ENERGY STUDY PROGRAM

Prepared for:

Resort Municipality of Whistler, Engineering Department

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STATEMENT OF LIMITATIONS

This Energy Study Program report has been prepared for the Resort Municipality of Whistler (RMOW) based on the heat pump heating system observations and measurements taken at six townhouses connected to the District Energy System in the Cheakamus Crossing community over a six month period, as well as other related energy analysis and data that was sourced through other agencies as noted in the references.

DEC Engineering's analysis and this report are intended to provide an overview and a representative comparison of these heat pump based heating systems efficiency and ownership costs compared to more conventional electric based heating systems in similar residential applications. This study and report is not intended to be a comprehensive and detailed assessment of every heating system operating in Cheakamus Crossing. Homeowners not participating in this study may experience different results than what are reported herein and should not use the conclusions of this study and report as indications of the quality of operation of their heating systems.

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EXECUTIVE SUMMARY

The 2010 Whistler Athlete's Village was originally designed and constructed with several key sustainability goals in mind. These goals included the achievement of new standards in renewable thermal energy use and efficiency, along with the corresponding reduction in GHG emissions for the residential buildings in the Village. These aspects were to remain as a proud legacy post Olympic games for the Resort Municipality of Whistler (RMOW) and the residents and homeowners that would call Cheakamus Crossing home. Energy systems were chosen and new energy systems were developed to enable the community to capture and use the heat energy contained in the clean effluent leaving the Cheakamus Crossing Waste Water Treatment Plant (WWTP). Heat pump (HP) technologies were used to both extract heat at the WWTP and to transform the extracted heat into space and water heating in the residential dwellings. To distribute the extracted, low temperature, heating energy to the buildings in the Village a new type of district energy system (DES) was developed.

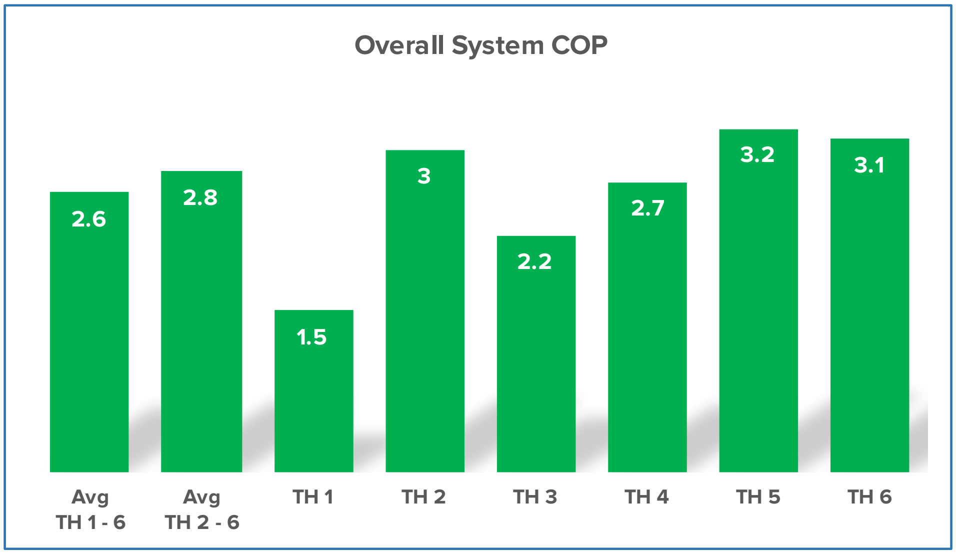
In 2015, approximately six years after the original energy systems were built and activated, the RMOW believed it was important to confirm if the typical DES connected residential HP system in Cheakamus Crossing was actually achieving the energy goals it was meant to. The decision was made to conduct the Energy Study Program (ESP) to measure, analyze and report on actual energy use within a sample group of townhouses and how it compares to townhouses using more conventional electric heating systems.

DEC Engineering, the original design firm of the DES and HP systems, in collaboration with the Engineering staff at the RMOW, developed the criteria and methodology of the ESP. A volunteer sample group of six townhouses (TH) were chosen for the ESP. Each HP system passed a technical inspection to ensure their HP systems were operating in good condition and hadn't been modified. Next, each HP system was equipped with an energy monitoring system that was used to record key amperages and temperatures needed to estimate the energy being used to produce space heating and DHW heating during the study period. The study period was set up to allow for six months of monitoring, beginning in January 2016 and lasting through to July 2016. The collected data was used by DEC Engineering personnel to analyze the energy efficiency and operating costs of the monitored systems, and to provide a comparison to more conventional electric heating scenarios. The following is a summary of the results.

ENERGY EFFICIENCY

When HP systems are working well they should achieve coefficient of performance (COP) values greater than 2.0. COP is the ratio of energy produced over energy consumed. A COP of 3.0 indicates that the HP system is producing 3 kW of heat energy for every 1 kW of electricity consumed. The COP values for the ESP study group, based on the monitored data and analysis, are compared in the following chart.

COP Values During the Monitoring Period



In five of the six homes in the study group the HP systems achieved overall system COP values well above 2.0, with the highest being 3.2. Overall system COP calculations include the ancillary energy used by the circulating pumps and backup heating elements.

TH 1 had an overall system COP value of less than 2.0. This is due to their HP system only being used to provide space heating. All of the DHW heating in TH 1 is being provided by the electric DHW tank elements, which only have a COP value of 1.0.

The monitoring data also indicated that the DHW tank elements in TH 3 were activated for part of the monitoring period, which contributed to its lower overall COP. TH 3 also utilized the electric heating element in the buffer tank, but only for a very brief time during the monitoring period.

Five out of six sample group HP systems were operating within the energy efficiency ranges they were designed to. The HP systems in TH 2, TH 4, TH 5 and TH 6 utilized the DES supplied renewable energy for 100% of their space and DHW heating; no backup heating element activation was recorded.

ENERGY AND OWNERSHIP COSTS

The cost analysis compared the energy and ownership costs of the HP systems in the study group to a more conventional electric hydronic heating system, which represent the first “business-as-usual” (BAU 1) alternative. A further general comparison to electric baseboard heating (BAU 2) was done as well.

ENERGY COSTS

Energy cost calculations were based on the following factors:

For the HP System:

- The cost of electricity to run the HP, the backup tank elements in both the DHW tank and the buffer tank, and the circulating pumps.
- A blended BC Hydro rate: $0.1036/kWh (assumption: HP system electricity use is billed based on 50% Step 1 and 50% Step 2).
- DES utility charges - $4.58/m^2/year

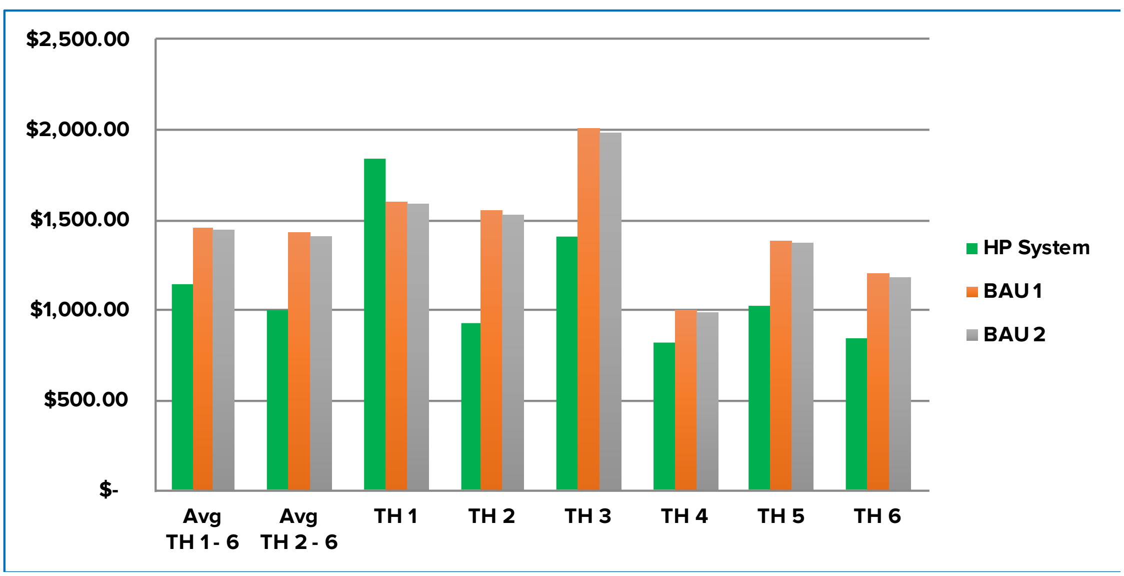
For the BAU 1 system:

- The cost of electricity to run an electric boiler (COP 1.0), in place of the HP, an electric DHW tank, and circulating pumps.
- A blended BC Hydro rate: $0.1166/kWh (assumption: electric boiler system electricity use is billed based on 37% Step 1 and 63% Step 2, due to the greater electricity consumption.)

For the BAU 2 system:

- The cost of electricity to run electric baseboards and an electric DHW tank.
- A blended BC Hydro rate: $0.1166/kWh (assumption: electric baseboard electricity use is billed based on 37% Step 1 and 63% Step 2, due to the greater electricity consumption.)

