
Cooling / Defrost Mode

ITEM	STATUS
RV1	ENERGIZED
EEV1	ACTIVE
EEV2	OPEN



REV	ECO#	IMPL BY	APVD BY	DATE
03	000270	D. RHEAULT	D. RHEAULT	12-FEB-2019
02	000253	D. RHEAULT	D. RHEAULT	01-JUL-2017
01	Initial Release	C. GEDDES	C. GEDDES	16-JUL-2014

Drawn By C.GEDDES	Date 16-JUL-2014	MARITIME GEOTHERMAL LTD. P.O. Box 2555 170 Plantation Rd. Petitcodiac, NB CANADA E4Z 6H4
Checked By C.GEDDES	Date 16-JUL-2014	Drawing Name
Eng. Approved By C.GEDDES	Date 16-JUL-2014	ATW-Series Refrigeration Circuit Cooling / Defrost Mode
Mfg. Approved By	Date	
Approved By	Date	Size LET · Drawing Number 001841RCD · Drawing Revision 03 · Sheet 1 / 1

MARITIME GEOTHERMAL LTD.

Installation and Service Manual

W-Series
Liquid to Water Geothermal Heat Pump

Two-Stage R410a
Model Sizes 25-80

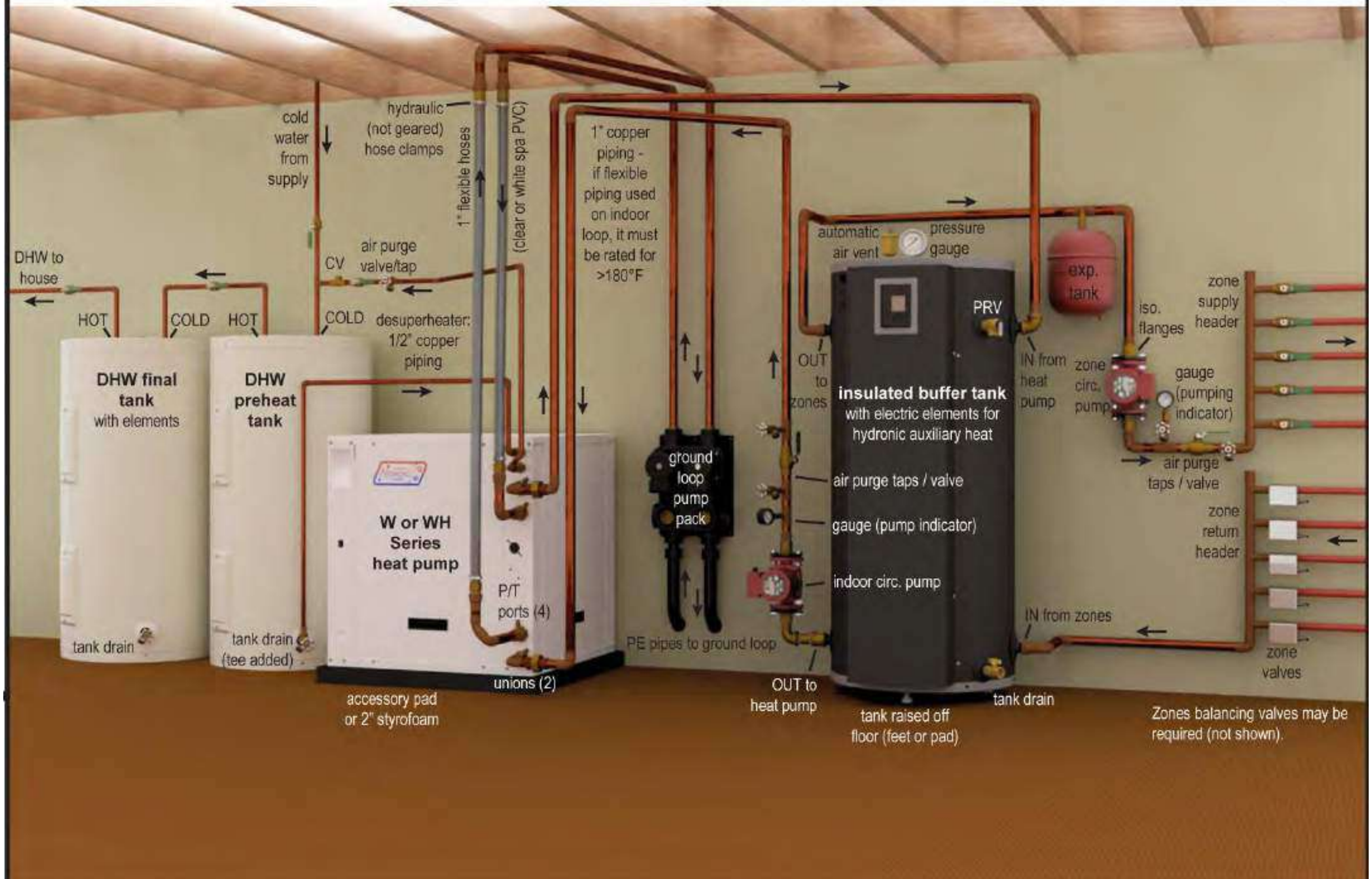
Maritime Geothermal Ltd.
P.O. Box 2555, 170 Plantation Road
Petitcodiac, NB E4Z 6H4
(506) 756-8135

info@nordicghp.com
www.nordicghp.com

001490MAN-03

ISSUE 02
6-Mar-2018

Typical Piping Connections - W/WH 25-80



See other diagrams and instructions in the manual for design, selection, and installation details of ground loop and hydronic heating accessories.

Many of the items illustrated in this diagram are available as accessories from Maritime Geothermal Ltd.. Other items are commonly available from plumbing or HVAC wholesalers.

There are multiple valid connection methods or details which differ from those shown, including:

- Open loop installation, which uses a well water system in place of a ground loop.
- Hydronic heating zones that use one pump per zone instead of zone valves.
- Piping routed differently from that shown, or different piping & component types.

01	Initial Rel.	Dan Rheault	Dan Rheault	1-Mar-2018
REV	ECO#	IMPL BY	APVD BY	DATE

Drawn By: Dan Rheault	Date: 1-Mar-2018
Checked By: Dan Rheault	Date: 1-Mar-2018
Eng. Approved By	Date
Mfg. Approved By	Date
Approved By	Date

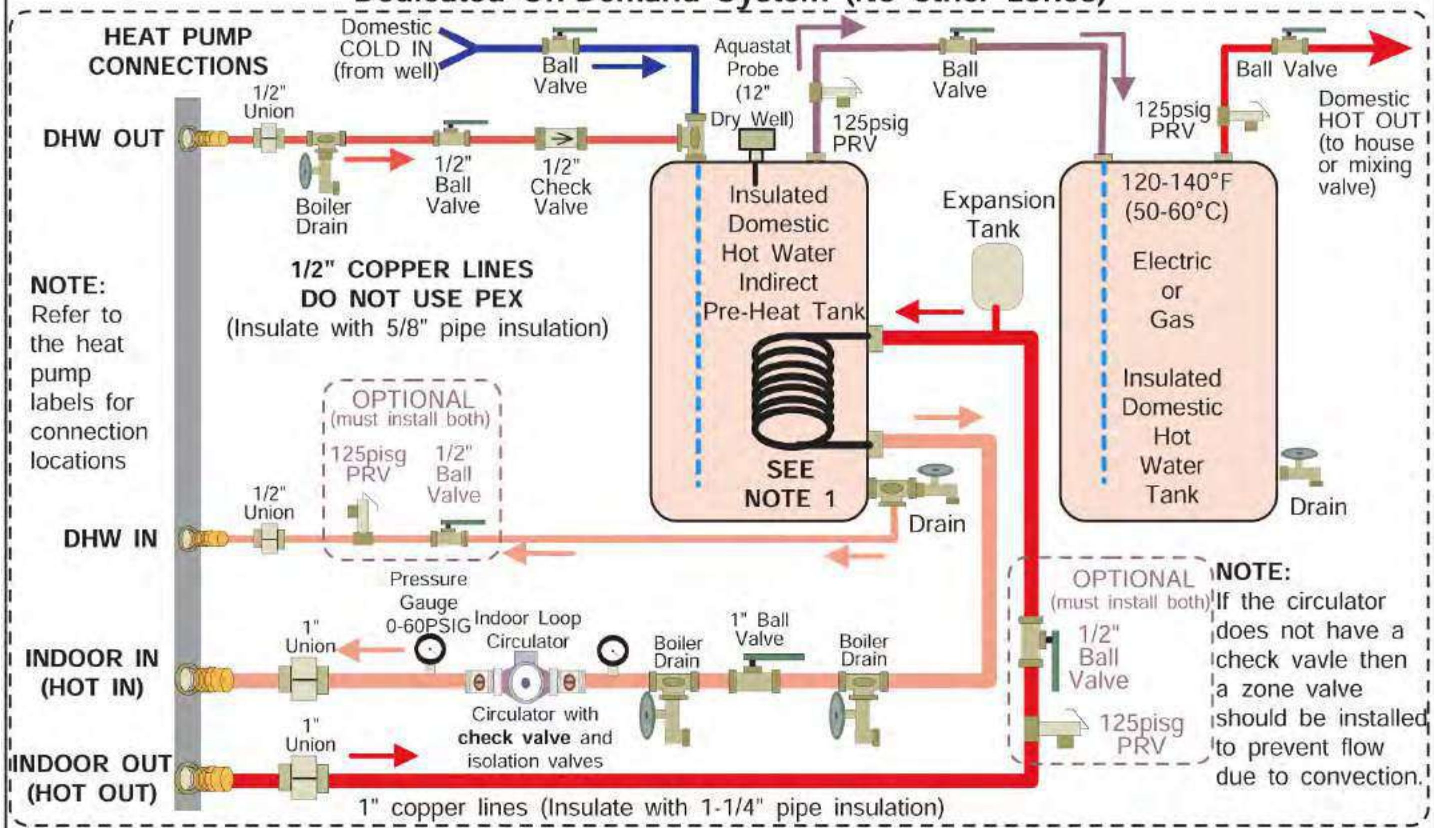
MARITIME GEOTHERMAL LTD. P.O. Box 2555 170 Plantation Rd. Petitcodiac, NB CANADA E4Z 6H4

