Lifecycle Space Heating Analysis of a 60 Unit Multi-Residential Building

Viran Uduman

University of British Columbia

CEEN 596

Dec 28, 2010

Lifecycle Space Heating Analysis of a 60 Unit Multi-Residential Building

Prepared For: Eric Mazzi, CEEN 596

Tom Awram, Adera

Viran Uduman

12/28/2010

Executive Summary

A detailed analysis of Adera's Seven35 development was performed in order to determine the most effective heating option between electric baseboard heating and a natural gas hydronic system run on Lonsdale Energy Corporation's district energy network. *HOT2000* was used to determine the seasonal and overall space heating requirements of Seven35. Following this, a lifecycle assessment (LCA) was conducted to determine capital costs, operating costs and emissions from each fuel type and construction materials. The LCA determined that electric baseboard heating significantly outperformed in capital and environmental costs, while the district energy system slightly outperformed in operating costs. Overall, a significant lifecycle cost advantage was observed with the electric baseboard heating system, with a present value cost saving of $410,229 over 50 years. A sensitivity analysis considering various levels of operating cost increases confirmed this observation and showed that electric baseboard heaters are a better option under the most likely scenarios.

Despite this result, hydronic heating from LEC's district energy network offers potential advantages including human comfort improvements, lower operating costs and the utilization of low or zero emissions energy sources in the future. Given Adera's current requirement to connect to LEC's system, it is recommended that a marketing effort touting the benefits of Adera's building quality and the district energy system be implemented in an attempt to increase the attractiveness of Seven35 suites and recover a larger portion of the capital costs.

Several factors that were not incorporated into the LCA were also discussed, as they have the potential to impact the final choice of the desired heating system. It is recommended that a detailed investigation into these issues be conducted in order to further expand the scope of the study and form a stronger conclusion.

Table of Contents

List of Figures

List of Tables

Introduction

Project Purpose and Background

In the current era of striving to reduce energy usage and greenhouse gas emissions, it is important to first target the end uses that consume the largest amounts of energy to realize the greatest savings in the shortest amount of time. In British Columbia's residential sector, space heating accounts for 24% of end use electricity consumption, which is the largest of any other end-use as shown in Figure 1 (Marbek Resource Consultants Ltd., 2007).

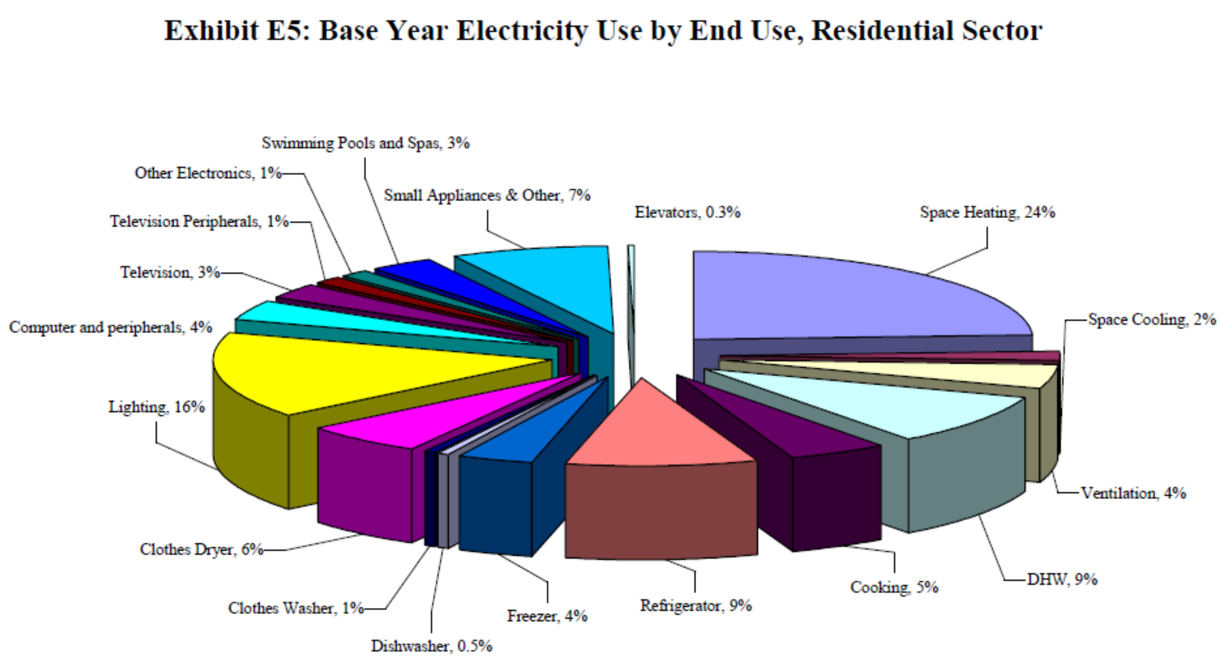

Figure 1: End use electricity breakdown in the B.C.'s residential sector

As a leading developer of multi-unit residential buildings in British Columbia, Adera is interested in analyzing various space heating possibilities on the basis of cost, environmental effectiveness and performance. The two primary systems being considered for new developments are the electric baseboard heater and in-floor hot water (hydronic) heating systems.

One of Adera's new projects, the Seven35 development in North Vancouver, falls under the service area of Lonsdale Energy Corporation (LEC). LEC is promoting the benefits of their new district energy system and under bylaw 8086 mandates that "any new building of more than 1,000 square meters is required to connect to the district heating system for heating purposes unless it is determined by the City's Director of Finance that the cost to the City would be excessive" (City of North Vancouver, 2010). Although there are many advantages to district energy that will be discussed further, the current system uses natural gas boilers to provide hydronic heating. Hydronic heating is considered desirable from perspectives such as comfort and operating costs; however, the combustion of natural gas has a significantly higher carbon footprint than electricity production in British Columbia. This report will aim to compare the cost, environmental effectiveness and performance of using electric baseboards to heat the Seven35 development compared to connecting to the natural gas district energy system. Other, non-quantitative comparisons will be made, such as flexibility of the system and user behaviour and their effects on energy usage.

This project is being undertaken as a natural progression of a co-op work term at Adera, where multi-unit residential heating models were developed and analyzed to target the best and most cost-effective materials to use in order to reduce energy requirements.

Objectives

The objectives of this report are as follows:

- Conduct a literature review on electric baseboard heaters and district energy systems to obtain background information and important data
- Conduct a life-cycle analysis (LCA) of electric baseboards and LEC's natural gas district energy hydronic heating system for Adera's Seven35 development
- Investigate other important factors not addressed in the LCA
- Provide conclusions and recommendations about the best choice for Adera, considering all factors

Electric Baseboard Literature Review

A thorough literature review of electric baseboard heaters was necessary to obtain background information and key data about materials, durability and effectiveness, all of which will be used in the analysis.

Operation and Efficiency

Electric baseboard heaters are very simple in both design and function. The heater consists of a heating element inside a metal pipe. During operation, electric current flows through the element, pulling and heating cold air from the bottom of the heater and expelling it from the top. Electric baseboard heaters are typically installed underneath windows. This placement allows the rising hot air produced by the heater to neutralize the cool air from the window glass, resulting in the most even heating distribution possible for a convective heating device (BC Hydro, 2010).

Since electric baseboard heaters operate by a direct conversion of electricity to heat, the efficiency is 100%. All of the energy input is converted and used as space heating. There is an efficiency hit in the production of electricity that will be considered; however, this loss is unrelated to the performance of the heater. For effective operation, electric baseboards should be connected to a thermostat so that the heaters are automatically shut off or turned on depending on the current and desired heating levels of the room.

The major factors influencing the size requirements of baseboard heaters are size of the heating space and the amount of insulation in the walls and ceiling. An approximate guideline to sizing an electric baseboard heater is 12.5 W/ft^2 for a poorly insulated space to as little as 7.5 W/ft^2 to a well insulated space (HouseNeeds, 2010). A well insulated space is defined as R19 wall insulation and R38 ceiling insulation – this scenario would be used when considering Adera's Seven35 development.

Table 1: Sizing data based on various levels of insulation (HouseNeeds, 2010)

Room Size (Sq Ft with 8 foot ceiling)	Watts (Poor Insulation)	Watts (Avg Insulation)	Watts (Fully Insulation)
20 square feet	250	250	250
40 square feet	500	500	500
60 square feet	750	750	450
80 square feet	1000	1000	750
100 square feet	1250	1000	750
120 square feet	1500	1250	1000
140 square feet	1750	1500	1250
160 square feet	2000	1750	1250
180 square feet	2250	2000	1500
200 square feet	2500	2000	1500
220 square feet	2750	2250	1750
240 square feet	3000	2400	2000

Materials and Construction

Element

The heating element is composed of a steel tube. Fins are usually placed over the tube to provide a greater heat transfer area, maximizing performance. The fins are made by passing a roll of paper-thin aluminum through a forming machine. The forming machine punches the outline of each fin and bores out circular holes through them. It then cuts out each fin and stacks them onto the steel tube. The length of the tube and number of fins is variable and depends on the size of the heater (Ouellet Electric Heating, 2010).

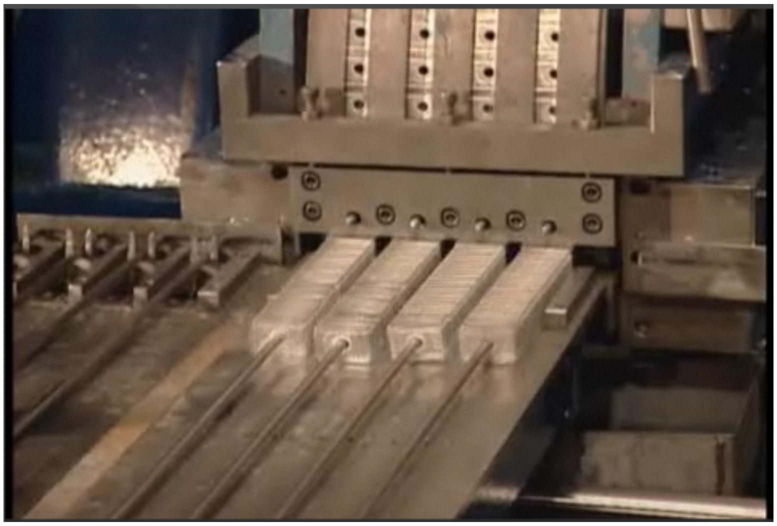

Figure 2: Aluminum fin production (Ouellet Electric Heating, 2010)

Casing

The casing of the baseboard heater is made out of cold rolled steel. This is important because shaping this type of steel does not require heat, which provides significant energy savings on the production. After adding some oil for lubrication, holes are punched for the wall mounts and attachment of the element. The steel is passed through a roll former, where 20 different rollers gradually bend and shape the steel to the appropriate design. A computer controlled die cuts the heater to the required length, which typically range from 0.5m for a 300W heater to 2.5m for a 2500W heater.

After exiting the roller, steel junction boxes are welded to each end of the casing to hold the wiring. The casing is then washed and coated with paint powder, which liquidizes in an oven (Ouellet Electric Heating, 2010).

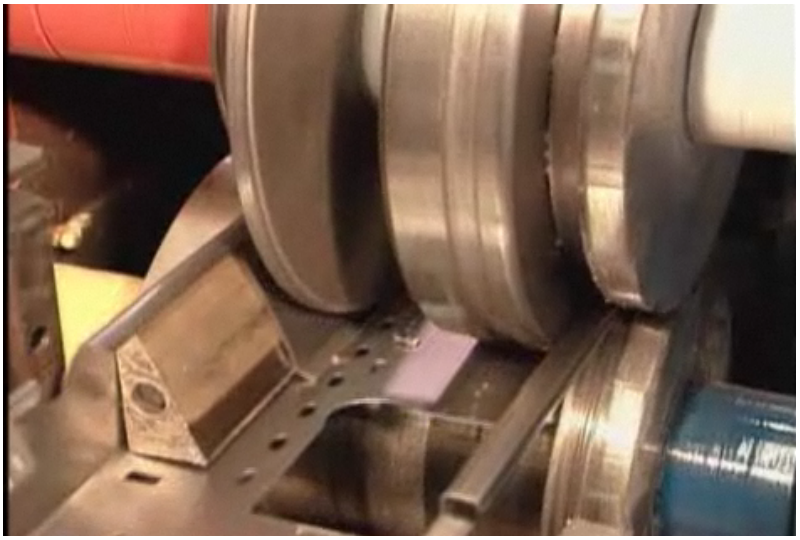

Figure 3: Roll former shaping the casing (Ouellet Electric Heating, 2010)

Finishing

The final step in construction is attaching the element to the casing and to complete the wiring. To prevent overheating and the possibility of fire, a linear high limit temperature control is added. This device contains a gas that expands when heated, which triggers the current to shut off when unsafe temperatures are reached. Following the wiring, a voltage test is performed, the casing is closed and the heater is packaged and ready for distribution.