Annual Energy Cost Comparison

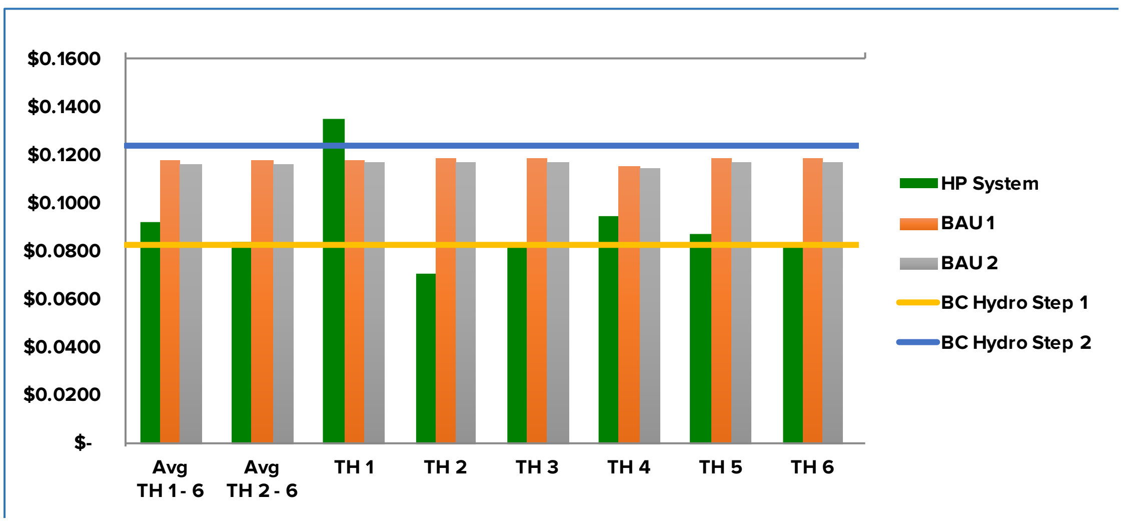


The HP systems in TH 2, 3, 4 and 5 have much lower annual energy costs to produce the same levels of heat energy output, compared to the BAU 1 and BAU 2 scenarios. The HP systems' annual energy costs were 17% to 40% less than the BAU systems, with an average annual savings of 30%. Annual energy cost savings ranged from $172 to $622. The average annual savings was $428 compared to BAU 1, and $408 compared to BAU 2. A typical service life expectancy for a HP is roughly twenty years. Multiplying the annual savings over that time equates to cost savings that range from $3,440 to $12,440 (in 2016 dollars). The analysis of the monitored data indicates that the more the heat pump is utilized the greater the savings are.

TH 1 was the exception, with annual energy costs much higher than the other townhouses in the sample group, and also higher than the BAU scenarios. As with the COP results, this exemplifies another impact of utilizing the HP system and the DES energy only for space heating. TH 1 continues to pay monthly DES charges even when space heating is not being used. During these periods, the monthly DES charge is an additional energy cost on top of the cost of electricity to operate the electric DHW tank elements. Added together this greatly inflates the cost of energy the customer pays for when they only require DHW production. Subsequently increasing their annual energy cost to a level well above the other townhouses and the BAU scenarios.

Another useful comparison is the cost per kWh of the systems' delivered heating energy, or energy outputs, versus BC Hydro's standard residential electricity rates.

Delivered Energy Cost - $/KWH



Other B.C. DES utility energy rates are typically benchmarked to be plus or minus 10% of BC Hydro's Step 2 energy rate: $0.1243/kWh. Their customers still have to take that energy and convert it to space and DHW heating. So their final delivered energy rate will be higher. The delivered energy rates for customers of the Cheakamus Crossing DES, which includes their DES utility charges plus the operating costs of their HP systems, are well below BC Hydro Step 2. Most are actually very close to the BC Hydro Step 1 rate: $0.0829. Based on this, the HP systems are quite energy and cost efficient compared to other DES systems in B.C., when they are operating as they were designed to.

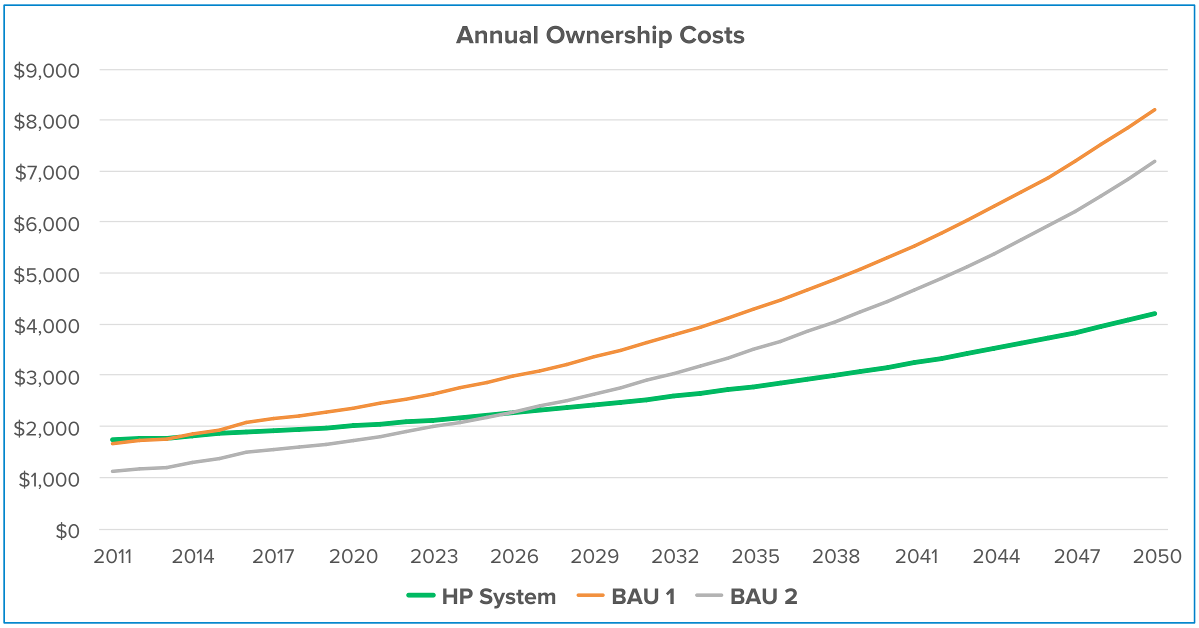
TH 1 is the obvious exception for the same reasons noted previously.

Compared to the BAU systems, the cost of the HP systems delivered energy ranges from being 17% to 40% less.

OWNERSHIP COSTS

Ownership costs include the cost of energy, the cost of routine maintenance, and the cost of equipment replacement at the end of its normal service life. The study estimated the average annual ownership costs of the HP systems in the sample group and compared them to the BAU 1 and BAU 2 systems. Costs were developed for 2016 and then discounted back to 2011 and projected[i] forward 2050.

Annual Average Ownership Cost Comparison



The chart above shows the HP system ownership cost increasing at a slower rate than the BAU 1 and BAU 2 systems. This is primarily due to the HP systems requiring less electricity to operate than the BAU systems. Consequently, their ownership costs are not impacted as much by BC Hydro rate increases over time. The associated cost of the DES utility rate was not escalated for this analysis, as per the recommendations of RMOW staff.

The BAU 1 electric boiler system is expected to have slightly lower maintenance and replacement costs than the HP systems, however, these savings were more than offset by the much lower energy costs of the HP systems.

The BAU 2 electric baseboard system has basically no maintenance cost and only a small replacement cost allowance for the DHW tank. Future increases in BC Hydro rates account for the majority of the increases in BAU 2 ownership costs over time. As the chart indicates, the lower energy costs of the HP system allow the BAU 2 ownership costs to catch up by year 16 (2026). After that the HP systems' ownership costs to trend below BAU 2, electric baseboard heating.

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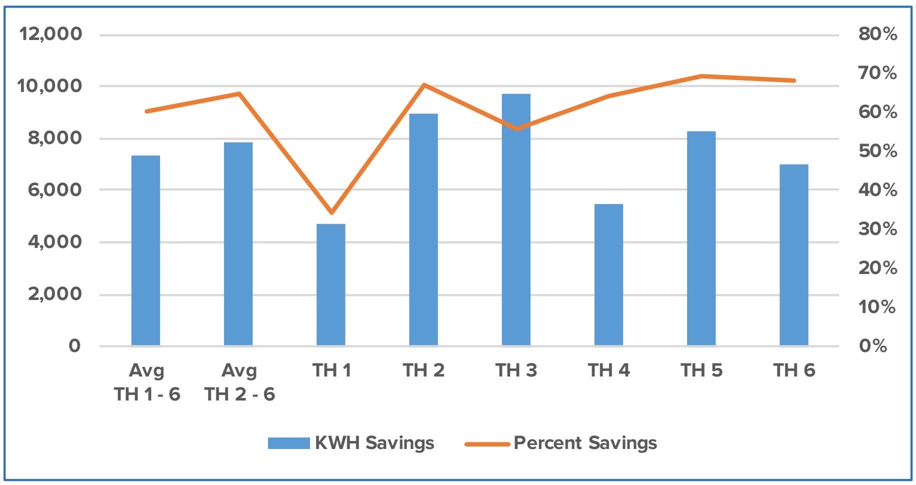
[i] *Based on published BC Hydro rate increases up to 2018 and 5.0% increase per year thereafter, and 1.29% annual Canadian inflation rate, and a 6% discount rate.*

