Manitoba Hydro

MANITOBA HYDRO MONITORING STUDY

Performance of Ground Source Heat Pumps in Manitoba

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1.0 Executive Summary:

Manufacturers of geothermal heat pumps have traditionally reported coefficients of performance (COP) of 3.1-to-4.0 and energy efficiency ratio (EER) of 14-to-24. These efficiency levels are based on instantaneous tests conducted under controlled conditions and do not consider all of the losses that may occur in an installed system operating in varying conditions.

This study monitored ten homes over an extended period during all heating, cooling and shoulder months to determine the average Seasonal Coefficient of Performance (SCOP) and Seasonal Energy Efficiency Ratio (SEER) of typical heat pump systems operating in an "as-installed" environment.

Test data for ten Manitoba homes shows that the SCOP of the monitored ground source heat pump systems range from 1.8 to 3.5 with an average of 2.8 for a one year period. SCOP is defined as the total energy (kWh) delivered by the system divided by the total electric energy input (kWh) to the system over one heating season. The average annual electric energy saved was 15,842 kWh when compared to conventional electric resistance heat. The systems operated for an average of 2041 equivalent full load hours in heating mode.

The average SEER of the ten monitored homes during the cooling season was 13.3. The estimated average annual energy saved was 17 kWh compared to a split central air conditioning system with a SEER of 13. The cooling savings with a ground source heat pump were minimal but this may not be a fair comparison since the SEER 13 assumed for the central air conditioner is based on controlled test conditions and is not based on actual monitored field data. The systems operated for an average of 218 equivalent full load hours in the cooling mode.

The desuperheater option reduced the average domestic hot water electric energy usage by 610 kWh (18%). It was found that 86% of the savings were produced during the heating season. Therefore, the heat pump had to operate longer to transfer this additional energy requirement. This additional energy requirement during the heating season only increased seasonal imbalance on the ground. Most of the systems operated with storage water tank temperatures lower than the 60 ^{o}Celsius (140 ^{o} Fahrenheit) that is the minimum temperature setting requirement of the National Plumbing Code for electric storage water heaters. One of the desuperheater pumps was replaced prior to the study period due to motor failure. Another pump failed during the study period. Considering all of these factors, the desuperheater option does not appear to provide the same benefit in a heating dominated climate as it would in a cooling dominated climate.

2.0 Background:

Manitoba Hydro has been promoting geothermal heat pump systems through the Residential Earth Power Program since April of 2002. Since program launch, over 950 customers have applied for the Residential Earth Power Loan. Manitoba Hydro has worked with industry and other partners to determine the actual geothermal system performance over an entire heating and cooling season. The performance levels reported by various manufacturers are based on an instantaneous test and do not consider all of the losses that occur in an actual system. The performance values reported in this study reflect measured performance values monitored at "as-installed" working systems.

In two previous case studies in Manitoba, where actual field performance was measured it was found that the seasonal coefficient of performance (SCOP) over an entire heating season for five homes ranged from 1.4 to 2.9. The case study that included four homes indicated that two of the homes produced SCOP's of 1.4 and 1.6 but lack of maintenance and improper use of the system was found to be the cause of their poor performance. The other two homes in that study had no operational issues and produced SCOP's of 2.5 and 2.8. The second previous case study was of a single home, measured a SCOP of 2.9 for one heating season, and an SCOP of only 2.2 in a subsequent heating season. The reduction in performance in the second year was caused by a control failure which caused the auxiliary heat to operate excessively.

Based on the two previous case studies and analysis of heat pump customer billing data, Manitoba Hydro uses an average ground source heat pump SCOP of 2.5 and an EER of 14 for calculating the energy savings claimed by our Earth Power program. Manitoba Hydro wanted to study more residential ground source heat pump installations to provide a larger and more varied sample. A larger sample was expected to more accurately represent heat pump SCOP's of reasonably installed systems and therefore ensure that the energy savings claimed by the program would be fair and realistic.

It was felt that more extensive research needed to be completed to clarify the circumstances under which a desuperheater is beneficial in a heating dominated climate such as Manitoba. This is important because the high cost of a desuperheater increases the initial cost of the system and the high cost barrier of geothermal systems has been identified as one of three main barriers to widespread adoption of the technology. Removing the desuperheater from this initial cost may reduce the simple payback period. Conversely, when circumstances make the desuperheater a worthwhile investment, the payback period on the overall system may actually be reduced. Actual desuperheater field performance needed to be measured.

Since Manitoba is a heating dominated climate there are concerns regarding the long term thermal performance of the ground loop. This study will measure the annual energy imbalance that is placed on the ground loop due to heating, cooling, and hot water (desuperheater). The annual energy imbalance is calculated by subtracting the quantity of heat rejected to the ground from the quantity of heat removed from the ground loop in a one year period.

3.0 Study Objectives:

The objectives of the study were to determine:

1. an average annual Seasonal Coefficient of Performance (SCOP for the heating season), and an average Seasonal Energy Efficiency Ratio (SEER for the cooling season),
2. the average annual water heating electric energy reduction due to the desuperheater, and
3. the average annual heating savings provided by a reasonably well installed ground source heat pump system in Manitoba.

The ten homes monitored are a biased sample since most of the homes were volunteered for the project by experienced and established heat pump contractors and /or distributors that were contacted and nine of the systems were relatively new (less than three years old). The one older system in the study was the only open loop (well to well system) in the study. This system was re-commissioned when it was discovered at the preliminary site visit that it was performing poorly (COP of 1.5) due to water supply issues.

4.0 Test Method:

Monitoring of these systems was achieved by sub-metering the ground loop energy (extraction and rejection), the electrical energy provided to all the electrical components connected to the heat pump unit, the energy provided by the desuperheater (DSH), and the electrical energy provided to the domestic hot water heater for ten homes located throughout Manitoba for an entire heating and cooling season.

4.1 Seasonal Coefficient of Performance (SCOP*)

The SCOP* of each unit was determined by summing the heat energy provided to the home by the ground loop with the heat energy provided to the home by the electrical components of the heat pump then dividing the sum by the electrical energy required to operate the heat pump for an entire heating season.

SCOP Calculation:

$$SCOP = \frac{kWh_{GL} + kWh_{EL1}}{kWh_{EL2}}$$

Where: kWh_{GL} = Ground Loop kWh Output
kWh_{EL1} = compressor, fan, DSH pump, aux. heater kWh usage
kWh_{EL2} = compressor, fan, DSH pump, aux. heater and ground loop pump kWh usage

4.2 Seasonal Energy Efficiency Ratio (SEER*)

The SEER* of each unit was determined by adding the heat energy (BTU) rejected to the ground loop and the desuperheater during the cooling season, subtracting the heat energy (BTU) provided to the ground loop and desuperheater loop by the electrical components then dividing this total by the electrical energy required to operate the heat pump for an entire cooling season.

SEER Calculation:

$$SEER = \frac{(BTU_{GL} + BTU_{DSH}) - (BTU_{EL})}{Wh_{EL}}$$

Where: BTU_{GL} = heat rejected to ground loop
BTU_{DSH} = heat rejected to desuperheater
BTU_{EL} = Compressor, Fan, and desuperheater pump electrical usage (kWh) converted to BTU

***The ground loop pump electrical energy consumption was not included in the electrical heat energy since it was already accounted for in the ground loop heat energy measurements.**

4.3 Desuperheater (DSH) Energy Savings

DSH Energy Savings (kWh) = $\underline{\mathbf{kWh_{DSH} - kWh_{ELDSH(heating\ Mode\ or\ Cooling\ Mode)}}}$

Where: kWh_{DSH} = DSH Output (kWh)

kWh_{ELDSH} = electrical energy into desuperheater energy output

kWh_{ELDSH} (Heating Mode) =DSH Output(kWh)/COP

kWh_{ELDSH} (Cooling Mode) = DSH pump energy(kWh)

5.0 Heat Pump System Monitoring Method:

To determine the SCOP and SEER of each heat pump system, the following values were required to be measured and applied to the SCOP and SEER Calculations:

1. Total kWh electrical energy input into the system
2. Total BTU Output from the ground loop heat exchanger.

Refer to Appendix C for a listing of measurement and monitoring devices and specifications.

5.1 Total Electrical Energy (kWh) Input into the System:

The following electrical loads were monitored to determine total kWh energy consumed by the heat pump system:

1. Compressor (Stage 1 and 2 if applicable)
2. Auxiliary Heat
3. Ground Loop Pump (1 or 2 pumps, Stage 1 and 2 as applicable)
4. Fan Motor (heating and cooling mode)
5. Desuperheater pump

Split-core current transducers (CT's) were placed on the conductor supplying each electrical component so that each component's consumption could be measured and monitored separately. One potential transducer (PT) was connected to the main electrical service panel to reference the line-to-line voltage supply to the heat pump system. This allowed the data logger to monitor correct Power Factor and kWh measurements of each component.

The CT's and PT's selected for this project have a manufacturer stated accuracy value of ± 1.0% of measured value.

Refer to Appendix C for detailed CT and PT specifications.

5.2 Total Energy (BTU) to and from the ground loop heat exchanger:

$$Q = m \cdot c_p \cdot \Delta T$$

Where: Q = heat energy transferred [BTU]
m = mass [pounds]
c_p = heat capacity [BTU/pound·°F]
ΔT = temperature difference

To determine the BTU output of the heat pump system, the temperature differential ΔT between the ground loop-in and out had to be measured as well as the total fluid mass through the heat exchanger. The following values and test points were monitored to determine total BTU energy produced through the heat exchanger:

1. Ground loop temperature Fahrenheit (°F) out
2. Ground loop temperature (°F) in
3. Temperature differential at heat exchanger ($\Delta T = °F_{in} - °F_{out}$)
4. Ground loop fluid flow rate (USGPM)
5. Ground loop fluid flow duration (minutes)

BTU values were converted to kWh by dividing by 3.413

5.2.1 Ground loop temperature measurements:

Ground loop temperatures were monitored using Type 385, 1000 Ohm platinum Resistance Temperature Detectors (RTD) installed directly in the fluid flow using compression fittings mounted to the ground loop piping before and after the heat exchanger coil. To minimize ambient effects on the RTD measurements, efforts were made to ensure, wherever possible, each RTD test point was of equal distance and positioning relative to each other and the heat exchanger input-output locations. To further minimize ambient effects, the data logger analog temperature channels were "locked" to the compressor current sensor channel so that ground loop temperatures were monitored and logged only when the compressor was running in heating/cooling modes of operation.

RTD's selected for this project were Class B accuracy giving an uncertainty of ± 1.5% at 32 °F (0°C) with a repeatability of better than 0.8% (-100°C to 100°C). Each individual RTD certainty produces an overall ΔT calculation uncertainty of ± 3.0% of measured value. Refer to Appendix C for detailed RTD specifications.

5.2.2 Ground loop fluid flow measurements:

To measure the ground loop fluid flow rate, an in-line flow meter was installed between the ground loop pump(s) and the heat exchanger. Measurement readings of each meter were recorded at the time of installation and verified periodically while conducting insitu testing at each installation within the test and monitoring period.

The flow meters selected were Dwyer Series type UV with an accuracy specification of ±2% @ 70 °F ± 2°F and 14.7 PSI with a repeatability of ± 1% Full Scale @ 70 °F ± 2°F and 14.7 PSI. (the ground loop fluid temperature span was measured at 30°F - 65°F at a static pressure of 14 PSI).
Refer to Appendix C for detailed flow meter specifications.

5.2.3 Ground loop fluid specific gravity verification:

With the exception of one open-loop heat pump system (well to well); nine closed-loop systems contained a standard 25% Methanol-to-water mixture. The specific gravity of the mixture determines the specific heat value which affects the kWh and BTU output calculations for each heat pump. To verify that the recommended 25% Methanol mixture was being used, ground loop fluid from a sampling of three heat pump installations were tested by the Manitoba Hydro Chemical Laboratory to verify their specific gravities. The test results were as follows:

Installation 1: SG = 0.9649 (24% Methanol)
Installation 2: SG = 0.9678 (25% Methanol)
Installation 3: SG = 0.9678 (25% Methanol)

An averaged specific gravity value of 0.97 was used for all pertinent calculations leading to the determination of SCOP and SEER values.

5.2.4 Ground loop flow meter correction factor:

The flow meter selected to measure the ground loop flow rate was calibrated for 100% water as a medium. A correction factor was therefore applied to determine the correct flow rate using a 25% Methanol mixture with an average specific gravity of 0.97.

Based on the flow meter manufacturer's correction formula, a correction factor of 1.02 was applied to all flow rate calculations. Refer to Appendix D for detailed information.

6.0 Desuperheater Monitoring Method

The energy provided to domestic hot water by the desuperheater (DSH) was calculated by the following equation:

Desuperheater contribution (kWh) = Total Domestic Hot Water Energy (kWh) minus Electrical energy consumed by the water heater (kWh)

Total Domestic Hot Water Energy (kWh) = Energy supplied to domestic hot water usage plus stand-by loss energy of the domestic hot water system.

Energy supplied to domestic hot water usage (flowing water) = $m \cdot c_p \cdot \Delta T$

Stand-by loss energy was calculated by subtracting the electrical energy supplied to the water heater when the desuperheater did not operate for an extended period (e.g. shoulder month) of time from the energy supplied to domestic hot water usage.

The following test points were measured to calculate the energy to domestic hot water usage.

1. water heater cold water temperature Fahrenheit (°F) in
2. water heater hot water temperature (°F) out
3. domestic hot water usage (litres)
4. kWh electrical energy consumed by the hot water tank

To ensure that the temperature measurements were recorded only when hot water was being used, two measures were taken:

1. A time delay relay was connected to the water meter pulse output so that whenever the pulse output contacts closed; indicating water flow through the hot water tank, the time delay relay would operate, thereby closing a set of normally open contacts. These contacts would remain closed as long as the water meter produced pulses. These contacts were connected to the data logger's digital input channel which recorded the total time that the contacts remained closed (run-time of the hot water tank).

2. Secondly, the temperature input channels were locked to the logger's digital input (run-time) channel so that temperature measurements were recorded only when there was water flowing through the hot water tank

7.0 Verification of Measurements & Accuracies:

Refer to Appendix D for a listing of all test instruments and reference standards used for the accuracy verification and insitu testing described in Sections 7.1 and 7.2 below.

7.1 Monitoring equipment accuracy and precision verification:

Individual data acquisition components integral to each complete monitoring system were sample tested to verify manufacturer stated accuracy and precision and to test for any possible defects.

7.1.1 Current Transducers (CT's):

Out of a total inventory of 116 CT's, random sample groups from each CT rating were tested for accuracy. The sample groups consisted of:

1. Ten 10 amp CT's,
2. Ten 30 amp CT's,
3. Eight 50 amp CT's, and
4. Eight 100 amp CT's.

Each sample group was tested at a minimum of six test points throughout their range. Each CT was connected to the current input channels of an ENERNET K20 logger.

The instantaneous current measurements from each logger channel were then compared to the current values measured by an NRC certified reference standard.