Durability

Since the electric baseboard heater is composed entirely of metal and wiring, it is extremely durable. Many manufacturers offer lifetime warranties on the heating elements because they very rarely break down (Cadet, 2010). It is safe to assume that the heater will last several decades or the lifetime of the building.

District Heating Literature Review

District heating utilizes a single source of energy to produce hot water and distribute it to surrounding buildings. As the heat from the water is used, it returns in a loop to be reheated. The district energy network increases efficiency and eliminates the need for each building to have a furnace or electric baseboard heaters (Enwave, 2010).

Countries such as Denmark rely heavily on district heating – currently 43% of their net heat demand is met through district heating. Additional plans include an increase of up to 70% in the near term, and eventually 100% as renewable technologies become increasingly cost-competitive (Lund, Moller, Mathiesen, & Dyrelund, 2010).

District heating has the potential to provide advantages to all stakeholders in terms of cost, technology, and environmental sustainability. A journal article by *Ghafghazi et al.* studied the interests of various stakeholders (developer, environmental group, community group) to determine the best overall input for a district energy system in British Columbia. The findings indicated that biomass wood pellets would be the best energy input, followed by sewer heat recovery, natural gas and geothermal energy. Factors considered were cost, GHG emissions, PM emissions, maturity of technology, traffic load and locality of source. The findings indicate that renewable energy such as geothermal and solar are far from being the best current choice, due to immaturity of the technology and high cost. The results also indicated that transparency and collaboration between stakeholders results in a better overall outcome (Ghafghazi, Sokhansanj, & Melin, 2010).

LEC's district heating system utilizes a number of mini-plants that generate heat and distribute it to the surrounding residential and commercial community for space and hot water heating. LEC has designed the system such that a variety of energy inputs are possible, from fossil fuels such as natural gas and coal to renewable energy like geothermal and solar. District heating systems often experience higher efficiencies and better pollution control than localized boilers. Since the mini-plants are located in the basements of various developments, there are significant space savings when compared to a large central plant. LEC's system uses Viessmann Vitocrossal condensing boilers, Vitodens condensing boilers, and Vitocell 300 domestic hot water tanks – all of these are certified by Environment Canada's "EcoLogo" Environmental Choice Program (City of North Vancouver, 2010).

LEC's energy source is chosen primarily on the basis of cost neutrality, placing less importance on the previously mentioned factors. While only introducing renewable technologies when they are economically competitive makes good financial sense, this may not be the ideal approach if the goal is to satisfy the largest number of stakeholders.

The Seven35 Development

Adera's Seven35 development is located on 735 West 15th Street in North Vancouver, B.C. and is expected to meet all bylaws of the District of North Vancouver. The development consists of three individual buildings of 20 units each for a total of 60 units. Each building has units with ten different orientations and configurations.

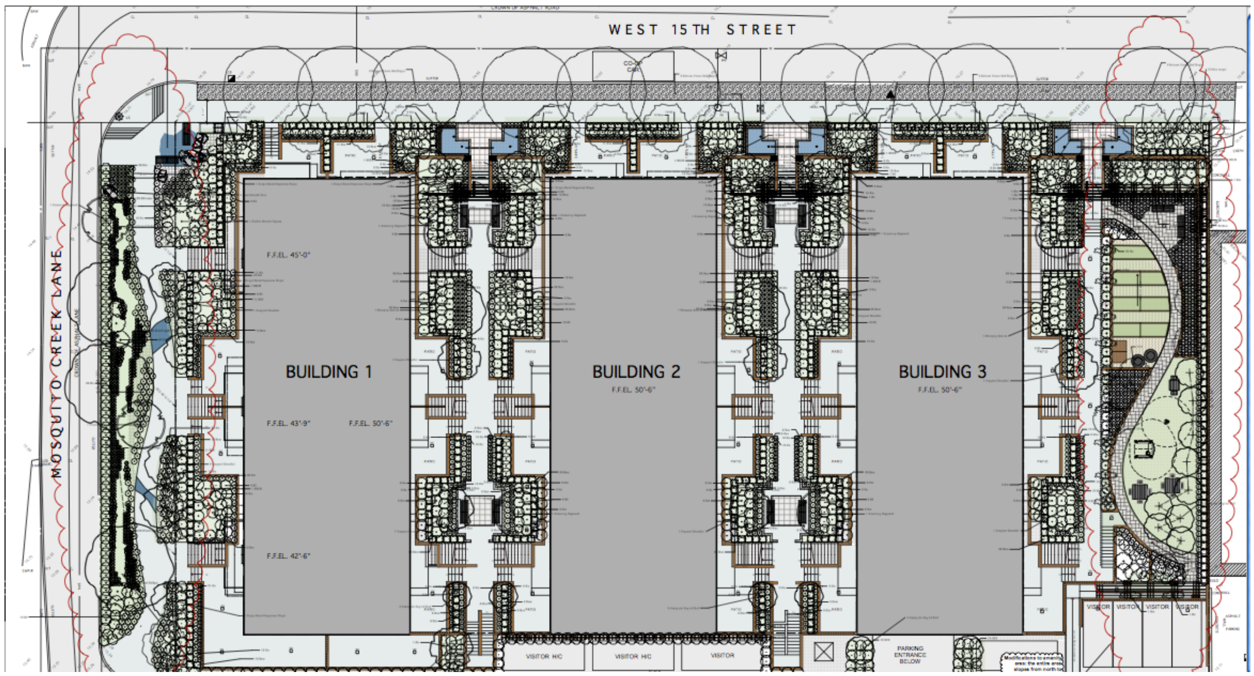

Figure 4: Conceptual drawing of Seven35

Seven35 was designed with energy efficiency in mind. Walls contain R30 Batt insulation, with 2" rigid insulation on the outside, and the roof contains R40 insulation.

Using architectural drawings from Adera, a *HOT2000* energy model was constructed by Troy Glasner, a Certified Energy Advisor and consultant to Adera. The model uses inputs from drawings and local weather data to determine the energy requirements of the building. *HOT2000* also provides an EnerGuide rating.

The EnerGuide Rating Service is a scale from 0-100 developed by The Office of Energy Efficiency of Natural Resources Canada. EnerGuide considers factors such as air leakage, insulation levels and energy consumption to arrive at an overall score (BC Hydro, 2010). The Seven35 model achieved a score of 82 based on the existing energy model. BC Hydro Power Smart categorizes homes based on their EnerGuide rating. A rating of 82 falls into the "Highly energy-efficient new house" category (Table 2). Ratings are confirmed with an air tightness test once construction is complete.

Table 2: BC Hydro EnerGuide Categories (BC Hydro, 2010)

Type of House	EnerGuide for Houses Rating
Older house not upgraded	0 to 50
Upgraded older house	51 to 65
Energy-efficient upgraded older or typical new house	66 to 74
Energy-efficient new house	75 to 79
Highly energy-efficient new house	80 to 90
House that uses little or no purchased energy (an "Advanced House")	91 to 100

The high EnerGuide rating reinforces Adera's commitment to improving the energy performance of their developments. It also indicates that the major step towards energy efficiency has been fulfilled, as space heating requirements will be lessened due to the strong performance of the building envelope. Nonetheless, heating requirements remain significant.

Data Sources and Methodology

The lifecycle analysis of each heating system will be approached in as similar a manner as possible. Many data sources will be drawn upon to obtain the required information. Table 3 summarizes the data source used for each step of the analysis.

Table 3: Summary of data sources

	Electric Baseboard	Natural Gas Hydronic
Heating requirements	*HOT2000* model (provided by Troy Glasner/Adera)	*HOT2000* model (provided by Troy Glasner/Adera)
Capital Cost	Adera	Adera
Operating Cost	B.C. Hydro electricity rates	LEC rates
Emissions	*GHGenius*	*GHGenius*
Emission Costs	Acceptable values from journal article	Acceptable values from journal article
Manufacturing Costs	Journal article (LCA of steel/aluminum)	Journal article (LCA of cross-linked polyethylene)

Heating Patterns of Low-Rise Residential Apartments

Before delving into the lifecycle analysis, it would be useful to examine the seasonal heating patterns of typical low-rise multi unit residential buildings such as Seven35. The 2007 CPR determined that the average low-rise apartment suite consumes 2,991 kWh of electricity per year for space heating (Marbek Resource Consultants Ltd., 2007). This was compared against data obtained from the *HOT2000* model of Seven35.

Table 4: Monthly distribution of Seven35 space heating requirements

Month	kWh/suite
Jan	695
Feb	472
Mar	319
Apr	100
May	12
Jun	0
Jul	0
Aug	0
Sep	0
Oct	111
Nov	466
Dec	698
Total	**2872**

The results from *HOT2000* using Vancouver weather data support the results of the CPR, with a similar average annual usage of 2,872 kWh per suite. The distribution of energy consumptions is strongly dependant on weather as one would expect. November, December, January and February are responsible for 81% of the annual consumption.

Gordon Monk, a project sponsor from BC Hydro, also provided some data on energy consumption and heating loads of apartments in Vancouver.

Table 5: Heating load summary from BC Hydro (Monk, 2010)

	Buildings	Suites	Suites Energy	Commons Energy	Ave kWh/Suite	Ave kWh/Com	Total kWh	Ave Heating Load per Suite	Vancouver Heating Load	Percent Heating Load
Low-rise	1,643	32,740	100,781,749	38,875,791	3,078	1,187	4,266	1,915	62,685,386	62.2%
High-rise	341	24,473	69,160,699	45,214,426	2,826	1,848	4,673	1,341	32,825,404	47.5%
Total	1,984	57,213	169,942,448	84,090,217	2,970	1,470	4,440			

Based on the similarity of the findings from three different sources, the space heating requirements of a typical low-rise residential suite can be accurately estimated to be 2800 – 3100 kWh annually.

Lifecycle Analysis

Baseline

Given the longevity of modern buildings, as well as the durability of both electric baseboard and hydronic heating systems, the following lifecycle analysis (LCA) will be based on a useful life of 50 years. Due to the length of the analysis, the selection of an appropriate discount rate is important. A discount rate of 5% per year will be used for future cash flows, as this is the same rate of return the City of North Vancouver targets on its investment in the LEC. A net present value calculation (NPV) will be performed for all annual costs such that all final values will be expressed in 2010 Canadian dollars.

Space Heating Requirements

The *HOT2000* energy model provided by Troy Glasner determined the estimated space heating requirements for each of the ten different units in one of the three buildings. Multiplying the results by the total number of units determined the total space heating requirement of Seven35.

Table 6: Seven35 space heating requirements

Unit	Unit Heating Load (MJ)	Quantity	Total Heating Load (MJ)	Total Heating Load (kWh)
Central Heating System (CHS)	17,707	3	53,121	14,756
A	4,951	6	29,706	8,252
A-East	2,260	6	13,560	3,767
B2	16,404	6	98,424	27,340
B2-East	10,691	6	64,146	17,818
C1-East	6,980	6	41,880	11,633
C1-West	6,878	6	41,268	11,463
C2-East	9,674	6	58,044	16,123
C2-West	9,792	6	58,752	16,320
C3-East	18,013	6	108,078	30,022
C3-West	Incl. In CHS	6	-	-
Total	103,350	60	566,979	157,494

Capital Costs

Baseboard Heating

Although the size and space heating requirements of some units vary significantly, Adera expects an average capital cost of $700 per unit based on prior experience. This cost includes the purchase cost of the baseboards as well as electrical infrastructure and installation costs

(Awram, 2010). Therefore, the total baseboard supply and installation costs for Seven35 are $42,000.

Natural Gas Hydronic Heating

The capital cost of hydronic heating systems are much higher than electric baseboards, and this serves as the major barrier preventing more widespread use of these systems in apartment buildings. One advantage to LEC's district energy system is that the cost of the boiler and related equipment will be paid back on a monthly basis and is considered an operating cost. Any mini-plants that may be required in new developments will also be covered by LEC (City of North Vancouver, 2010). However, the cost of construction and materials of the in-floor hydronic system are still are still an order of magnitude higher than they are for the baseboard heating system, at $7,600 per unit. This cost includes the standard two zones of heating - there is an additional cost of $1,200 for each additional zone (Awram, 2010). This report will consider the standard two zone configuration for each unit. The total supply and installation cost for 60 units is $456,000.

A connection charge also applies to the developer based on the energy capacity of the building. The rate has recently been revised from a fixed cost of $20,000 and an additional $30/kW capacity to a single charge of $60/kW of capacity. Removing the fixed cost encourages developers to design energy-efficient buildings with the incentive of lowering their connection charge (City of North Vancouver, 2010). Each building of the Seven35 development has an estimated 61.5kW of capacity for a total of 184.5kW. The connection charge would be $11,070, for a total capital cost of $467,070.