ENERGY CONSUMPTION AND GHG EMISSIONS

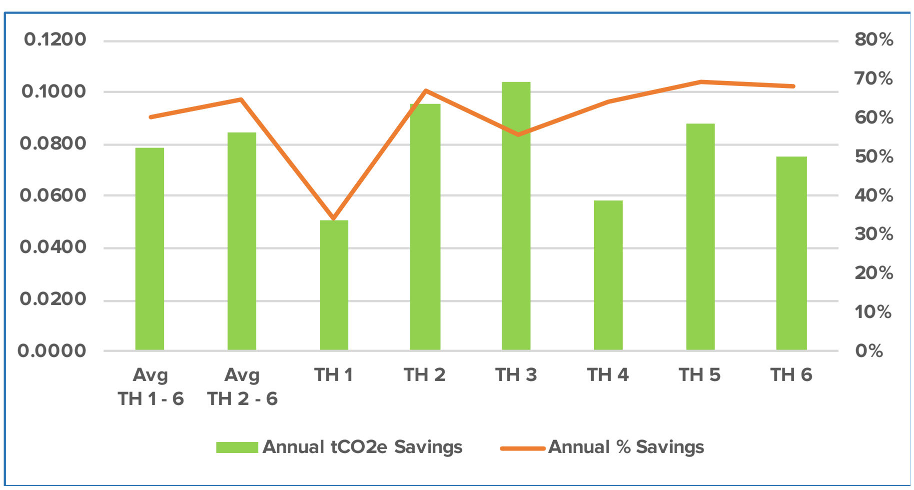
Comparing the HP systems to both the BAU 1 and BAU 2 scenarios demonstrates a major difference in energy consumption. Looking at this on an annual and a twenty-year projected basis shows the HP systems have substantial energy consumption savings, along with the associated reductions in GHG emissions. Savings in both electricity consumption and related GHG emissions range from 34 percent to 69 percent. The average savings for TH 2 – 6 was significant at 65%. Although TH 1 again had the lowest performance, it still achieved a 34% savings compared to the BAU systems.

Note: BAU 2 doesn't use any circulating pump energy, but this represents only a very minor energy use. For this reason, we considered BAU 1 and 2 energy use to be equivalent for the following comparison values:

HP SYSTEM vs BAU 1 & 2: ANNUAL ENERGY SAVINGS



HP SYSTEM vs BAU 1 & 2: ANNUAL GHG EMISSION REDUCTIONS



20 YEAR ENERGY CONSUMPTION AND GHG EMISSIONS

	Avg TH 1 - 6	Avg TH 2 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
KWH Consumption								
HP System	**103,114**	**87,775**	179,807	87,203	150,326	62,368	73,337	65,640
BAU 1 & 2	**250,103**	**245,337**	273,932	266,612	344,244	171,908	238,081	205,842
20 Year Savings	**146,990**	**157,563**	94,125	179,409	193,918	109,539	164,744	140,202
Percent savings	**60%**	**65%**	34%	67%	56%	64%	69%	68%
GHG Emissions - tCO2e								
HP System	**1.1002**	**0.9366**	1.9185	0.9305	1.6040	0.6655	0.7825	0.7004
BAU 1 & 2	**2.6686**	**2.6178**	2.9229	2.8447	3.6731	1.8343	2.5403	2.1963
20 Year Savings	**1.5684**	**1.6812**	1.0043	1.9143	2.0691	1.1688	1.7578	1.4960
Percent savings	**60%**	**65%**	34%	67%	56%	64%	69%	68%

Based on an average annual energy savings of **7,878 kWh**, every 3.7 years each townhouse HP system could potentially save enough electricity to completely power an average Whistler house for a full year[ii]. The potential average annual savings from the 174 Cheakamus Crossing townhouses is **1,370,772 kWh**. This represents enough electricity to completely power **52** average Whistler houses each year.

[ii] *Based on 26,500 kWh per average house per year. Pique News Magazine. "Price of Power" by Andrew Mitchell published June 16, 2013.*

KEY CONCLUSIONS OF THE ENERGY STUDY

- Five of the six HP Systems in the study group are achieving the energy efficiency levels they were originally intended to and designed for. The one HP system in the study group that did not, had its HP DHW heating disabled and therefore was not being operated as it was designed to be. These results indicate that the HP systems are capable of meeting the WDC 2020 energy and environmental performance targets they were designed to. They also indicate that the HP system's performance is sensitive to how it's being operated.
- The HP systems are significantly more energy efficient than other conventional (BAU) electric heating systems. The study results indicate they are consuming on average 65% less electricity per year, to provide space and water heating. This corresponds to an average 65% reduction in related GHG emissions.
- The HP systems average 40 year estimated ownership cost NPV is $10,740 less than the NPV cost for an equivalent electric boiler hydronic system (BAU 1), and $698 less than the NPV cost for an electric baseboard and DHW system (BAU 2).
- After 16 years, or by 2026, the electric baseboard ownership costs are projected to be higher than the HP system. This is primarily due to the projected increase in BC Hydro electricity rates and the much lower energy consumption of the HP systems.
- The HP systems average 20 year savings in electrical energy compared to both BAUs is 157,563 KWh, or 65%.
- The added value of the greater thermal comfort provided by radiant floor heating was not included in this analysis.
- Based on an average annual energy savings of 7,878 kWh, every 3.7 years each townhouse HP system could potentially save enough electricity to completely power an average Whistler house for a full year[iii]. The potential average annual savings from the 174 Cheakamus Crossing townhouses is 1,370,772 kWh. This represents enough electricity to completely power 52 average Whistler houses each year.

[iii] *Based on 26,500 kWh per average house per year. Pique News Magazine. "Price of Power" by Andrew Mitchell published June 16, 2013.*

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LIST OF ABBREVIATIONS

BAU........Business as Usual
COP........Coefficient of Performance
DES........District Energy System
DHW........Domestic Hot Water
ESP........Energy Study Program
EUI........Energy use intensity
Gpm........Gallons per minute
HP........Heat Pump
Htg........Heating
NPV........Net Present Value
PV........Present Value
ROE........Return on Equity
ROI........Return on Investment

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1.0 OBJECTIVE

On behalf of the Resort Municipality of Whistler (RMOW), DEC Engineering (DEC) has completed the Energy Study Program (ESP) for townhouses in the Cheakamus Crossing District Energy Sharing System (DES) service area. The purpose of the ESP was to measure the energy efficiency of a sample of townhouse heat pump systems and analyze the ownership and operating costs of using the heat pump systems for space and domestic hot water (DHW) heating in these townhouses. The findings on energy consumption, efficiency and operating costs are compared to "business-as-usual" (BAU) scenarios, assuming conventional electric heating.

2.0 HEAT PUMP SYSTEM OVERVIEW

Each townhouse connected to the DES is equipped with a Climatemaster Tranquility water-to-water heat pump to provide space and DHW heating. The heat pump extracts low-grade heat (10-15C) from the DES and upgrades the energy to create high-temperature water (50-60C). The high temperature water can provide heating energy to the space heating buffer tank or to the DHW storage tank. The heat pump switches between "space heating mode" and "DHW heating mode" based on the temperatures and setpoints of the two tanks. Typically, DHW heating mode is the priority.

Both tanks are equipped with backup electric resistance heating elements, that can operate to maintain tank temperature if the heat pump is unable to meet the demand, or is offline.

Most townhouses also have two electric baseboard heaters; one in the storage room and one in the second floor washroom. The usage of these electric heaters varies from resident to resident. This heating energy use was not measured as a part of this study, and it is unrelated to the performance of the HP systems. Heating provided by the electric baseboard heaters is expected to be minimal and is not included in the following results.

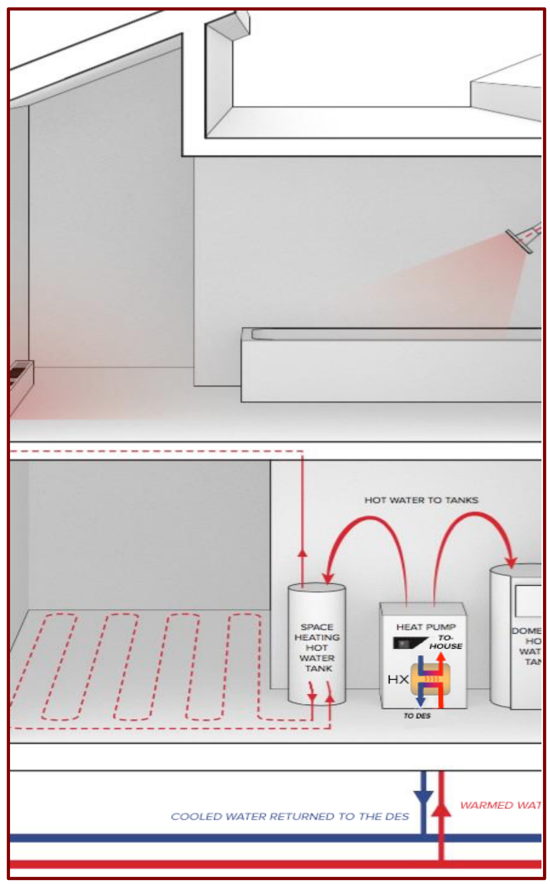

Figure 1: Typical Townhouse HP System

3.0 SAMPLE GROUP AND DATA COLLECTION

In December 2015, RMOW conducted a campaign seeking Cheakamus Crossing townhouse homeowners to volunteer for participation in the ESP. From the applications received, eleven candidate homes were shortlisted representing a cross section of the original development phases. The heating systems in these homes underwent a technical inspection to verify that they hadn't been modified from the original design, and that they would meet the operating requirements of the six month study. This resulted in a final list of seven homes that met all of the ESP requirements.