Drawing Name: **Typical Piping Connections - W/WH 25-80**

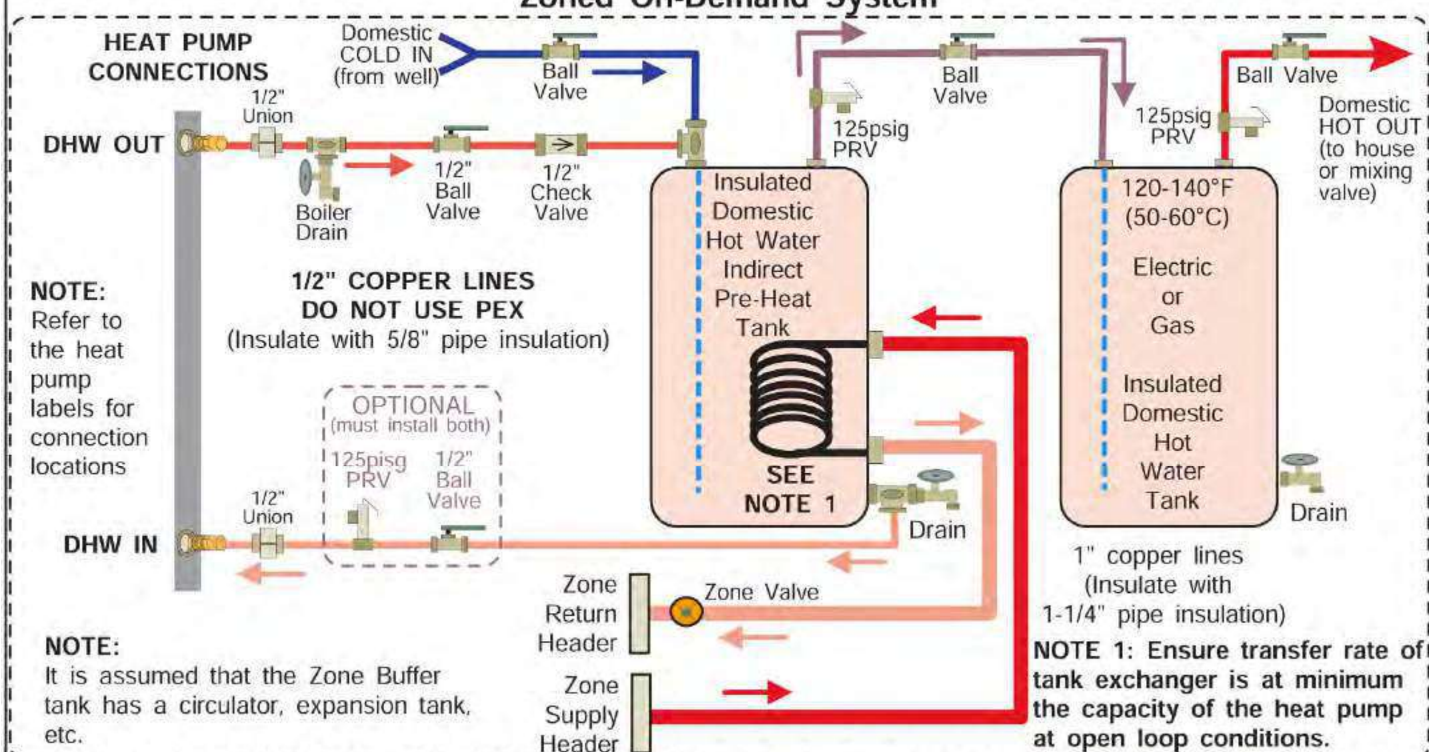
Size	Drawing Number	Revision	Sheet
LET	002287PDG	01	1 / 2

Single Unit Connection to On-Demand Domestic Hot Water Pre-Heat Tank

Dedicated On-Demand System (No other zones)



Zoned On-Demand System



02	000161	C. GEDDES	C. GEDDES	05 FEB 10
01	Initial Release	C. GEDDES	C. GEDDES	29 JUN 09
REV	ECO #	IMPL BY	APVD BY	DATE

Drawn By Chris Geddes	Date 29 JUN 09
Checked By Chris Geddes	Date 29 JUN 09
Approved By (ENG) Chris Geddes	Date 29 JUN 00
Approved By (MFG)	Date
Approved By	Date

MARITIME GEOTHERMAL LTD. 170 Plantation Rd. Petitcodiac, NB E4Z 6H4

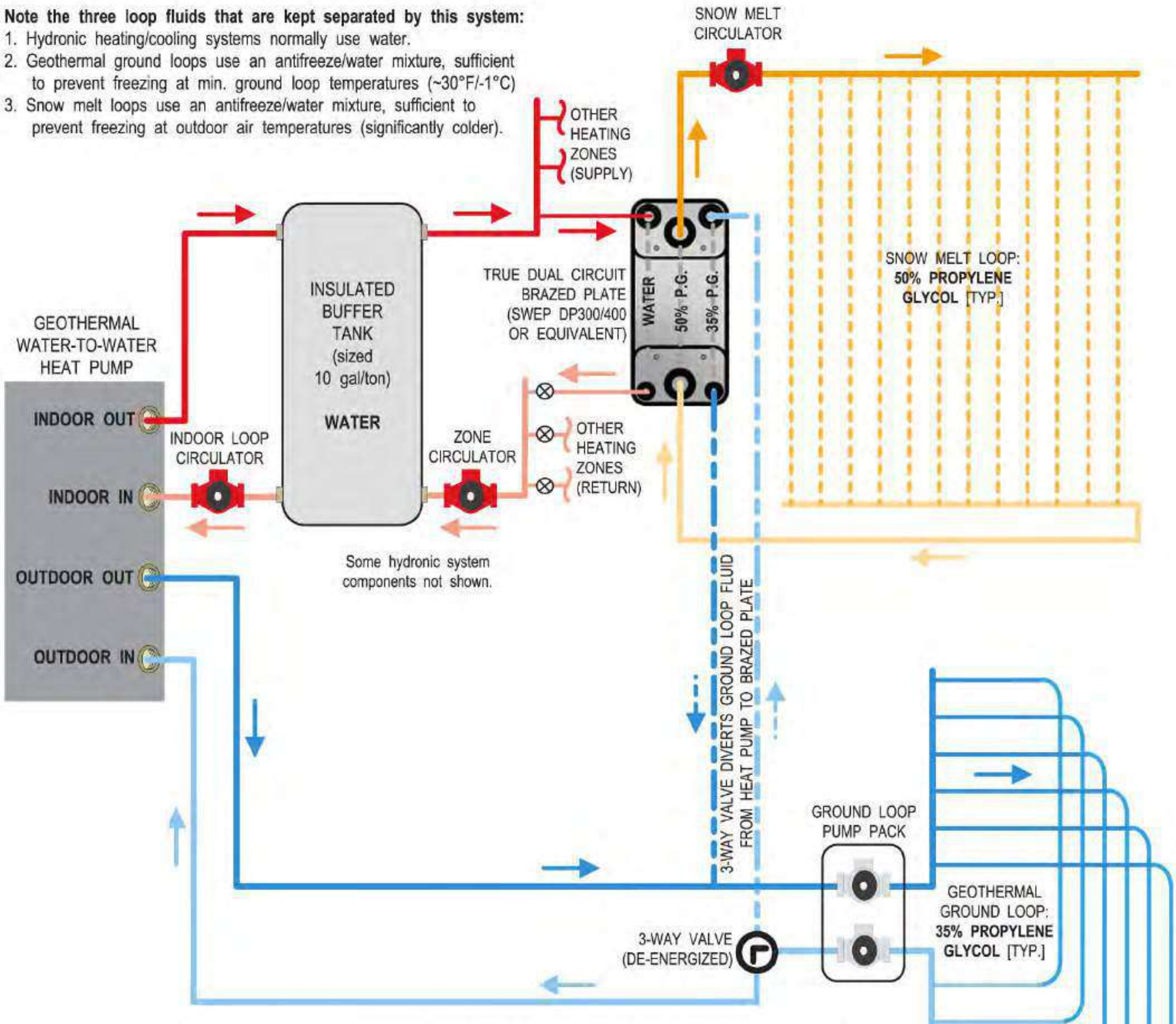
Drawing Name	Single Unit Connection toOn-Demand DHW Pre-Heat Tank (Brass FPT)		
Size	Drawing Number	REV	SHEET
A	001055PDG	02	1 of 1

Geothermal Snow Melt System with Warm-Weather Ground Loop Re-heating

The geothermal snow melt system, designed according to ASHRAE guidelines, will efficiently **melt snow and ice** in the winter, and will act as a **solar collector** during warm weather to re-heat the geothermal ground loop and increase its cold-weather performance.

Note the three loop fluids that are kept separated by this system:

1. Hydronic heating/cooling systems normally use water.
2. Geothermal ground loops use an antifreeze/water mixture, sufficient to prevent freezing at min. ground loop temperatures (~30°F/-1°C)
3. Snow melt loops use an antifreeze/water mixture, sufficient to prevent freezing at outdoor air temperatures (significantly colder).



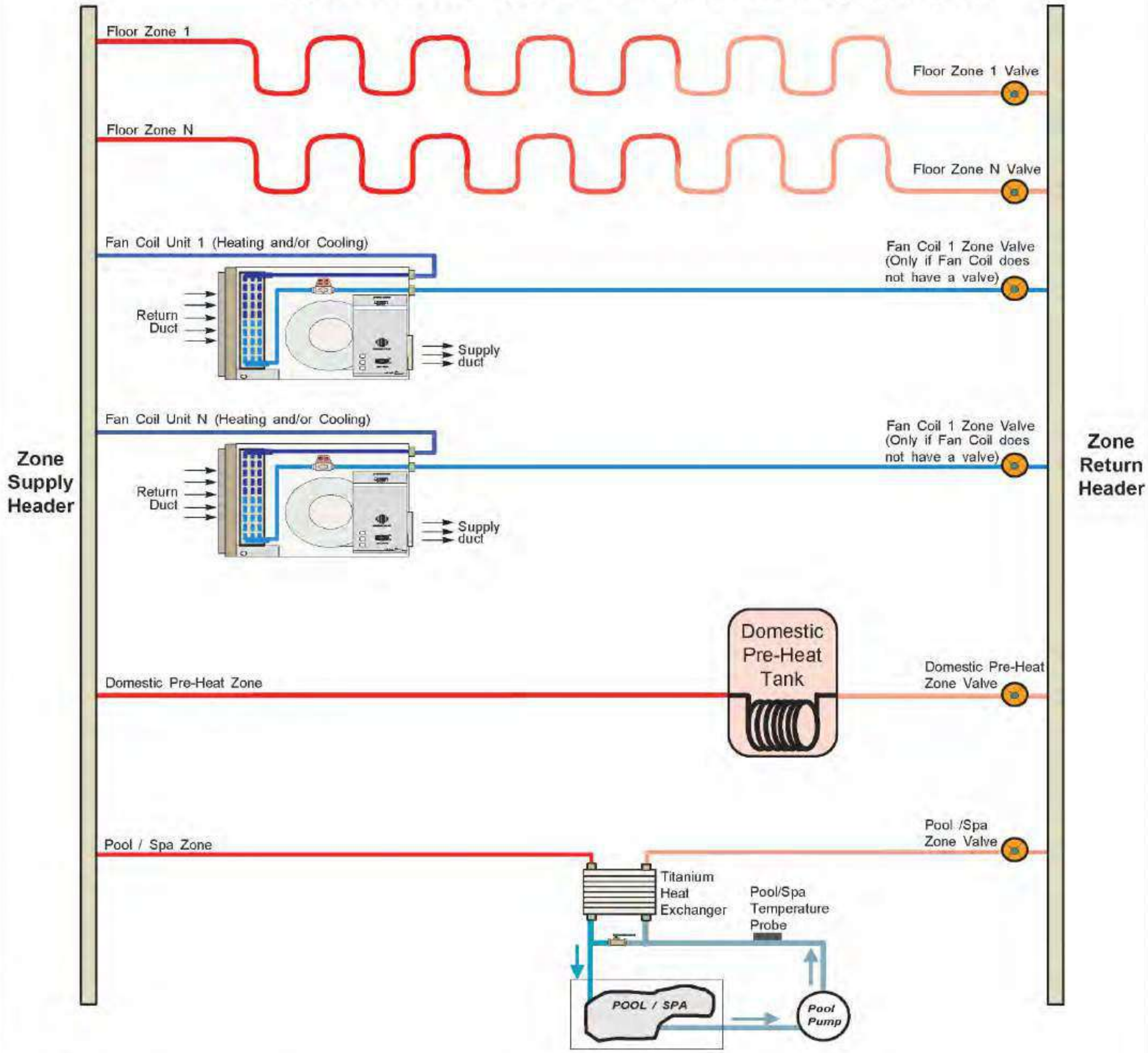
3-way valve is energized and snow melt circulator / ground loop pump pack are started by controller to activate ground loop re-heating mode when all of the following conditions are met:

1. Heat pump heating and cooling modes are not active
2. Snow melt loop fluid temperature is above a setpoint, e.g. 50°F / 10°C
3. Geothermal ground loop temperature is lower than snow melt loop temperature by e.g. 10°F / 5°C

When 3-way valve is energized, snow melt hydronic heating zone is locked out.