Operating Costs

BC Hydro Utility Bill Components

With the introduction of the Harmonized Sales Tax on July 1, 2010, the format of residential utility bills has been modified. A credit has been added to offset the increase in taxes due to the HST, and the 0.4% Innovative Clean Energy (ICE) Fund Levy has been removed. A summary of the current components is shown below.

Table 7: Components of BC Hydro utility rates (BC Hydro, 2010)

Charge	Rate	Purpose
Basic Charge	$0.1341/day	Recover fixed costs of providing service, regardless of whether electricity is consumed
Usage Charge	$0.0627/kWh, $0.0878/kWh	Tier 1 price applies to the first 1,350kWh consumed in a two-month billing cycle. Higher Tier 2 price discourages consumption
Rate Rider	4.00% before taxes and levies	Pays down BC Hydro's deferral accounts, used towards unexpected costs and to prevent sudden rate fluctuations
Regional Transit Levy	$0.0624/day	Collected on behalf of TransLink
HST	12%	Harmonized Sales Tax
Residential Energy Credit	7%	Credit for residential buildings to offset the increased tax as a result of HST

Electric Baseboard Heating

Table 4 was used to calculate the annual cost of the 60 units of the Seven35 development. A usage charge of $0.07/kWh will be used to account for the likelihood that some of the larger units may enter Tier 2 pricing during colder months, when space heating requirements are high and other electric appliances are also used.

The issue of predicting future electricity rates is very complex. British Columbia currently has one of the lowest rates in the province, as seen in Figure 5. There is clearly room for large rate hikes in the future, especially with the emergence of a large number of Independent Power Producers (IPPs) that are commanding higher rates. In fact, BC Hydro recently increased rates by 6.11% on April 1, 2010 and has proposed additional rate hikes of 6%, 12% and 6% for the next three years (CBC, 2010). However, from the period of 2005 to 2009, average residential rates at the 750kWh level have only increased by a total of 3.06% (BC Hydro, 2009). Given the history of smaller increases but the potential of large increases it is difficult to accurately predict utility rates decades into the future. A constant increase of 3%/year will be used for the baseline comparison. Other rate hike scenarios will be investigated in the sensitivity analysis.

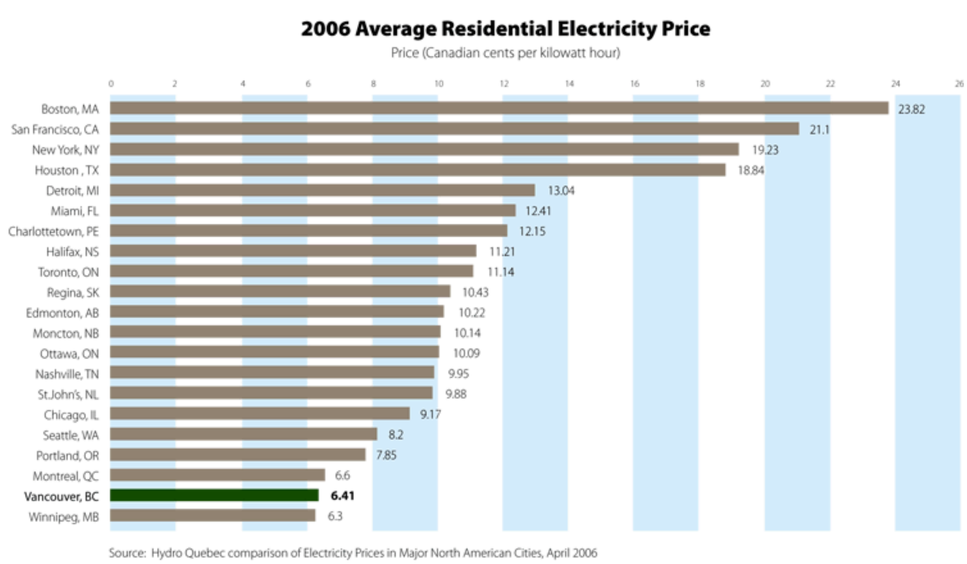

Figure 5: Comparison of BC's electricity rates with other major North American cities

Using the estimated heating requirements and assumptions explained previously, the electricity charges were determined for all 60 units of Seven35 for 50 years. Table 8 shows the operating cost for Year 1.

Table 8: Summary of Year 1 operating costs for electric baseboard heating

Basic Charge	$2,936.79
Usage Charge	$11,024.58
Rate Rider	$558.45
Regional Transit Levy	$1,366.56
HST	$1,906.37
Residential Energy Credit	-$1,016.39
Total	**$16,776.36**

The assumed 3% annual electricity rate increase results in an operating cost of $71,403 in Year 50. The total present value operating cost is $565,491 over the 50 year analysis period. Full details can be seen in Appendix B.

Natural Gas Hydronic Heating

The operating costs for LEC's natural gas hydronic system are composed of three components, which are explained in Table 9.

Table 9: Summary of LEC's operating charges (City of North Vancouver, 2010)

Charge	Cost	Description	Type
Meter Charge	$150/month	Charge for each connection to recover capital cost of meter and heat exchanger, and operating costs such as meter reading, maintenance and invoicing	Fixed
Capacity Charge	$2.93/kW x energy capacity	Charge to recover capital and operating costs of the boiler plants and distribution system	Fixed
Commodity Charge	$/kWh	Energy consumption charge, based on recover of natural gas charges by Terasen Gas	Variable

The capacity charge is based on "the energy capacity nominated by a customer, as determined by a professional engineer qualified for such purposes and described in kilowatts" (City of North Vancouver, 2010). As this is not possible to determine at this stage, another method was used. The *HOT2000* model estimates an energy capacity for each unit, in BTU/h. Table 10 shows the monthly capacity charges for each unit based on this data.

Table 10: Monthly capacity charge summary based on HOT2000 data

Unit	Capacity (BTU/h)	Capacity (kW)	Unit Charge ($2.93/kW)	Quantity	Total Charge
Central Heating System (CHS)	15,355	4.50	$13.18	3	$39.53
A	8,530	2.50	$7.32	6	$43.92
A-East	3,412	1.00	$2.93	6	$17.57
B2	15,355	4.50	$13.18	6	$79.06
B2-East	10,236	3.00	$8.78	6	$52.70
C1-East	10,236	3.00	$8.78	6	$52.70
C1-West	10,236	3.00	$8.78	6	$52.70
C2-East	11,942	3.50	$10.25	6	$61.49
C2-West	11,942	3.50	$10.25	6	$61.49
C3-East	15,355	4.50	$13.18	6	$79.06
C3-West	incl. in CHS	-	-	6	-
Total			**$96.62**	**60**	**$540.21**

The commodity charge is based on the rate structure for residential consumers set by Terasen Gas. LEC receives an input tax credit on gas purchases, and as a result HST is not included in the rates for LEC customers. Historically, the price of natural gas has been highly variable, with large fluctuations in both directions (Figure 6).

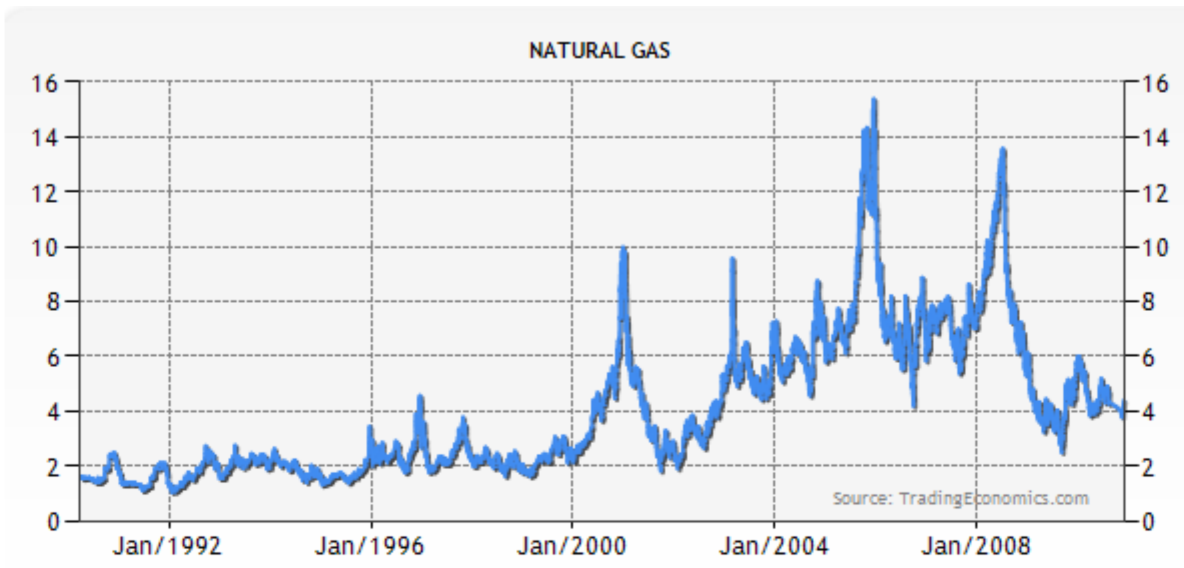

Figure 6: Natural gas prices since 1992 (Trading Economics, 2010)

Since LEC's inception, the commodity charges of its customers have varied as much as 16% in both directions in the span of just three months. The most recent adjustment, on July 1, 2010, was a 9.69% reduction on April 2010 rates (Table 11).

Table 11: Lonsdale Energy Corporation's most recent commodity charges

Current Adjustment	QTY	UNIT PRICE	1-Apr-10	QTY (updated)	UNIT PRICE	1-Jul-10
Basic Charge ($/month)	1.00	132.52	132.52	1.00	132.52	132.52
Delivery (per GJ)	1,000.00	2.219	2,219.00	1,000.00	2.219	2,219.00
Commodity Midstream (per GJ)	1,000.00	1.281	1,281.00	1,000.00	1.281	1,281.00
Cost of Gas (per GJ)	1,000.00	5.609	5,609.00	1,000.00	4.976	4,976.00
ICE Fund Levy (0.4%)			36.97			34.43
Carbon Tax	1,000.00	0.7449	744.90	1,000.00	0.9932	993.20
PST			646.91			
			10,670.29			9,636.15
Change ($)		$	704.54		$	(1,034.14)
Change (%)			7.07%			-9.69%
Commodity Charge $/Kw.hr			0.04370			0.03946

The high variability of natural gas rates makes it impossible to accurately predict the future commodity charges of natural gas. However, LEC has committed to introducing other sustainable energy inputs as they become cost-competitive. Based on this, the best way to determine the future operating cost of LEC customers is to estimate the overall trend of sustainable energy prices in the future. The 50 year analysis will consider the case that energy prices will increase at 2.5%/year. This rate is relatively low, but was chosen due to the recent rate reduction and the fact that many technologies that LEC plans to incorporate such as solar and geothermal are still being optimized, with potential for significant operating cost reductions over time compared to more mature technologies such as hydroelectric dams and gas boilers.

Table 12: Summary of Year 1 operating costs for electric baseboard heating

Meter Charge	$5,400.00
Capacity Charge	$6,482.52
Commodity Charge	$6,060.37
Total	**$17,942.89**

Table 12 shows the summary of operating costs for the district energy hydronic heating system. The total present value operating cost is $502,596 over the 50 year analysis period. Full details can be seen in Appendix B.

Environmental Costs

Because of Adera's concern for the environment and stance toward sustainability, the environmental impact of each heating system needs to be considered in addition to the capital and operating costs. The emissions of each type of system will be determined on a lifecycle basis, from production to disposal over the 50 year assessment period. In order to maintain the same baseline, each emission will have a cost associated with it, allowing the total environmental cost to be determined as a dollar value.

It is difficult to place an accurate dollar value on environmental pollutants. The costs used for carbon dioxide and equivalent (CO2e) emissions will be those reflected in British Columbia's carbon tax. Because tenants using LEC's district energy system already pay carbon tax as part of their utility bill, the CO2e emissions in the operation phase will not be counted as an environmental cost. However, CO2e emissions from production and disposal of raw materials will still be considered. The costs of other emissions will be taken from *Sustainable Energy* by Michael Golay shown in Table 1 (Bi, 2009)**.**

Table 13: Cost of environmental pollutants

Pollutant	Cost ($/tonne)
CO_2	$ 30
CH_4	$ 254
CO	$ 1,034
N_2O	$ 4,770
NOx as NO_2	$ 6,474
SOx	$ 2,325
PM	$ 3,167

To determine the emissions associated with each type of fuel, a life-cycle analysis program, *GHGenius*, was used. *GHGenius* is specifically meant to be used for transportation comparisons, but their emissions data can be used for a variety of applications.