Six homes were needed for the ESP sample group and the seventh qualified home provided some redundancy in case a participant had to withdraw unexpectedly. This unfortunately did happen to one of the selected candidates before the study commenced, but the ESP six home sample group was maintained.

In early January 2016, the digital monitoring equipment was installed on the heating systems in the six home sample group. Nine points of data were monitored for the ESP:

- Heat pump compressor current (amps)
- DHW tank electric element current (amps)
- Space buffer tank electric element current (amps)
- DES (source) supply and return temperatures
- DHW heat exchanger loop supply and return (to the HP) temperatures
- Space heating supply and return (to the HP) temperatures

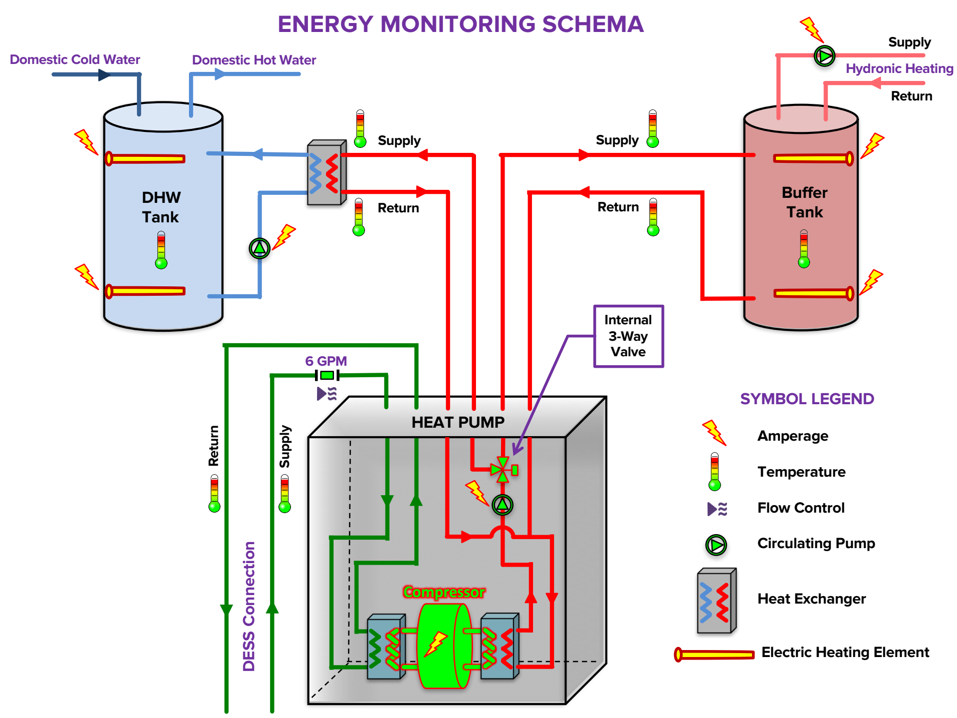

Figure 2: Energy Monitoring Schema

The data was measured at fifteen (15) minute intervals over the duration of the six month monitoring period.

4.0 ENERGY DATA ANALYSIS

4.1 HEAT PUMP RUNTIME

From the monitored data, heat pump runtime, electricity consumption, and thermal energy delivery have been calculated. Runtime of the heat pump has been categorized into Space Heating and DHW Heating. The following table presents the runtime data for each house in the study group.

Table 1: Heat Pump Runtime Results

	Units	Avg TH 1 - 6	Avg TH 2 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
HP DHW Runtime	hrs	160	192	0	294	172	133	211	150
HP Space Htg Runtime	hrs	460	479	364	602	662	221	492	420
TOTAL Runtime	hrs	620	671	364	895	833	353	703	570
Monitoring Period	days	186	183	199	208	204	104	192	208
Percent Runtime		14%	15%	8%	18%	17%	14%	15%	11%

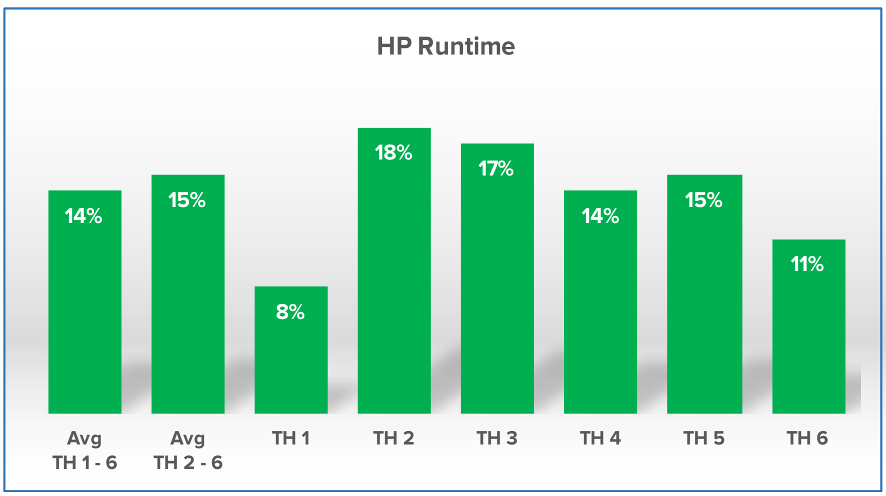

Figure 3: Heat Pump Runtime

As can be seen above, each heat pump ran for a varying number of hours during the study period. Heat pump runtime ranged from 8% - 18%. This is most likely due to variations in thermostat settings and different heating demands in each of the townhouses. Townhouses with higher thermostat settings, northern or shaded exposures, and less internal heat gains (from occupants, cooking, appliances, etc.) would be expected to experience higher percent runtimes than units with lower thermostat settings, tighter building envelope construction, and large solar heat gains from south facing exposures.

Note that the TH 1 HP system did not run in DHW heating mode during the study period. The HP DHW function is turned off, so all DHW heating in this townhouse is provided by the backup electric tank element rather than by the DES and heat pump.

To mitigate the effects of varying runtime on the results of this analysis, each townhouse is analyzed individually, and compared to an identical townhouse using all electric heat and no DES energy, for the business case analysis.

4.2 SPACE AND DHW HEATING DELIVERY

Using the DES (source) supply and return temperatures and the pre-set, fixed, source side flow rate of 6.0 gpm, the total DES energy utilized by the HP in each 15 minute measurement interval can be determined. Compressor amperage and the equipment voltage can be used to determine the electricity consumed by the heat pump in each measurement interval. From this data, the delivered space or DHW heating energy can be calculated as well as the efficiency of the heat pump system.

The following table presents the heating energy delivered and the electricity consumed by the HP compressor, circulation pumps, and tank backup heating elements for DHW and Space heating during the study period for each townhouse system. The coefficient of performance (COP)[4] is calculated for space heating, DHW heating, and an overall system COP (including backup electric elements and pump electricity).

Table 2: Space and DHW Heating, Energy Use, and COP

	Units	Avg TH 1 - 6	Avg TH 2 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
HP DHW Heating	kWh	**N/A**	**1,824**	0	2,566	1,622	1,354	1,982	1,594
DHW HP Electricity Used	kWh	**N/A**	**610**	0	899	595	459	585	514
DHW Heating COP		**N/A**	**3.0**	N/A	2.9	2.7	2.9	3.4	3.1
DHW Pump Elec. Used	kWh	**N/A**	**46**	0	71	41	32	49	35
Backup Element Heating	kWh	**N/A**	**200**	2,371	0	1,000	0	0	0
HP Space Heating	kWh	**3,955**	**4,100**	3,232	4,443	6,248	1,938	4,090	3,779
Space HP Elec. Used	kWh	**1,200**	**1,278**	810	1,266	2,167	676	1,169	1,114
Space Heating COP		**3.4**	**3.2**	4.0	3.5	2.9	2.9	3.5	3.4
Space Pump Elec. Used	kWh	**87**	**90**	69	104	126	44	98	80
Backup Element Heating	kWh	**263**	**14**	1,512	0	68	0	0	0
Total Heating	kWh	**6,300**	**6,137**	7,115	7,009	8,938	3,292	6,072	5,374
Heating from Heat Pump	kWh	**5,475**	**5,923**	3,232	7,009	7,871	3,292	6,072	5,374
HP Utilization		**89%**	**98%**	45%	100%	88%	100%	100%	100%
Total Source Energy Used	kWh	**3,892**	**4,125**	2,727	4,935	5,199	2,204	4,502	3,783
Overall System COP		**2.6**	**2.8**	1.5	3.0	2.2	2.7	3.2	3.1