Each of the four sample groups produced average accuracies of better than 0.42% with standard deviations of less than ±0.74%.

7.1.2 Potential Transducers (PT's):

Out of a total inventory of 14 PT's, a random sample of 2 PT's was tested for accuracy.

Each PT was tested at a minimum of six test points throughout their range. Each PT was connected to the potential input channels 1 and 2 of an ENERNET K20 logger The instantaneous potential measurements from each logger channel were then compared to the potential values measured by an NRC certified reference standard.

Each of the PT's produced average accuracies of better than -0.19% with a standard deviation of less than ±0.12%.

7.1.3 RTD Temperature sensors:

Out of a total inventory of 79 RTD's, a random sample of 10 units were tested for accuracy and precision.

Each RTD was connected to the analog input channels of an ENERNET K20 logger. Testing was conducted at two test points, 25°F and 90°F, which were selected to include the typical range of temperatures expected from seasonal ground loop operation (30°F to 65°F). The RTD's were placed into a temperature bath and the measurements recorded by the data logger channels were compared to a Measurement Canada certified (NRC traceable) digital thermometer.

An average accuracy for the RTD's, was measured at the logger analog inputs, and was tested to be within ±0.67 °F (1.2 °C) of the measured reading throughout the 25°F to 90°F (-4 °C to 32°C range.

An average precision value of ±0.74°F (1.3 °C) was measured between the RTD's. This means that there is a maximum average uncertainty of ±0.74°F (1.3 °C) when calculating ΔT differential between the input and output of the ground loop and desuperheater heat exchangers.

7.1.4 Enernet K20 Data Logger:

Each of the logger's eight analog input channels was verified for precision using RTD simulators of various known resistances.

7.1.5 Ground loop and desuperheater flow meters:

Due to the simplicity of construction, lack of test equipment and reference standard, these devices were not tested. Refer to the manufacturer published accuracy and repeatability specifications in Appendix C.

7.2 Installation and post-installation verification (IN SITU) testing:

A verification test was conducted when the monitoring system was initially installed. The purpose of the verification test was to confirm the following variables:

1. Correct data logger programming and referencing,
2. Correct CT and PT referencing, connection and sizing,
3. Confirm accurate measurement of volts, amps, watts and power factor by the data logger,
4. Confirm accurate measurement and logging of the ground loop and desuperheater input/output temperature differentials,
5. Compare flow meter readings to manufacturer ratings of the ground loop pump(s) and desuperheater pump,
6. Correct operation and logging of the water meter, time delay relay and compressor relay contact closures.

After a number of weeks (or months) of normal operation, a follow-up In Situ test was conducted to confirm the variables listed above as well as the Potential Transformers and to verify any changes or defects in the monitoring equipment.

8.0 Test Site Selection:

The intent of the site selection was to monitor various heat pump makes, models and loop configurations, in different geographic locations within Manitoba. It was also intended to monitor only heat pump systems that were designed and installed by established and experienced contractors. All units were equipped with the desuperheater option.

The breakdown is as follows:

1. Locations: One test site in northern Manitoba
   One test site in central Manitoba
   Eight test sites in southern Manitoba (mix of urban and rural)

   See Map in Appendix B

2. Manufacturers: Six different heat pump brands were monitored

3. Heat Pump Types: Five single stage units
   Five dual stage units
   Nine water to air units
   One water to air and water (combination) unit
   Six heat pumps were equipped with a brushless permanent magnet DC type fan motor
   Four heat pumps were equipped with permanent split capacitor fan motors (PSC motors)

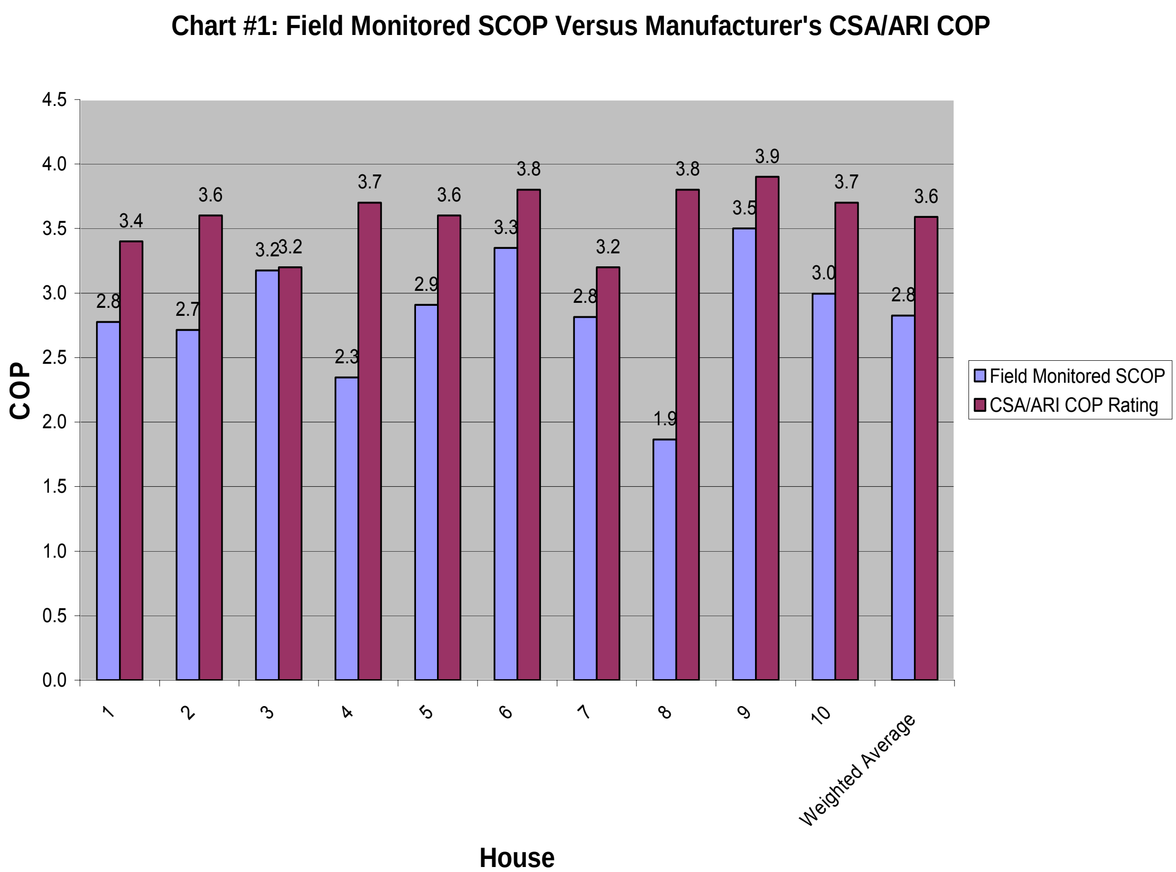
4. Loop Types: Three closed horizontal slinky loops
   One closed horizontal two pipe loops
   Four closed vertical loops
   One well to well system (open loop)
   One lake loop (closed)

9.0 Heating Season Performance

9.1 Energy Efficiency

The manufacturers ARI tested COP's ranged from 3.2 to 3.9 with an average COP of 3.6. The field monitored test data showed that the seasonal coefficient of performance (SCOP) during the heating season of the monitored ground source heat pump systems ranged from 1.9 to 3.5 with an average of 2.8 over a one year period (see Chart #1 below). SCOP is defined as the total energy (heat) delivered by the system divided by the total energy input to the system over one heating season.

The actual annual energy savings compared to an electric resistance heating system ranged from 3,934 to 29,657 kWh with an average of 15,842 kWh.



The actual seasonal performance of a ground source heat pump was expected to be lower than the manufacturer stated COP (COP based on CAN/CSA 13256 Test Standard "Water-source heat pumps-Testing and rating for performance").
This is because the test standard does not account for:

1. the energy consumed by an auxiliary heater that may be required
2. shortcomings in the actual system field installation and design
3. fluid pumping power required to overcome the external resistance of the ground loop heat exchanger piping. The standard includes for only internal resistance of the unit itself.
4. the fan motor power required to overcome the external resistance of the connected ductwork. The standard only includes for the internal resistance of unit itself.
5. any start-up and shut down cycling losses
6. variations in entering water temperatures
7. equipment malfunctions
8. variable homeowner operation and lifestyle
9. any lack of system maintenance (air filters etc.)
10. improper system commissioning.

The ground loop pumps delivered an average of 0.75 LPS (11.9 USGPM) and had an average electrical draw of 695 watts. The CSA test standard allows for a default pumping power of 115 watts moving 11.9 USGPM of fluid. Therefore, the average electrical draw for ground loop pumps in the field was 580 watts higher than the amount allowed for in the CSA test standard.

The fan power allowance determined by the formula in the CSA 13256 test standard was 256 watts. This formula is intended to estimate only the fan power required to overcome the internal resistance of the average heat pump unit. In this study, the actual average fan power draw monitored was 592 watts. Therefore, the average electrical draw for fan motors in the field was 336 watts higher than the amount allowed for in the CSA test standard.

The average electrical consumption of the auxiliary heaters was 190 kWh which was less than 1% of the average annual heating energy provided to the homes by the heat pump systems.

The closed loop systems operated with average annual entering water temperature of 36.0^{o}F (4.2 ^{o}C) which is slightly greater than the 32 ^{o}F (0 ^{o}C) temperature that is required by the CSA/ARI test. This should have resulted in slightly improved field performance figures for closed loop systems. Conversely the well to well system operated at an average annual entering water temperature of 44.9 ^{o}F (7.2 ^{o}C) which is slightly lower than the 50 ^{o}F (10 ^{o}C) temperature that is required by the CSA/ARI test. This should have resulted in slightly decreased field performance figures for the well to well system..

Homeowner operation did not appear to significantly affect the system efficiency during the study period for any of the homes.

It is, possible to calculate an estimated SCOP once the following parameters are known:

- average entering fluid temperature
- additional fan power in watts ($fan_{additional}$)
- additional pump power in watts ($pump_{additional}$)
- estimated annual heating energy requirement ($AHER_{kWh}$)
- estimated annual heating energy requirement provided by the auxiliary heating (Aux_{kWh})

The estimated SCOP calculation example below is based on the overall average system in the monitoring study and assumes the actual average entering fluid temperature (heating mode) is nominally the same as the CSA/ARI test requirement.

Average Heat Pump Unit performance (based on CSA/ARI test):

$Output_{test}$: 11,758 watts
$Input_{test}$: 3275 watts
COP_{test}: 3.59

Field installed instantaneous COP (COP_{field}) = $\frac{Output_{test} + fan_{additional} + pump_{additional}}{Input_{test} + fan_{additional} + pump_{additional}}$

$$COP_{field} = \frac{11{,}758 \text{ watts} + 336 \text{ watts} + 580 \text{ watts}}{3{,}275 \text{ watts} + 336 \text{ watts} + 580 \text{ watts}}$$

$COP_{field} = 3.02$

$$\text{Estimated SCOP} = \frac{AHER_{kWh}}{(AHER_{kWh} / COP_{field}) + Aux_{kWh}}$$

$$\text{Estimated SCOP} = \frac{24{,}523 \text{ kWh}}{(24{,}523 \text{ kWh}/3.02) + 190 \text{ kWh}}$$

$$\text{Estimated SCOP} = \frac{24{,}523 \text{ kWh}}{8{,}310 \text{ kWh}}$$

Estimated SCOP = 2.95

The estimated SCOP of 2.95 is greater than the annual average SCOP of 2.82 obtained from the actual monitoring of the 10 homes in the study. It is assumed that the difference is caused by items that are not accounted for in the estimation calculation such as cycling losses, actual equipment performance, and equipment maintenance.

9.2 Cost Savings

The heat pump systems provided 6,855 to 42,277 kWh of heating energy to the homes. The average quantity of heating energy provided to the 10 homes was 24,523 kWh.

Average annual electricity savings of 15,842 kWh during the heating season equates to $998 (based on April 1, 2009 PUB approved Manitoba Hydro Residential Electricity Rates) when compared to electric resistance heat.

This annual savings amount would be reduced to $578 when compared to a high efficiency natural gas furnace (natural gas prices based on May 1, 2009 PUB approved Manitoba Hydro Residential Natural Gas Rates and includes the Basic Monthly Charge of $13/month).

9.3 Auxiliary Heat

The ground source heat pump systems provided 97 to 100% (average of 99%) of the total heating energy required by the homes. The remainder was provided by electric resistance auxiliary (back-up) heaters. The auxiliary heaters in the monitored homes used 0 to 929 kWh of electricity. The average electrical consumption was 190 kWh for auxiliary heat.

It appears that all of the heat pump systems were sized to meet the total heating energy requirements for the monitored houses. Since all of the closed loop systems were relatively new, the study does not have enough data to determine what percentage of the annual heating energy requirements the heat pump systems will provide in the long term (10 to 20 years from now). More detailed long term monitoring would be required to determine the sustainability of this performance.

9.4 Entering Fluid Temperatures

The weighted average annual entering fluid temperature for the nine closed loop systems ranged from 32.8 ^{o}F to 39.5 ^{o}F (0.4 ^{o}C to 4.2 ^{o}C) with a weighted average of 36.0^{o}F (4.2 ^{o}C) see Chart #2 below. This is just slightly greater than the 32 ^{o}F (0 ^{o}C) temperature that is required by the CSA/ARI test for closed loop heat pumps.

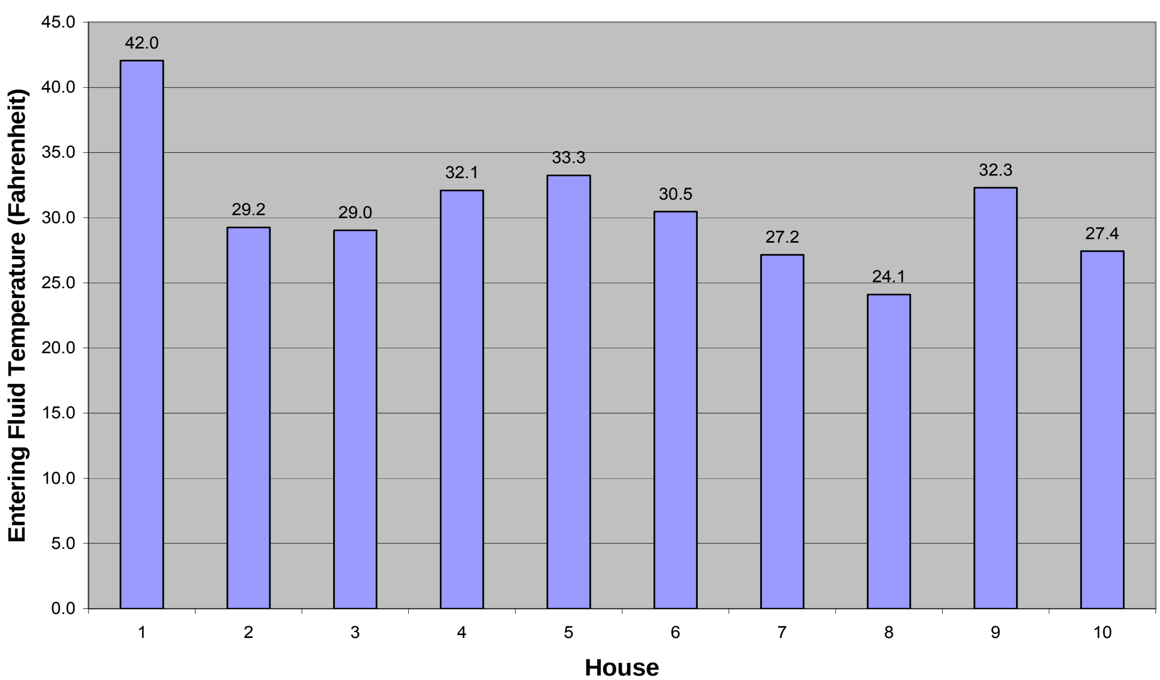
The well to well system had a weighted average annual entering water temperature of 44.9 ^{o}F (7.2 ^{o}C) which is slightly lower than the 50 ^{o}F (10 ^{o}C) entering water temperature which is the test temperature requires by the CSA/ARI test for open loop systems.