GHGenius takes data from various sources for different parts of the application. For criteria air contaminants (CACs) which will be used in the report, much of the data is obtained from US AP-42 documents, produced by the U.S. Envrionmental Protection Agency. The documents reflect an average of all available data of acceptable quality and are assumed to be representative of long-term averages of all facilities in the source category (U.S Environmental Protection Agency, 2010). *GHGenius* also continually updates their data and frequently release new versions of their software. It can be safely assumed that the emissions data used in the following analysis is reliable to a good degree of accuracy.

Electric Baseboard Heating

GHGenius provided estimates on emissions per kilowatt of distributed electricity, factoring in generation and distribution losses.

Table 14: Emissions per kWh of distributed energy (GHGenius, 2009)

Pollutant	Coal	Fuel Oil	Nat. Gas	Nuclear	Wind	Other C.	Biomass	Hydro
CO_2	1072.35	826.74	545.14	434.91	5.52	0.00	695.40	0.00
CH_4	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.13
CO	0.13	0.17	0.39	0.31	0.00	0.00	0.14	3.68
N_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.06
NO_x as NO_2	2.82	0.76	0.65	0.60	0.00	0.00	0.65	1.35
SO_x	8.17	3.55	0.01	0.01	0.00	0.00	5.93	1.32
PM	0.26	0.14	0.04	0.02	0.00	0.00	0.14	0.49
PM_{10}	0.12	0.10	0.04	0.02	0.00	0.00	0.10	0.00
$PM_{2.5}$	0.05	0.07	0.04	0.02	0.00	0.00	0.08	0.00

The sources used to generate electricity in British Columbia vary in magnitude from year to year, but are predominately from hydro. A typical distribution is shown in Table 15.

Table 15: Distribution of British Columbia's electricity sources (BC Hydro, 2004)

Electricity Source	Percentage Used
Coal	0.0%
N.G.	6.0%
Hydro	92.8%
Nuclear	0.0%
Oil	0.2%
Biomass	1.0%
Other Renewables	0.0%

By using the *GHGenius* emissions data and applying it to Table 15 and the Seven35 heating requirements, the annual emissions and associated costs for electric baseboard heating were determined.

Table 16: Annual environmental operating cost of electric baseboard heating

Pollutant	Emissions (g/kWh delivered)	Annual Emission (t)	Annual Cost
CO_2	39.400	6.2052	$186.16
CH_4	0.304	0.0479	$12.17
CO	0.060	0.0095	$9.83
N_2O	0.001	0.0001	$0.45
NOx as NO_2	0.054	0.0085	$55.08
SOx	0.021	0.0033	$7.59
PM	0.025	0.0039	$12.37
Total			**$283.63**

The environmental impact of the production of baseboard materials was also considered on a lifecycle basis. The two major materials to consider are steel and aluminum. It is estimated that these materials are present in a 90% to 10% ratio by weight, respectively. A lifecycle study from "cradle to gate" has shown aluminum to have a global warming potential of 22.4 $kgCO_2e/kg$, and acidification potential of 0.131 $kgSO_2e/kg$. Steel has a global warming potential of 2.3 $kgCO_2e/kg$, and acidification potential of 0.020 $kgSO_2e/kg$ (Norgate, Jahanshahi, & Rankin, 2007).

In order to estimate the emissions from material production, some approximations were made about the number and weight of electric baseboard heaters in the Seven35 development. Based on freely available baseboard heaters, a weight of 0.01lb/W is assumed (Amazon.com, 2010). Based on the 184.5 kW total capacity of Seven35, the total weight of baseboards would be 1845 pounds. Table 17 summarizes the environmental costs from material production of electric baseboards.

Table 17: Environmental cost due to electric baseboard materials

	Weight (kg)	CO2e (t)	SO2e (t)	Cost
Aluminum	83.86	1.8785	0.0110	$81.90
Steel	754.77	1.7360	0.0151	$87.18
Total				**$169.08**

The environmental cost of the materials is $169.08. Since this is a non-recurring cost, it is a very small component of the overall costs. The value will be applied to the capital cost in the summary.

The total present value total of environmental costs is $5,178 over the 50 year analysis period.

Natural Gas Hydronic Heating

A different *GHGenius* dataset was used to analyze the natural gas hydronic heating option. Due to the variability in boiler systems and their efficiencies, the most accurate approach available is to apply the efficiency of LEC boiler system to determine the input energy required, and use input energy emission data to determine the cost. LEC constantly monitors the system efficiency by measuring the amount of heat delivered against the amount of gas purchased from the provider. Though each of LEC's mini-plants has an efficiency of 87-98%, the overall system efficiency has been as low as 80% (City of North Vancouver, 2010).

Using the 80% efficiency of the system, the annual energy input required for Seven35 space heating is 709GJ. Table 18 summarizes the input emissions and total annual environmental cost of LEC's natural gas hydronic system (excluding the cost of carbon dioxide as it is already accounted for by the carbon tax).

Table 18: Annual environmental cost of natural gas hydronic heating

Pollutant	Emissions (g/GJ input)	Annual Emissions (t)	Annual Cost
CO2	50,066	35.4970	N/A
CH4	0.97	0.0007	$0.18
CO	35.58	0.0252	$26.09
N2O	0.04	0.0000	$0.12
NOx as NO_2	59.73	0.0423	$274.16
SOx	0.62	0.0004	$1.02
PM	9.66	0.0068	$21.69
Total			**$323.26**

Material costs of the hydronic system were also considered. It was assumed that the tubing was made of cross-linked polyethylene (PEX), a common choice due to its low cost, durability and heat exchange properties. The length of PEX tubing required is approximately 1.55ft per square foot of heating space (HouseNeeds, 2010). This translates into a total tube length of 73,386 ft based on the total suite area of 47,346 ft^2. A journal article by *Perzon et al.* studied the lifecycle of PEX pipes used for district heating. PEX pipe was found to have a global warming potential of 120 gCO_2e/m, and acidification potential of 1.4 gSO_2e/m (Perzon, Johansson, & Froling, 2007). Applying these values with the estimated length of pipe and emission costs results in an environmental cost of materials of $153.33. This number will be applied to the capital cost in the summary.

Based on the 5% discount rate, and assuming emission costs remain the same, the total environmental cost for the analysis period is $5,901.

Summary

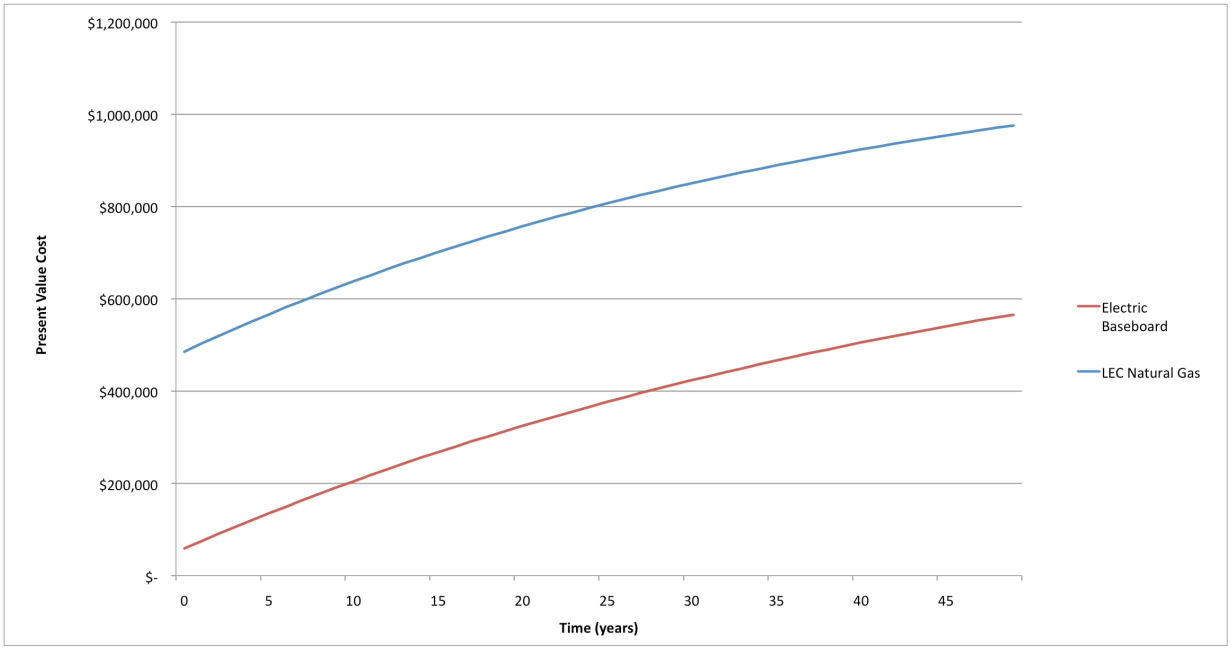

Figure 7: Comparison of total lifecycle present value costs

The above summary shows the total present value cost for the 50-year analysis period. The total present value cost of the electric baseboard system is $565,491, compared to a cost of $975,720 for the district energy system. It is clear that the capital cost of the hydronic system is the major differentiating factor between the two systems. Based on the assumptions made, the operating costs of the electric baseboard option are slightly higher but not nearly enough to bridge the gap caused by the capital cost of the hydronic system. Environmental air pollutant costs are higher in the natural gas system but do contribute significantly in financial terms. Based on lifecycle costing alone, the electric baseboard heater seems to be the desirable option over the lifetime of the analysis. However, other factors must be investigated to confirm or refute this observation.

Sensitivity Analysis

It is important to recognize the fact that several assumptions were made in the LCA, and there is potential for deviation from factors such as fluctuating energy costs, different discount rates that cannot be accurately predicted. Although the magnitude is at this point impossible to determine, there is a strong likelihood that the price of electricity in British Columbia will increase. Natural gas prices are even more variable in that they have proven to both rise and drop unpredictably. When considering LEC's district energy system, the meter charge and commodity charge may also change.

To determine the validity of the initial observations drawn from Figure 7, the variables of both systems must be investigated through a sensitivity analysis that will analyze potential scenarios that may occur. Table 19 describes the five conditions that will be tested.

Table 19: Five scenarios considered in the sensitivity analysis

	Electric Baseboard Rate Hike	Natural Gas Hydronic Rate Hike	Discount Rate	Analysis Period
Scenario 1	4%	2%	5%	50 years
Scenario 2	6%	2%	5%	50 years
Scenario 3	3%	2.5%	3%	50 years
Scenario 4	$0.13/kWh	2.5%	5%	50 years
Scenario 5	3%	2.5%	5%	25 years

The results from the sensitivity analysis are as follows:

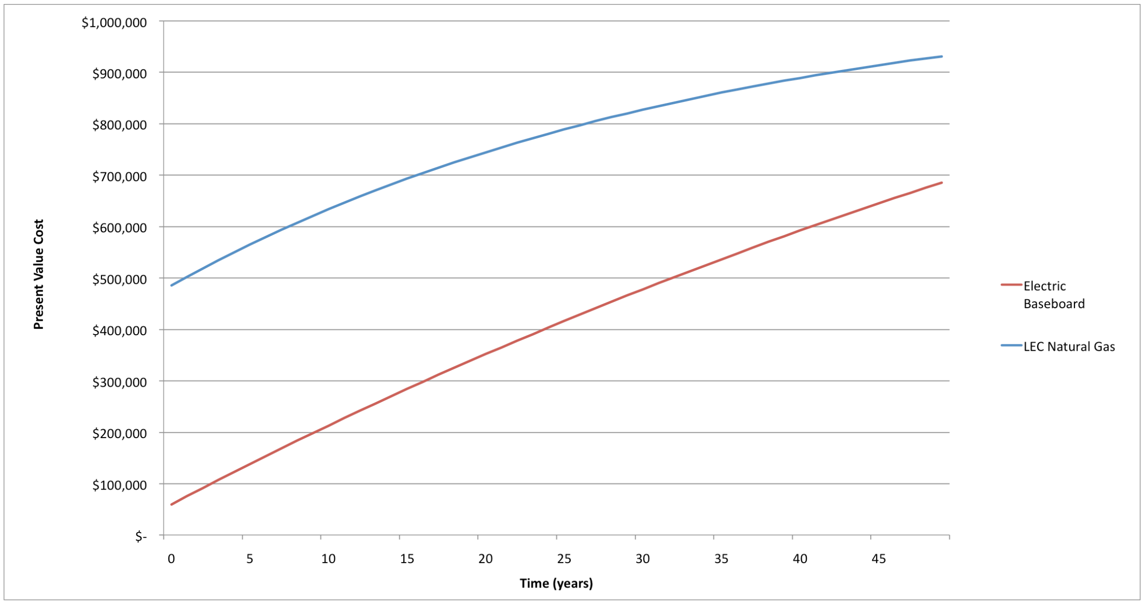

Figure 8: Sensitivity analysis – Scenario 1

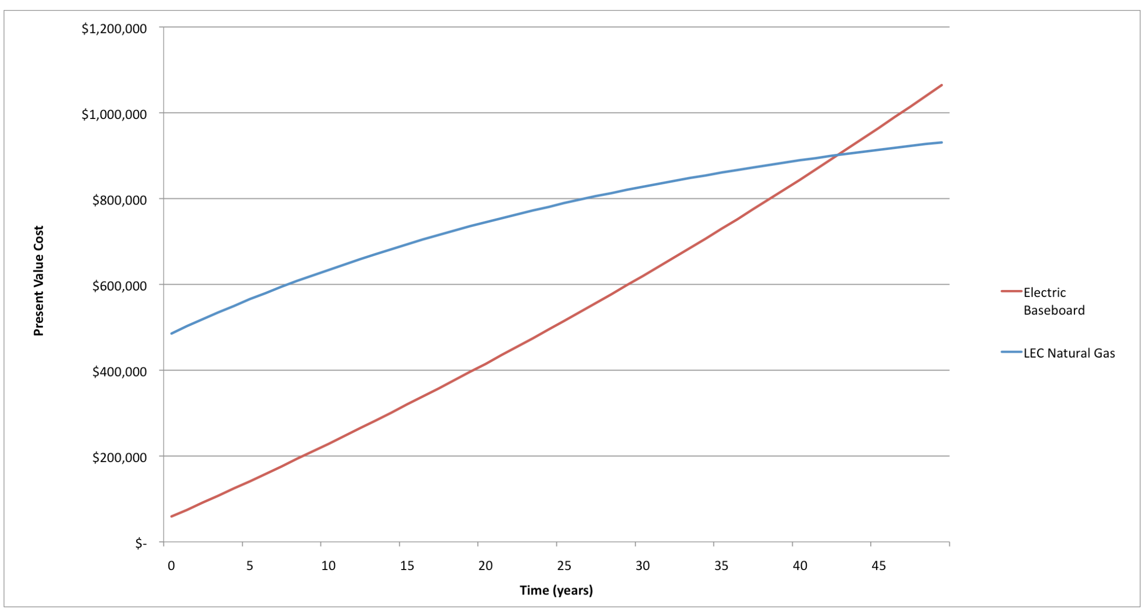

Figure 9: Sensitivity analysis - Scenario 2

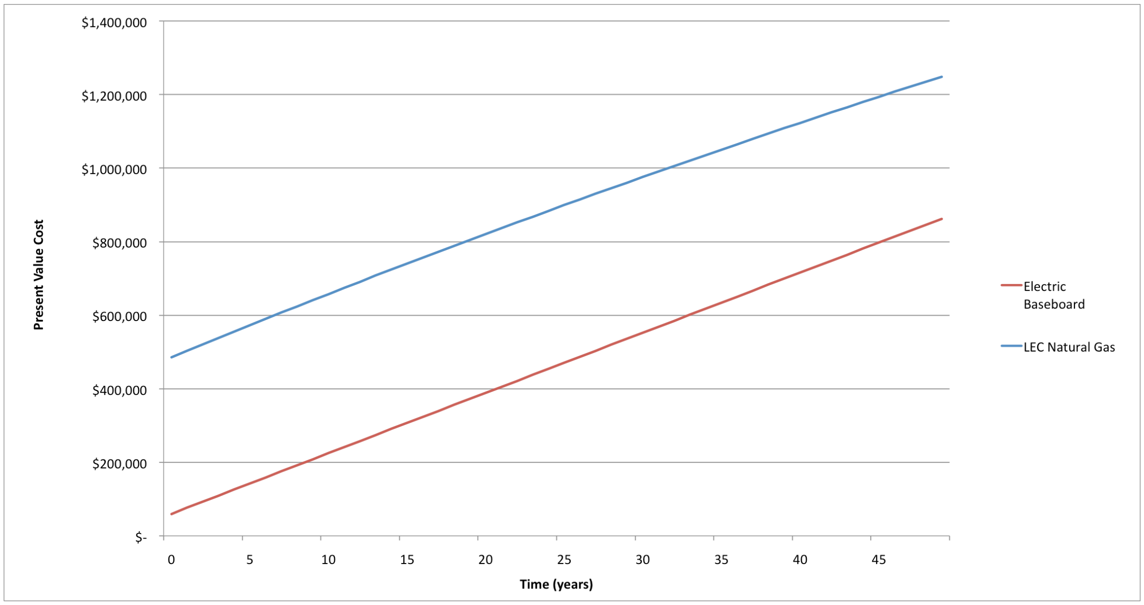

Figure 10: Sensitivity analysis - Scenario 3

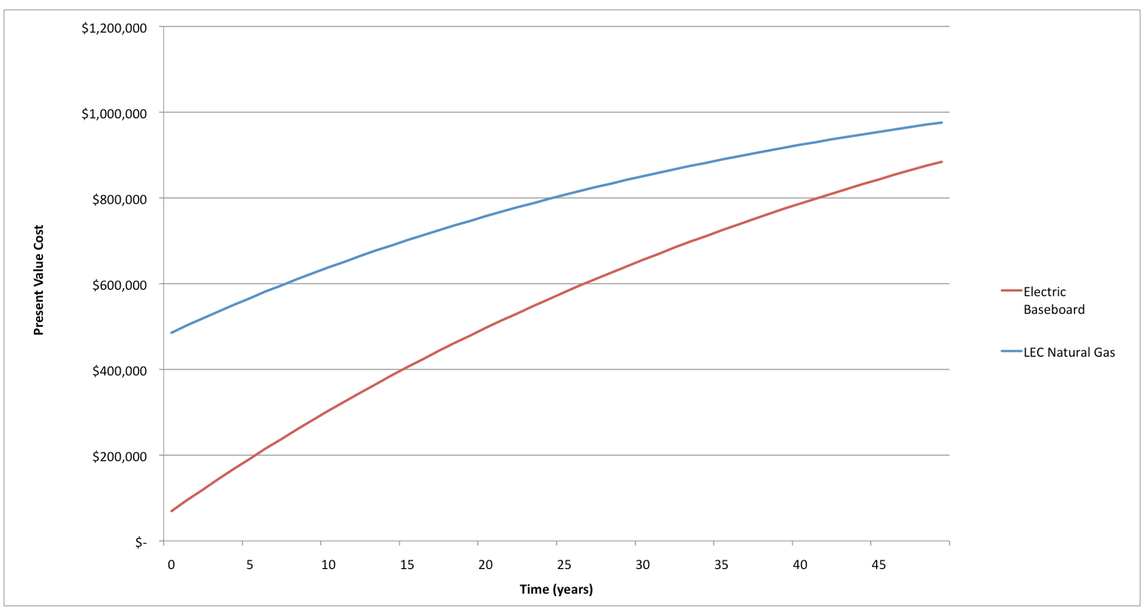

Figure 11: Sensitivity analysis - Scenario 4

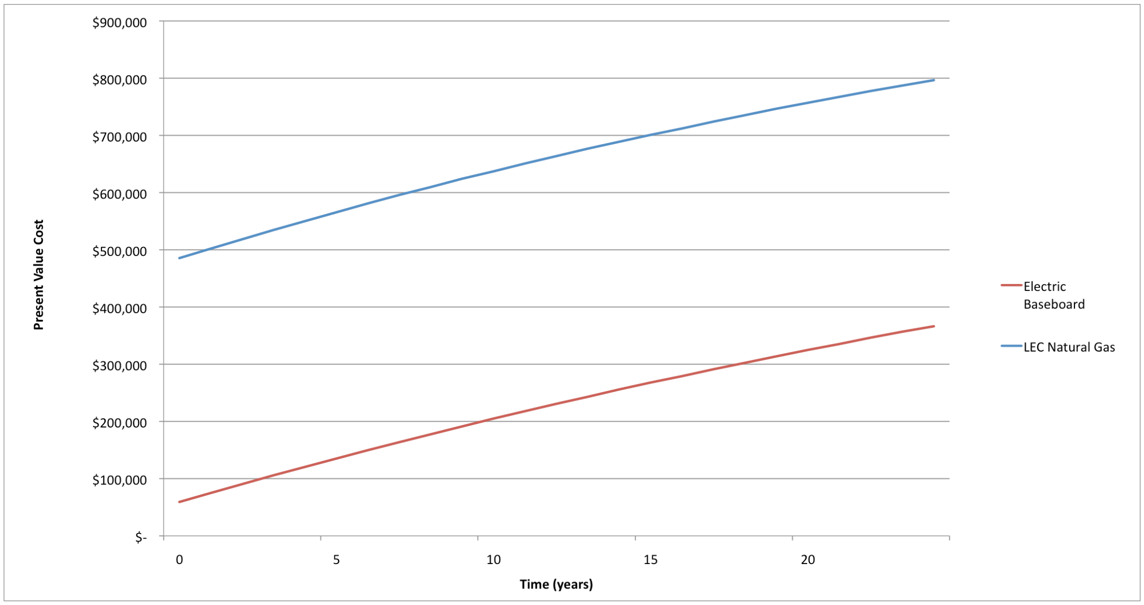

Figure 12: Sensitivity analysis - Scenario 5

The analysis provided some interesting results. All but one scenario (Scenario 2) still favoured electric baseboard heaters. In Scenario 2, the electric baseboard annual rate increase was 6% compared to a much lower natural gas rate increase of 2%. Even so, the natural gas system would have to run 43 years before being the preferred option on a present value costing basis. This long payback period makes it unlikely that it would be selected over electric baseboards. The scenario of a 6% annual rate increase in B.C. Hydro electricity is also unlikely to occur over such a lengthy timeframe, especially if costs of other types of energy grow at a slower rate as is tested in Scenario 2.

The conclusions drawn from the sensitivity analysis support the result of the lifecycle assessment. Based on the information considered in the lifecycle analysis including present value capital, operating and environmental costs over 50 years, electric baseboards are the better option.

Limitations and Considerations

LEC Energy Choice

The LCA conducted was based on the fact that the Lonsdale Energy Corporation is using natural gas boilers to supply electricity for space heating. Despite the district heating configuration being more efficient and more effective than a traditional centralized boiler, the fact remains that natural gas is a fossil fuel and has a greater environmental impact than most renewable and sustainable energy technologies. Because of this, the current preference for electric baseboard heating is rather obvious, considering over 90% of it comes from low-impact hydropower, and the large capital cost savings that can be realized.

When making a decision that will have an impact decades into the future, things become more complicated. Considering the longevity of modern buildings, it is prudent to plan for the future as much as possible. LEC has committed to bringing in renewable energy sources as they become cost competitive, and have designed their system for easy fuel switching. Their long term goal is "to produce green energy for several areas in the City of North Vancouver" (City of North Vancouver, 2010). LEC has already constructed 120 solar hot water panels, and are actively looking into geothermal energy. There is little doubt that more sustainable energy will be added to the system over time, making future years more promising from an environmental perspective; however, the timing of these actions remains uncertain.

Stakeholders

The LCA was based on a complete analysis of capital, operating and environmental costs. These were lumped together to form a conclusion about the recommended system. In reality, different stakeholders will be concerned about various parts of the total analysis and are unlikely to place an equal importance on each. Adera's primary concern as a developer is the capital cost, as well as the environmental cost due to their stance toward sustainability. Operating costs are not as pressing of a concern because Adera does not directly benefit from low operating costs.

The interests of the owner and occupants of the suite are different. Capital cost is of concern for the owner, but many will place equal importance on operating costs if they intend to live there for any significant length of time. Renters would be concerned primarily about operating costs. Environmental costs could be a concern of both groups depending on their feelings about renewable and sustainable energy.

Comfort

In-floor radiant heating is growing in popularity because it offers advantages over convective systems such as baseboards in terms of human comfort. Radiant heating offers a more uniform temperature distribution, and a study by ASHRAE has indicated that people can be comfortable at lower heating temperatures. Additionally, low-emissivity glass can reflect the long-wave radiation emitted by radiant heating systems. This can provide a greenhouse effect and reduce heat loss (Watson, 1992).

Radiant energy can also be configured to provide cooling. Although in British Columbia this may only be desired a few days per year, it is another additional benefit that the hydronic system offers over electric baseboards that is difficult to attach a cost to.

Maintenance Costs

The 50 year lifecycle did not consider any maintenance or replacement costs. This was due to the longevity of the two systems, as well as the fact that the LEC provides the equipment for the district heating system and recovers the capital cost through operating charges. However, it is unclear if equipment replacement such as the heat exchanger, which typically may last 25 years, would be covered by the LEC or by the developer. This needs to be determined, and if the developer is responsible, heat exchanger replacement cost needs to be determined and accounted for.