[4] *Coefficient of performance (COP) is a measurement of heat pump efficiency. COP is calculated as (heat output) ÷ (electricity input). A COP of 3.0 means that for 1 kWh of electricity consumed, 3 kWh of heat is produced.*

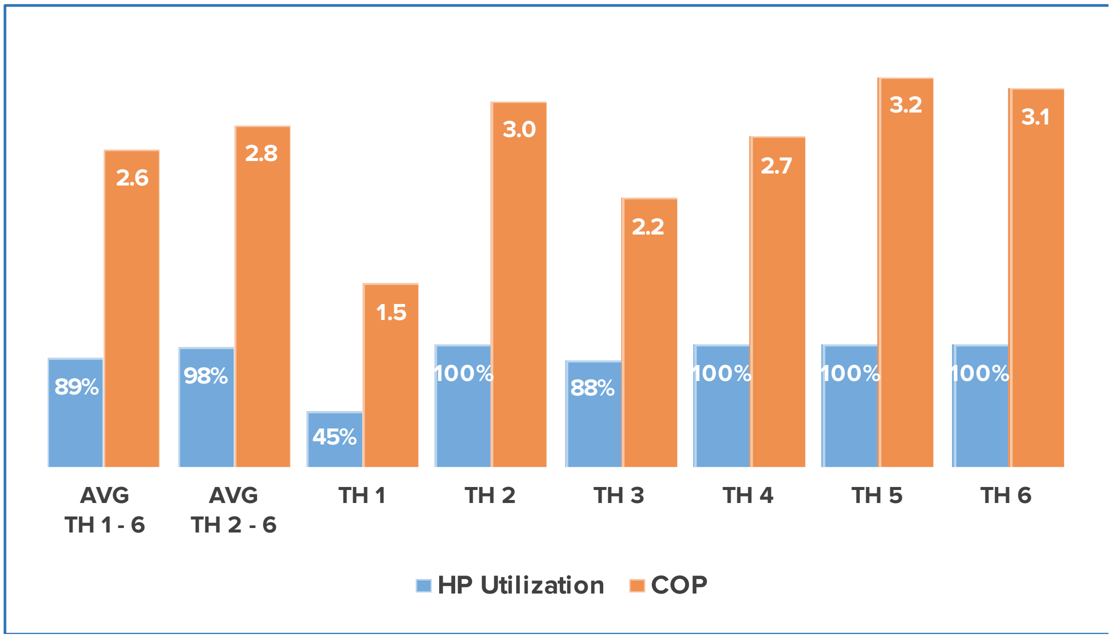

Figure 4: HP Utilization & COP

The above shows that five out of six townhouses use the HP for 88%-100% of their space and DHW heating needs[5] and the overall heating system COP ranges from a low of 1.5 to a high of 3.2 for the homes in the study program.

TH 1 shows the lowest overall COP because the DHW tank electric elements are ON and the HP isn't being used for DHW heating. The DHW heating COP for TH 1 (on full electric) is only 1.0, which reduces this homeowner's average COP. Excluding TH 1, the other homeowners are using the HP for nearly all their space and DHW heating needs and have an average overall system COP of 2.8 (including pumping energy and minor backup electric element heating loads). TH 3 is also a little below the COP average at 2.2 overall. The monitored data shows that a 1,000 kWh of electricity was used by their DHW electric tank elements during the monitoring period. Similar to TH 1, the extended use of the DHW elements reduced the overall system efficiency.

The following table shows the townhouse space and DHW heating loads on a per square meter basis. This metric, referred to as "energy use intensity" (EUI), is an indication of how much space and water heating energy each house is demanding from the heating system. Variations between customers is normal and expected due to the differences in resident life styles, that is reflected in thermostat settings, hot water use, and heating demands of each customer.

Table 3: Space and DHW Heating EUI

	Units	Avg	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
Townhouse Floor Area	m^2	**133**	198	105	136	109	140	109
DHW EUI	$kWh/m^2/year$	**33**	22	43	35	44	27	26
Space Heating EUI	$kWh/m^2/year$	**63**	47	82	90	35	57	68

[5] *Excluding upstairs washroom and garage electric resistance heat.*

Most customers in the study group had EUIs for space and DHW heating that are within the range expected for townhouses in Whistler BC. Houses 5 and 6 had very low DHW EUIs which may be due to low numbers of occupants, or behavior patterns that reduce DHW demand such as vacations, dining out, or showering off-site (e.g. at the gym).

The variation in energy use displayed in Table 3 is beneficial to the results of this study as it means the study group included a diverse range of occupants who have varying lifestyles and family sizes.

5.0 COST ANALYSIS

The cost to meet the heating loads of each townhouse have been calculated for the DES connected HP systems and compared to the cost to meet the same heating loads to the same townhouses under a "business-as-usual" electric heating system scenario (BAU1). The BAU1 heating system consists of a standard electric DHW tank and an electric hydronic boiler to provide hot water to the hydronic heating system. The hydronic bedroom fan coils and in-floor radiant system and the envelope heat loss are assumed to be identical in both the HP system and BAU 1 scenarios. These assumptions maintain a consistent quality and demand of energy delivery between the scenarios. In-floor radiant systems are typically recognized for providing greater thermal comfort at lower temperatures and are often featured in expensive luxury homes.

5.1 ENERGY COST ANALYSIS

The following table presents the energy costs to the DES customers to provide the space and DHW heating loads summarized in Table 2. Electricity charges are based on measured electricity consumption and the average of BC Hydro Step 1 and Step 2 rates posted as of March 2016[6]. Annual DES utility charges are based on the published DES utility rates of $4.58/m^2/year multiplied by the townhouse floor area. DES utility charges are prorated based on the number of days in the study period for each townhouse.

Table 4: HP System Annual Energy Costs

	Units	Avg TH 1 - 6	Avg TH 2 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
DHW Heating Electricity	$	**$115**	**$89**	$246	$100	$170	$51	$66	$57
Space Heating Electricity.	$	**$161**	**$143**	$248	$142	$244	$75	$131	$124
DES Utility Charges	$	**$313**	**$277**	$494	$274	$348	$142	$337	$284
Total HP System Energy Cost	$	**$589**	**$509**	$988	$517	$762	$267	$534	$464
per square meter	$/m^2	**$4.35**	**$4.22**	$4.99	$4.92	$5.60	$2.46	$3.82	$4.28
per kWh delivered	$/kWh	**$0.092**	**$0.083**	$0.139	$0.074	$0.085	$0.081	$0.088	$0.086

Energy costs per meter square range from a low of $2.46 to a high of $5.60 and are largely influenced by the individual space and DHW EUIs of each townhouse. Customers that use more energy per square meter, pay a higher cost per square meter.

Energy costs per kWh of thermal energy delivered is a better way to compare the performance of the HP systems. Delivered energy costs range from $0.074 to $0.139 /kWh. Because the DES

[6] *BC Hydro Step 1: $0.0829 /kWh Step 2: $0.1243 /kWh. Annual heat pump system electricity is assumed to be 50% in Step 1, 50% in Step 2. Blended electricity rate of $0.1036 /kWh is used.*

utility connection charge is fixed (based on floor area) and doesn't vary with consumption, those customers who use more energy pay less per kWh than customers who use less energy.

The following table summarizes the cost to produce the same space and DHW heating energy - as shown in Table 2 – using the BAU 1 heating system. More electricity is consumed in the BAU 1 scenario, therefore a higher blended electricity rate is used for the BAU 1 calculations[7]. Under the BAU 1 scenario, the DES utility connection is not required so DES Utility charges are not included.

Table 5: BAU1 Energy Costs

	Units	Avg TH 1 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
BAU1 DHW Heating Elec.	$	**$243**	$277	$299	$306	$158	$231	$186
BAU1 Space Heating Elec.	$	**$502**	$561	$530	$751	$231	$488	$450
Total BAU Energy Cost	$	**$745**	$838	$830	$1,057	$389	$720	$636
per square meter	$/m2	**$5.75**	$4.24	$7.91	$7.77	$3.58	$5.15	$5.86
per kWh delivered	$/kWh	**$0.118**	$0.118	$0.118	$0.118	$0.118	$0.119	$0.118

On average, energy costs per square meter of floor area were significantly lower in the DES connected HP System than the BAU 1 case ($4.22/ m^2 vs $5.75/ m^2.) during the study period. Average energy cost per kWh of thermal energy delivered was also lower in the DES than the BAU 1 case ($0.083 vs $0.118 /kWh).

The following table compares the energy costs of the HP system to the BAU 1 system, over the study period and over a full year of operation. Expected full year savings are calculated based on projected full-year DHW and space heating loads for each townhouse in the study group.