From information provided by several heat pump designers, most systems in Manitoba are designed with minimum entering water temperatures of 25 ^{o}F to 30 ^{o}F. (-4 ^{o}C to -1 ^{o}C) The actual minimum entering water temperature ranged from 24.1 ^{o}F to 33.3 ^{o}F (-4.4 ^{o}C to 0.7 ^{o}C) for the closed loop systems and 44.2 ^{o}F (6.6 ^{o}C) for the well to well system (See Chart #3).

The horizontal loops provided the highest entering water temperatures.

All of the vertical loops were drilled in overburden ranging from 50 to 200 feet deep.

Chart #3: Minimum Entering Fluid Temperature (Heating Mode)

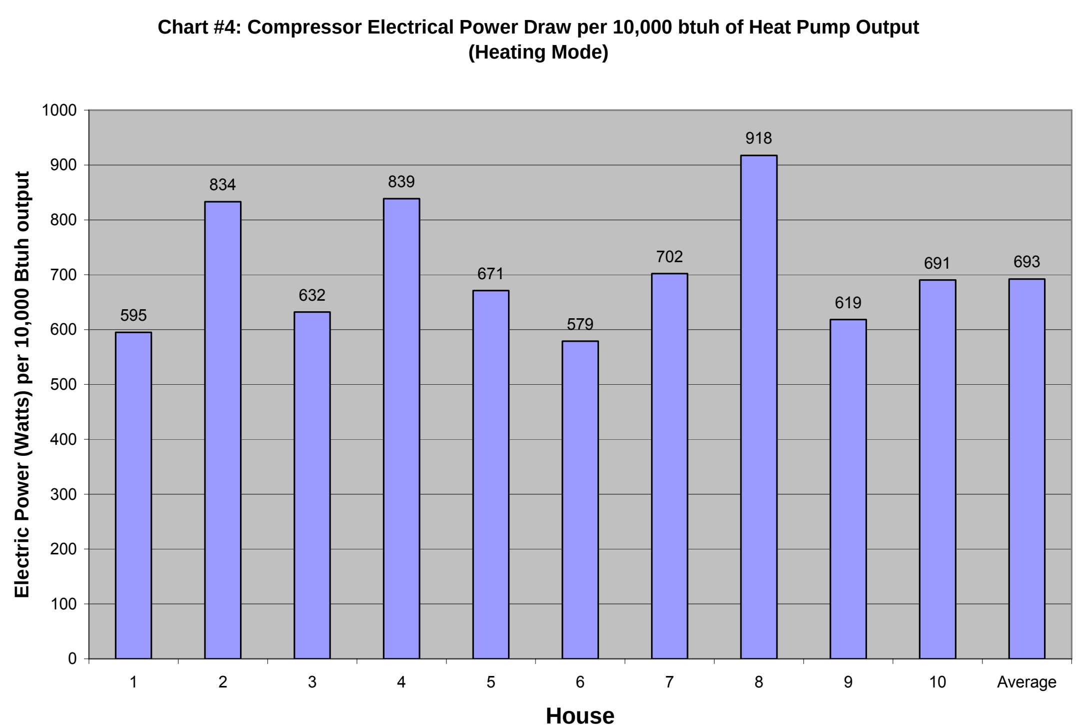


9.5 Compressor

There were five two stage and five single stage compressor systems monitored in the study. The electrical power draw required to drive the compressors ranged from 579 watts to 918 watts per 10,000 BTUh of heat pump output with an average of 690 watts per 10,000 BTUh (See Chart #4 below).

The two compressors with the highest electrical power draw per 10,000 BTUh of heat pump energy output are of the same make and model (839 and 918 watts per 10,000 BTUh of heat pump output). There were three compressors of this model in the study. The third had the lowest energy input when compared to heat pump output (579 watts per 10,000 BTUh of heat delivered). These three compressors are reciprocating compressors that reverse their direction of rotation before mechanically engaging the second stage.

During the monitoring period these three compressors would periodically get stuck in stage one operation even though the system was electrically calling for second stage operation. The COP of the systems was lower during these events since the fan speed was increased to meet second stage heating. If the system could not meet the home's heating requirements when the compressor was still operating in first stage, the auxiliary heater would come on to meet the heating requirements. This would lower the COP even more. According to the equipment supplier, these compressors have had a high failure rate and they are currently being replaced on warranty with an improved type of compressor.

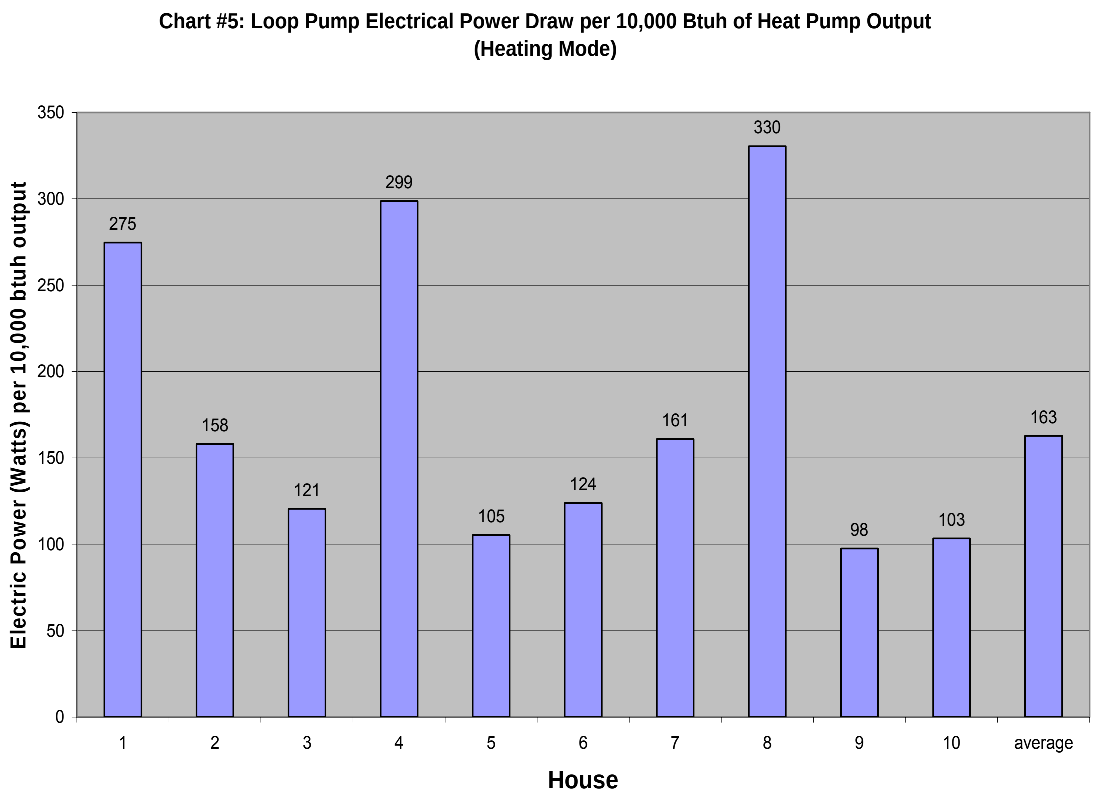


9.6 Ground Loop Pump

The electric power draw for the ground loop pumps ranged of 98 to 330 watts per 10,000 BTUh of heat pump output (heating mode) with a weighted average draw of 163 watts per 10,000 BTUh (see Chart #5 below).

The two poorest performers were on closed loop two stage systems that had pumps that were not staged and were fixed at the second stage flow rate whether the system was on first stage or second stage heating. These systems had a fluid flow rate of approximately 6 usgpm/nominal ton on first stage heating. The third highest pump draw of 275 watts per 10,000 BTUh of heat pump output was for the only open loop system being monitored.

The loop pumps on the seven other homes had draws of less than 161 watts per 10,000 BTUh of heat pump output (heating mode). Five of these systems were single stage units and one was a two stage heat pump that also had a two stage ground loop pump system.



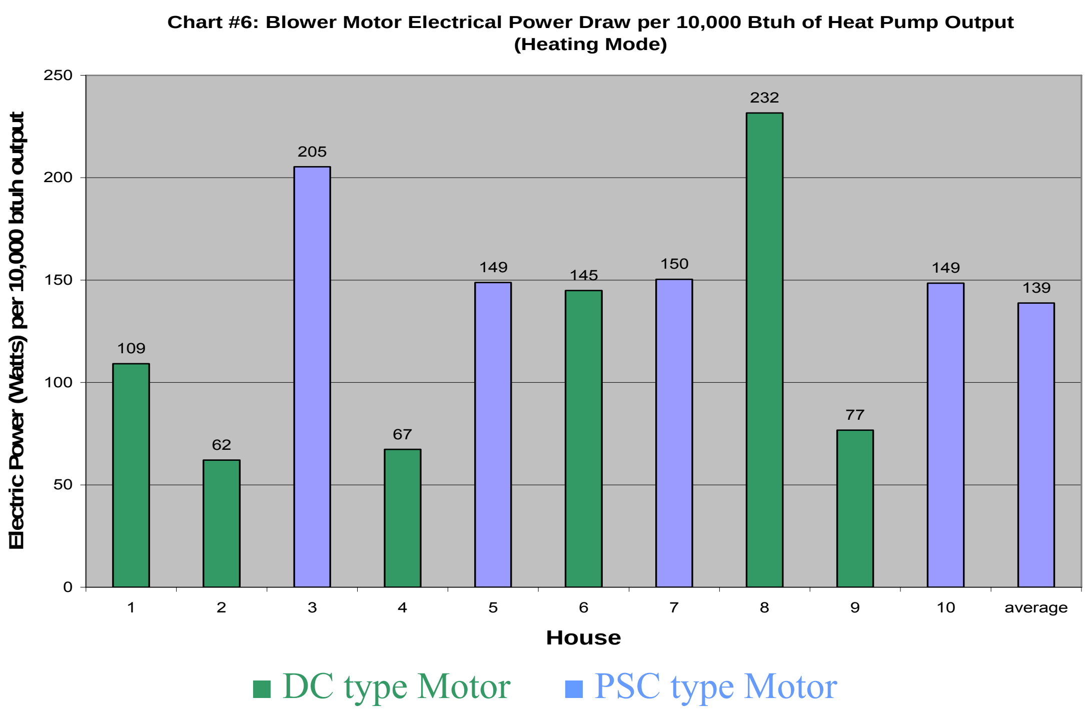
9.7 Fan Motor

Six of the ten units have an energy efficient brushless permanent magnet DC type motor and four have a permanent split capacitor (PSC) motor. One unit (house # 3) was a combination unit that had a PSC fan motor and hydronic loop pumps included in the fan energy. The electrical power draw ranged from 62 to 232 watts per 10,000 BTUh of heat pump output (heating mode) with an average of 139 watts (See Chart #6 below).

Three of the four PSC motors had approximately the same fan motor energy consumption (149-150 watts per 10,000 BTUh of heat pump output). The fourth PSC motor had a fan motor energy consumption of 205 watts per 10,000 BTUh of heat pump output. Three of the brushless permanent magnet DC type motors had the lowest power consumption (62 to 77 watts per 10,000 BTUh of heat pump output) but the consumption for all six varied greatly (62 to 232 watts per 10,000 BTUh of heat pump output).

The fan motor with the highest usage (232 watts/10,000 Btu) was actually a DC type motor. Duct design did not appear to be the cause of this high usage. Part of the reason that this fan motor used more energy than expected was that it ran a lot of hours at high speed while the compressor was stuck in first stage heating. The two other DC motors had fan motor consumptions that were slightly lower than the PSC motors.

A brushless permanent magnet DC type motor should use less than half of the energy as a PSC type motor.



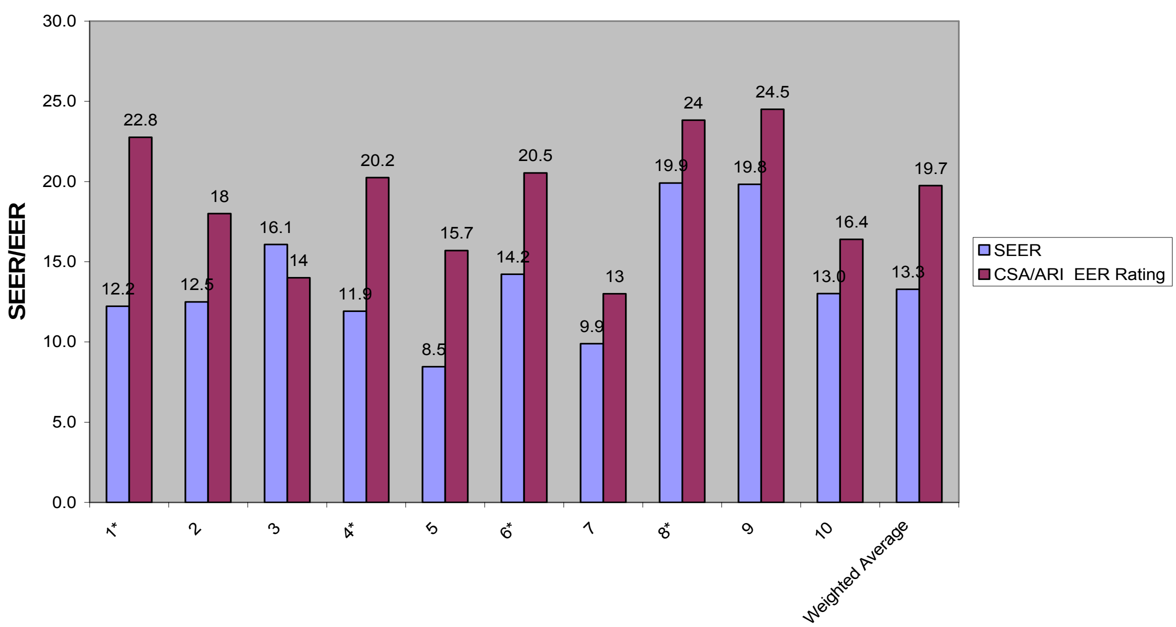
10.0 Cooling Season Performance

The ground source heat pump CSA 13256 test standard “Water-source heat pumps-Testing and rating for performance” rates cooling efficiency by an Energy Efficiency Ratio. Similar to the COP ratio, the EER is an instantaneous test based on specified conditions.