Exergy

When discussing energy sources and their end uses, the concept of exergy is often overlooked but is important to consider. Exergy is a measure of the “order” of energy. Exergy shows that electricity is a much more valuable form of energy than heat energy. Electricity can provide energy to many uses including lower level heat energy. Heat produced from natural gas combustion, however, cannot be up-converted to more useful forms of energy without sacrificing large losses. Therefore, despite the fact that the LCA determined electric baseboards to be the better option, the fact that electricity has high exergy and is a much more useful form of energy than heat should be considered for future analyses.

Other Environmental and Social Concerns

Though the lifecycle analysis did incorporate environmental impacts, only air pollutants were considered, as their quantities and costs could be estimated with a good degree of accuracy. However, many other environmental factors need to be considered for a higher level analysis. Some of the major ones include land and water use impacts and social impact on First Nations communities – all of which are important issues in British Columbia. Electricity production has a much greater effect on all of these than does natural gas. For a single development such as Seven35, there will be little to no impact for these issues. However, it does carry an incremental impact and does contribute to B.C.'s increasing electricity consumption. British Columbia is continually constructing large and small hydropower projects as well as other types of electricity generation projects. Cumulatively these have a great effect on land use, water use, and First Nations communities.

The purpose of the LCA conducted was to assign a cost to as many factors as possible. This may not be an option for land use, water use and First Nations impacts. However, these do need to be examined in detail in further studies. A good starting reference point is a *Microsoft Excel* spreadsheet created by Eric Mazzi and Conor Reynolds that estimates environmental impacts of home heating options using a compilation of various data sources (Mazzi, 2010).

Conclusions

A detailed analysis of Adera's Seven35 development was performed in order to determine the best space heating option between electric baseboard heating and a natural gas hydronic system run on a district energy network. *HOT2000* was used to determine the seasonal and overall space heating requirements of Seven35. Following this, a lifecycle assessment (LCA) was conducted to determine capital costs, operating costs and emissions from each fuel type. The LCA determined that electric baseboard heating considerably outperformed in capital and environmental costs, while the district energy system slightly outperformed in operating costs. Overall, a significant cost advantage was observed with the electric baseboard heating system, with a present value cost saving of $410,229 over 50 years. A sensitivity analysis analyzing the impacts of several variables including energy price, discount rate and analysis period confirmed this observation and showed that electric baseboard heaters are a better suited under most likely scenarios.

Recommendations

According to Bylaw 7575, Adera's Seven35 development must connect to LEC's district energy system. Were it a free choice, the electric baseboard heating option would be more cost-effective on a lifecycle basis. Despite this, there are numerous advantages to the district energy system, especially if LEC is able to introduce cost-competitive renewable energies in the near future. If Adera is required to install the district energy hydronic heating system, they should look into ways to offset the high capital costs. By effectively marketing the energy efficiency of

Seven35, as well as the potential benefits of renewable energy district heating in terms of the environment and human comfort, Adera may be able to increase the value of the suites by appealing to environmentally-conscious consumers and those with a longer-term outlook on operating costs. The success of this effort will depend greatly on market economics, but some additional revenue aimed at offsetting a portion of capital costs ought to be attainable.

It is further recommended that the limitations and considerations discussed be further investigated, as together they have the potential to significantly impact the final decision. A detailed investigation into these issues combined with the observations drawn from this report could together provide a concrete conclusion and action plan for a path forward.

Works Cited

Amazon.com. (2010). *CADET 05524 Electric Baseboard Heater 48" 120V/1000W Almond (4F1000-1A)*. Retrieved November 24, 2010 from http://www.amazon.com/05524-Electric-Baseboard-Heater-4F1000-1A/dp/B000IHHMWO

Awram, T. (2010, November 19). Baseboard Costing. (V. Uduman, Interviewer)

BC Hydro. (2004). *Electricity Choices*. Retrieved November 15, 2009 from http://www.energyplan.gov.bc.ca/bcep/default.aspx?hash=7

BC Hydro. (2009, December 22). Electricity Rate Comparison Report - Second Annual Report. Vancouver, B.C., Canada.

BC Hydro. (2010, September 30). *EnerGuide Rating Service*. Retrieved November 13, 2010 from http://www.bchydro.com/powersmart/builders_developers/new_home_program/energuide_for_new_houses.html

BC Hydro. (2010). *Heat Smarter With Electric Baseboard Heaters.* Retrieved October 18, 2010 from http://www.bchydro.com/etc/medialib/internet/documents/Power_Smart_FACT_sheets/FACTS_Electric_Baseboard_Heaters.Par.0001.File.FACTS_electric_baseboard_heaters.pdf

BC Hydro. (2010). *Residential Rates*. Retrieved November 15, 2010 from https://www.bchydro.com/youraccount/content/residential_rates.jsp

Bi, T. (2009, November 11). *Chapter 6: Environmental cost and total cost of energy systems.* Retrieved November 20, 2010 from https://courses.chml.ubc.ca/manhat2009-bin/send_file?crs=MENG/CEEN523&id=luuvhtxntsowce&user=xb4408&fname=fil_11112009222042_cowEvm&info=inf_11112009222042_Sceezb&attach=1&grp=12&ext=.pdf

Cadet. (2010). *The Cadet Electric Baseboard*. Retrieved October 24, 2010 from http://www.cadetco.com/show_product.php?prodid=1004

CBC. (2010, March 3). *BC Hydro seeks 33% rate hike over 4 years*. Retrieved November 16, 2010 from CBC News: http://www.cbc.ca/canada/british-columbia/story/2010/03/03/bc-hydro-rate-increases.html

City of North Vancouver. (2010). *Lonsdale Energy Corporation*. Retrieved October 15, 2010 from http://www.cnv.org//server.aspx?c=2&i=98

City of North Vancouver. (2010). *Lonsdale Energy Corporation FAQs*. Retrieved November 21, 2010 from http://www.cnv.org//server.aspx?c=2&i=242

Enwave. (2010). *District Heating*. Retrieved November 25, 2010 from http://www.enwave.com/heating.php

Ghafghazi, S., Sokhansanj, S., & Melin, S. (2010). A multicriteria approach to evaluate district heating options. *Elsevier* , 1134-1140.

GHGenius. (2009). *A model for lifecycles assessment of transportation fuels*. Retrieved November 4, 2009 from http://www.ghgenius.ca/

HouseNeeds. (2010). *Retrofitting with a PEX Radiant Floor Heating System*. Retrieved November 27, 2010 from http://www.houseneeds.com/shop/HeatingProducts/RadiantHeating/radiantheatretrofit.asp
HouseNeeds. (2010). *What size Electric Baseboard or Space Heater do you need?* Retrieved October 20, 2010 from
http://www.houseneeds.com/shop/HeatingProducts/heatingunits/electrical/electricindexsizingpage.asp

Lund, H., Moller, B., Mathiesen, B., & Dyrelund, A. (2010). The role of district heating in future renewable energy systems. *Elsevier* , 1381-1390.

Marbek Resource Consultants Ltd. (2007). *BC Hydro 2007 Conservation Potential Review.* Ottawa.

Monk, G. (2010, November 29). (V. Uduman, Interviewer)

Norgate, T., Jahanshahi, S., & Rankin, W. (2007). Assessing the environmental impact of metal production processes. *Journal of Cleaner Production* , 838-848.

Ouellet Electric Heating. (2010). *OFM Electric Baseboard Heater*. Retrieved October 22, 2010 from http://www.ouellet.com/ofm_video/en.html

Perzon, M., Johansson, K., & Froling, M. (2007). Life Cycle Assessment of District Heat Distribution in Suburban Areas Using PEX Pips Insulated with Expanded Polystyrene. *Chemical Environmental Science* , 320-327.

U.S Environmental Protection Agency. (2010, December 17). *Emmissions Factors & AP 42, Compilation of Air Pollutant Emission Factors.* Retrieved December 24, 2010 from http://www.epa.gov/ttnchie1/ap42/
http://www.osha.gov/SLTC/healthguidelines/carbonmonoxide/recognition.html

Watson, R. D. (1992, June). *Radiantec*. Retrieved November 27, 2010 from Advantages of radiant heat by Richard D. Watson: http://www.radiantec.com/why/technical-explanation.php

Appendix A – HOT2000 Data

HOT2000
Natural Resources CANADA
Version 10.51

File: ADERA 735 - H2K 10-5 - Rev 10 - GOOD - Upgrade 1- Aluminum Wndws
Application Type:

User Weather File:

Weather Data for ,

Builder Code:

Data Entry by: Troy Glasner
Date of entry: 14/9/2010
Company:

Client name: ,
Street address:

City:
Postal code:

Region:
Telephone:

GENERAL HOUSE CHARACTERISTICS

House type:	Attached Triplex		
Number of storeys:	Three storeys		
Plan shape:	Rectangular		
Front orientation:	North		
Year House Built:	2010		
Wall colour:	Default	**Absorptivity:**	0.40
Roof colour:	Medium brown	**Absorptivity:**	0.84
Soil Condition:	Normal conductivity (dry sand, loam, clay)		
Water Table Level:	Normal (7-10m/23-33ft)		

House Thermal Mass Level: (A) Light, wood frame

Effective mass fraction 1.000

BUILDING PARAMETERS SUMMARY

ZONE 1 : Above Grade

Component	Area ft^2 Gross	Area ft^2 Net	Effective (R)	Heat Loss Mil.BTU	% Annual Heat Loss
Ceiling	2514.00	2514.00	35.64	8.10	2.99
Main Walls	5725.98	3363.70	16.33	32.71	12.09
Doors	205.00	82.22	6.47	2.20	0.81
Exposed floors	138.00	138.00	30.90	0.71	0.26
East Windows	641.12	641.12	3.46	31.99	11.83
North Windows	663.39	663.39	3.51	32.67	12.08
West Windows	975.55	975.55	3.38	49.95	18.47
Slab on Grade	1304.00	1304.00	12.39	4.93	1.82
		ZONE 1 Totals:		163.26	60.35

ZONE 2 : Basement

Component	Area ft^2 Gross	Area ft^2 Net	Effective (R)	Heat Loss Mil.BTU	% Annual Heat Loss

ZONE 3: Crawl Space Foundation

Component	Area ft^2 Gross	Area ft^2 Net	Effective (R)	Heat Loss Mil.BTU	% Annual Heat Loss
Foundation	4303.75	4303.75	-	23.93	8.85
		ZONE 3 Totals:		23.93	8.85

AIR LEAKAGE AND VENTILATION

Building Envelope Surface Area: 10987.98 ft^2

Air Leakage Test Results at 50 Pa.(0.2 in H_2O) = 5.00 ACH

Equivalent Leakage Area @ 10 Pa = 706.10 in^2

Terrain Description	Height	ft
@ Weather Station : Open flat terrain, grass	Anemometer	32.8
@ Building site : Suburban, forest	Bldg. Eaves	35.0

Local Shielding: **Walls:** Heavy
Flue : Light

Leakage Fractions- **Ceiling:** 0.000 **Walls:** 0.000 **Floors:** 0.000

Normalized Leakage Area @ 10 Pa: 0.0643 in^2/ft^2

Estimated Airflow to cause a 5 Pa Pressure Difference: 1533 cfm

Estimated Airflow to cause a 10 Pa Pressure Difference: 2406 cfm

F326 VENTILATION REQUIREMENTS

Bachelor, 1-Bedroom	3 units @ 7.1 cfm: 95.3 cfm
2-Bedroom	2 units @ 10.6 cfm: 95.3 cfm
3-Bedroom	1 units @ 14.2 cfm: 63.6 cfm
4 or More Bedroom	1 units @ 17.7 cfm: 79.5 cfm

Basement Rooms : 21.2 cfm

CENTRAL VENTILATION SYSTEM

System Type: Fans w/o HR
Manufacturer:
Model Number:

Fan and Preheater Power at : Watts
Fan and Preheater Power at : Watts
Preheater Capacity: Watts
Sensible Heat Recovery Efficiency at %
Sensible Heat Recovery Efficiency at %
Total Heat Recovery Efficency in Cooling Mode %

Low Temperature Ventilation Reduction: %
Low Temperature Ventilation Reduction: Airflow Adjustment (%)

Vented combustion appliance depressurization limit: 5.00 Pa.