Table 6: HP System vs BAU 1 Energy Cost

Study Period	Units	Avg TH 1 - 6	Avg TH 2 - 6	TH 1	TH 2	TH 3	TH 4	TH 5	TH 6
HP System Energy Cost	$	**$589**	**$509**	$988	$517	$762	$267	$534	$464
BAU 1 Energy Cost	$	**$745**	**$577**	$838	$830	$1,057	$389	$720	$636
Study Period Savings	$	**$156**	**$218**	-$150	$313	$295	$122	$186	$172
percent savings	%	**22%**	**30%**	-18%	38%	28%	31%	26%	27%
Annual Estimates (2016)									
HP System Energy Cost	$	**$1,141**	**$1,002**	$1,837	$932	$1,402	$820	$1,020	$837
BAU 1 Energy Cost	$	**$1,459**	**$1,431**	$1,597	$1,555	$2,008	$1,003	$1,388	$1,200
Annual Savings	$	**$317**	**$428**	-$240	$623	$606	$182	$369	$363
percent savings	%	**22%**	**29%**	-15%	40%	30%	18%	27%	30%

[7] *Annual BAU space and DHW heating electricity is assumed to be 37% in Step 1, 63% in Step 2. Blended electricity rate of $0.1166 /kWh is used.*

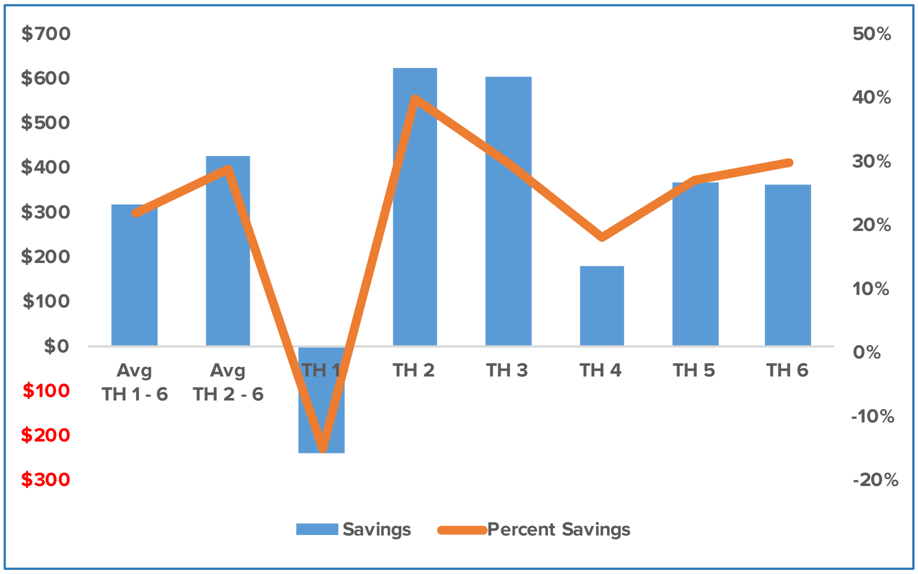

Figure 5: Annual Energy Cost Savings - HP vs BAU 1

Annual energy cost savings of the HP system vs. the BAU 1 system range from negative $240 (a cost premium) to a savings of $623. TH 1 does not have any cost savings because this home uses 100% electric heat for the DHW. Through the year, the TH 1 homeowner is paying their DES utility charges but only using DES energy for space heating. In warmer months when space heat is not required, they are paying electricity costs for their electric DHW heating *plus* the DES utility charge. Those townhouses that use the heat pump for DHW heating use significantly less electricity and therefore pay less per kWh of delivered DHW.

TH 6 has the lowest cost savings compared to BAU 1 amongst the homes in the study group. TH 6 is one of the largest townhouses in the study group, but has the lowest total energy use intensity[8] (63 kWh/m^2 vs. a group average of 90 kWh/ m^2). Since the DES utility charges are fixed (based only on floor area, not varying with energy use), those customers who use less heating energy do not realize as much savings over BAU 1 as those customers who use more heating energy.

Based on an average annual energy savings of 7,878 kWh, every 3.7 years each townhouse HP system could potentially save enough electricity to completely power an average Whistler house for a full year[9]. The potential average annual savings from the 174 Cheakamus Crossing townhouses is 1,370,772 kWh. This represents enough electricity to completely power 52 average Whistler houses each year.

5.2 TOTAL COST ANALYSIS

An analysis of total ownership cost of the HP systems from the homeowner perspective has been completed. Total cost includes: energy costs, regular maintenance costs, and equipment replacement costs.

[8] *Combined space and DHW EUIs.*
[9] *Based on 26,500 kWh per average house per year. Pique News Magazine. "Price of Power" by Andrew Mitchell published June 16, 2013.*

- Energy costs include annual electricity charges for operating the heat pump, circulating pumps, and backup electric heat elements in the tanks, as well as DES utility charges. The average 2016 energy cost of the ESP study group townhouses is used[10].
- Regular maintenance includes the yearly cost of completing the routine annual maintenance described in the *Cheakamus Crossing DES Technical Service Guide* and is based on one service visit per year for a system that is operating normally.
- Equipment replacement costs includes periodic replacement of major components of the system that reach the end of their useful service life. This is presented as an Annual Equipment Replacement Budget, which is a small annual contribution towards the periodically required major equipment replacement costs[11].

Summaries of expected regular maintenance and replacement costs are included in **Appendix A** and the 40 Year Life Cycle Cost Analysis table is included in **Appendix C**.

The average estimated annual cost for the HP system is presented in the following table and is compared to the average annual cost of the all-electric hydronic heating BAU 1 scenario described above.

Table 7: Average Annual Ownership Cost (2016) – BAU 1 Comparison

	HP System	BAU1	Savings
Average (TH 2 – 6) Energy Cost	$1,003	$1,431	**$428**
Routine Maintenance Costs	$350	$300	**- $50**
Equipment Replacement Budget	$543	$354	**- $189**
Total Annual Cost of Ownership	**$1,895**	**$2,085**	**$190**

The above table shows that the HP system has the lowest average annual energy cost, but slightly more expensive costs for maintenance and replacement budgets, compared to the BAU 1 estimates. Altogether, the analysis indicates the HP system will be a little less expensive to own and operate, with an estimated annual ownership cost savings of $190. This is based on the published 2016 BC Hydro electricity rates.

The same total cost analysis has been completed including projections for future BC Hydro rate increases. As BC Hydro electricity rates go up, the annual energy costs for homeowners on all-electric systems will rise. While BC Hydro rates are forecasted to rise on average 5.0% per year over the next twenty years, DES Utility rates are forecast to remain constant. So the energy costs of those homeowners primarily using DES energy should not increase as significantly as those using all-electric heat. The projected total annual ownership cost for year 2036 (BC Hydro forecasted rates, constant DES utility charges, and Canadian average inflation of 1.29% on maintenance and replacement costs) is presented in the following table.

[10] *Excluding TH 1 which was using all electric for DHW heating.*
[11] *Equipment replacement frequency is subject to variation depending on the operation, maintenance, and general wear & tear placed on the component and does not account for above average incidence of failure due to faulty installation, poor water quality, neglect, or misuse.*

Table 8: Projected Annual Ownership Cost (2036) – BAU 1 Comparison

	HP System	BAU1	Savings
Average (TH 2 – 6) Energy Cost	$1,703	$3,636	**$1,933**
Routine Maintenance Costs	$452	$388	**- $64**
Equipment Renewal Budget	$702	$457	**- $245**
Total Annual Cost of Ownership	**$2,857**	**$4,481**	**$1,624**

Total ownership cost of the DES-connected HP system is expected to be substantially lower than the cost of the BAU 1 all-electric hydronic heating system by year 2036. This is due primarily to the impacts of the projected future increases in BC Hydro's electricity rates and the greater electricity consumption of the BAU 1 system. Should actual rate increases be higher than the average 5.0% forecast for BC Hydro, the HP system may provide even greater savings compared to the all-electric BAU 1.

6.0 EVALUATION OF ELECTRIC BASEBOARD

6.1 TOTAL COST ANALYSIS

A comparison of the HP system to a second BAU scenario (BAU 2) consisting of electric baseboard heaters and an electric DHW tank has been completed. The total annual cost of ownership for the HP system was compared to the projected total annual cost of ownership of the electric baseboard (BAU 2) system. The results of this comparison are presented in the following table. Total annual cost of ownership includes energy costs, routine annual maintenance costs, and an annual contribution to an equipment replacement budget designed to cover the cost of periodic replacements of components at the end of their service life. A breakdown of expected annual maintenance and replacement costs is provided in **Appendix A**.

A key factor in comparing electric baseboard heating is the recognition that the heat loss of a townhouse constructed with radiant floor heating may not be the same as a townhouse constructed with electric baseboard heating. The heat loss of a radiant floor heated house is greatly impacted by the performance of the insulation that is applied to the bottom and sides of the concrete slab that is heated. As heat loss analysis was outside of the scope of this study, we have opted to use the same heating demand loads that were used for the study group of townhouses.

Table 9: Average Annual Ownership Cost (2016) – BAU 2 Comparison

	HP System	BAU 2	Savings
Average (TH 2 – 6) Energy Cost	$1,003	$1,399	**$396**
Routine Maintenance Costs	$350	$0	**- $350**
Equipment Replacement Budget	$543	$94	**- $449**
Total Annual Cost of Ownership	**$1,895**	**$1,493**	**- $402**

Annual energy costs are much higher for the electric baseboard BAU 2 compared to the HP System, but the significantly lower maintenance and replacement costs result in a lower overall annual ownership cost. However, as BC Hydro rates increase over time, the annual energy cost of the BAU 2 is projected to rise much faster than the DES connected HP system, eroding the savings. The estimated total cost of ownership for the electric baseboard BAU 2 in year 2035 is presented in the following table.