					Drawn By Dan Rheault	Date 31-Jan-2018	MARITIME GEOTHERMAL LTD.			www.nordicghp.com
					Checked By Dan Rheault	Date 31-Jan-2018				
					Approved By (ENG) Dan Rheault	Date 31-Jan-2018	Drawing Name	Piping for Snow Melt with Ground Loop Re-heating		
					Approved By (MFG)	Date				
01	Initial Release	D. RHEAULT	D. RHEAULT	31-Jan-2018			Size	Drawing Number	REV	SHEET
REV	ECO #	IMPL BY	APVD BY	DATE	Approved By	Date	A	002286PDG	01	1 of 1

Typical Zone Types for Hydronic Applications



NOTES:

1. Floor zones are heating only. Cooling a floor zone will cause condensation in the floor. Floor zone valves should be wired through a relay that is controlled by the cooling signal (O) that breaks the signal when in cooling mode to ensure that they cannot accidentally be energized.
2. There may be multiple floor zones.
3. There may be multiple fan coil units, (heating and /or cooling). A zone valve is not required if the unit has a internal valve.
4. Domestic Pre-Heat Tank is for on-demand apllications. The tank must have a heat eaxchanger in it or an external one must be used to separate the zone loop from the potable water supply.
5. Ensure the floor circulator is adequately sized to accomodate the type and number of zones connected to the system.
6. The pool aquastat will operate the Pool/Spa Zone Valve.

					Drawn By Chris Geddes	Date 06 SEP 07	MARITIME GEOTHERMAL LTD.	170 Plantation Rd. Petitcodiac, NB E4Z 6H4
					Checked By Chris Geddes	Date 06 SEP 07	Drawing Name	
					Approved By (ENG) Chris Geddes	Date 06 SEP 07	Typical Zone Types for Hydronic Applications	
01	Initial Release	C. GEDDES	C. GEDDES	06 SEP 07	Approved By (MFG)	Date	Size A / Drawing Number 000530PDG	REV 01 / SHEET 1 of 1
REV	ECO #	IMPL BY	APVD BY	DATE	Approved By	Date		

Performance Tables (continued)

Heating Mode (Full Load)

W-75-HACW-P-1T																R410a 60 Hz
Source Data (Outdoor Loop)						Power Consumption				Sink Data (Indoor Loop)						
ELT	Evap. Temp	Flow	LLT	Delta T	HAB	Total		Effective	COPh	EWT	Cond. Temp.	Flow	LWT	Delta T	Net Output	
°F	°F	gpm	°F	°F	Btu/hr	Watts	Amps	Watts	W/W	°F	°F	gpm	°F	°F	Btu/hr	
°C	°C	L/s	°C	°C	Watts					°C	°C	L/s	°C	°C	Watts	
24.0	15	16.0	20.2	3.8	28,577	4,419	22.8	4,635	**2.79**	104.0	112	16.0	109.5	5.5	**44,057**	
-4.4	-9.4	1.009	-6.5	2.1	8,373					40.0	44.4	1.009	43.1	3.1	**12,909**	
30.0	20	16.0	25.8	4.2	32,106	4,414	22.8	4,630	**3.01**	104.0	112	16.0	110.0	6.0	**47,569**	
-1.1	-6.7	1.009	-3.5	2.3	9,407					40.0	44.4	1.009	43.3	3.3	**13,938**	
36.0	25	16.0	31.2	4.8	36,549	4,462	23.0	4,677	**3.27**	104.0	113	16.0	110.5	6.5	**52,174**	
2.2	-3.9	1.009	-0.4	2.7	10,709					40.0	45.0	1.009	43.6	3.6	**15,287**	
42.0	30	16.0	36.5	5.5	41,744	4,451	23.0	4,666	**3.60**	104.0	113	16.0	111.2	7.2	**57,331**	
5.6	-1.1	1.009	2.5	3.1	12,231					40.0	45.0	1.009	44.0	4.0	**16,798**	
48.0	35	16.0	41.9	6.1	46,409	4,649	23.2	4,856	**3.78**	104.0	114	16.0	111.8	7.8	**62,622**	
8.9	1.7	1.009	5.5	3.4	13,598					40.0	45.6	1.009	44.4	4.4	**18,348**	
54.0	40	16.0	47.3	6.7	51,266	4,634	23.1	4,840	**4.08**	104.0	114	16.0	112.4	8.4	**67,427**	
12.2	4.4	1.009	8.5	3.7	15,021					40.0	45.6	1.009	44.7	4.7	**19,756**	
60.0	45	16.0	52.6	7.4	56,104	4,676	23.3	4,882	**4.35**	104.0	115	16.0	113.1	9.1	**72,408**	
15.6	7.2	1.009	11.5	4.1	16,438					40.0	46.1	1.009	45.0	5.0	**21,215**	
66.0	50	16.0	57.9	8.1	61,671	4,659	23.2	4,866	**4.69**	104.0	115	16.0	113.7	9.7	**77,917**	
18.9	10.0	1.009	14.4	4.5	18,070					40.0	46.1	1.009	45.4	5.4	**22,830**	
Compressor: ZPS60K5E-PFV																

Cooling Mode (Full Load)

W-75-HACW-P-1T																R410a 60 Hz
Source Data (Indoor Loop)						Power Consumption				Sink Data (Outdoor Loop)						
ELT	Evap. Temp	Flow	LLT	Delta T	HAB	Total		Effective	Efficiency	ELT	Cond. Temp.	Flow	LLT	Delta T	Rejection	
°F	°F	gpm	°F	°F	Btu/hr	Watts	Amps	Watts	EER	°F	°F	gpm	°F	°F	Btu/hr	
°C	°C	L/s	°C	°C	Watts				COPc	°C	°C	L/s	°C	°C	Watts	
53.6	38.0	16.0	45.5	8.1	**64,550**	2,666	15.0	2,884	**6.6**	53	70	16.0	62.7	9.7	73,647	
12.0	3.3	1.009	7.5	4.5	**18,913**				**22.4**	12	21.1	1.009	17.1	5.4	21,578	
53.6	38.5	16.0	45.8	7.8	**62,721**	2,853	15.7	3,071	**6.0**	58	75	16.0	67.5	9.5	72,458	
12.0	3.6	1.009	7.6	4.4	**18,377**				**20.4**	14	23.9	1.009	19.7	5.3	21,230	
53.6	39.0	16.0	46.0	7.6	**60,462**	3,043	16.5	3,262	**5.4**	64	80	16.0	73.3	9.3	70,849	
12.0	3.9	1.009	7.8	4.2	**17,715**				**18.5**	18	26.7	1.009	23.0	5.2	20,759	
53.6	39.5	16.0	46.3	7.3	**58,355**	3,240	17.3	3,458	**4.9**	69	85	16.0	78.1	9.1	69,413	
12.0	4.2	1.009	7.9	4.1	**17,098**				**16.9**	21	29.4	1.009	25.6	5.1	20,338	
53.6	40.0	16.0	46.5	7.1	**56,526**	3,462	18.2	3,678	**4.5**	75	90	16.0	84.0	9.0	68,343	
12.0	4.4	1.009	8.1	3.9	**16,562**				**15.4**	24	32.2	1.009	28.9	5.0	20,024	
53.6	40.5	16.0	46.7	6.9	**54,825**	3,679	19.1	3,894	**4.1**	80	95	16.0	88.9	8.9	67,382	
12.0	4.7	1.009	8.2	3.8	**16,064**				**14.1**	27	35.0	1.009	31.6	4.9	19,743	
53.6	41.0	16.0	47.0	6.6	**53,105**	3,909	20.0	4,124	**3.8**	85	100	16.0	93.7	8.7	66,445	
12.0	5.0	1.009	8.3	3.7	**15,560**				**12.9**	29	37.8	1.009	34.3	4.9	19,468	
53.6	41.5	16.0	47.2	6.4	**51,428**	4,153	21.1	4,369	**3.4**	90	105	16.0	98.6	8.6	65,603	
12.0	5.3	1.009	8.4	3.6	**15,068**				**11.8**	32	40.6	1.009	37.0	4.8	19,222	
Compressor: ZPS60K5E-PFV																