Central split air conditioning systems which are the most common residential cooling systems in Manitoba are rated by SEER (Seasonal Energy Efficiency Ratio). The SEER rating is supposed to provide a customer with a more accurate value to compare operating costs between units over an entire cooling season. The current minimum SEER rating for a central air conditioner is 13.

The test data showed that the field monitored Seasonal Energy Efficiency Ratio (SEER) during the cooling season for these ground source heat pump systems ranged from 8.5 to 19.9 with an average of 13.3 over the 2007 cooling season. SEER is defined as the total energy (heat) removed by the heat pump system (Btu’s) divided by the total energy input to the system (watt hours) over one cooling season. The weighted average manufacturer rated EER of the ten units included in this study is 19.7 based on the CSA 13256 test standard (see chart # 7 below).

Chart # 7: Field Monitored SEER versus ARI/CSA EER Rating



* CSA/ARI EER Ratings for two stage units is a weighted average of the part load and full load ratings based on actual compressor part load and full load run hours (cooling mode).

Similar to COP, the SEER of a ground source heat pump will generally be lower than the manufacturer's stated EER (EER based on CAN/CSA 13256 Test Standard "Water-source heat pumps-Testing and rating for performance").

This is due to the fact the test standard:

1. is an instantaneous test that does not include cycling losses
2. may not reflect actual system installation and design
3. only includes the fluid pumping power required to overcome the resistance of the unit itself (not the bore field piping).
4. only includes the fan power required to overcome the resistance of the unit itself (not the connected ductwork)
5. does not account for variations in entering water temperatures
6. does not account for variable homeowner operation
7. does not account for lack of system maintenance

The ground loop pumps delivered an average of 0.75 LPS (11.9 USGPM) per minute and had an electric draw of 750 watts. The CSA test standard allows for a default pumping power energy of 115 watts to move11.9 USWG of fluid.

The calculated fan energy (based on the CSA 13256 test standard) to only include the power to overcome the resistance of the average size of heat pump within the study was 256 watts. The actual average fan power draw in the homes that were monitored was 536 watts.

The average annual electricity consumption for these units during the cooling season was 772 kWh ($49). The estimated average annual cooling savings compared to a central air conditioner with a SEER of 13 is 17 kWh was $1. This may not be fair comparison since the assumed SEER of 13 for central air conditioners is at test conditions and may not reflect the actual field performance of these units. Actual field performance of conventional central air conditioners could also be expected to be lower than laboratory test results which could increase the potential cooling savings.

The single stage ground source heat pumps operated between 94 and 348 hours in the cooling mode. The two stage units operated between 195 and 541 hours in the cooling mode. The average equivalent full load cooling hours was 218 hours.

11.0 Domestic Hot Water Heater Savings

The ground source heat pump desuperheater provides energy for water heating and thereby reduces electric water heating energy consumption.

In the winter, when the heat pump is delivering heat energy to the house, some of that heat energy is diverted to heat the domestic hot water; therefore it is assumed that the energy being delivered to the domestic hot water system is at the same COP as the heating system.

In summer, the heat pump is removing heat from the house and rejecting it to the ground loop. Some of this heat energy is diverted to the desuperheater and to the domestic hot water heater. This energy is considered “free” heat because it would have otherwise been rejected to the ground. However, in heating dominated climates with significantly unbalanced ground loads, the desuperheater also utilizes some of the heat that could have been rejected back to the ground in the cooling season. This causes the ground load to be even more seasonally unbalanced. This can be compensated for by increasing the size of the borefield (closed-loop systems) but this would increase the initial capital cost.

One desuperheater pump failed during the study period, therefore the desuperheater did not provide any heat to the domestic hot water system. Another pump was found to be defective at the start of the study but was replaced.

The homeowner’s estimated annual savings ranged from 0 kWh to 1142 kWh with an average annual savings of 610 kWh at a value of $38, including the one system that was not working. The average savings increased to 678 kWh ($43) per year when the failed unit was excluded from the average.

A common trade practice to improve the output of a desuperheater that is directly connected to an electric storage water heater is to lower the temperature setting on the bottom element. The lower setting allows the desuperheater to provide more heat to the water heater since the element will not come on as frequently and it provides a lower inlet water temperature to the desuperheater which increases the output of the desuperheater. An issue was discovered during the study related to this practice. The hot water heater could only have a reduced temperature setting on the lower element during the heating season. The setting had to be increased in the non-heating season to meet the customer’s hot water requirements. This was determined to be necessary because the heat pump did not operate for many hours in the summer period therefore the desuperheater could not provide much heat to the hot water heater and the customers would run out of hot water. A more effective solution promoted by contractors is to install a second water heater as a pre-heat tank. Although more effective, this increases the capital cost to the customer by an additional cost that is estimated at $500-$800.

The National Plumbing Code of Canada (2005) requires that the temperature setting of electric water heaters be 60 ^{o}C (140 ^{o}F) to minimize the potential of bacterial growth in the water heater. This is also the factory setting of electric water heaters. Almost all of the homes in the study had hot water delivery temperatures lower than 60 ^{o}C (140 ^{o}F). Lowering the hot water heater temperature to increase the heat energy benefit provided by the desuperheater could potentially promote the growth of bacteria in the water heater which could become a health hazard.

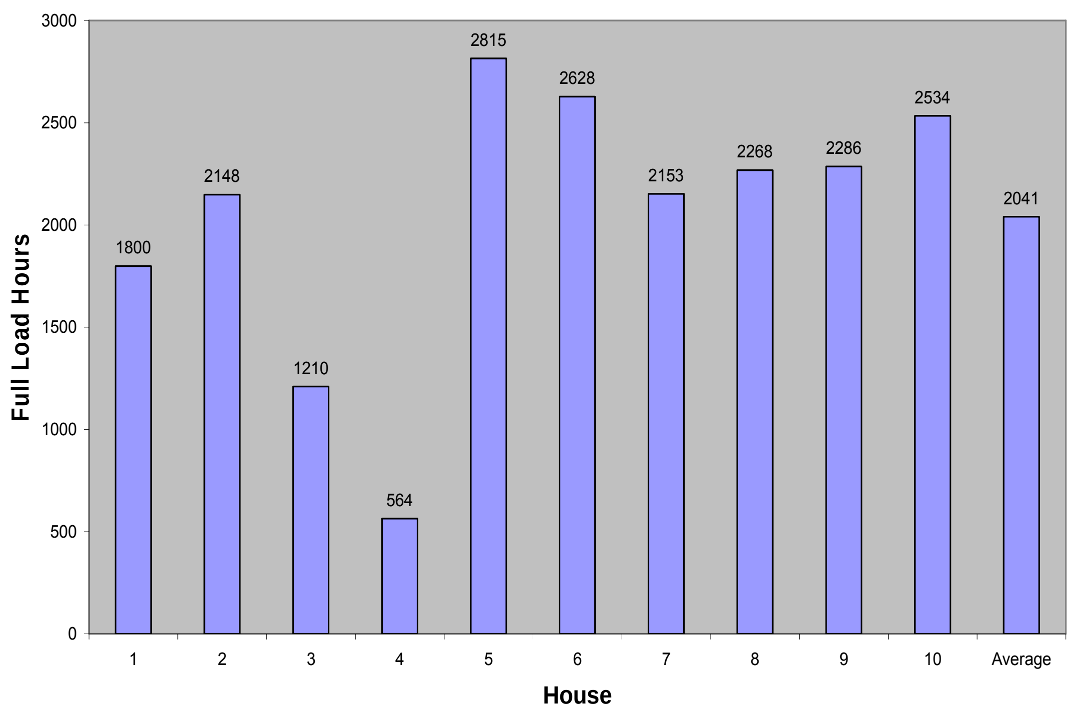
12.0 Operating Statistics

12.1 Run Hours Heating

The heat pumps operated between 564 and 2815 full load hours with an average of 2041 equivalent full load hours in the heating mode (see Chart #7 below). The home that had the lowest run hours had the heating requirements offset by constantly operating three dehumidifiers throughout the winter. These dehumidifiers effectively operated as space heaters at an SCOP of 1. The other homes did not operate any significant electrical loads in the home and did not utilize any other sources of heat.

House # 3 had the second lowest heating run hours (1,210) and the lowest cooling run hours (94). This was probably due to the heat pump unit itself being over-sized for the application. The unit is a single stage model that has a heating capacity output that was greater than most others in the study. The unit was installed in a new smaller energy efficient home that used the lowest amount of energy during the study period.

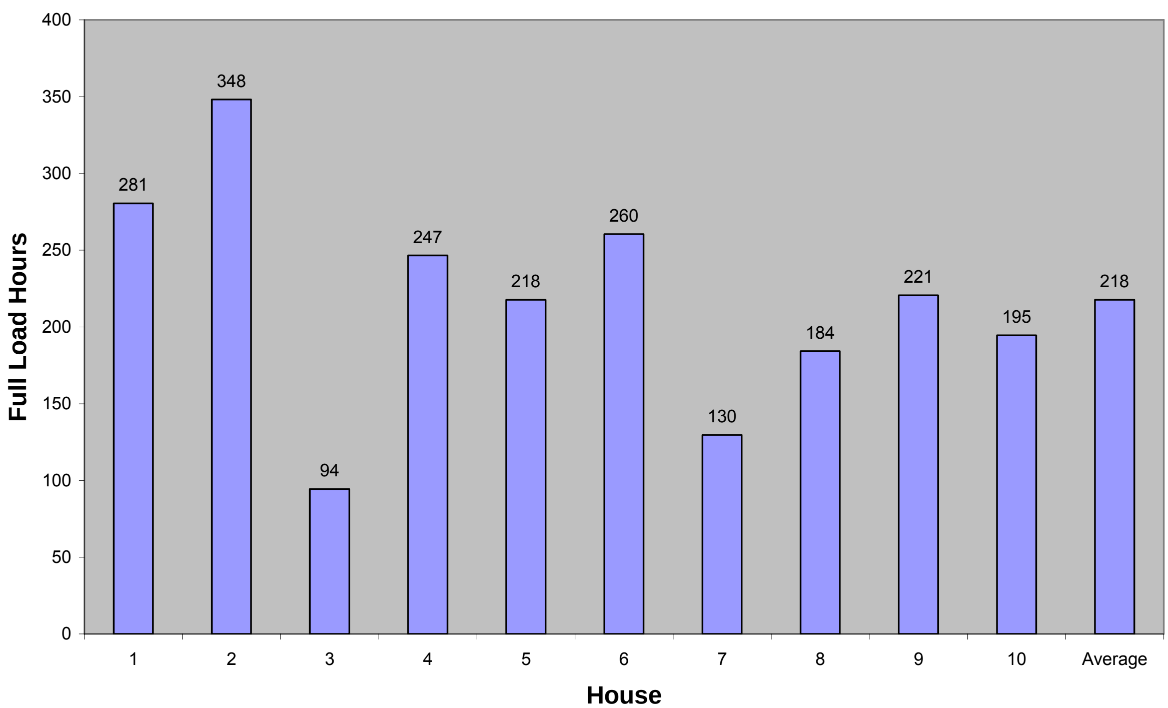
Chart # 8: Equivalent Annual Full Load Hours (Heating)



12.2 Run Hours Cooling

In cooling mode, the homes operated between 94 and 348 full load hours with an average of 218 equivalent full load hours (See Chart # 8 below). The average operating hours for all two stage units showed that they operated 82% of the time on first stage cooling. One of the two stage unit's had an actual annual run time of 541 hours in the cooling mode.

Chart # 9: Equivalent Annual Full Load Hours (Cooling)



There are significant variations in the heating and cooling requirements of homes in Manitoba. The study demonstrated that this variation equated to a load imbalance on the ground loop of approximately 5 units of heat extracted during the heating season for every 1 unit rejected to the ground loop in the summer. This imbalance must be considered when designing and installing a ground loop system.

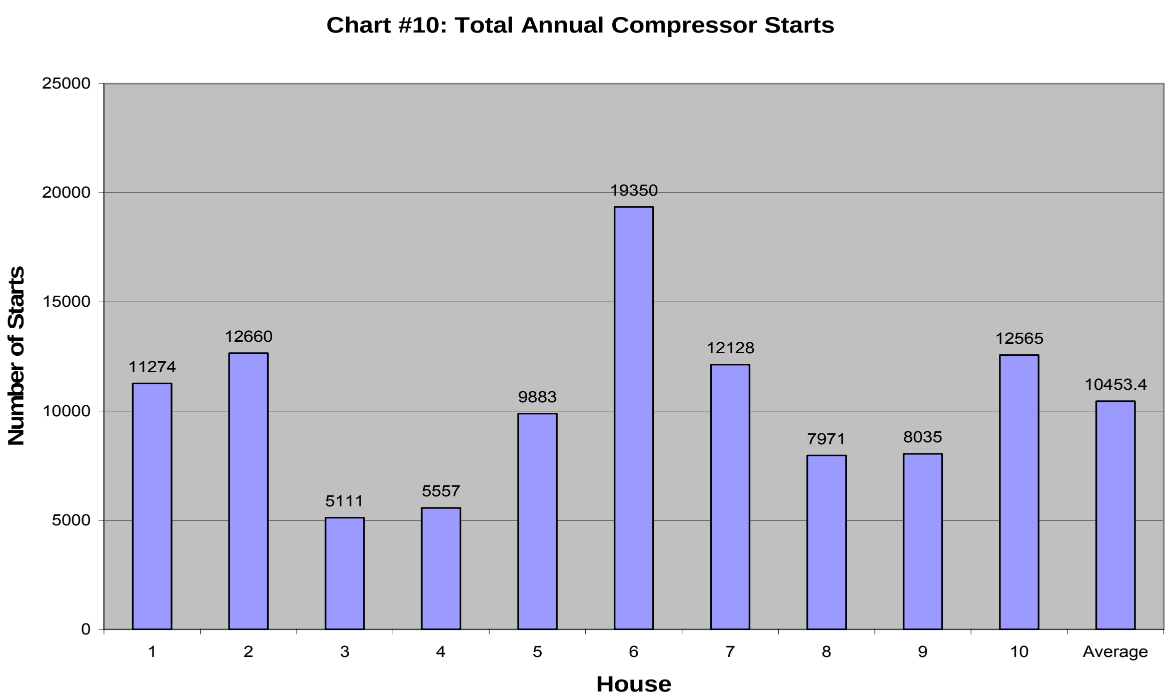
12.3 Number of Starts

The systems started between 3,026 to 19,350 times per year, with an average of 10,453 starts (see Chart # 10 on page 25). The average number of starts in the heating mode was 9,351 and the average number of starts in the cooling mode was 1,102.