Ventilation Supply Duct

Location:	Main floor	**Type:**	Flexible
Length:	4.9 ft	**Diameter:**	6.0 in
Insulation:	4.0 R	**Sealing Characteristics:**	Sealed

Ventilation Exhaust Duct

Location:	Main floor	**Type:**	Flexible
Length:	4.9 ft	**Diameter:**	6.0 in
Insulation:	4.0 R	**Sealing Characteristics:**	Sealed

Operating schedule for Fans w/o HR

Month	% of Time	Added Vent. Rate (cfm)	Month	% of Time	Added Vent. Rate (cfm)
Jan	0.00	0.00	Jul	0.00	0.00
Feb	43.25	0.00	Aug	0.00	0.00
Mar	100.00	0.00	Sep	0.00	0.00
Apr	0.00	0.00	Oct	0.00	0.00
May	0.00	0.00	Nov	90.85	0.00
Jun	0.00	0.00	Dec	0.00	0.00
Dryer		Continuous		-	0.00

Dryer is vented outdoors

AIR LEAKAGE AND VENTILATION SUMMARY

F326 Required continous ventilation: 21.189 cfm (0.08 ACH)
Central Ventilation Rate (Balanced): 0.000 cfm (0.03 ACH)
Central Ventilation Exhaust Rate (Balanced): 40.000 cfm (0.03 ACH)
Total house ventilation is Balanced

Gross Air Leakage and Ventilation Energy Load:	98.929 Mil.BTU
Seasonal Heat Recovery Ventilator Efficiency:	0.000 %
Estimated Ventilation Electrical Load: Heating Hours:	0.000 Mil.BTU
Estimated Ventilation Electrical Load: Non-Heating Hours:	0.000 Mil.BTU
Net Air Leakage and Ventilation Load:	97.721 Mil.BTU

UNIT-BY-UNIT DESIGN HEATING AND COOLING LOADS SUMMARY

Unit Name	Floor Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)	Ventilation Flow Heating (cfm)	Ventilation Flow Cooling (cfm)
Unit B2	887	12468	14272	196	777
Unit B2 EAST	885	10064	14178	158	772
UnitA	419	5293	7577	83	413
UnitA EAST	419	3175	7577	50	413
Unit C1 - EAST	950	10027	13347	158	727
Unit C1 - WEST	950	9952	13497	156	735
Unit C2 - EAST	950	11591	13439	182	732
Unit C2 - WEST	950	11668	13594	183	741
Unit C3 - WEST	950	14895	12488	234	680
Unit C3- EAST	950	15693	15209	247	828
Whole house	8310	104825	125178	1647	6819
Latent cooling	-	-		-	-
Totals	8310	104825	125178	1647	6819

UNIT-BY-UNIT DESIGN HEATING AND COOLING LOAD DETAILS

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit B2					
W:Header	23.68	62.6	62.6	147	8
W:Wall - 1	15.06	563.2	249.5	924	51
-G:Window - N	3.15	7.0	7.0	124	103
-G:Window - N Entr	3.10	3.9	3.9	70	55
-G:Window - N Pict	3.66	39.8	39.8	607	733
-G:Window - N Pict2	3.54	22.8	22.8	359	402
-G:Window - N SGD	3.16	40.0	40.0	707	618
-G:Window - W	3.54	22.8	22.8	359	1019
-G:Window - W 2	3.66	39.8	39.8	607	1856
-G:Window - W 3	3.54	22.8	22.8	359	1019
-G:Window - W 4	3.65	35.4	35.4	542	1645
-G:Window - W 6	3.65	35.4	35.4	542	1645
-G:Window - W5	3.57	23.6	23.6	370	1068
-D:Door - 1	6.47	20.5	20.5	71	-0
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
Total Loss/Gain	-	-	-	5988	10428
Air Change	-	-	-	3790	330
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	9778	14272
Air Flow Rate (cfm)	-	-	-	242	701

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 15355 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 16404 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.13
Critical month total ACH: 0.13
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 35.43 L/s

Foundation included in this unit: Crawlspace - B2 west

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit B2 EAST					
W:Wall - 1 copy	15.06	563.2	249.5	924	51

-G:Window - E	3.85	22.8	22.8	330	968
-G:Window - E 2	3.66	39.8	39.8	607	1856
-G:Window - E 3	3.54	22.8	22.8	359	1019
-G:Window - E 4	3.65	35.4	35.4	542	1645
-G:Window - E 5	3.57	23.6	23.6	370	1068
-G:Window - E 6	3.65	35.4	35.4	542	1645
-G:Window - N Entr copy	3.10	3.9	3.9	70	55
-G:Window - N Pict copy	3.66	39.8	39.8	607	733
-G:Window - N Pict2 copy	3.54	22.8	22.8	359	402
-G:Window - N SGD copy	3.16	40.0	40.0	707	618
-G:Window - N copy	3.15	7.0	7.0	124	103
-D:Door - 1 copy	6.47	20.5	20.5	71	-0
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
W:Wall - Header	23.68	62.6	62.6	147	8
Total Loss/Gain	-	-	-	5959	10377
Air Change	-	-	-	3404	287
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	9363	14178
Air Flow Rate (cfm)	-	-	-	186	633

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 10236 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 10691 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.19
Critical month total ACH: 0.19
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 15.51 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
UnitA					
W:Wall - 1 copy	13.61	174.0	82.6	339	19
-G:Window - W 4 copy	3.65	35.4	35.4	542	1645
-G:Window - W 6 copy	3.65	35.4	35.4	542	1645
-D:Door - 1 copy	6.47	20.5	20.5	71	-0
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
W:Wall -Header	23.51	19.3	19.3	46	3
Total Loss/Gain	-	-	-	1741	3834
Air Change	-	-	-	1794	228

Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	3535	7577
Air Flow Rate (cfm)	-	-	-	98	259

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 8530 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 4951 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.09
Critical month total ACH: 0.09
EnerGuide target ventilation 0.31 ACH
EnerGuide added mechanical ventilation. 22.90 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
UnitA EAST					
W:Wall - 1 copy	13.61	174.0	82.6	339	19
-G:Window - W 4 copy	3.65	35.4	35.4	542	1645
-G:Window - W 6 copy	3.65	35.4	35.4	542	1645
-D:Door - 1 copy	6.47	20.5	20.5	71	-0
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
W:Wall -Header	23.51	19.3	19.3	46	3
Total Loss/Gain	-	-	-	1741	3834
Air Change	-	-	-	1237	228
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	2978	7577
Air Flow Rate (cfm)	-	-	-	54	259

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 3412 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 2260 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.13
Critical month total ACH: 0.13
EnerGuide target ventilation 0.46 ACH
EnerGuide added mechanical ventilation. 22.90 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C1 - EAST					
C:Ceiling - 1 copy	35.64	419.0	419.0	656	360
W:Roof Wall Hatch copy	17.76	116.0	104.5	328	15
-G:Window - E2	1.60	11.5	11.5	401	699
W:Wall - 2nd Floor copy	12.44	154.6	52.3	234	13
-G:Window - E1	3.64	68.3	68.3	1046	3163
-G:Window - E3	3.64	34.1	34.1	523	1582
W:Wall - Header	23.51	19.3	19.3	46	3
W:Wall - Header	23.51	19.3	19.3	46	3
W:Wall - Main Flr copy	14.54	174.0	84.4	324	18
-G:Window - E1	3.65	35.4	35.4	542	1645
-G:Window - E3	3.37	10.0	10.0	166	419
-G:Window -E2	3.57	23.6	23.6	370	1068
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
F:Floor - OV Entry copy	30.90	23.0	23.0	42	-2
-G:Window - E1	3.65	35.4	35.4	542	1645
-G:Window - E3	3.37	10.0	10.0	166	419
-G:Window -E2	3.57	23.6	23.6	370	1068
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
Total Loss/Gain	-	-	-	6343	13156
Air Change	-	-	-	5032	328
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	11376	16998
Air Flow Rate (cfm)	-	-	-	139	584

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 10236 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 6980 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.35
Critical month total ACH: 0.35
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C1 - WEST					

C:Ceiling - 1 copy	35.64	419.0	419.0	656	360
W:Roof Wall Hatch copy	17.64	116.0	102.0	323	15
-G:Window - W2 copy	1.62	14.0	14.0	483	855
W:Wall - 2nd Floor copy	12.44	154.6	52.3	234	13
-G:Window - W1 copy	3.64	68.3	68.3	1046	3163
-G:Window - W3 copy	3.64	34.1	34.1	523	1582
W:Wall - Main Flr copy	14.54	174.0	84.4	324	18
-G:Window - W1 copy	3.65	35.4	35.4	542	1645
-G:Window - W2 copy	3.57	23.6	23.6	370	1068
-G:Window - W3 copy	3.37	10.0	10.0	166	419
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
W:Wall -Header	23.51	19.3	19.3	46	3
F:Floor - OV Entry copy	30.90	23.0	23.0	42	-2
Total Loss/Gain	-	-	-	5025	9657
Air Change	-	-	-	4927	325
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	9952	13497
Air Flow Rate (cfm)	-	-	-	140	592

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 10236 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 6878 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.34
Critical month total ACH: 0.34
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C2 - EAST					
C:Ceiling - 1 copy	35.64	419.0	419.0	656	360
W:Roof Wall Hatch copy	17.76	116.0	104.5	328	15
-G:Window - W2 copy	1.60	11.5	11.5	401	699
W:Wall - 2nd Floor copy	17.26	360.0	257.6	833	46
-G:Window - W1 copy	3.64	68.3	68.3	1046	3163
-G:Window - W3 copy	3.64	34.1	34.1	523	1582
W:Wall - Header	23.51	19.3	19.3	46	3
W:Wall - Main Flr copy	14.54	174.0	84.4	324	18
-G:Window - W1 copy	3.65	35.4	35.4	542	1645
-G:Window - W2 copy	3.57	23.6	23.6	370	1068
-G:Window - W3 copy	3.37	10.0	10.0	166	419

-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
F:Floor - OV Entry copy	30.90	23.0	23.0	42	-2
-G:Window - W1 copy	3.65	35.4	35.4	542	1645
-G:Window - W2 copy	3.57	23.6	23.6	370	1068
-G:Window - W3 copy	3.37	10.0	10.0	166	419
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
Total Loss/Gain	-	-	-	6896	13186
Air Change	-	-	-	6044	390
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	12940	17091
Air Flow Rate (cfm)	-	-	-	155	585

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 11942 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 9674 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.41
Critical month total ACH: 0.41
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C2 - WEST					
C:Ceiling - 1 copy	35.64	419.0	419.0	656	360
W:Roof Wall Hatch copy	17.64	116.0	102.0	323	15
-G:Window - W2 copy	1.62	14.0	14.0	483	855
W:Wall - 2nd Floor copy	17.26	360.0	257.6	833	46
-G:Window - W1 copy	3.64	68.3	68.3	1046	3163
-G:Window - W3 copy	3.64	34.1	34.1	523	1582
W:Wall - Main Flr copy	14.54	174.0	84.4	324	18
-G:Window - W1 copy	3.65	35.4	35.4	542	1645
-G:Window - W2 copy	3.57	23.6	23.6	370	1068
-G:Window - W3 copy	3.37	10.0	10.0	166	419
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	524
W:Wall -Header	23.51	19.3	19.3	46	3
F:Floor - OV Entry copy	30.90	23.0	23.0	42	-2
Total Loss/Gain	-	-	-	5623	9690

Air Change	-	-	-	6044	390
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	11668	13594
Air Flow Rate (cfm)	-	-	-	157	594

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 11942 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 9792 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.41
Critical month total ACH: 0.41
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C3 - WEST					
C:Ceiling - 1	35.64	419.0	419.0	656	360
W:Roof Wall Hatch	17.76	116.0	104.5	328	15
-G:Window - W2 copy	1.60	11.5	11.5	401	699
W:Wall - 2nd Floor	15.51	360.0	184.4	663	36
-G:Window - N1	3.64	68.3	68.3	1046	1249
-G:Window - N2	3.52	19.5	19.5	309	342
-G:Window - N3	3.52	19.5	19.5	309	342
-G:Window - W1 copy	3.64	34.1	34.1	523	1582
-G:Window - W2 copy	3.39	11.5	11.5	190	485
-G:Window - W3 copy	3.54	22.8	22.8	359	1019
W:Wall - Header	23.64	42.5	42.5	100	6
W:Wall - Main Flr	15.78	382.5	203.0	718	39
-G:Window - N1	3.65	35.4	35.4	542	650
-G:Window -N2	3.55	25.5	25.5	401	452
-G:Window -N3	3.55	25.5	25.5	401	452
-G:Window - W1	3.66	39.8	39.8	607	1856
-G:Window - W2	3.37	10.0	10.0	166	419
-G:Window - W3	3.54	22.8	22.8	359	1019
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
F:Floor - OV Entry	30.90	23.0	23.0	42	-2
-G:Window - N1	3.65	35.4	35.4	542	650
-G:Window -N2	3.55	25.5	25.5	401	452
-G:Window -N3	3.55	25.5	25.5	401	452
-G:Window - W1	3.66	39.8	39.8	607	1856
-G:Window - W2	3.37	10.0	10.0	166	419
-G:Window - W3	3.54	22.8	22.8	359	1019
-D:Door - 1 copy	6.47	20.5	20.5	71	-4

--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
Total Loss/Gain	-	-	-	11135	16273
Air Change	-	-	-	6507	369
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	17642	20157
Air Flow Rate (cfm)	-	-	-	234	680

The unit is using the central heating system.