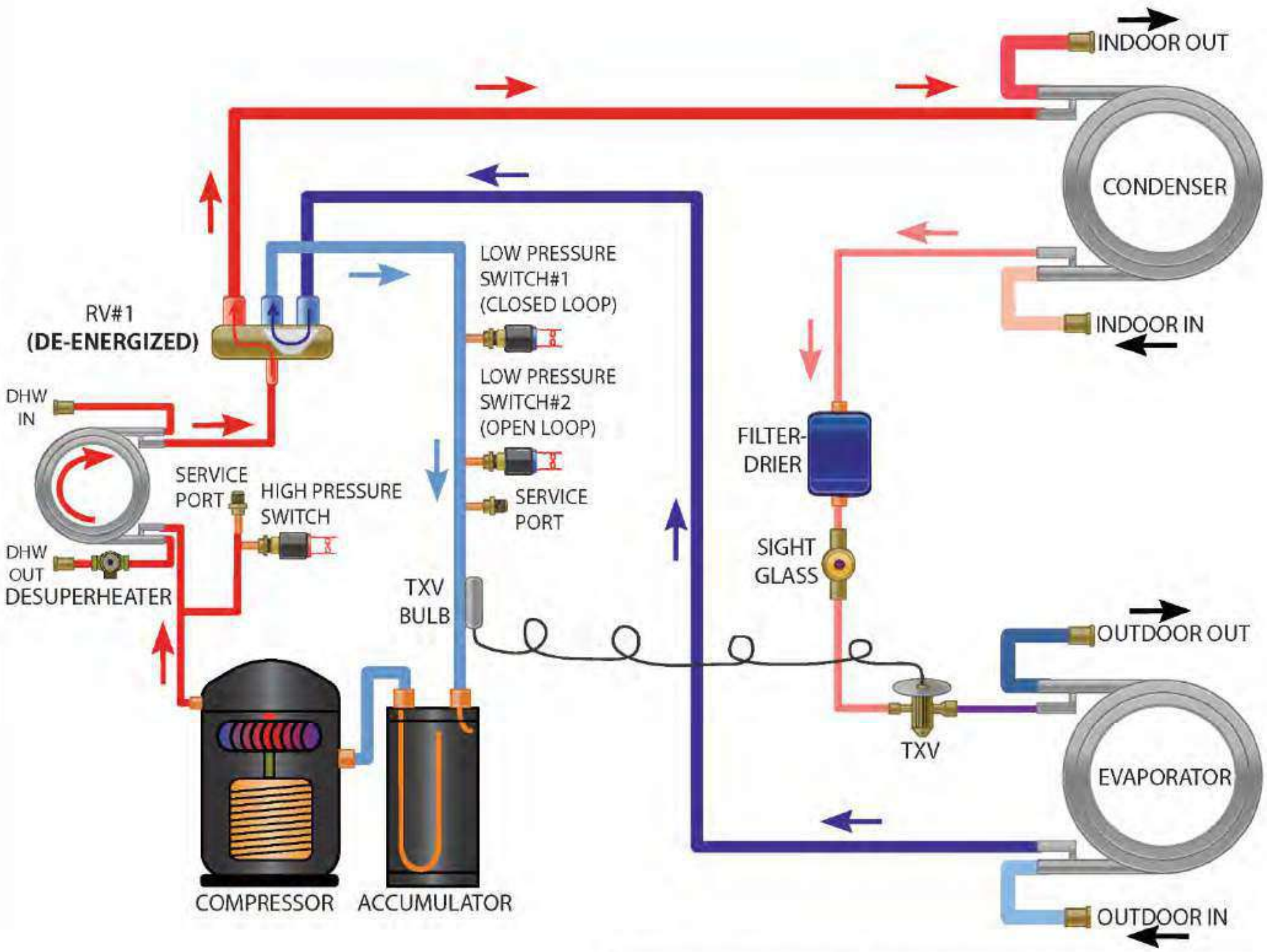
Electrical Specifications

TABLE 19	Nomenclature Identifier	Power Supply			Compressors (each)		FLA	MCA	Maximum Fuse/Breaker	Minimum Wire Size
		V-ø-Hz	MIN	MAX	RLA	LRA	Amps	Amps	Amps	ga
W-25	1	230-1-60	187	253	**11.7**	**58**	**17.5**	**20.4**	**30**	**#10-2***
	2	208-3-60	187	229	**6.5**	**55**	**12.3**	**13.9**	**20**	**#12-3***
	4	460-3-60	414	506	**3.5**	**28**	**4.3**	**5.2**	**15**	**#14-3**
	5	-	-	-	-	-	-	-	-	-
	6	220-1-50	187	253	**9.2**	**52**	**15.0**	**17.3**	**30**	**#10-2**
	7	380-3-50	342	418	**3.2**	**27**	**9.0**	**9.8**	**15**	**#14-2**
W-45	1	230-1-60	187	253	**15.6**	**83**	**21.4**	**25.3**	**40**	**#8-2***
	2	208-3-60	187	229	**11.6**	**73**	**17.4**	**20.3**	**30**	**#10-3***
	4	460-3-60	414	506	**5.7**	**38**	**6.5**	**7.9**	**15**	**#14-3**
	5	575-3-60	518	632	**4.0**	**26**	**4.8**	**5.8**	**15**	**#14-3**
	6	220-1-50	187	253	**12.4**	**67**	**18.2**	**21.3**	**30**	**#10-2**
	7	380-3-50	342	418	**5.1**	**38**	**10.9**	**12.2**	**15**	**#14-2**
W-55	1	230-1-60	187	253	**21.2**	**104**	**29.0**	**34.3**	**50**	**#8-2***
	2	208-3-60	187	229	**14.0**	**83**	**21.8**	**25.3**	**40**	**#8-3***
	4	460-3-60	414	506	**6.4**	**41**	**7.2**	**8.8**	**15**	**#14-3**
	5	575-3-60	518	632	**4.6**	**33**	**5.4**	**6.6**	**15**	**#14-3**
	6	220-1-50	187	253	**15.5**	**100**	**23.3**	**27.2**	**40**	**#8-2**
	7	380-3-50	342	418	**6.1**	**43**	**13.9**	**15.4**	**20**	**#12-2**
W-65	1	230-1-60	187	253	**27.1**	**153**	**34.9**	**41.7**	**60**	**#6-2***
	2	208-3-60	187	229	**16.5**	**110**	**24.3**	**28.4**	**40**	**#8-3***
	4	460-3-60	414	506	**7.2**	**52**	**8.0**	**9.8**	**15**	**#14-3**
	5	575-3-60	518	632	**5.5**	**39**	**6.3**	**7.7**	**15**	**#14-3**
	6	220-1-50	187	253	**21.5**	**126**	**29.3**	**34.7**	**50**	**#8-2**
	7	380-3-50	342	418	**6.9**	**52**	**14.7**	**16.4**	**20**	**#12-2**
W-75	1	230-1-60	187	253	**29.7**	**179**	**37.5**	**44.9**	**60**	**#6-2***
	2	208-3-60	187	229	**17.6**	**136**	**25.4**	**29.8**	**40**	**#8-3***
	4	460-3-60	414	506	**8.5**	**66**	**9.3**	**11.4**	**20**	**#12-3**
	5	575-3-60	518	632	**6.3**	**55**	**7.1**	**8.7**	**15**	**#14-3**
	6	220-1-50	187	253	**29.5**	**176**	**37.3**	**44.7**	**60**	**#6-2**
	7	380-3-50	342	418	**8.5**	**67**	**16.3**	**18.4**	**30**	**#10-2**
W-80	1	230-1-60	187	253	**32.1**	**148**	**39.9**	**47.9**	**60**	**#6-2***
	2	208-3-60	187	229	**22.4**	**149**	**30.2**	**35.8**	**50**	**#8-3***
	4	460-3-60	414	506	**10.6**	**75**	**11.4**	**14.1**	**20**	**#12-3**
	5	575-3-60	518	632	**7.7**	**54**	**8.5**	**10.4**	**20**	**#12-3**
	6	-	-	-	-	-	-	-	-	-
	7	380-3-50	342	418	**10.6**	**74**	**18.4**	**21.1**	**30**	**#10-2**

* additional conductor required if connecting 115VAC circulators to the unit

W Series Refrigeration Circuit
Heating Mode

ITEM	STATUS
RV#1	DE-ENERGIZED



01	Initial Release	C. GEDDES	C. GEDDES	14 JUN 2011
REV	ECO#	IMPL BY	APVD BY	DATE

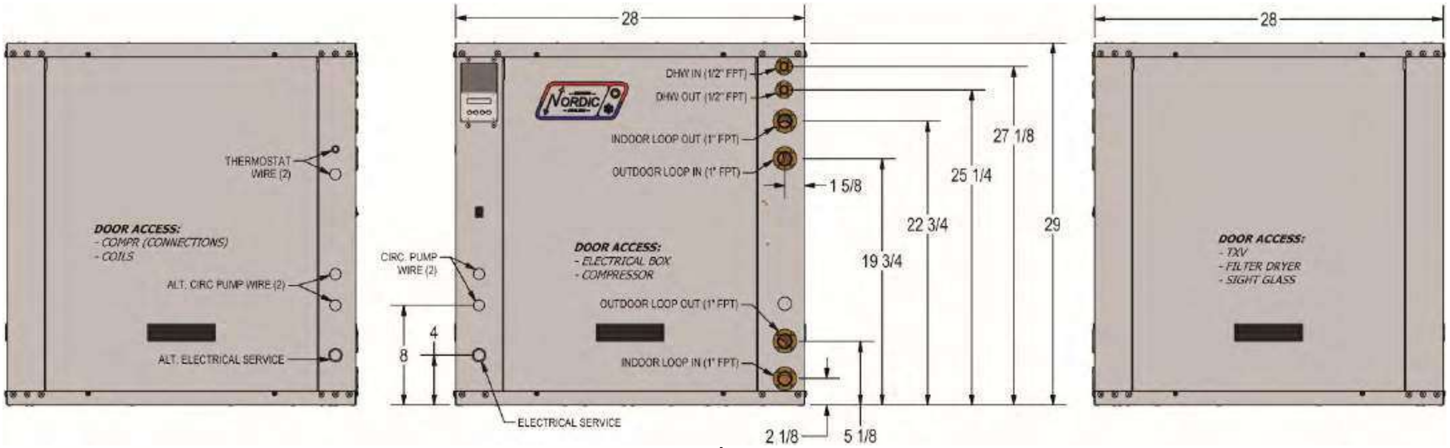
Drawn By C.GEDDES	Date 14 JUN 2011
Checked By C.GEDDES	Date 14 JUN 2011
Eng. Approved By C.GEDDES	Date 14 JUN 2011
Mfg. Approved By	Date
Approved By	Date

MARITIME GEOTHERMAL LTD.
P.O. Box 2555
170 Plantation Rd.
Petitcodiac, NB CANADA E4Z 6H4

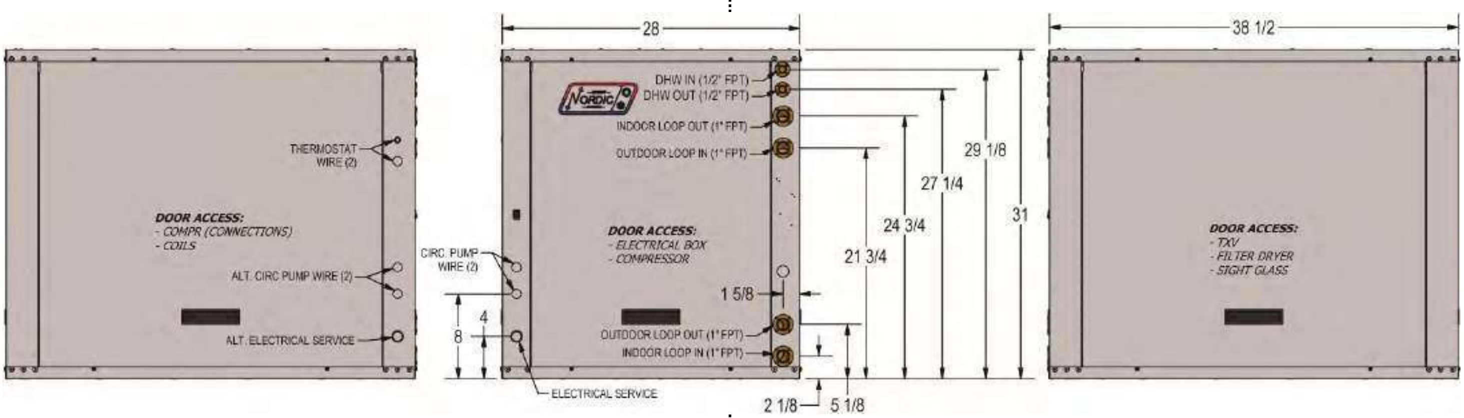
Drawing Name
W-Series Refrigeration Circuit
Heating Mode

Size	Drawing Number	Drawing Revision	Sheet
LET	001488RCD	01	1 / 1

Dimensions: W-25/45/55



Dimensions: W-65/75/80



MARITIME GEOTHERMAL LTD.