The high number of starts is significant because it can cause power quality issues in some homes. The most significant issue appears to be the frequent flickering or momentary dimming of lights in some homes when the heat pump unit starts due to the high in-rush current required to start the compressor. The compressor in-rush current lasts a fraction of a second and is approximately 10 times the running current. Compact fluorescent lights appear to be less susceptible to flicker compared to other types of lights. Incandescent sources including halogen lights appear to be the most flicker susceptible type of light source.

Manitoba Hydro has installed and tested two high torque start kits (basically an additional capacitor) on two different compressors to determine whether the start kits could significantly reduce the in-rush currents at compressor start-up. These kits are intended for hard starting compressors but it has been suggested that they can significantly reduce the in-rush current of the compressor motor. In both cases, the kits only slightly reduced the in-rush current and did not alleviate the issue of dimming lights (flicker).

Manitoba Hydro has recently installed and tested a newly released electronic soft start device that can be installed on specific models of heat pumps and compressors. This device appears to significantly reduce the in-rush current of the compressor motor. The preliminary test of this device on one compressor showed a 60% reduction of in-rush current at start-up. Manitoba Hydro will be conducting further field tests of this device.



13.0 Conclusion

The results of this study indicate that there are potentially significant energy savings in a Manitoba climate when utilizing a ground source heat pump compared to electric resistance heat.

Annual energy savings estimates for a ground source heat pump compared to electric heat should utilize an estimated Seasonal Coefficient of Performance (SCOP) instead of the ARI/CSA certified steady state COP. The estimated SCOP can be calculated by accounting for the additional fan, pump, and auxiliary heater electricity requirements that are not included in the CSA/ARI test standard.

The cooling season savings when compared to a new central air conditioner does not appear to be significant. The major benefit for a ground source heat pump compared to a central air conditioner is that the unit itself is indoors and not exposed to the outdoor elements.

Domestic water heating savings from the desuperheater in a heating dominated climate may not justify the capital cost and maintenance costs connected to the desuperheater. There may also be a health and safety issue with respect to the water heater storage temperatures being set lower than the National Plumbing Code requirement. This practice may increase the effectiveness of the desuperheater but could promote bacterial growth in the water heater.

Entering fluid temperature data collected during the study period were within reasonable design parameters. However, the closed systems being monitored were still relatively new, between one and three years old. This study does not provide enough data to determine the sustainability of long term loop and system performance.

The systems operated for an average of 2041 equivalent full load hours in heating mode and only 218 hours in cooling mode. This causes an imbalance to the ground of approximately 5 to1 for heat being extracted from the ground versus heat that is being rejected to the ground. This thermal imbalance could cause significant issues with the heat pump's long term sustainable performance if it was not properly considered at the design phase.

The significant in-rush currents and the high numbers of starts associated with the compressors have the potential to cause a momentary dimming of lights (flicker) or other power quality issues. Ensuring that the electrical system supplying power to the heat pump is robust and utilizing lights that are less susceptible to flicker could help reduce the effects of flicker.

14.0 Recommendations

Customers should be provided with energy usage and savings based on an estimated Seasonal Coefficient of Performance (SCOP) that can be achieved and sustained over the expected operating life of the system.

During the monitoring period, several problems with some of the heat pump systems were discovered by the data collected through the monitoring equipment. For this reason, systems should be commissioned after the original installation and re-commissioned periodically to ensure proper operation. Installation of basic, permanently mounted metering equipment such as a flow meter, temperature probes on the ground loop and a run hour meter on the heat pump itself could be of significant benefit to both customers and geothermal contractors in diagnosing /trouble shooting problems and maintain proper operation.

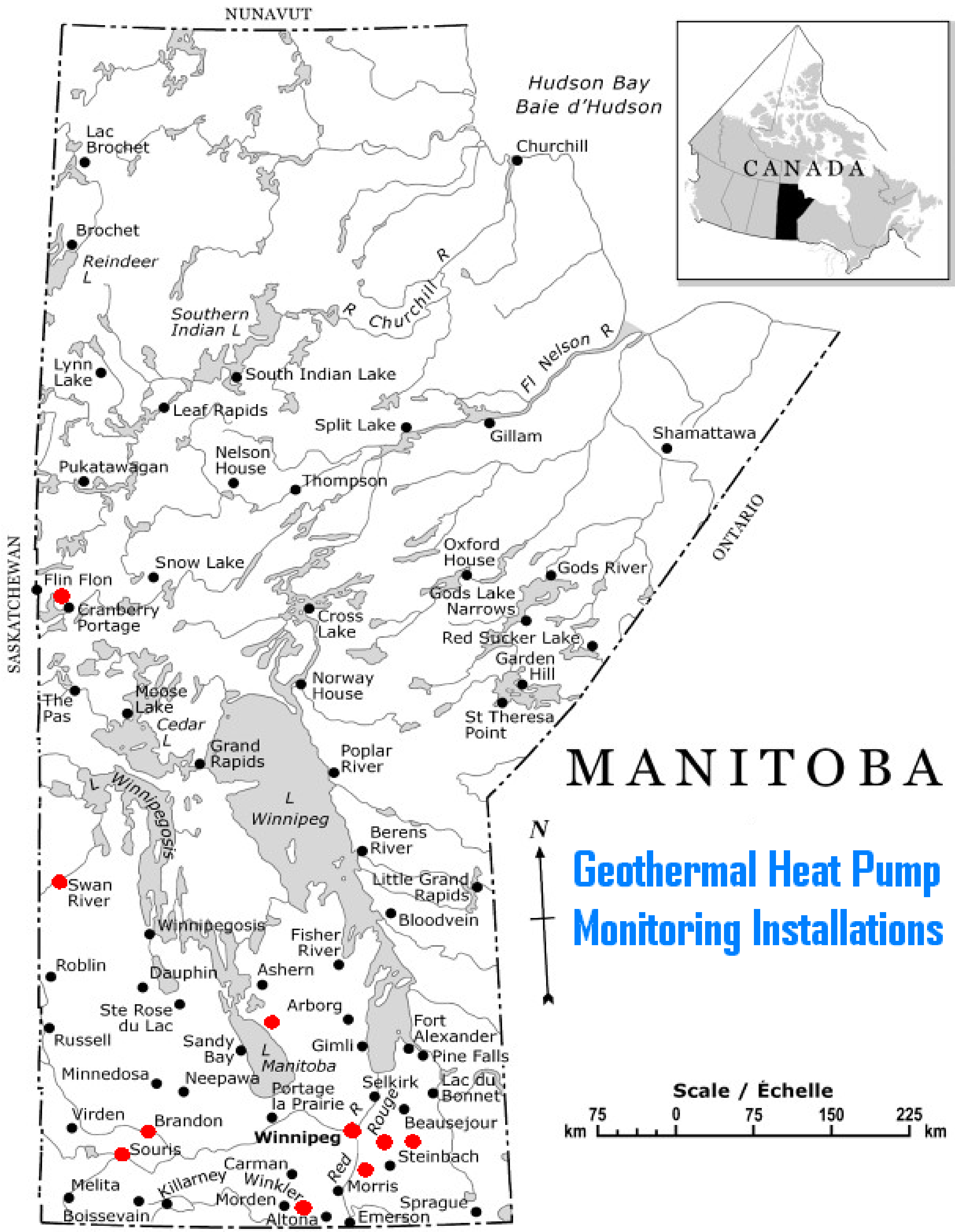
Long term monitoring of bore fields in a cold climate such as Manitoba should be undertaken to determine the long term impact on the bore field due to the annual energy imbalance placed on the bore field.

More research and development (R&D) is required to find solutions for the power quality issues created by the starting characteristics of heat pump compressor motors. The R&D should include devices that can reduce the in-rush current, heat pump design, and electrical system design.

Contractors should ensure that the temperature setting of a customer's electric storage water heater is no less than 60 ^{o}C (140 ^{o}F) as required by the National Plumbing Code of Canada (2005) to avoid bacterial growth in the water heater.

Appendix B

Map of Monitored Sites


NUNAVUT
Hudson Bay
Baie d'Hudson
CANADA
SASKATCHEWAN
ONTARIO
MANITOBA
N
Geothermal Heat Pump
Monitoring Installations
Scale / Échelle
km 75 0 75 150 225 km
Lac Brochet
Churchill
Brochet
Reindeer L
Churchill R
Southern Indian L
Lynn Lake
South Indian Lake
Fl Nelson R
Leaf Rapids
Split Lake
Gillam
Shamattawa
Nelson House
Pukatawagan
Thompson
Oxford House
Gods River
Snow Lake
Flin Flon
Gods Lake Narrows
Cranberry Portage
Cross Lake
Red Sucker Lake
Garden Hill
Norway House
The Pas
Moose Lake
Cedar L
St Theresa Point
Grand Rapids
Poplar River
L Winnipegosis
L Winnipeg
Berens River
Swan River
Little Grand Rapids
Bloodvein
Winnipegosis
Fisher River
Roblin
Dauphin
Ashern
Ste Rose du Lac
Arborg
Fort Alexander
Russell
Sandy Bay
Gimli
Pine Falls
L Manitoba
Minnedosa
Neepawa
Selkirk
Lac du Bonnet
Portage la Prairie
Virden
Brandon
Rouge R
Beausejour
Winnipeg
Souris
Steinbach
Carman
Red R
Melita
Killarney
Winkler
Morris
Morden
Sprague
Boissevain
Altona
Emerson

Appendix C

Data Acquisition Devices

C.1 RTD Temperature Sensors:

Specifications: Elkor Technologies Inc.
No: ET-TP-U-1000/4
Type: 385, 1000 Ohm, Platinum, 4" Probe
Enclosure: 1/4" stainless steel (316) tubing
Conductor: 11' 105°C rated

Accuracy: Class B
± 0.5 °F @ 32 °F to ± 8.3 °F @ 1562 °F
± 0.3 °C @ 0 °C to ± 4.6 °C @ 850 °C

Note: Ground source temp span = 32°F to 65°F (0°C to 18°C)
Class B approximate errors:
Avg Error = ± 1.5% (per RTD)
Avg ΔT error = ± 3.0 %

Repeatability: better than 0.8% (-100°C to 100°C)

Response Time: Probe T (0.625) better than 10 seconds

C.2 Current Transducers:

Specifications: Magnalab Inc.
Type: SCT-0750
Output: 0.333 mV

Accuracy: ± 1.0% of measured value
(10% to 130% of rated current)

C.3 Potential Transducers:

Specifications: Highland.
Type: C282
Output: 0.333 mV

Accuracy: ± 1.0% of measured value

C.4 Ground Loop Flow Meter:

Specifications:	Dwyer Instruments Inc. Type: UV-3112 range 2.0-20.00 GPM (8-76 LPM) UV-5112 range 4.0-40.00 GPM (20-150 LPM)
Accuracy:	± 2% @ 70 °F ± 2°F (21.1°C) and 14.7 PSIA
Repeatability:	± 1% Full Scale @ 70 °F ± 2°F(21.1°C) and 14.7 PSIA
Scale Resolution:	0.5 USWG (2 litres)
Correction Factor:	For 25% Methanol with Specific Gravity of 0.95423

Correction Factor = Instrument Reading x 1.02

C.5 Water Meter:

Specifications:	ABB Water Meters Inc. Type: Industrial Positive Displacement C-700 Bronze, Magnetic Drive
Pulse Output:	Pulser Type "B" (2P) One contact closure = 1 litre

C.6 Data Logger:

Specifications:	ENERNET Corporation Type: K20 Energy Recorder
	RMS Current - 8 Channels RMS Voltage - 8 Channels RMS Power - 8 Channels kWh - 8 Channels kVAh - 8 Channels Power Factor - 8 Channels
	Analog Inputs -8 Channels
	Pulse/Runtime/- 8 Form "A" Channels Rate Counter
	Communications: Local RS-232 and modem.
Accuracy:	Power/kWh: ± 0.4% of reading 100% to 5% of full scale at Unity to 0.5 PF.
	Amps/Volts: ± 0.4% of full scale.
	Power Factor: ± .02 PF, 100% to 5% of full scale.
	Analog: ± 0.25% full scale
Resolution:	Power: 0.1% FS minimum
	kWh: 0.05% FS minimum
	Amps/Volts: 0.1% FS minimum
	Power Factor: 0.01 PF
Analog:	Voltage: 1.0 mV Resistance: 0.3 ohms Temperature: 0.1°C

Appendix D

Test Instruments and Reference Standards

D1. **Reference Standards** (used to verify the accuracies of the insitu test instruments and data acquisition devices of the heat pump monitoring system) **:**

Digital thermometer:

Model:	Guideline Instruments Ltd. 50 °C to -30°C
Serial No:	57806
Certified by:	Measurement Canada (NRC Traceable)
Certificate No:	V05-0368

Voltmeter and Ammeter:

Model:	Radian Research Inc RM-15-14
Serial No:	501457
Certified by:	Measurement Canada (NRC Traceable)
Certificate No:	EP-04-048

D2. **Test Instruments** (used for insitu testing of each heat pump installation)**:**

Voltmeter and (Clip-on) Ammeter:

Model:	IDEAL 61-766
Serial No / ID No:	51001231 / MH05-118599

Power Quality Analyzer:

Model:	FLUKE 434
Serial No / ID No:	DM8980092 / MH05-118226

Digital Thermometer:

Model:	FLUKE 52 II
Serial No / ID No:	89870057 / MH05-118878

Temperature Probes (two probes):

Model:	FLUKE 80PK-8
ID No's:	MH05-118878-PCTP-01 and PCTP-01

Appendix E

SCOP and SEER Calculation Constants

D.1 Specific Heat for 25% Methanol:

25% Methanol SH = 0.95423 Btu/lb·F (3.995 kJ/kg·C)

D.2 Specific Gravity for 25% Methanol:

25% Methanol SG = 0.9678
(Confirmed by chemical analysis lab reports conducted on two samples of GL fluid)

D.3 Density of 25% Methanol:

Density 25% Methanol = 8.09 lb/USWG (0.97 kilogram/litre)

(8.34 lb/USG(density of water) x 0.97 S.G = 8.09 lb/USWG).