Table 10: Average Annual Ownership Cost (2036) – BAU 2 Comparison

	HP System	BAU 2	Savings
Average (TH 2 – 6) Energy Cost	$1,703	$3,386	$1,683
Annual Routine Maintenance Costs	$452	$0	- $452
Annual Equipment Replacement Budget	$702	$122	- $580
Total Annual Cost of Ownership	**$2,857**	**$3,508**	**$651**

The above table shows that the total annual ownership cost of the HP system is expected to be $651 less than the electric baseboard BAU 2 by year 2036. This is due primarily to the forecasted increases in BC Hydro's electricity rates, which will have a greater impact on the energy cost of an all-electric heating option.

The following chart provides a comparison of the 20 year (2016 – 3036) ownership costs for the HP System versus the BAU 1 and BAU 2 scenarios.

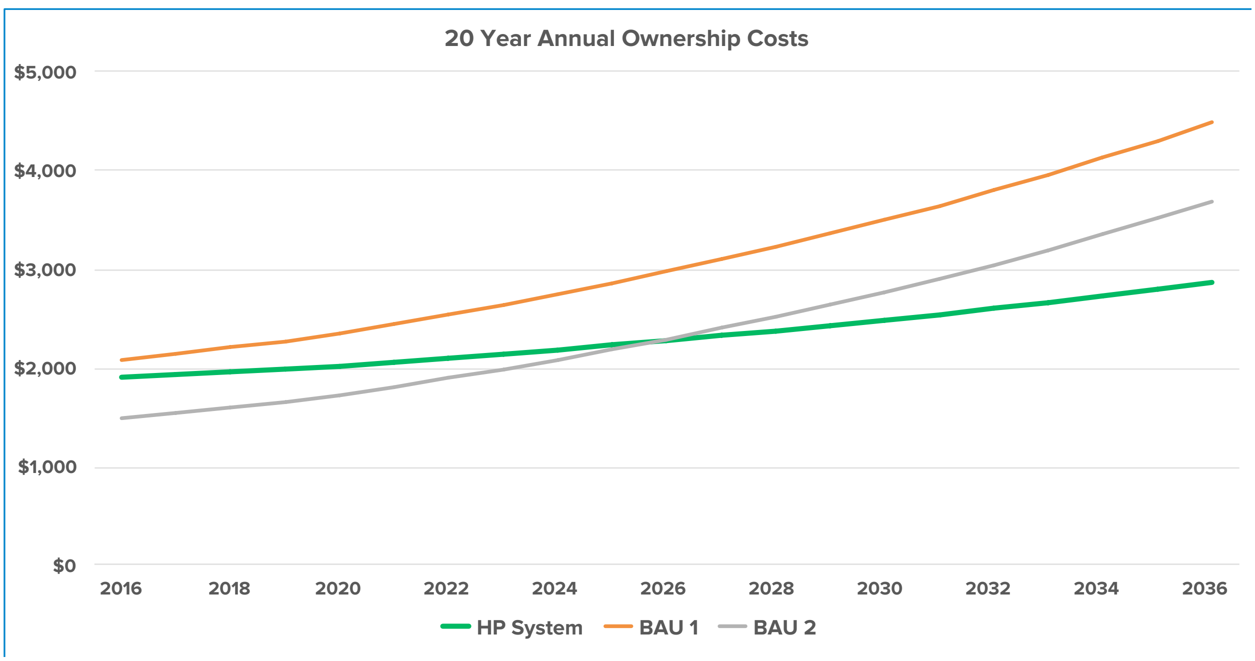

Figure 6: Annual Ownership Costs Over 20 Years

7.0 CONCLUSIONS

1) Of the six townhouses in the study group, the monitored data indicates the HP systems in townhouses 2,3,4,5 and 6 are operating as they were designed to be operated, providing nearly 100% of the DHW and space heating energy. The total system COP for these homes (including all pumping and backup electric element energy) ranged from a low of 2.2 to a high of 3.2, with an average COP of 2.8 during the study period. This performance is in-line with the heat pump manufacturer's data for operation at the observed system temperatures. It also indicates that the HP systems are achieving substantial energy savings compared to conventional electric heating systems.
2) Based on an average annual energy savings of 7,878 kWh, every 3.7 years each townhouse HP system could potentially save enough electricity to completely power an average Whistler house for a full year[12]. The potential average annual savings from the 174 Cheakamus Crossing townhouses is 1,370,772 kWh. This represents enough electricity to completely power 52 average Whistler houses each year.
3) The HP system in Townhouse 1 is operating for space heating only and 100% of the DHW heating is being provided by the electric tank elements. The monitored data for this home indicates much greater electricity consumption compared to the other houses in the sample group. The resulting total system COP is only 1.5, which is significantly lower than the other systems in the sample group. The lower COP indicates Townhouse 1 will consume approximately 87% more electricity per kWh of delivered energy than the average of the other five homes studied.
4) Energy costs per kWh of thermal energy delivered were lower for the HP systems than the all-electric BAU scenarios: $0.083/kWh for the HP system vs. $0.118 for the BAUs. Excluding TH 1, DES energy cost was even lower at $0.070/kWh thermal energy delivered.
5) Excluding TH 1, and based on the results of the monitoring period data, the projected average annual energy cost savings of the HP system over the BAU 1 was $428 per year, which equals 29%. Because of the fixed-rate nature of the DES utility charges, homeowners who use more energy will realize greater savings, compared to BAU 1, than those homeowners who use less energy.
6) Including the maintenance and replacement costs associated with the HP system, the DES customers are expected to have a lower total annual cost of ownership ($1,895/year) compared to the all-electric hydronic heating BAU 1 ($2,085/year). The lower cost is due to the lower annual energy cost for the HP system. Maintenance and replacement costs are similar between the heat pump and electric boiler systems.
7) Future increases in BC Hydro electricity rates will have a greater impact on the energy costs for the electric boiler (BAU 1) and the electric baseboard (BAU 2) scenarios, than they will have on the energy costs for the DES-connected HP systems. This is due to the DES customer's energy cost being largely correlated to the fixed DES utility charges. RMOW does not forecast any increases to DES utility rates, at this time. Based on the

[12] *Based on 26,500 kWh per average house per year. Pique News Magazine. "Price of Power" by Andrew Mitchell published June 16, 2013.*

available forecast data, the projected total annual cost of ownership for the DES connected HP systems in year 2036 is significantly lower than it is for the BAU 1 ($2,857/year for the HP system vs $4,481/year for the BAU 1).

8) Electric baseboard heating was evaluated as a second business as usual (BAU 2) scenario. The total annual (2016) ownership cost of electric baseboard heating: $1,493/year - is significantly lower than ownership cost of the HP systems: $1,895/year. This is primarily due to the negligible BAU 2 maintenance and replacement costs. However, future increases in BC Hydro's electricity rates will have a greater impact on the total energy cost for the BAU 2. Based on the available forecast data, in year 2036 the projected total annual cost of ownership for the BAU 2 system rises to $3,508/year, which is $651 more than the projected ownership costs for the HP system: $2,857/year.

   A factor not evaluated in our analysis of the BAU 2 scenario is a measure of the greater thermal comfort of radiant floor heating versus electric baseboards.

   As well, construction practice differences between homes built with hydronic radiant floor systems versus electric baseboard heating can lead to differences in envelope heat loss performance. An accurate determination of this was beyond the scope of the study, therefore identical envelope heat loss values were assumed for all scenarios.

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APPENDICES

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APPENDIX A

MAINTENANCE AND REPLACEMENT COST ESTIMATES

The following tables present estimated costs to maintain and replace HP system and BAU system components. These costs are estimates provided for cost comparison between options. Actual costs may vary.

Annual Routine Maintenance Costs	HP System	BAU 1	BAU 2 (Elec BB)	Notes
Hydronic System Maintenance	$350	$350	N/A	Once per year assuming system is operating normally.

Expected Lifecycle Replacement Costs	HP System	Frequency (years)	Annual Budget	BAU 1	Frequency (years)	Annual Budget
Heat Pump						
Compressor Replacement	$2,500	20	$125	N/A		
Coaxial HX Coil Replacement	$1,500	25	$60	N/A		
Refrigerant Recharge	$200	10	$20	N/A		
DHW System						
DHW Tank Replacement (see note 1)	$1000	12	$83	$850	9	$94
DHW Circulator Pump Replacement	$400	12	$33	N/A		
DHW HEX Replacement	$400	20	$20	N/A		
Space Heating System						
Buffer Tank Replacement	$1000	16	$63	N/A		
Electric Boiler Replacement	N/A			$2,200	16	$138
Radiant Circulator Pump Replacement	$400	12	$33	$400	12	$33
Zone Valves	$360	9	$40	$360	9	$40
Controls Transformer	$150	8	$19	$150	8	$19
Make-up-water valve, air relief vent, expansion tank	$450	15	$30	$450	15	$30
DES Connection						
DES (Source) Control Valve Replacement	$250	15	$17	$0		
Annual Equipment Renewal Budget			**$543**			**$354**

Notes:

1. HP System based on 80 USG replacement tank with backup element – slightly oversized tank allows for extended life of tank and HP compressor. BAU 1 & 2 based on 60 USG electric DHW tanks.
2. Lifecycle replacement costs for BAU 2 (electric baseboard) only includes replacement of 60 USG electric DHW tank.