Installation and Service Manual

WH-Series
High Temperature
Water-to-Water Heat Pump

Single Stage R134a
Model Sizes 25-80 (Heating/Cooling)
Model Size 85 (Domestic Hot Water)

WH-45-H

WH-85-H (DHW)

WH-80-HACW

Maritime Geothermal Ltd.
P.O. Box 2555, 170 Plantation Road
Petitcodiac, NB E4Z 6H4
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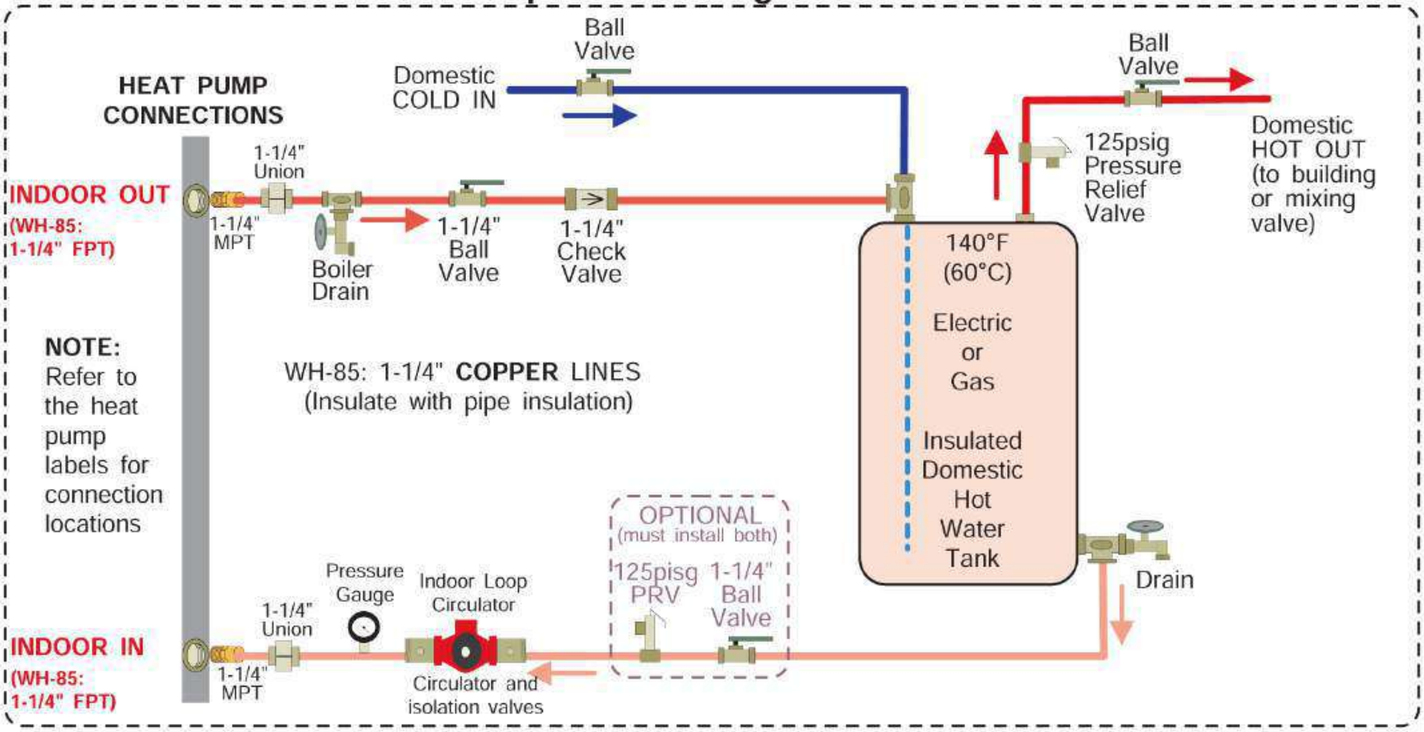
002028MAN-03

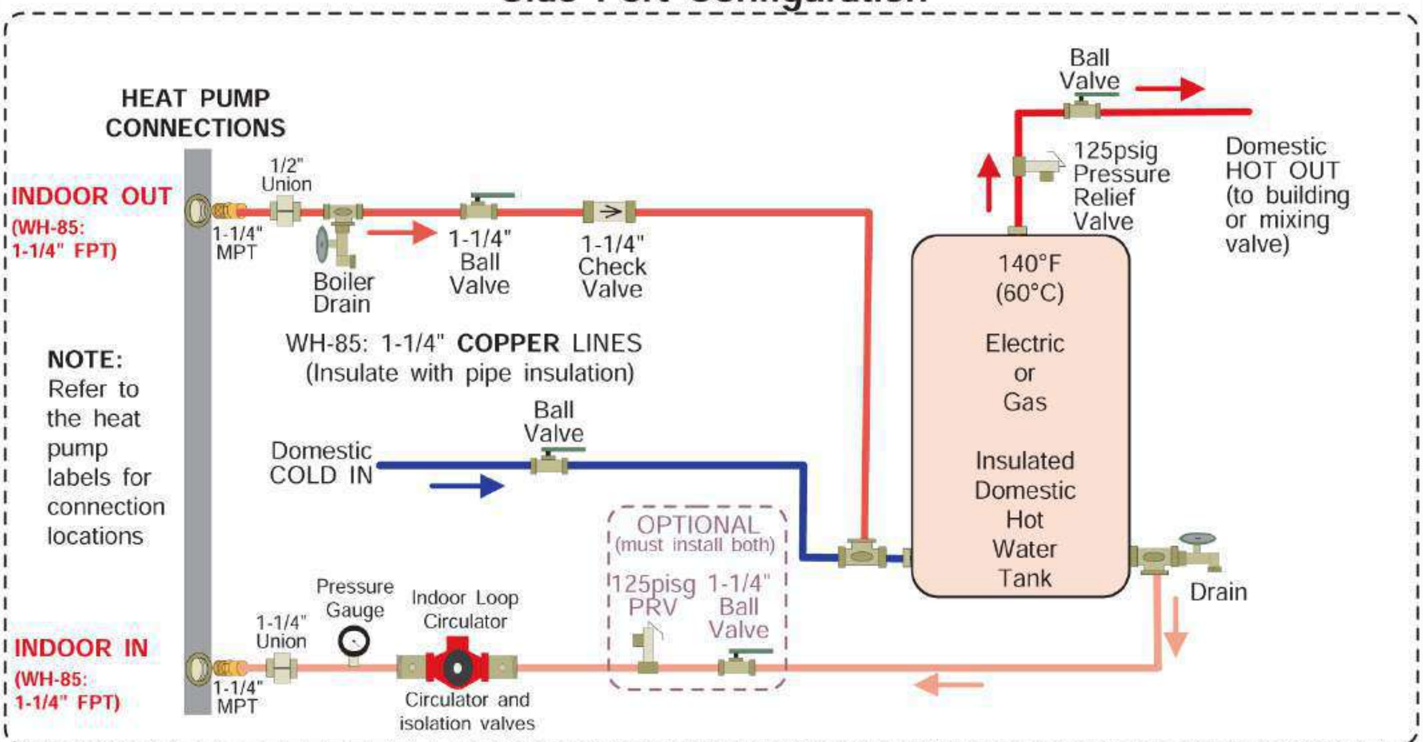
ISSUE 02
1-Jul-2019

High Temperature Heat Pump *with Double Wall Condenser* : Dedicated Domestic Hot Water Heating

Top Port Configuration



Side Port Configuration



REV	ECO #	IMPL BY	APVD BY	DATE
02	-	D. RHEAULT	D. RHEAULT	01 SEP 17
01	Initial Release	C. GEDDES	C. GEDDES	09 AUG 12

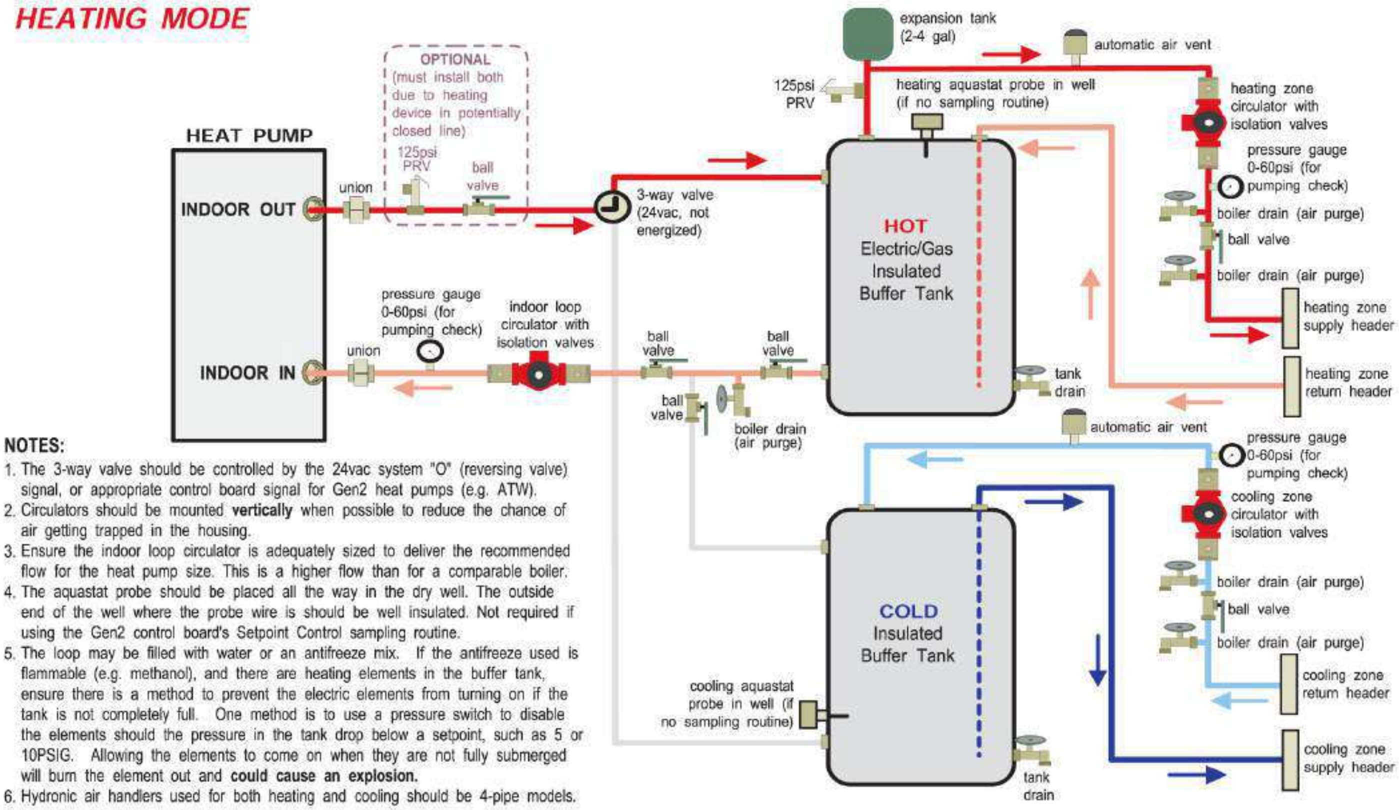
Drawn By: Chris Geddes	Date: 09 AUG 12
Checked By: Chris Geddes	Date: 09 AUG 12
Approved By (ENG): Chris Geddes	Date: 09 AUG 12
Approved By (MFG)	Date
Approved By	Date

MARITIME GEOTHERMAL LTD. 170 Plantation Rd. Petitcodiac, NB E4Z 6H4

Drawing Name	High Temperature Double Wall Unit Connection to DHW Tank		
Size: A	Drawing Number: 001684PDG	REV: 02	SHEET: 1 of 1