D.4 Ground Loop Flow Meter correction factor: for 25% Methanol:

Correction Factor = Flow Meter Reading x 1.02

Based on Dywer manufacturer's correction formula:

$$Q2 = Q1 \times \sqrt{1/S.G}$$

Where: Q2 = True Flow Value
Q1 = Flow meter reading
S.G = Specific Gravity of fluid

D.5 Specific Gravity of Water = 8.34 lb/USWG (1 kilogram/litre)

D.6 Specific Heat of Water = 1.0 Btu/lb·F (4.19 kJ/kg·C)

Appendix F

Monthly Heat Pump Energy Data

Table # 1: House # 1 Monthly Heat Pump Data for 2007

Electricity Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	1,802	1,898	1,106	642	322	269	436	293	308	532	944	1,168	9,720
Auxiliary Heater	46	210	56	44	-	-	-	-	8	-	42	-	406
Compressor Total	1,022	991	600	334	161	124	203	112	127	275	650	922	5,525
Compressor Heating	1,022	991	600	311	111	20	-	8	83	266	650	922	4,985
Compressor Cooling	-	-	-	23	51	105	203	105	44	9	-	-	539
FAN Total	204	205	135	98	75	88	113	92	90	114	156	186	1,556
FAN heating	187	192	103	54	18	3	-	3	28	59	125	143	914
FAN Cooling	-	-	-	7	16	33	64	39	17	3	-	-	180
FAN Circulating	17	13	33	37	41	51	49	58	58	53	31	43	484
Ground Loop Pump Total	487	466	302	175	98	88	145	79	75	150	297	324	2,687
Ground Loop Heating	487	466	302	160	61	11	-	4	44	143	297	324	2,300
Ground Loop Pump Cooling	-	-	-	15	38	77	145	75	31	7	-	-	388
Desuperheater Pump Total	45	29	32	18	11	10	15	9	9	18	35	46	277
Desuperheater Pump Heating	45	29	32	16	7	1	-	1	5	17	35	46	235
Desuperheater Pump Cooling	-	-	-	2	4	9	15	8	3	1	-	-	42
DHW Tank Electricity Consumption	130	183	258	310	317	345	327	304	332	326	216	174	3,223

	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Ground Loop Heat of Extraction (kWh)*	3,470	4,108	2,351	1,369	388	66	-	26	288	962	2,196	2,772	17,995
Ground Loop Heat of Rejection (Btu)*	-	-	-	764,111	1,347,844	2,940,561	5,636,730	2,958,484	1,240,686	267,989	-	-	15,156,404

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
Average COP	2.64	2.91	2.84	3.04	2.63	2.54	N/A	N/A	2.42	2.65	2.62	2.67	2.75
Average EER	N/A	N/A	N/A	15.5	11.7	12.2	12.0	12.1	12.3	12.8	N/A	N/A	12.2

Table # 2: House # 2 Monthly Heat Pump Data for 2007

Electricity Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	1,996	1,820	1,221	453	93	218	729	331	526	560	1,263	1,929	11,139
Auxiliary Heater	11	0	-	1	-	0	-	46	4	-	9	0	72
Compressor Total	1,532	1,401	913	344	68	151	520	201	449	428	954	1,474	8,435
Compressor Heating	1,532	1,401	913	344	61	21	2	20	427	856	954	1,474	8,005
Compressor Cooling	-	-	-	0	7	130	518	181	22	-	-	-	858
FAN Total	119	106	95	26	8	18	52	23	19	33	75	115	689
FAN heating	119	106	95	26	5	2	0	2	18	33	75	115	596
FAN Cooling	-	-	-	0	2	16	52	19	1	-	-	-	90
FAN Circulating	0	0	(0)	0	1	0	0	3	0	0	0	-	4
Ground Loop Pump Total	313	286	191	72	15	42	137	53	48	86	199	305	1,747
Ground Loop Heating	313	286	191	72	13	4	0	4	44	86	199	305	1,518
Ground Loop Pump Cooling	-	-	-	0	2	38	136	49	3	-	-	-	229
Desuperheater Pump Total	32	27	24	9	2	6	20	8	7	13	26	34	208
Desuperheater Pump Heating	32	27	24	9	2	1	0	1	6	13	26	34	174
Desuperheater Pump Cooling	-	-	-	0	0	6	20	7	0	-	-	-	34

													Totals
Ground Loop Heat of Extraction (kWh)*	4,126	3,849	2,526	959	205	83	4	77	728	1,342	2,473	2,914	19,287
Ground Loop Heat of Rejection (Btu)*	-	-	-	412	166,193	2,864,155	10,360,466	3,784,009	252,843	-	-	-	17,428,079

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

													Weighted Average
Average COP	2.9	3.0	2.9	3.0	3.4	3.8	2.5	2.0	2.4	2.3	2.8	2.4	2.7
Average EER	N/A	N/A	N/A	10.8	14.0	13.7	12.1	13.2	7.7	N/A	N/A	N/A	12.5

Table # 3: House # 3 Heat Pump Data for 2006**

Electricity Usage (kWh)	January***	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	435	1,116	907	327	212	69	152	70	147	465	762	1,049	5711
Auxiliary Heater	0	0	0	0	0	0	0	0	0	0	0	0	0
Compressor Total	300	746	631	234	156	39	89	43	99	298	527	732	3894
Compressor Heating	300	746	631	234	156	27	0	0	78	296	527	732	3727
Compressor Cooling	0	0	0	0	0	13	89	43	21	2	0	0	167
FAN Total	23	55	34	13	4	15	31	13	8	22	40	56	314
FAN heating	23	55	34	13	4	15	0	0	2	20	40	56	261
FAN Cooling	0	0	0	0	0	0	31	13	6	0	0	0	51
FAN Circulating	0	0	0	0	0	0	0	0	0	1	0	0	1
Ground Loop Pump Total	65	150	115	41	27	14	30	13	19	52	96	137	759
Ground Loop Heating	65	150	115	41	27	14	0	0	13	51	96	137	710
Ground Loop Pump Cooling	0	0	0	0	0	0	30	13	6	0	0	0	49
Desuperheater Pump Total	3	7	5	2	1	1	2	1	1	2	6	8	38
Desuperheater Pump Heating	3	7	5	2	1	1	0	0	0	2	6	8	35
Desuperheater Pump Cooling	0	0	0	0	0	0	2	1	0	0	0	0	3
Primary Hydronic Pump	20	48	40	15	11	0	0	0	5	16	28	43	226
Zone Pumps	25	110	82	22	13	0	0	0	15	76	65	73	480

**Used 2006 Data - Faulty temperature probe for part of 2007

***Installed 12 January, 2006

													Totals
Ground Loop Heat of Extraction (kWh)*	984	2,503	2,063	703	431.0	115	0	0	166	1,141	1,932	2,503	12539
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	0	365,052	2,555,321	1,192,992	558,587	47524	0	0	4719477

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

													Weighted Average
Average COP	3.11	3.10	3.14	3.01	2.90	2.76	0.00	0.00	2.35	3.36	3.40	3.25	3.17
Average EER	0.0	0.0	0.0	0.0	0.0	25.3	15.1	16.4	16.5	15.2	0.0	0.0	16.1

Table # 4: House # 4 Monthly Heat Pump Data for 2006***

Electricity Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December**	Totals
Total Heat Pump System	1162	448	206	223	98	254	471	333	91	284	433	222	4,227
Auxiliary Heater	7	0	0	0	0	0	0	0	0	0	0	0	7
Compressor Total	821	313	141	156	68	173	322	244	63	176	266	128	2,870
Compressor Heating	821	313	141	156	48	0	0	0	13	176	266	128	2,062
Compressor Cooling	0	0	0	0	20	173	322	244	50	0	0	0	808
FAN Total	48	36	39	19	15	38	70	27	6	15	36	39	389
FAN heating	40	24	15	11	5	0	0	0	1	15	26	27	165
FAN Cooling	0	0	0	0	2	30	53	17	5	0	0	0	108
FAN Circulating	9	11	24	8	8	9	17	10	0	0	10	11	116
Ground Loop Pump Total	259	98	44	49	22	51	96	71	21	83	124	58	976
Ground Loop Heating	259	98	44	49	13	0	0	0	6	83	124	58	734
Ground Loop Pump Cooling	0	0	0	0	7	51	96	71	15	0	0	0	241
Desuperheater Pump Total	36	13	6	7	2	0	0	0	1	11	17	8	101
Desuperheater Pump Heating	36	13	6	7	2	0	0	0	1	11	17	8	100
Desuperheater Pump Cooling	0	0	0	0	0	0	0	0	0	0	0	0	1

**2006 Data used - problem with downloading of data in 2007

***December 1-15, 2006 Data

	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Ground Loop Heat of Extraction (kWh)*	1,703	583	268	321	87	N/A	N/A	N/A	43	581	876	404	4,866
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	0	4,525,307	6,397,173	4,813,960	1,089,557	0	0	0	16,825,995

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
Average COP	2.25	2.11	2.14	2.25	2.12	N/A	N/A	N/A	2.48	2.81	2.81	2.73	2.31
Average EER	N/A	N/A	N/A	N/A	N/A	15.1	10.9	11.9	12.9	N/A	N/A	N/A	11.9

Table # 5: House # 5 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May***	June***	July	August	September	October	November	December	Totals
Total Heat Pump System	2,669	2,399	1,393	904	599	171	367	146	180	483	965	2,034	**12,309**
Auxiliary Heater	407	386	28	24	18	0	0	0	2	1	1	63	929
Compressor Total	1,630	1,448	989	639	415	109	238	95	132	350	706	1,437	8,186
Compressor Heating	1,630	1,448	989	639	408	26	0	0	129	350	706	1,437	7,759
Compressor Cooling	0	0	0	0	7	84	238	95	4	0		0	427
FAN Total	370	332	220	141	88	33	78	31	27	77	152	311	1,860
FAN heating	370	332	220	141	85	5	0	0	26	77	152	311	1,720
FAN Cooling	0	0	0	0	2	28	78	31	1	0	0	0	140
FAN Circulating	0	0	0	0	0	0	0	0	0	0	0	0	0
Ground Loop Pump Total	263	234	156	100	62	22	52	21	19	54	106	222	1,311
Ground Loop Heating	263	234	156	100	60	4	0	0	18	54	106	222	1,218
Ground Loop Pump Cooling	0	0	0	0	2	19	52	21	1	0	0	0	94
Desuperheater Pump Total**	0	0	0	0	16	6	0	0	0	0	0	0	23
Desuperheater Pump Heating	0	0	0	0	16	1	0	0	0	0	0	0	17
Desuperheater Pump Cooling	0	0	0	0	0	5	0	0	0	0	0	0	6

**DSH disconnected

***2006 Data:Communication Failed

													Totals
Ground Loop Heat of Extraction (kWh)*	5,637	4644	2,724	1,761	1,346	73	N/A	N/A	289	883	1,798	4,278	23,434
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	145,140	1,813,875	4,019,586	1,499,425	43,080	0	0	0	7,521,105

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

													Weighted Average
Average COP	3.01	2.84	2.84	2.84	3.19	2.94	N/A	N/A	2.55	2.72	2.75	2.99	2.91
Average EER				N/A	10	11	8	7	5	N/A	N/A	N/A	8

Table # 6: House # 6 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	2,337	2,295	1,696	1,059	503	286	485	466	548	786	1,455	2,440	14,356
Auxiliary Heater	0	0	0	0	0	0	0	0	0	0	0	0	0
Compressor Total	1,614	1,578	1,095	663	289	137	261	265	320	474	917	1,625	9,238
Compressor Heating	1,614	1,578	1,095	663	289	58	3	33	208	456	917	1,625	8,539
Compressor Cooling	0	0	0	0	0	79	258	232	112	18	0	0	698
FAN Total	349	342	301	212	132	108	146	131	148	196	306	419	2,790
FAN heating	337	336	284	182	82	21	1	7	59	143	277	408	2,136
FAN Cooling	0	0	0	0	0	29	85	67	38	7	0	0	226
FAN Circulating	12	7	16	30	50	58	60	57	51	46	29	11	428
Ground Loop Pump Total	336	343	250	148	63	33	63	58	65	94	191	346	1,993
Ground Loop Heating	336	343	250	148	63	12	1	6	39	90	191	346	1,826
Ground Loop Pump Cooling	0	0	0	0	0	21	63	52	26	4	0	0	167
Desuperheater Pump Total	38	32	50	36	19	7	14	11	14	22	41	50	335
Desuperheater Pump Heating	38	32	50	36	19	3	0	1	8	21	41	50	299
Desuperheater Pump Cooling	0	0	0	0	0	4	14	11	6	1	0	0	36

	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Ground Loop Heat of Extraction (kWh)*	5,827	5,727	3,974	2,404	1,049	208	14	138	898	1,979	3,703	5,985	31,906
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	0	2,457,275	7,303,671	5,449,659	2,756,938	476,925	0	0	18,444,468

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
Average COP	3.35	3.34	3.19	3.16	3.14	3.05	3.56	3.80	3.70	3.63	3.43	3.30	3.33
Average EER	N/A	N/A	N/A	N/A	N/A	16.5	15.4	12.7	13.0	13.9	N/A	N/A	14.2

Table # 7: House # 7 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	1,948	2,055	1,308	767	376	87	388	74	330	609	1,292	2,065	**11,298**
Auxiliary Heater	7	0	0	0	0	0	0	0	0	0	0	0	7
Compressor Total	1,330	1,416	899	526	258	54	242	46	230	423	895	1,422	7,739
Compressor Heating	1,330	1,416	899	526	258	14	0	0	221	423	895	1,422	7,402
Compressor Cooling	0	0	0	0	0	40	242	46	9	0	0	0	337
FAN Total	297	305	193	112	55	16	70	13	48	88	192	300	1,688
FAN heating	293	305	193	112	55	3	0	0	45	88	192	300	1,585
FAN Cooling	0	0	0	0	0	13	70	13	3	0	0	0	98
FAN Circulating	4	0	0	0	0	0	0	0	0	0	0	0	4
Ground Loop Pump Total	307	332	204	118	57	15	68	13	48	88	199	342	1,793
Ground Loop Heating	307	332	204	118	57	3	0	0	46	88	199	342	1,696
Ground Loop Pump Cooling	0	0	0	0	0	13	68	13	3	0	0	0	97
Desuperheater Pump Total	8	2	12	10	6	2	8	2	5	10	6	1	71
Desuperheater Pump Heating	8	2	12	10	6	0	0	0	4	10	6	1	60
Desuperheater Pump Cooling	0	0	0	0	0	1	8	2	0.3	0	0	0	12

	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Ground Loop Heat of Extraction (kWh)*	4067	4543	2824	1604	759	42	0	0	646	1209	2296	3204	21,194
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	0	2,457,275	7,303,671	5,449,659	2,756,938	476,925	0	0	18,444,468

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
Average COP	2.93	3.05	3.00	2.94	2.87	2.95	N/A	N/A	2.90	2.84	2.62	2.39	2.81
Average EER	N/A	N/A	N/A	N/A	N/A	10.28	9.60	11.13	9.57	N/A	N/A	N/A	9.89

Table # 8: House # 8 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	2,262	2,359	1,578	831	336	166	416	185	245	710	1,433	2,362	**12,884**
Auxiliary Heater	29	83	47	72	5	0	0	0	0	5	3	35	280
Compressor Total	1,351	1,389	901	437	181	73	205	85	130	404	852	1,411	**7,417**
Compressor Heating	1,351	1,389	901	433	153	6	0	0	117	403	852	1,411	7,016
Compressor Cooling	0	0	0	4	27	67	205	85	13	1	0	0	401
FAN Total	366	418	232	112	56	42	69	45	47	95	183	380	**2,046**
FAN heating	363	416	224	94	25	1	0	1	22	77	171	376	1,770
FAN Cooling	0	0	0	1	8	17	48	20	3	0.1	0	0	98
FAN Circulating	3	2	8	16	23	24	20	24	23	17	12	4	177
Ground Loop Pump Total	455	415	348	183	83	44	125	48	59	181	347	475	**2,764**
Ground Loop Heating	455	415	348	181	69	2	0	0	51	181	347	475	2,526
Ground Loop Pump Cooling	0	0	0	2	14	42	125	48	8	0.4	0	0	238
Desuperheater Pump Total	61	53	49	26	12	6	18	7	8	26	49	61	**376**
Desuperheater Pump Heating	61	53	49	26	10	0.3	0	0	7	26	49	61	342
Desuperheater Pump Cooling	0	0	0	0	2	6	18	7	1	0.0	0	0	34