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APPENDIX B

RATE INPUTS AND ASSUMPTIONS

BC Hydro Fiscal Year (Apr 1)	Step 1 ($/kWh)	Step 2 ($/kWh)	Blended Rate HP Systems 50% Step 1 50% Step 2 ($/kWh)	Blended Rate BAU Systems 37% Step 1 63% Step 2 ($/kWh)	Published / Forecast % Increase	Cumulative factor over April 1 2015 rates.
2010	$0.0627	$0.0878	$0.0753	$0.0785	Published	
2011	$0.0667	$0.0962	$0.0815	$0.0853	Published	
2012	$0.0680	$0.1019	$0.0850	$0.0894	Published	
2013	$0.0690	$0.1034	$0.0862	$0.0907	Published	
2014	$0.0752	$0.1127	$0.0940	$0.0988	Published	
2015	$0.0797	$0.1195	$0.0996	$0.1048	Published	
2016	$0.0829	$0.1243	$0.1036	$0.1090	Published	1.060
2017			$0.1142	$0.1201	4.00%	1.102
2018			$0.1182	$0.1243	3.50%	1.141
2019			$0.1218	$0.1281	3.00%	1.175
2020			$0.1278	$0.1345	5.00%	1.234
2021			$0.1342	$0.1412	5.00%	1.296
2022			$0.1409	$0.1483	5.00%	1.360
2023			$0.1480	$0.1557	5.00%	1.428
2024			$0.1554	$0.1635	5.00%	1.500
2025			$0.1632	$0.1716	5.00%	1.575
2026			$0.1713	$0.1802	5.00%	1.654
2027			$0.1799	$0.1892	5.00%	1.736
2028			$0.1889	$0.1987	5.00%	1.823
2029			$0.1983	$0.2086	5.00%	1.914
2030			$0.2082	$0.2191	5.00%	2.010
2031			$0.2186	$0.2300	5.00%	2.111
2032			$0.2296	$0.2415	5.00%	2.216
2033			$0.2411	$0.2536	5.00%	2.327
2034			$0.2531	$0.2663	5.00%	2.443
2035			$0.2658	$0.2796	5.00%	2.565
2036			$0.2791	$0.2936	5.00%	2.694
2037			$0.2930	$0.3082	5.00%	2.828
2038			$0.3077	$0.3236	5.00%	2.970
2039			$0.3230	$0.3398	5.00%	3.118
2040			$0.3392	$0.3568	5.00%	3.274
2041			$0.3562	$0.3747	5.00%	3.438
2042			$0.3740	$0.3934	5.00%	3.610
2043			$0.3927	$0.4131	5.00%	3.790
2044			$0.4123	$0.4337	5.00%	3.980
2045			$0.4329	$0.4554	5.00%	4.179
2046			$0.4546	$0.4782	5.00%	4.388
2047			$0.4773	$0.5021	5.00%	4.607
2048			$0.5011	$0.5272	5.00%	4.837
2049			$0.5262	$0.5535	5.00%	5.079
2050			$0.5525	$0.5812	5.00%	5.333

BC Hydro Rate Sources:

- *https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/revenue-requirements/FY17-FY19-rra-application-technical-briefing-deck-20160728.pdf*
- *BC Hydro Residential Tariffs: 2011 - 2014*
- *RMOW*

Canada 4 year average inflation: 1.29%

- Source*: http://www.inflation.eu/inflation-rates/canada/historic-inflation/cpi-inflation-canada.aspx*

APPENDIX C

40 YEAR OWNERSHIP COST ANALYSIS

Analysis Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fiscal Year (Begins Apr 1)		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BC Hydro Rates: Published / Forecast Change		Pub	Pub	Pub	Pub	Pub	Pub	4.0%	3.5%	3.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Inflation (4 yr avg Bank of Canada)	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%
DES Utility Rate: Published / Forecast Change		Pub	Pub	Pub	Pub	Pub	Pub	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DESS HP System																					
Electricity Cost		$357	$373	$378	$412	$437	$455	$473	$489	$504	$529	$556	$584	$613	$643	$676	$709	$745	$782	$821	$862
DESS Utility Cost		$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548
Maintenance		$328	$333	$337	$341	$346	$350	$355	$359	$364	$368	$373	$378	$383	$388	$393	$398	$403	$408	$413	$419
Replacement Budget		$509	$516	$522	$529	$536	$543	$550	$557	$564	$571	$579	$586	$594	$602	$609	$617	$625	$633	$641	$650
TOTAL Cost		$1,743	$1,769	$1,785	$1,830	$1,866	$1,895	$1,925	$1,953	$1,980	$2,017	$2,055	$2,095	$2,137	$2,180	$2,225	$2,272	$2,320	$2,371	$2,423	$2,478
Net Present Value	**$33,990**																				
BAU 1 - Electric Boiler Hydronic System																					
Energy Cost		$1,046	$1,096	$1,112	$1,212	$1,285	$1,431	$1,488	$1,540	$1,586	$1,666	$1,749	$1,836	$1,928	$2,024	$2,126	$2,232	$2,344	$2,461	$2,584	$2,713
Maintenance		$281	$285	$289	$292	$296	$300	$304	$308	$312	$316	$320	$324	$328	$332	$337	$341	$345	$350	$354	$359
Replacement Budget		$332	$336	$341	$345	$350	$354	$359	$363	$368	$373	$377	$382	$387	$392	$397	$402	$408	$413	$418	$424
TOTAL Cost		$1,660	$1,717	$1,742	$1,850	$1,931	$2,085	$2,150	$2,211	$2,266	$2,354	$2,446	$2,543	$2,644	$2,749	$2,860	$2,975	$3,097	$3,224	$3,356	$3,496
Net Present Value	**$44,730**																				
BAU 2 - Electric Baseboard System																					
Energy Cost		$1,031	$1,080	$1,096	$1,195	$1,267	$1,399	$1,455	$1,506	$1,551	$1,629	$1,710	$1,796	$1,886	$1,980	$2,079	$2,183	$2,292	$2,407	$2,527	$2,653
Maintenance		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Replacement Budget		$89	$90	$91	$92	$93	$94	$96	$97	$98	$99	$101	$102	$103	$105	$106	$107	$109	$110	$112	$113
TOTAL Cost		$1,120	$1,170	$1,187	$1,287	$1,360	$1,494	$1,551	$1,603	$1,649	$1,728	$1,811	$1,898	$1,989	$2,085	$2,185	$2,290	$2,401	$2,517	$2,638	$2,766
Net Present Value	**$34,688**																				

Analysis Year		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Fiscal Year (Begins Apr 1)		2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
BC Hydro Rates: Published / Forecast Change		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Inflation (4 yr avg Bank of Canada)	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%	1.29%
DES Utility Rate: Published / Forecast Change		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DESS HP System																					
Electricity Cost		$905	$951	$998	$1,048	$1,100	$1,155	$1,213	$1,274	$1,338	$1,404	$1,475	$1,548	$1,626	$1,707	$1,792	$1,882	$1,976	$2,075	$2,179	$2,288
DESS Utility Cost		$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548	$548
Maintenance		$424	$430	$435	$441	$447	$452	$458	$464	$470	$476	$482	$488	$495	$501	$508	$514	$521	$527	$534	$541
Replacement Budget		$658	$666	$675	$684	$693	$702	$711	$720	$729	$738	$748	$758	$767	$777	$787	$797	$808	$818	$829	$839
TOTAL Cost		$2,535	$2,594	$2,656	$2,720	$2,787	$2,857	$2,929	$3,005	$3,084	$3,166	$3,252	$3,342	$3,435	$3,533	$3,635	$3,741	$3,852	$3,968	$4,089	$4,216
BAU 1 - Electric Boiler Hydronic System																					
Energy Cost		$2,849	$2,991	$3,141	$3,298	$3,463	$3,636	$3,817	$4,008	$4,209	$4,419	$4,640	$4,872	$5,116	$5,372	$5,640	$5,922	$6,218	$6,529	$6,856	$7,198
Maintenance		$364	$368	$373	$378	$383	$388	$393	$398	$403	$408	$413	$419	$424	$430	$435	$441	$446	$452	$458	$464
Replacement Budget		$429	$435	$440	$446	$452	$457	$463	$469	$475	$482	$488	$494	$500	$507	$513	$520	$527	$534	$540	$547
TOTAL Cost		$3,641	$3,794	$3,954	$4,121	$4,297	$4,481	$4,674	$4,875	$5,087	$5,309	$5,541	$5,785	$6,040	$6,308	$6,589	$6,883	$7,191	$7,515	$7,854	$8,210
BAU 2 - Electric Baseboard System																					
Energy Cost		$2,786	$2,925	$3,071	$3,225	$3,386	$3,556	$3,733	$3,920	$4,116	$4,322	$4,538	$4,765	$5,003	$5,253	$5,516	$5,792	$6,081	$6,385	$6,705	$7,040
Maintenance		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Replacement Budget		$114	$116	$117	$119	$120	$122	$124	$125	$127	$128	$130	$132	$133	$135	$137	$139	$141	$142	$144	$146
TOTAL Cost		$2,900	$3,041	$3,189	$3,344	$3,507	$3,678	$3,857	$4,045	$4,243	$4,450	$4,668	$4,897	$5,137	$5,388	$5,653	$5,930	$6,222	$6,528	$6,849	$7,186