Two Tank System Piping with a Reversing Heat Pump

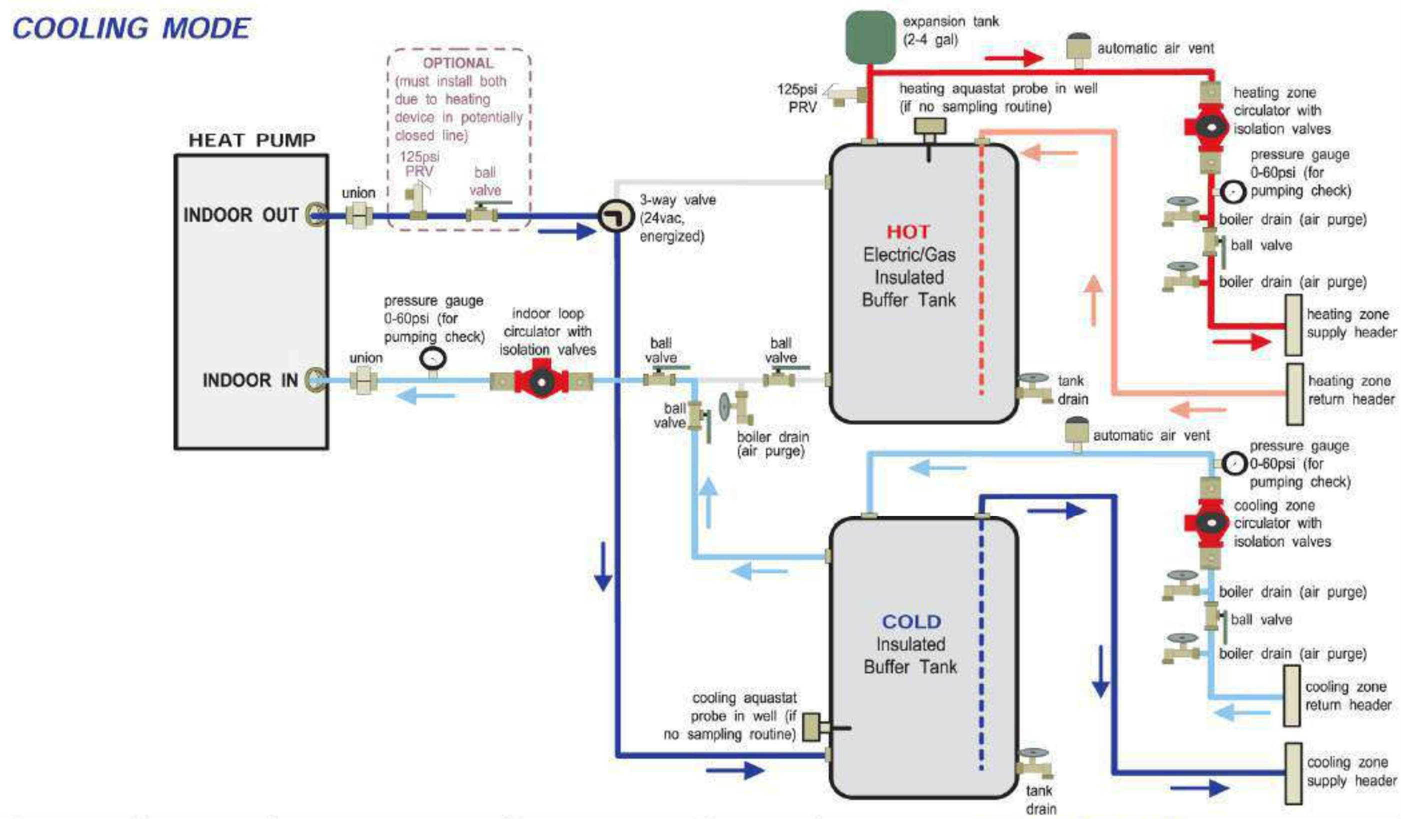
HEATING MODE



NOTES:

1. The 3-way valve should be controlled by the 24vac system "O" (reversing valve) signal, or appropriate control board signal for Gen2 heat pumps (e.g. ATW).
2. Circulators should be mounted **vertically** when possible to reduce the chance of air getting trapped in the housing.
3. Ensure the indoor loop circulator is adequately sized to deliver the recommended flow for the heat pump size. This is a higher flow than for a comparable boiler.
4. The aquastat probe should be placed all the way in the dry well. The outside end of the well where the probe wire is should be well insulated. Not required if using the Gen2 control board's Setpoint Control sampling routine.
5. The loop may be filled with water or an antifreeze mix. If the antifreeze used is flammable (e.g. methanol), and there are heating elements in the buffer tank, ensure there is a method to prevent the electric elements from turning on if the tank is not completely full. One method is to use a pressure switch to disable the elements should the pressure in the tank drop below a setpoint, such as 5 or 10PSIG. Allowing the elements to come on when they are not fully submerged will burn the element out and **could cause an explosion.**
6. Hydronic air handlers used for both heating and cooling should be 4-pipe models.

COOLING MODE



REV	ECO #	IMPL BY	APVD BY	DATE
02	-	D. RHEAULT	D. RHEAULT	1-Mar-2018
01	Initial Release	D. RHEAULT	D. RHEAULT	25-Oct-2017

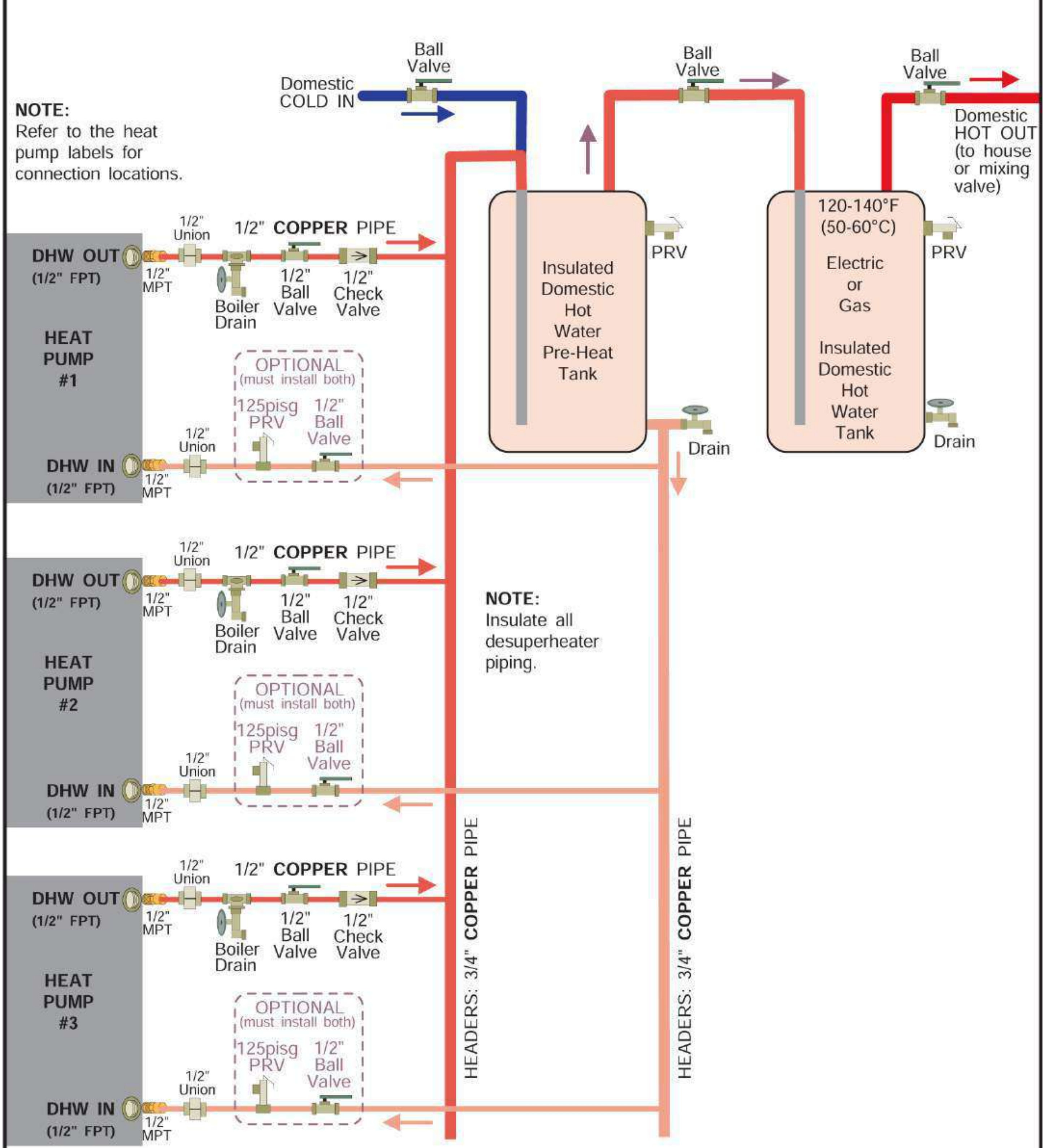
	Date
Drawn By Dan Rheault	25-Oct-2017
Checked By Dan Rheault	25-Oct-2017
Approved By (ENG) Dan Rheault	25-Oct-2017
Approved By (MFG)	
Approved By	

MARITIME GEOTHERMAL LTD.
170 Plantation Rd.
Petitcodiac, NB
E4Z 6H4

Drawing Name: Two Tank System Piping with a Reversing Heat Pump

Size	Drawing Number	REV	SHEET
A	002252PDG	02	1 of 1

Desuperheater Connection to DHW Pre-Heat Tank - Multiple Units



01	Initial Release	D. RHEAULT	D. RHEAULT	24-Apr-2019	Drawn By Dan Rheault	Date 24-Apr-2019	MARITIME GEOTHERMAL LTD.		170 Plantation Rd. Petitcodiac, NB E4Z 6H4		
REV	ECO #	IMPL BY	APVD BY	DATE	Checked By Dan Rheault	Date 24-Apr-2019	Drawing Name	Multiple Unit Desuperheater Connection to DHW Pre-Heat Tank (Brass FPT)			
					Approved By (ENG) Dan Rheault	Date 24-Apr-2019	Size	Drawing Number		REV	SHEET
					Approved By (MFG)	Date	A	002384PDG		01	1 of 1
					Approved By	Date					

Performance Tables

WH-55-H***-B-1S *R134a, 60 Hz, ZR42K5E-PFV*

	OUTDOOR LOOP						ELECTRICAL		INDOOR LOOP						
HEATING	ELT (°F)	Evap. Temp.	Flow (gpm)	LLT (°F)	Delta T (°F)	Heat Abs. (Btu/hr)	Compressor Current (A)	Input Power (W)	EWT (°F)	Cond. Temp.	Flow (gpm)	LWT (°F)	Delta T (°F)	**Heating** (Btu/hr)	**COP_H**
	50	41	12	47	3	17,134	16.3	2,229	116	128	12		4	**24,523**	**3.22**
	60	49	12	56	4	22,189	16.2	2,172	115	128	12		5	**29,383**	**3.96**
	70	57	12	66	5	27,256	16.2	2,133	114	129	12	120	6	**34,317**	**4.71**
	80	66	12	75	6	33,165	16.2	2,174	113	131	12		7	**40,367**	**5.44**
	90	74	12	83	7	40,591	16.1	2,381	112	133	12		8	**48,498**	**5.97**
	50	41	12	48	2	14,515	22.4	2,725	136	147	12		4	**23,599**	**2.54**
	60	49	12	57	3	19,363	22.5	2,641	135	148	12		5	**28,159**	**3.12**
	70	58	12	66	4	23,871	22.5	2,671	135	150	12	140	6	**32,770**	**3.59**
	80	67	12	75	5	29,310	22.5	2,797	133	151	12		6	**38,639**	**4.05**
	90	76	12	84	6	36,600	22.4	2,993	132	153	12		8	**46,597**	**4.56**
	50	42	12	48	2	12,446	30.2	3,044	156	165	12		4	**22,617**	**2.18**
	60	51	12	57	3	16,188	29.9	3,142	155	165	12		5	**26,692**	**2.49**
	70	59	12	67	3	20,261	29.5	3,247	154	166	12	160	5	**31,124**	**2.81**
	80	68	12	76	4	25,590	29.0	3,342	153	166	12		6	**36,778**	**3.22**
	90	77	12	85	5	32,497	28.6	3,532	152	167	12		7	**44,335**	**3.68**