													Totals
Ground Loop Heat of Extraction (kWh)*	2,548	2,755	1,687	787	241	12	0	0	209	677	1,427	2,517	12,860
Ground Loop Heat of Rejection (Btu)*	0	0	0	54,057	908,292	2,824,635	8,321,438	3,175,225	450,375	11,034	0	0	15,745,056

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

													Weighted Average
Average COP	1.90	1.97	1.82	1.72	1.62	2.05	N/A	N/A	1.76	1.68	1.73	1.84	1.84
Average EER	N/A	N/A	N/A	5.3	16.8	21.4	20.4	19.5	18.3	7.3	N/A	N/A	19.9

Table # 9: House # 9 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Total Heat Pump System	1,040	1,038	710	275	167	165	240	82	148	266	527	941	5,599
Auxiliary Heater	0	0	0	0	0	0	0	0	0	0	0	0	0
Compressor Total	771	782	526	204	95	77	129	31	67	162	378	709	3,932
Compressor Heating	771	782	526	204	88	11	0	0	55	162	378	709	3,686
Compressor Cooling	0	0	0	0	7	64	129	31	12	0	0	0	244
FAN Total	104	101	74	28	52	65	75	42	66	70	71	87	837
FAN heating	95	98	70	27	12	1	0	0	7	21	47	78	457
FAN Cooling	0	0	0	0	1	12	23	6	2	0	0	0	44
FAN Circulating	9	3	5	1	39	51	52	36	57	49	24	9	336
Ground Loop Pump Total	126	119	84	33	16	17	27	7	11	26	59	110	635
Ground Loop Heating	126	119	84	33	15	2	0	0	9	26	59	110	581
Ground Loop Pump Cooling	0	0	0	0	1	15	27	7	3	0	0	0	53
Desuperheater Pump Total	39	36	26	10	4.8	5.2	8.4	2.1	3.4	8	18	34	195
Desuperheater Pump Heating	39	36	26	10	4.4	0.5	0.0	0.0	2.6	8	18	34	178
Desuperheater Pump Cooling	0	0	0	0	0.4	4.5	8.4	2.1	0.8	0	0	0	16

	January	February	March	April	May	June	July	August	September	October	November	December	Totals
Ground Loop Heat of Extraction (kWh)*	2,603	2,632	1,802	721	337	42	0	0	245	694	1,523	2,243	12,842
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	202,364	2,009,248	3,627,434	912,176	335,824	0	0	0	7,087,046

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
Average COP	3.40	3.43	3.44	3.51	3.71	3.81	N/A	N/A	4.24	4.09	3.91	3.29	3.50
Average EER	N/A	N/A	N/A	5.3	16.8	21.4	20.4	19.5	18.3	7.3	N/A	N/A	19.9

Table # 10: House # 10 Monthly Heat Pump Data for 2007

Heat Pump Usage (kWh)	January	February	March	April	May	June	July	August	September	October	November**	December**	Totals
Total Heat Pump System	2,130	2,019	1,371	605	235	266	310	133	177	548	1,333	1,697	**10,824**
Auxiliary Heater	76	119	0	0	0	0	0	0	0	0	0	0	195
Compressor Total	1,481	1,368	986	436	155	155	199	80	98	399	961	1,219	**7,535**
Compressor Heating	1,481	1,368	986	436	136	15	0	0	98	399	961	1,219	7,097
Compressor Cooling	0	0	0	0	19	140	199	80	0	0	0	0	438
FAN Total	320	295	210	92	52	78	70	36	63	82	207	266	**1,772**
FAN heating	320	295	210	92	31	3	0	0	19	82	207	266	1,526
FAN Cooling	0	0	0	0	6	48	57	22	0	0	0	0	132
FAN Circulating	0	0	0	0	15	27	13	14	44	0	0	0	114
Ground Loop Pump Total	222	208	149	66	24	28	35	14	14	58	141	182	**1,140**
Ground Loop Heating	222	208	149	66	20	2	0	0	14	58	141	182	1,062
Ground Loop Pump Cooling	0	0	0	0	4	26	35	14	0	0	0	0	78
Desuperheater Pump Total	32	30	25	11	4.1	4.9	6	2	2	10	24	30	**182**
Desuperheater Pump Heating	32	30	25	11	3.5	0.4	0	0	2	10	24	30	169
Desuperheater Pump Cooling	0	0	0	0	0.6	4.5	6	2	0	0	0	0	14

**2006 Data:Temperature Probe Failed

	January	February	March	April	May	June	July	August	September	October	November**	December**	Totals
Ground Loop Heat of Extraction (kWh)*	4501	4091	2897	1288	349	40	0	0	269	1159	2727	3793	21,115
Ground Loop Heat of Rejection (Btu)*	0	0	0	0	457,841	3,423,369	4,520,959	1,753,028	0	0	0	0	10,155,197

*Ground Loop Heat of Extraction and Heat of Rejection include loop pump electric power

	January	February	March	April	May	June	July	August	September	October	November**	December**	Weighted Average
Average COP	3.01	2.92	3.00	3.02	2.72	2.80	N/A	N/A	2.91	3.01	2.94	3.13	3.00
Average EER	N/A	N/A	N/A	N/A	N/A	13.5	13.2	12.8	N/A	N/A	N/A	N/A	13.0

Appendix G

Domestic Hot Water Data

Table # 11: Annual Domestic Hot Water Data for Monitored Houses

A	B	C	D	E	F	G	H	I	J	K
House	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
1	7.5	55.5	55776	3105	1797	4901	3223	1678	569	1109
2	16.6	53.5	50954	2185	1865	4050	2260	1790	649	1142
3	15.3	49.6	45779	1834	2134	3967	3057	910	260	650
4	13.6	49.9	30176	1274	2448	3721	3334	388	153	235
5	12.9	44.0	23088	831	1211	2042	2042	0	0	0
6	12.8	52.5	43294	1995	909	2903	2224	679	216	463
7	14.4	50.0	47222	1950	1155	3105	2805	301	98	202
8	15.2	58.4	61728	3097	757	3854	2521	1333	748	585
9	14.6	46.0	46476	1700	1101	2800	1692	1109	272	836
10	12.1	48.8	55169	2352	927	3279	2026	1254	396	879
Average	13.5	50.8	45966	2032	1430	3462	2518	944	336	610

*Electric energy to heat pump in heating mode is the energy provided by the desuperheater divided by the COP of the heat pump system. The heat pump runs longer to satisfy the home's heating requirements since its heating capacity was reduced by the desuperheater.

*Electric energy to heat pump in cooling mode is the electric energy to the desuperheater pump only.

Table 12: Domestic Hot Water Data for House # 1

House # 1 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	6.9	55.2	4629	260	153	412	130	282	107	176
February	6.9	56.4	4560	262	138	400	183	216	74	142
March	7.0	54.6	5334	295	153	447	258	189	66	123
April	6.9	55.1	5166	289	148	436	310	126	39	87
May	7.3	56.1	4282	242	153	395	317	77	23	55
June	8.2	57.2	4449	253	148	400	345	55	12	43
July	7.5	55.6	4340	242	153	395	327	68	18	50
August	8.5	55.8	3840	211	153	363	304	59	8	51
September	8.3	57.1	4560	258	148	406	332	74	22	52
October	8.1	55.2	4827	264	153	417	326	90	33	57
November	7.4	52.5	4546	238	148	386	216	170	65	105
December	7.1	55.2	5243	292	153	445	174	271	101	169
Annual	7.5	55.5	55776	3105	1797	4901	3223	1678	569	1109

Table 13: Domestic Hot Water Data for House # 2

House # 2 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	16.8	53.8	3554	153	158	311	60	251	86	164
February	16.8	53.8	3528	152	143	295	62	233	79	154
March	15.9	53.1	4806	208	158	366	174	192	66	126
April	15.1	52.4	5008	217	153	370	264	106	36	70
May	15.6	53.3	5160	226	158	385	352	33	9	24
June	17.5	56.6	4718	214	153	367	319	49	7	42
July	18.9	53.8	4312	175	158	333	300	33	20	12
August	18.8	53.9	3254	133	158	291	229	62	10	52
September	16.9	51.6	4111	165	153	319	201	117	47	71
October	15.9	51.3	4027	166	158	324	165	159	70	89
November	17.6	53.5	3949	164	153	318	73	245	87	157
December	13.9	54.6	4527	214	158	372	61	311	132	179
Annual	16.6	53.5	50954	2185	1865	4050	2260	1790	649	1142

Table 14: Domestic Hot Water Data for House # 3

House # 3 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	14.0	46.1	1929	72	181	253	81	172	55	117
February	13.0	48.5	4752	196	164	359	220	139	45	94
March	12.4	53.9	5071	244	181	425	347	78	25	53
April	12.9	49.7	3423	146	175	322	294	28	9	19
May	15.2	53.1	3728	164	181	345	312	34	12	22
June	14.9	49.2	3511	140	175	315	300	15	5	9
July	16.8	48.8	3956	147	181	328	296	32	0	32
August	17.7	49.7	3968	147	181	329	291	38	0	38
September	17.1	50.5	4155	161	175	336	281	55	13	42
October	17.7	48.8	3911	141	181	322	240	83	24	58
November	16.5	48.3	3662	135	175	310	198	112	33	79
December	15.5	48.1	3713	140	181	322	198	124	38	86
Annual	15.3	49.6	45779	1834	2134	3967	3057	910	260	650

Table 15: Domestic Hot Water Data for House # 4

House # 4 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	11.9	51.1	2403	109	208	317	264	53	23	29
February	14.9	49.6	2282	92	188	279	228	51	24	27
March	15.7	50.1	2421	96	208	304	239	66	31	35
April	11.9	49.7	2571	113	201	314	309	5	2	3
May	12.8	49.4	2810	120	208	327	326	1	1	1
June	14.4	48.7	2399	96	201	297	295	2	0.2	1
July	13.1	49.5	3376	143	208	351	341	10	0.4	9
August	13.5	50.5	2878	123	208	331	319	12	0.3	12
September	14.1	50.0	3226	134	201	336	314	22	8	14
October	12.7	49.4	2590	110	213	323	323	0	0	0
November	13.6	50.6	2277	98	201	299	269	30	11	19
December	14.3	50.8	943	40	208	248	107	141	52	89
Annual	13.6	49.9	30176	1274	2448	3721	3334	388	153	235

Table 16: Domestic Hot Water Data for House # 5

House # 5 Domestic Hot Water Data

A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	11.2	40.0	1546	52	119	171	171	0	0	0
February	10.6	40.8	1447	51	110	160	160	0	0	0
March	12.1	42.4	1801	63	114	178	178	0	0	0
April	12.3	41.7	1972	67	112	180	180	0	0	0
May	11.1	47.9	2067	88	87	175	175	0	0	0
June	14.5	44.5	2086	73	87	160	160	0	0	0
July	14.2	46.1	1817	67	92	159	159	0	0	0
August	15.7	46.5	1874	67	94	161	161	0	0	0
September	13.2	45.4	3202	120	104	224	224	0	0	0
October	14.6	46.4	1552	57	83	140	140	0	0	0
November	13.4	45.6	1900	71	89	160	160	0	0	0
December	12.4	40.2	1824	59	116	175	175	0	0	0
Annual	12.9	44.0	23088	831	1211	2042	2042	0	0	0

2006 Data

The desuperheater pump failed on this unit and was not replaced.

Table 17: Domestic Hot Water Data for House # 6

House # 6 Domestic Hot Water Data

A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	10.8	52.6	2902	141	77	218	138	79	24	56
February	11.0	52.6	2467	119	70	189	130	59	18	41
March	10.6	53.6	2977	148	77	226	148	78	24	53
April	13.0	50.0	2132	92	75	166	128	38	12	26
May	13.3	49.6	2117	89	77	166	131	35	11	24
June	12.8	49.5	2539	108	75	183	170	13	6	7
July	14.6	55.0	3667	172	77	249	221	28	14	14
August	14.2	54.1	5745	266	77	343	331	12	11	1
September	16.2	51.3	4299	175	75	250	215	35	11	23
October	15.2	50.5	6009	246	77	323	220	103	28	75
November	12.1	53.0	3006	142	75	217	157	60	17	42
December	9.7	55.1	5434	286	77	363	234	130	39	90
Annual	12.8	52.5	43294	1995	909	2903	2224	679	216	463

Table 18: Domestic Hot Water Data for House # 7

House # 7 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	13.3	49.0	4694	195	98	293	221	72	24	47
February	13.0	49.5	2936	124	89	213	177	36	12	24
March	12.0	49.0	1932	83	98	181	130	51	17	34
April	11.9	49.6	4424	194	95	289	279	10	3	6
May	13.4	50.6	4540	196	98	294	288	6	2	4
June	17.3	53.0	4349	180	95	275	267	9	2	7
July	15.1	49.4	3785	151	98	249	237	12	8	4
August	15.8	49.6	3928	154	98	252	221	31	2	30
September	16.5	50.0	3358	131	95	226	204	21	7	14
October	16.1	50.0	4859	192	98	290	280	10	3	6
November	15.2	49.2	3788	149	95	244	223	21	8	13
December	13.3	50.9	4629	202	98	300	278	22	9	13
Annual	14.4	50.0	47222	1950	1155	3105	2805	301	98	202

Table 19: Domestic Hot Water Data for House # 8

House # 8 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	16.7	59.1	4851	239	64	303	133	171	96	74
February	16.5	58.7	4720	231	58	289	120	170	91	78
March	15.0	58.4	5336	269	64	333	167	165	97	68
April	14.0	59.0	5146	269	62	331	237	94	61	33
May	13.4	56.5	5391	270	64	334	271	63	40	22
June	13.2	57.9	5929	307	62	369	328	41	7	34
July	15.9	59.3	5855	295	64	359	297	62	18	44
August	15.4	58.7	4685	236	64	300	268	32	7	25
September	15.2	58.2	3917	195	62	257	217	41	27	14
October	16.3	58.7	4988	246	64	310	202	108	72	37
November	15.7	58.0	5080	250	62	312	148	164	102	62
December	15.0	58.8	5830	296	64	360	134	226	129	97
Annual	15.2	58.4	61728	3097	757	3854	2521	1333	748	585