COOLING*	ELT (°F)	Cond. Temp.	Flow (gpm)	LLT (°F)	Delta T (°F)	Heat Rej. (Btu/hr)	Compressor Current (A)	Input Power (W)	EWT (°F)	Evap. Temp.	Flow (gpm)	LWT (°F)	Delta T (°F)	**Cooling** (Btu/hr)	**EER**
	60**		12								12				
	65**		12								12				
	70**		12								12				
	75**		12						54		12				
	80		12								12				
	85		12								12				
	90		12								12				
	95		12								12				

METRIC

	OUTDOOR LOOP						ELECTRICAL		INDOOR LOOP						
HEATING (METRIC)	ELT (°C)	Evap. Temp.	Flow (L/s)	LLT (°C)	Delta T (°C)	Heat Abs. (W)	Compressor Current (A)	Input Power (W)	EWT (°C)	Cond. Temp.	Flow (L/s)	LWT (°C)	Delta T (°C)	**Heating** (W)	**COP_H**
	10.0	5.0	0.76	8.4	1.6	5,020	16.3	2,229	46.7	53.1	0.76		2.3	**7,185**	**3.22**
	15.6	9.4	0.76	13.5	2.1	6,501	16.2	2,172	46.2	53.4	0.76		2.7	**8,609**	**3.96**
	21.1	13.9	0.76	18.6	2.5	7,986	16.2	2,133	45.7	54.0	0.76	49	3.2	**10,055**	**4.71**
	26.7	18.6	0.76	23.6	3.1	9,717	16.2	2,174	45.1	54.9	0.76		3.7	**11,827**	**5.44**
	32.2	23.3	0.76	28.5	3.8	11,893	16.1	2,381	44.4	55.9	0.76		4.5	**14,210**	**5.97**
	10.0	5.0	0.76	8.7	1.3	4,253	22.4	2,725	57.8	64.0	0.76		2.2	**6,914**	**2.54**
	15.6	9.6	0.76	13.8	1.8	5,673	22.5	2,641	57.4	64.7	0.76		2.6	**8,251**	**3.12**
	21.1	14.2	0.76	18.9	2.2	6,994	22.5	2,671	57.1	65.3	0.76	60	3.0	**9,602**	**3.59**
	26.7	19.3	0.76	24.0	2.7	8,588	22.5	2,797	56.3	66.2	0.76		3.6	**11,321**	**4.05**
	32.2	24.4	0.76	28.8	3.4	10,724	22.4	2,993	55.6	67.1	0.76		4.3	**13,653**	**4.56**
	10.0	5.6	0.76	8.8	1.2	3,647	30.2	3,044	69.0	73.9	0.76		2.1	**6,627**	**2.18**
	15.6	10.3	0.76	14.1	1.5	4,743	29.9	3,142	68.4	74.1	0.76		2.5	**7,821**	**2.49**
	21.1	15.0	0.76	19.2	1.9	5,936	29.5	3,247	67.9	74.3	0.76	71	2.9	**9,119**	**2.81**
	26.7	19.8	0.76	24.3	2.4	7,498	29.0	3,342	67.3	74.5	0.76		3.4	**10,776**	**3.22**
	32.2	24.7	0.76	29.2	3.0	9,522	28.6	3,532	66.7	74.9	0.76		4.1	**12,990**	**3.68**

COOLING* (METRIC)	ELT (°C)	Cond. Temp.	Flow (L/s)	LLT (°C)	Delta T (°C)	Heat Rej. (W)	Compressor Current (A)	Input Power (W)	EWT (°C)	Evap. Temp.	Flow (L/s)	LWT (°C)	Delta T (°C)	**Cooling** (W)	**COP_C**
	15.6**		0.76								0.76				
	18.3**		0.76								0.76				
	21.1**		0.76								0.76				
	23.9**		0.76						12		0.76				
	26.7		0.76								0.76				
	29.4		0.76								0.76				
	32.2		0.76								0.76				
	35.0		0.76								0.76				

* *Cooling mode is only available on reversing models (HAC/HACW)*

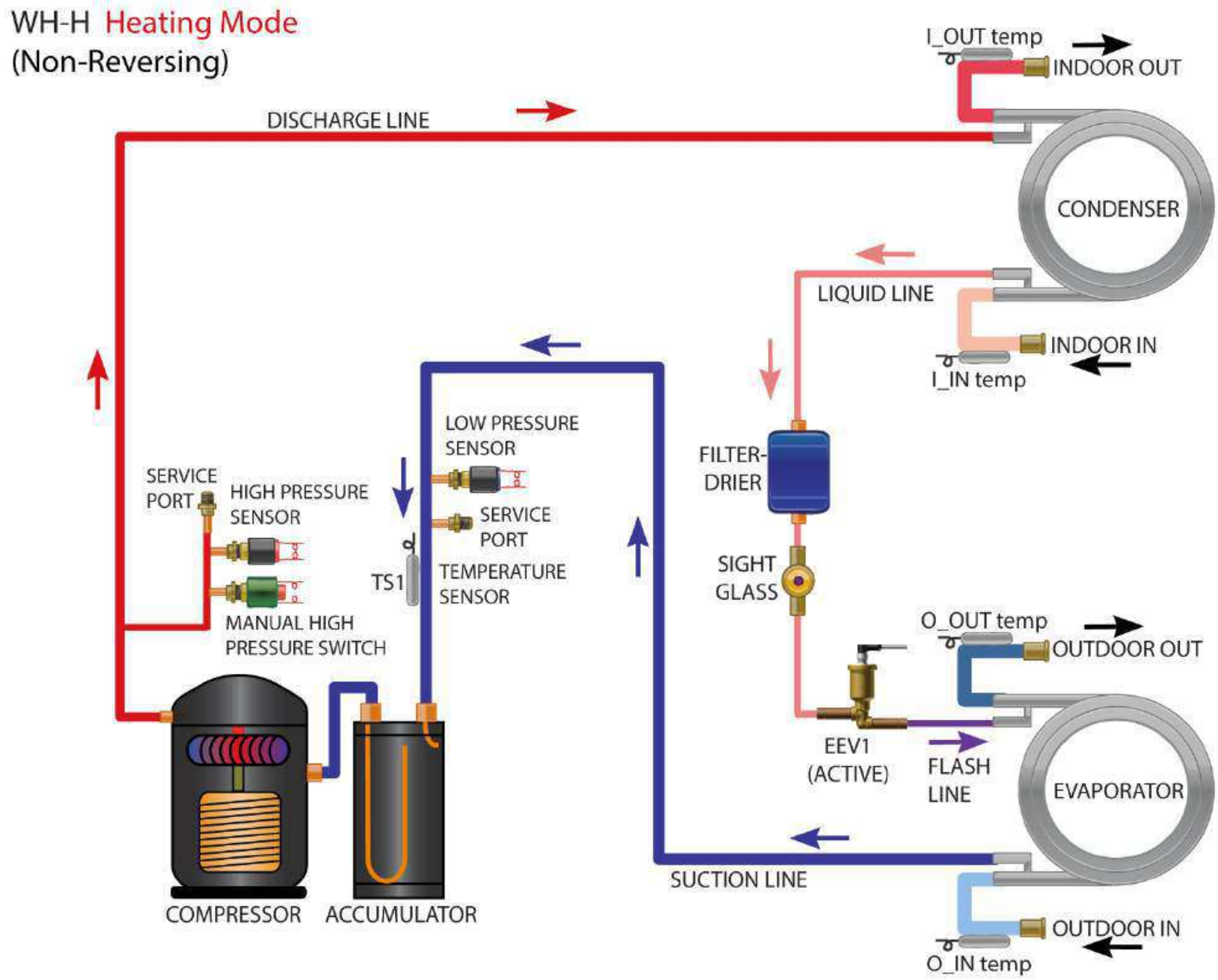
** *Lower cooling mode ELT's may require flow control via accessory 0-10V modulating water valve in outdoor loop*

Electrical Specifications

TABLE 25	Code	Power Supply			Compressor		Circulators	FLA	MCA	Max. Breaker	Min. Wire
		V-ø-Hz	MIN	MAX	RLA	LRA	Max. A	Amps	Amps	Amps	ga
WH-25	1	208/230-1-60	187	253	10.8	56	5.0	16.0	18.7	30	#10-2*
	2	208-3-60	187	229	7.7	58	5.0	12.9	14.8	20	#12-3*
	4	460-3-60	414	506	3.8	29	N/A	4.0	5.0	15	#14-3
	5	-	-	-	-	-	-	-	-	-	-
	6	220-1-50	187	253	9.3	54	5.0	14.5	16.8	30	#10-2
	7	380-3-50	342	418	3.8	29	5.0	9.0	10.0	15	#14-4**
WH-45	1	230-1-60	187	253	15.4	87	5.0	20.6	24.5	40	#8-2*
	2	208-3-60	187	229	10.8	73	5.0	16.0	18.7	30	#10-3*
	4	460-3-60	414	506	5.8	38	N/A	6.0	7.5	15	#14-3
	5	575-3-60	518	632	4.2	28	N/A	4.4	5.5	15	#14-3
	6	220-1-50	187	253	12.8	79	5.0	18.0	21.2	30	#10-2
	7	380-3-50	342	418	5.8	38	5.0	11.0	12.5	20	#12-4**
WH-55	1	230-1-60	187	253	19.9	104	7.0	27.1	32.1	50	#8-2*
	2	208-3-60	187	229	12.8	93	7.0	20.0	23.2	30	#10-3*
	4	460-3-60	414	506	5.8	48	N/A	6.0	7.5	15	#14-3
	5	575-3-60	518	632	4.7	38	N/A	4.9	6.1	15	#14-3
	6	220-1-50	187	253	17.3	129	7.0	24.5	28.8	50	#8-2
	7	380-3-50	342	418	5.8	48	7.0	13.0	14.5	20	#12-4**
WH-65	1	230-1-60	187	253	25.3	137	7.0	32.5	38.8	60	#6-2*
	2	208-3-60	187	229	15.4	114	7.0	22.6	26.5	40	#8-3*
	4	460-3-60	414	506	7.1	52	N/A	7.3	9.1	15	#14-3
	5	575-3-60	518	632	5.3	40	N/A	5.5	6.8	15	#14-3
	6	220-1-50	187	253	19.2	133	7.0	26.4	31.2	50	#8-2
	7	380-3-50	342	418	7.1	52	7.0	14.3	16.1	20	#12-4**
WH-75	1	230-1-60	187	253	23.7	144	7.0	30.9	36.8	60	#6-2*
	2	208-3-60	187	229	18.6	128	7.0	25.8	30.5	50	#8-3*
	4	460-3-60	414	506	9.0	63	N/A	9.2	11.5	20	#12-3
	5	575-3-60	518	632	6.6	49	N/A	6.8	8.5	15	#14-3
	6	-	-	-	-	-	-	-	-	-	-
	7	380-3-50	342	418	9.0	66	7.0	16.2	18.5	30	#10-4**
WH-80	1	230-1-60	187	253	28.8	176	7.0	36.0	43.2	60	#6-2*
	2	208-3-60	187	229	18.6	156	7.0	25.8	30.5	50	#8-3*
	4	460-3-60	414	506	9.0	75	N/A	9.2	11.5	20	#12-3
	5	575-3-60	518	632	7.4	54	N/A	7.6	9.5	15	#14-3
	6	220-1-50	187	253	27.6	150	7.0	34.8	41.7	60	#6-2
	7	380-3-50	342	418	9.0	74	7.0	16.2	18.5	30	#10-4**
WH-85	1	-	-	-	-	-	-	-	-	-	-
	2	208-3-60	187	229	25.3	195	7.0	32.5	38.8	60	#6-3*
	4	460-3-60	414	506	11.5	95	N/A	11.7	14.6	20	#12-3
	5	575-3-60	518	632	10.3	80	N/A	10.5	13.1	20	#12-3
	6	-	-	-	-	-	-	-	-	-	-
	7	380-3-50	342	418	11.5	95	7.0	18.7	21.6	30	#10-4**

* For 208/230-1-60 and 208-3-60, 1 additional conductor (neutral) is required if connecting 115VAC circulators to the unit.

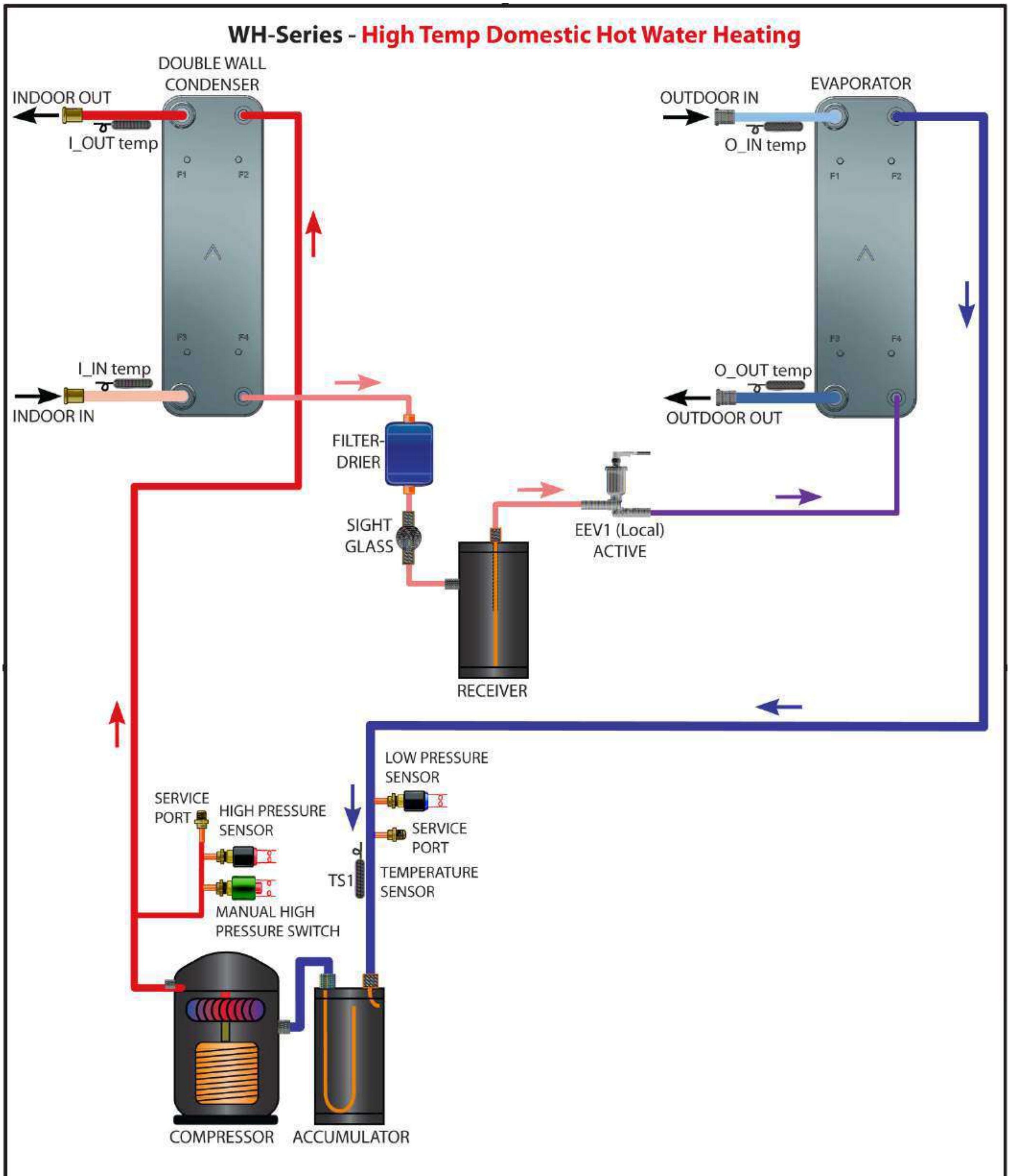
** For 380-3-50, only 3 conductors are required (no neutral) if not using desuperheater and not connecting 220V circulators to the unit.



REV	ECO#	IMPL BY	APVD BY	DATE
01a	-	D. RHEAULT	D. RHEAULT	1 JUL 2019
01	Initial Release	C. GEDDES	C. GEDDES	29 OCT 2014

Drawn By: C.GEDDES	Date: 29 OCT 2014	MARITIME GEOTHERMAL LTD.	P.O. Box 2555, 170 Plantation Rd., Petitcodiac, NB CANADA E4Z 6H4
Checked By: C.GEDDES	Date: 29 OCT 2014	Drawing Name: WH-H Series Refrigeration Circuit (Non-Reversing)	
Eng. Approved By: C.GEDDES	Date: 29 OCT 2014		
Mfg. Approved By	Date		
Approved By	Date	Size: LET; Drawing Number: 001877RCD	Drawing Revision: 01a; Sheet: 1 / 1

Refrigeration Circuit Diagram - Size 85



REV	ECO#	IMPL BY	APVD BY	DATE
02	000222	C. GEDDES	C. GEDDES	01 NOV 2014
01	Initial Release	C. GEDDES	C. GEDDES	31 JUL 2012

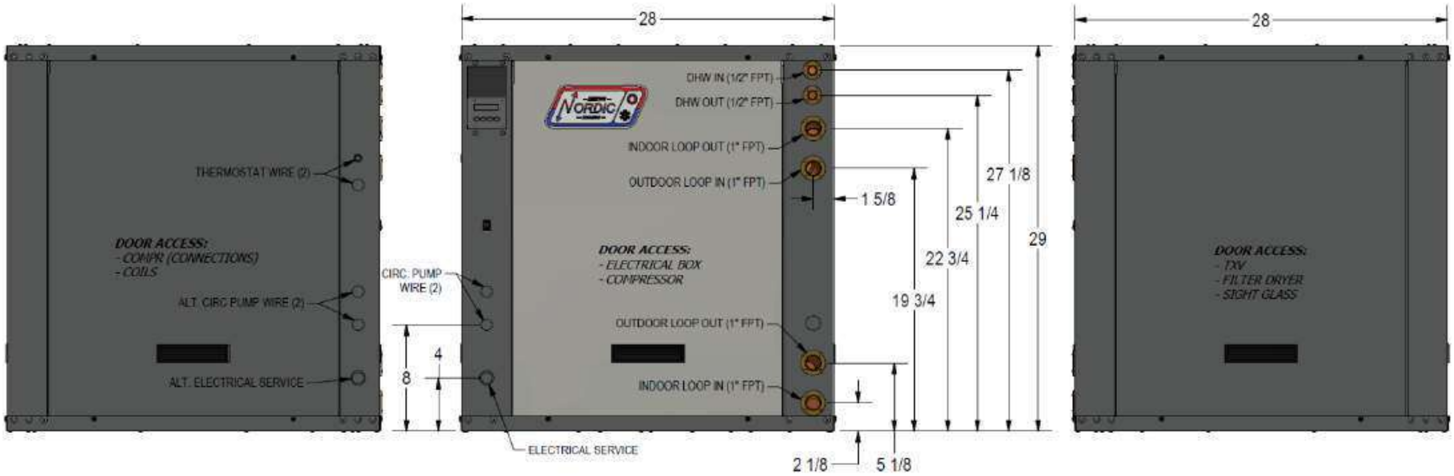
Drawn By C.GEDDES	Date 31 JUL 2012
Checked By C.GEDDES	Date 31 JUL 2012
Eng. Approved By C.GEDDES	Date 31 JUL 2012
Mfg. Approved By	Date
Approved By	Date

MARITIME GEOTHERMAL LTD.
P.O. Box 2555
170 Plantation Rd.
Petitcodiac, NB CANADA E4Z 6H4

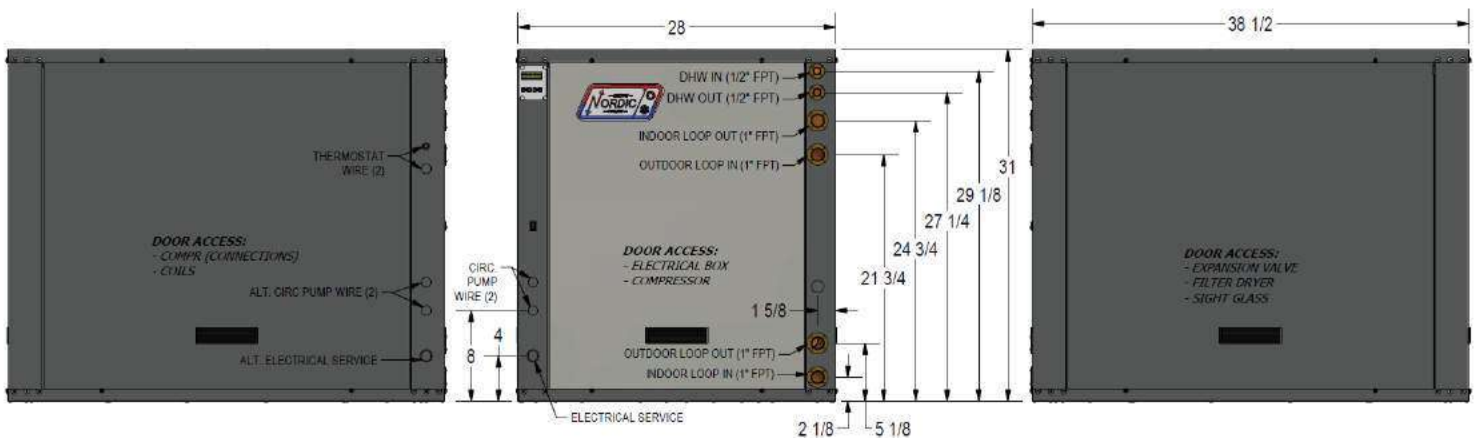
Drawing Name
WH-Series High Temp
Domestic Hot Water Heating

Size	Drawing Number	Drawing Revision	Sheet
LET	001674RCD	02	1 / 1

Dimensions: WH-25/45/55



Dimensions: WH-65/75/80



Dimensions: WH-85