Table 20: Domestic Hot Water Data for House # 9

House # 9 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	14.1	44.6	3873	137	93	231	92	138	41	98
February	13.9	43.8	2511	87	84	172	64	107	31	76
March	14.2	46.0	4005	148	93	241	115	126	37	89
April	13.2	46.0	4637	176	90	267	171	96	27	69
May	13.4	45.4	4485	167	93	260	193	68	17	50
June	19.0	51.9	4472	171	90	261	207	54	6	48
July	14.3	45.4	4122	149	93	242	170	72	8	64
August	15.5	45.3	3180	110	93	203	150	53	2	51
September	15.5	43.7	3792	124	90	214	153	61	12	49
October	15.0	45.9	4174	149	93	243	159	84	21	64
November	14.4	46.7	3663	137	90	228	116	112	29	83
December	12.3	47.4	3562	145	93	238	101	137	42	96
Annual	14.6	46.0	46476	1700	1101	2800	1692	1109	272	836

Table 21: Domestic Hot Water Data for House # 10

House # 10 Domestic Hot Water Data										
A	B	C	D	E	F	G	H	I	J	K
Month	Average Water Heater Inlet Temperature (degrees Celsius)	Average Water Heater Outlet Temperature (degrees Celsius)	Hot Water Usage (litres)	Energy delivered to water usage (kWh)	Calculated Stand-By Loss (kWh)	Total Hot Water Energy (kWh) E + F	Hot Water Heater Electricity Usage (kWh)	Energy provided by Desuperheater (kWh) G-H	Electric Energy to Heat Pump (kWh)*	Net energy savings (kWh) I-J
January	10.5	50.6	4349	202	79	281	70	211	70	141
February	9.4	50.3	4637	220	71	292	84	207	71	136
March	9.0	48.8	4343	200	79	279	136	143	48	96
April	9.0	47.7	5043	226	76	302	239	64	21	43
May	11.0	47.6	5382	229	79	308	293	14	5	9
June	12.8	48.4	4908	203	76	279	267	13	5	8
July	15.8	47.7	1689	63	79	141	119	22	6	16
August	17.3	49.1	4979	184	79	262	231	31	2	28
September	16.5	47.9	4209	153	76	230	199	31	11	20
October	14.6	47.5	4862	186	79	264	210	54	18	36
November	10.4	49.1	5381	242	76	318	173	145	67	78
December	8.9	51.4	5387	265	79	344	4	340	72	268
Annual	12.1	48.8	55169	2352	927	3279	2026	1254	396	879

Appendix H

Run Hours and Starts Data

Table 22: Heat Pump Annual Run-Hours

House		January	February	March	April	May	June	July	August	September	October	November	December	Totals
1	Total	578	518	392	229	138	126	199	113	105	212	402	399	3,410
	Stage 1	370	260	321	191	135	125	184	112	101	209	364	288	2,660
	Stage 2	208	258	71	38	3	1	15	1	4	3	38	111	750
2		476	438	289	109	23	65	208	80	68	128	283	329	2,497
3		115	266	204	74	9	25	53	23	33	49	171	244	1266
4	Total	394	149	67	75	33	79	150	110	32	123	188	89	1,488
	Stage 1	385	149	67	74	30	52	104	73	22	123	187	88	1,354
	Stage 2	9	0	0	1	3	27	46	36	10	0	1	1	134
5		607	540	358	229	148	54	120	47	44	125	247	512	3,032
6	Total	609	599	567	391	201	80	150	122	160	242	398	618	4,137
	Stage 1	235	189	408	335	199	57	101	64	117	196	290	306	2,498
	Stage 2	375	410	159	56	1	23	49	58	42	46	107	312	1,640
7		392	428	265	153	74	21	92	17	63	117	253	408	2,282
8	Total	660	603	510	270	123	65	186	71	88	270	384	637	3,867
	Stage 1	423	282	393	237	116	61	181	66	86	266	323	394	2,830
	Stage 2	236	321	117	33	8	4	5	4	2	3	61	243	1,037
9		475	491	348	135	65	70	114	29	46	106	236	392	2,507
10		529	494	355	156	58	70	87	34	33	139	338	435	2,728
Average Run Hours		483	453	336	182	87	65	136	65	67	151	290	406	2721
Average Equivalent Full Load Run Hours		413	409	276	140	63	51	107	49	51	111	232	353	2254

Two Stage Heat Pump: First stage provides 50% output capacity of second stage

Two Stage Heat Pump: First stage provides 70% output capacity of second stage. First stage and second stage run hours were not seperated.

Average Equivalent Full Load Run Hours is equal to stage # 1 run hours/percent of full load capacity plus stage # 2 run hours

Table 23: Heat Pump Run Hours (Heating Mode)

Heat Pump Run Hours (Heating Mode)														
House		January	February	March	April	May	June	July	August	September	October	November	December	Totals
1	Total	578	518	392	210	85	16	0	6	62	203	402	399	2870
	Stage 1	370	260	321	174	82	16	0	6	60	200	364	288	2,140
	Stage 2	208	258	71	36	3	0	0	0	2	3	38	111	730
2		476	438	289	109	19	7	1	6	63	128	283	329	2,148
3		115	266	204	74	47	17	0	0	23	48	171	244	1210
4	Total	394	149	67	75	22	0	0	0	9	123	188	89	1114
	Stage 1	385	149	67	74	20	0	0	0	8	123	187	88	1,101
	Stage 2	9	0	0	1	2	0	0	0	0	0	1	1	14
5		607	540	358	229	144	9	0	0	42	125	247	512	2,815
6	Total	609	599	567	391	201	32	2	12	96	231	398	618	3,757
	Stage 1	235	189	408	335	199	27	2	6	73	188	290	306	2,257
	Stage 2	375	410	159	56	1	6	0	6	24	44	107	312	1,499
7		392	428	265	153	74	4	0	0	60	117	253	408	2,153
8	Total	659	603	510	267	103	3	0	2	76	269	384	637	3515
	Stage 1	423	282	393	234	99	2	0	2	75	266	323	394	2,494
	Stage 2	236	321	117	33	4	1	0	0	2	3	61	243	1,021
9		475	491	348	135	60	7	0	0	36	106	236	392	2,286
10		529	494	355	156	49	5	0	0	33	139	338	435	2,534
Average		483	453	336	180	80	10	0	3	50	149	290	406	2440
Average Equivalent Full Load Run Hours		413	409	276	139	60	8	0	2	39	110	232	353	2041

Table 24: Heat Pump Run Hours (Cooling Mode)

Heat Pump Run Hours (Cooling Mode)														
House		January	February	March	April	May	June	July	August	September	October	November	December	Totals
1	Total	0	0	0	19	54	110	199	107	43	9	0	0	541
	Stage 1	0	0	0	17	53	110	184	106	41	9	0	0	520
	Stage 2	0	0	0	2	1	1	15	1	1	0	0	0	20
2		0	0	0	0	4	58	207	74	5	0	0	0	348
3		0	0	0	0	0	8	53	23	11	1	0	0	94
4	Total	0	0	0	0	11	79	150	110	23	0	0	0	373
	Stage 1	0	0	0	0	10	52	104	73	14	0	0	0	253
	Stage 2	0	0	0	0	1	27	46	36	10	0	0	0	120
5		0	0	0	0	4	45	120	47	2	0	0	0	218
6	Total	0	0	0	0	0	48	148	110	63	11	0	0	380
	Stage 1	0	0	0	0	0	30	99	57	44	9	0	0	240
	Stage 2	0	0	0	0	0	18	49	53	19	3	0	0	140
7		0	0	0	0	0	17	92	17	3	0	0	0	130
8	Total	0	0	0	3	20	63	186	69	11	0	0	0	352
	Stage 1	0	0	0	3	16	60	181	64	11	0	0	0	336
	Stage 2	0	0	0	0	4	3	5	4	0	0	0	0	16
9		0	0	0	0	5	62	114	29	11	0	0	0	221
10		0	0	0	0	9	65	87	34	0	0	0	0	195
Average		0	0	0	2	11	55	135	62	17	2	0	0	285
Average Equivalent Full Load Run Hours		0	0	0	1	7	43	107	47	12	1	0	0	218

Table 25: Annual Heat Pump Compressor Starts

House		January	February	March	April	May	June	July	August	September	October	November	December	Totals
1	**Total**	**2027**	**1513**	**1494**	**700**	**684**	**412**	**402**	**262**	**434**	**1,010**	**1,003**	**1,333**	**11,274**
	Heating	2027	1513	1494	625	457	115	0	38	318	971	1,003	1,333	9,894
	Cooling	0	0	0	75	227	297	402	224	116	39	0	0	1,380
2	**Total**	**1600**	**1193**	**1278**	**519**	**165**	**312**	**1,320**	**660**	**509**	**1,025**	**1,611**	**2,468**	**12,660**
	Heating	1600	1193	1278	518	162	59	8	53	503	1,025	1,611	2,468	10,478
	Cooling	0	0	0	1	3	253	1,312	607	6	0	0	0	2,182
3	**Total**	**330**	**805**	**772**	**311**	**206**	**111**	**258**	**114**	**205**	**234**	**773**	**992**	**5,111**
	Heating	330	805	772	311	206	77	0	0	154	232	773	992	4,652
	Cooling	0	0	0	0	0	34	258	114	51	2	0	0	459
4	**Total**	**1263**	**780**	**249**	**302**	**143**	**62**	**169**	**129**	**103**	**1,041**	**990**	**326**	**5,557**
	Heating	1263	780	249	302	128	0	0	0	75	1,041	990	326	5,154
	Cooling	0	0	0	0	15	62	169	129	28	0	0	0	403
5	**Total**	**703**	**673**	**1117**	**799**	**701**	**502**	**1,238**	**559**	**294**	**807**	**1,303**	**1,187**	**9,883**
	Heating	703	673	1117	799	661	43	0	0	272	807	1,303	1,187	7,565
	Cooling	0	0	0	0	39	459	1,238	559	22	0	0	0	2,317
6	**Total**	**3129**	**2863**	**3214**	**1831**	**738**	**294**	**227**	**236**	**582**	**827**	**1,686**	**3,723**	**19,350**
	Heating	3129	2863	3214	1831	738	205	7	52	458	802	1,686	3,723	18,708
	Cooling	0	0	0	0	0	89	220	184	124	25	0	0	642
7	**Total**	**1592**	**1253**	**1381**	**1008**	**591**	**209**	**885**	**213**	**611**	**1,224**	**1,401**	**1,760**	**12,128**
	Heating	1592	1253	1381	1008	591	28	0	0	570	1,224	1,401	1,760	10,808
	Cooling	0	0	0	0	0	181	885	213	41	0	0	0	1,320
8	**Total**	**1612**	**1351**	**913**	**412**	**201**	**222**	**457**	**226**	**176**	**366**	**644**	**1,391**	**7,971**
	Heating	1612	1351	913	393	130	7	0	6	129	355	644	1,391	6,931
	Cooling	0	0	0	19	71	215	457	220	47	11	0	0	1,040
9	**Total**	**1044**	**807**	**1066**	**447**	**344**	**259**	**359**	**179**	**293**	**722**	**1,193**	**1,322**	**8,035**
	Heating	1044	807	1066	447	339	46	0	0	256	722	1,193	1,322	7,242
	Cooling	0	0	0	0	5	213	359	179	37	0	0	0	793
10	**Total**	**1649**	**1319**	**1867**	**949**	**516**	**257**	**205**	**65**	**357**	**1,343**	**2,004**	**2,034**	**12,565**
	Heating	1649	1319	1867	949	502	59	0	0	357	1,343	2,004	2,034	12,083
	Cooling	0	0	0	0	14	197	205	65	0	0	0	0	481
verage Number of Starts		**1,495**	**1,256**	**1,335**	**728**	**429**	**264**	**552**	**264**	**356**	**860**	**1,261**	**1,654**	**10,453**

Appendix I

Entering Fluid Temperature Data

Table 26: Average Entering Fluid Temperature (Heating Mode)

Monthly Average Entering Fluid Temperature Heating (Fahrenheit)													
House	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
1	44.3	44.3	44.4	44.3	44.8	N/A	N/A	N/A	46.3	45.8	45.1	43.4	44.1
2	32.0	32.0	32.7	33.7	46.9	57.6	67.5	61.1	53.8	46.5	38.9	32.9	35.1
3	32.1	31.2	31.1	32.1	32.7	35.1	N/A	N/A	54.8	50.3	42.3	34.3	34.6
4	36.7	38.8	39.2	38.4	42.5	N/A	N/A	N/A	48.8	44.8	41.7	40.6	39.4
5	35.7	34.5	35.8	36.6	38.3	49.9	N/A	N/A	54.0	48.2	45.6	37.5	37.7
6	31.8	31.1	31.2	31.5	32.3	35.5	43.5	51.7	50.3	46.3	43.1	36.1	34.7
7	34.1	31.0	35.0	37.5	40.6	45.2	N/A	N/A	46.5	43.8	39.3	33.5	35.4
8	29.6	27.0	29.3	30.6	34.7	36.7	N/A	45.6	41.1	38.7	34.0	30.2	30.9
9	36.4	33.5	34.6	36.0	43.4	46.4	N/A	N/A	56.8	53.5	50.1	37.8	38.5
10	31.9	29.9	32.8	34.0	39.8	42.8	N/A	N/A	47.7	44.2	40.4	34.3	34.4

Table 27: Average Entering Fluid Temperature (Cooling Mode)

Monthly Average Entering Fluid Temperature Cooling (Fahrenheit)													
House	January	February	March	April	May	June	July	August	September	October	November	December	Weighted Average
1	48.5	51.0	N/A	44.7	45.2	45.5	45.6	46.7	47.1	47.7	N/A	N/A	44.0
2	N/A	N/A	N/A	37.7	41.2	60.9	70.7	69.1	58.2	N/A	N/A	N/A	68.3
3	33.4	N/A	N/A	34.7	N/A	39.1	46.6	54.2	56.9	54.6	44.7	N/A	49.0
4	40.9	43.8	42.5	37.9	48.8	53.0	57.0	58.0	56.7	54.2	49.8	47.9	56.1
5	N/A	N/A	42.9	47.6	N/A	51.7	54.9	56.1	58.3	N/A	48.9	N/A	55.1
6	35.2	N/A	32.7	33.5	36.4	38.6	47.5	53.1	52.5	49.9	N/A	N/A	49.0
7	N/A	N/A	N/A	N/A	N/A	47.6	54.0	54.8	52.4	N/A	N/A	N/A	53.2
8	32.2	29.3	31.2	34.2	41.1	44.6	49.9	50.0	47.8	40.7	N/A	N/A	48.2
9	48.3	N/A	N/A	N/A	41.5	50.3	56.6	59.0	59.8	59.9	N/A	N/A	54.9
10	N/A	N/A	N/A	50.9	46.4	52.0	57.5	60.0	N/A	48.9	N/A	N/A	55.6

Table 28: Minimum/Maximum Entering Fluid Temperature

	House									
Entering Fluid Temperature (Fahrenheit)	1*	2	3	4	5	6	7	8	9	10
Minimum (Heating)	42.0	29.2	29.0	32.1	33.3	30.5	27.2	24.1	32.3	27.4
Maximum (Cooling)	57.0	88.5	73.4	84.4	66.7	74.5	80.3	66.9	72	83.1

* House 1 is an open system (well to well)