The unit is using the central domestic hot water system.

The unit is using the central ventilation system.
Critical month natural ACH: 0.46
Critical month total ACH: 0.46
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component	R-value	Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
Unit C3- EAST					
C:Ceiling - 1 copy	35.64	419.0	419.0	656	360
W:Roof Wall Hatch copy	17.76	116.0	104.5	328	15
-G:Window - W2 copy	1.60	11.5	11.5	401	699
W:Wall - 2nd Floor copy	15.51	360.0	184.4	663	36
-G:Window - N1 copy	3.64	68.3	68.3	1046	1249
-G:Window - N2 copy	3.52	19.5	19.5	309	342
-G:Window - N3 copy	3.52	19.5	19.5	309	342
-G:Window - W1 copy	3.64	34.1	34.1	523	1582
-G:Window - W2 copy	3.39	11.5	11.5	190	485
-G:Window - W3 copy	3.54	22.8	22.8	359	1019
W:Wall - Header	23.64	42.5	42.5	100	6
W:Wall - Main Flr copy	15.78	382.5	203.0	718	39
-G:Window - N1 copy	3.65	35.4	35.4	542	650
-G:Window -N2 copy	3.55	25.5	25.5	401	452
-G:Window -N3 copy	3.55	25.5	25.5	401	452
-G:Window - W1 copy	3.66	39.8	39.8	607	1856
-G:Window - W2 copy	3.37	10.0	10.0	166	419
-G:Window - W3 copy	3.54	22.8	22.8	359	1019
-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
F:Floor - OV Entry copy	30.90	23.0	23.0	42	-2
-G:Window - N1 copy	3.65	35.4	35.4	542	650
-G:Window -N2 copy	3.55	25.5	25.5	401	452
-G:Window -N3 copy	3.55	25.5	25.5	401	452
-G:Window - W1 copy	3.66	39.8	39.8	607	1856
-G:Window - W2 copy	3.37	10.0	10.0	166	419
-G:Window - W3 copy	3.54	22.8	22.8	359	1019

-D:Door - 1 copy	6.47	20.5	20.5	71	-4
--G:Window - N Pict2 copy	3.41	12.3	12.3	201	206
Total Loss/Gain	-	-	-	11135	16273
Air Change	-	-	-	7304	471
Internal Gain: People	-	-	-	-	717
Internal Gain: Appliances	-	-	-	-	2798
Total Room Load	-	-	-	18439	20259
Air Flow Rate (cfm)	-	-	-	234	680

The unit is using an independant heating system.

System type: Baseboard/Hydronic/Plenum
Fuel type: Electricity
System Capacity: 15355 Btu/h
System Efficiency: 100 %
Energy consumption for space heating: 18013 MJ

The unit is using the central domestic hot water system.

The unit is using an independant ventilation system.
Critical month natural ACH: 0.46
Critical month total ACH: 0.46
EnerGuide target ventilation 0.30 ACH
EnerGuide added mechanical ventilation. 0.00 L/s

Unit Component		Gross Area (ft^2)	Net Area (ft^2)	Heating Load (BTU/hr)	Cooling Load (BTU/hr)
	0.00	0.0	0.0	0	0
	0.00	0.0	0.0	0	0
	0.00	0.0	0.0	0	0
Total Loss/Gain	-	-	-	0	0
Air Change	-	-	-	0	0
Internal Gain: People	-	-	-	-	0
Internal Gain: Appliances	-	-	-	-	0
Total Room Load	-	-	-	0	0
Air Flow Rate (cfm)	-	-	-	0	0

CENTRAL SPACE HEATING SYSTEM

Primary Heating Fuel:	Electricity
Equipment:	Baseboard/Hydronic/Plenum(duct) htrs.
Manufacturer:	
Model:	
Calculated* Output Capacity:	15354.63 BTU/hr
* Design Heat loss X 1.00 + 0.5 kW	
Steady State Efficiency:	100.00 %
Central heating system energy consumption:	17706.65 Mil.BTU

CENTRAL DOMESTIC WATER HEATING SYSTEM

Primary Water Heating Fuel:		Electricity
Water Heating Equipment:		Heat pump
Energy Factor:	1.90	
Manufactuer:		
Model:		
Secondary Water Heating Fuel:		Electricity
Water Heating Equipment:		Heat pump
Energy Factor:	1.90	
Manufactuer:		
Model:		

SPACE HEATING SYSTEMS ANNUAL SUMMARY

Design Heat Loss at 15.80 °F (1.25 BTU/hr / Ft3):		107719.62 BTU/hr
Gross Space Heat Loss:	270.51 Mil.BTU	
Gross Space Heating Load:	270.51 Mil.BTU	
Usable Internal Gains:	138.78 Mil.BTU	
Usable Internal Gains Fraction:	51.30 %	
Usable Solar Gains:	38.72 Mil.BTU	
Usable Solar Gains Fraction:	14.31 %	
Auxilary Energy Required:	93.01 Mil.BTU	
Space Heating Systems Load:	98.16 Mil.BTU	

ANNUAL DOMESTIC WATER HEATING SUMMARY

Daily Hot Water Consumption:	307.96 Imp Gal
Hot Water Temperature:	131.00 °F
Estimated Domestic Water Heating Load:	90.09 Mil.BTU

Annual Domestic Water Heating Energy Consumption:	50000.84 Mil.BTU
Primary Domestic Water Heating Energy Consumption:	35.54 Mil.BTU
Primary System Seasonal Efficiency:	190.10%
Secondary Domestic Water Heating Energy Consumption:	11.85 Mil.BTU
Secondary System Seasonal Efficiency:	190.10%

BASE LOADS SUMMARY

	kwh/day	Annual kWh
Interior Lighting	17.00	6205.00
Appliances	80.00	29200.00
Other	17.00	6205.00
Exterior Use	3.00	1095.00
HVAC Fans		
HRV/Exhaust	0.00	0.00
Space Heating	0.16	58.86
Space Cooling	0.00	0.00
Total Average Electrical Load	117.16	42763.86

Natural gas Stove **Location:** Main floor
Energy consumption: 0.00 UNITS/Day

Natural gas Dryer **Location:** Outside
Energy consumption: 0.00 UNITS/Day

FAN OPERATION SUMMARY (kWh)

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	0.00	307.60	0.00
Neither	0.00	0.00	0.00
Cooling	0.00	0.00	0.00
Total	0.00	307.60	0.00

ENERGUIDE FOR HOUSES ENERGY CONSUMPTION SUMMARY REPORT

Estimated Annual Space Heating Energy Consumption	= 103349.91 MJ	= 28708.31 kWh
Ventilator Electrical Consumption: Heating Hours	= 0.00 MJ	= 0.00 kWh
Estimated Annual DHW Heating Energy Consumption	= 50000.84 MJ	= 13889.12 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 153350.75 MJ	= 42597.43 kWh
ENERGUIDE RATING (0 to 100)	82	
EnerGuide Required Ventilation Capacity (Central)	179.65 cfm	

Estimated Greenhouse Gas Emissions 46.53 tonnes/year

ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY

Fuel	Space Heating	Space Cooling	DHW Heating	Appliance	Total
Electricity (kWh)	29475.58	0.00	13889.12	42704.99	86069.69

ESTIMATED ANNUAL FUEL CONSUMPTION COSTS

Fuel Costs Library = C:\H2KEGH~1\StdLibs\fuelLib.flc

RATE	Electricity (Ottawa08)	Natural Gas (Ottawa08)	Oil (Ottawa08)	Propane (Ottawa97)	Wood (Sth Ont)	Total
$	8794.37	0.00	0.00	0.00	0.00	8794.37

MONTHLY ESTIMATED ENERGY CONSUMPTION BY DEVICE (Mil.BTU.)

Month	Space Heating		DHW Heating		Lights &	HRV &	Air
	Primary	Secondary	Primary	Secondary	Appliances	FANS	Conditioner
Jan	23.7	0.0	3.3	3.9	12.4	0.0	0.0
Feb	16.1	0.0	3.0	3.6	11.2	0.0	0.0
Mar	10.9	0.0	3.3	3.9	12.4	0.0	0.0
Apr	3.4	0.0	3.1	3.7	12.0	0.0	0.0
May	0.4	0.0	3.0	3.6	12.4	0.0	0.0
Jun	0.0	0.0	2.8	3.3	12.0	0.0	0.0
Jul	0.0	0.0	2.8	3.3	12.4	0.0	0.0
Aug	0.0	0.0	2.7	3.3	12.4	0.0	0.0
Sep	0.0	0.0	2.7	3.2	12.0	0.0	0.0
Oct	3.8	0.0	2.9	3.5	12.4	0.0	0.0
Nov	15.9	0.0	2.9	3.5	12.0	0.0	0.0
Dec	23.8	0.0	3.2	3.8	12.4	0.0	0.0
Ann	98.0	0.0	35.5	42.7	145.7	0.0	0.0

ESTIMATED FUEL COSTS (Dollars)

Month	Electricity	Natural Gas	Oil	Propane	Wood	Total
Jan	1221.47	0.00	0.00	0.00	0.00	1221.47
Feb	945.71	0.00	0.00	0.00	0.00	945.71
Mar	847.46	0.00	0.00	0.00	0.00	847.46

Apr	583.69	0.00	0.00	0.00	0.00	583.69
May	505.13	0.00	0.00	0.00	0.00	505.13
Jun	471.81	0.00	0.00	0.00	0.00	471.81
Jul	482.93	0.00	0.00	0.00	0.00	482.93
Aug	481.42	0.00	0.00	0.00	0.00	481.42
Sep	468.03	0.00	0.00	0.00	0.00	468.03
Oct	599.11	0.00	0.00	0.00	0.00	599.11
Nov	968.44	0.00	0.00	0.00	0.00	968.44
Dec	1219.18	0.00	0.00	0.00	0.00	1219.18
Ann	8794.37	0.00	0.00	0.00	0.00	8794.37

Appendix B – FULL LCA Data Tables (Cumulative Present Value)

Electric Baseboard Heating				
Year	Capital	Operating	Environmental	Total
0	$42,169.08	$16,776.36	$283.63	$59,229.07
1	$42,169.08	$31,650.64	$527.38	$74,347.11
2	$42,169.08	$47,025.26	$772.39	$89,966.74
3	$42,169.08	$62,107.03	$1,005.74	$105,281.85
4	$42,169.08	$76,901.53	$1,227.97	$120,298.58
5	$42,169.08	$91,414.23	$1,439.62	$135,022.93
6	$42,169.08	$105,650.49	$1,641.19	$149,460.76
7	$42,169.08	$119,615.59	$1,833.16	$163,617.83
8	$42,169.08	$133,314.69	$2,015.99	$177,499.76
9	$42,169.08	$146,752.85	$2,190.12	$191,112.05
10	$42,169.08	$159,935.05	$2,355.95	$204,460.08
11	$42,169.08	$172,866.15	$2,513.88	$217,549.12
12	$42,169.08	$185,550.95	$2,664.30	$230,384.33
13	$42,169.08	$197,994.14	$2,807.55	$242,970.77
14	$42,169.08	$210,200.31	$2,943.98	$255,313.37
15	$42,169.08	$222,173.98	$3,073.92	$267,416.98
16	$42,169.08	$233,919.59	$3,197.66	$279,286.33
17	$42,169.08	$245,441.47	$3,315.52	$290,926.06
18	$42,169.08	$256,743.88	$3,427.76	$302,340.72
19	$42,169.08	$267,831.01	$3,534.66	$313,534.74
20	$42,169.08	$278,706.95	$3,636.46	$324,512.50
21	$42,169.08	$289,375.74	$3,733.42	$335,278.24
22	$42,169.08	$299,841.31	$3,825.76	$345,836.15
23	$42,169.08	$310,107.53	$3,913.71	$356,190.32
24	$42,169.08	$320,178.21	$3,997.47	$366,344.76
25	$42,169.08	$330,057.07	$4,077.23	$376,303.38
26	$42,169.08	$339,747.76	$4,153.20	$386,070.04
27	$42,169.08	$349,253.86	$4,225.56	$395,648.50
28	$42,169.08	$358,578.89	$4,294.46	$405,042.44
29	$42,169.08	$367,726.31	$4,360.09	$414,255.48
30	$42,169.08	$376,699.49	$4,422.59	$423,291.16
31	$42,169.08	$385,501.75	$4,482.11	$432,152.94
32	$42,169.08	$394,136.35	$4,538.80	$440,844.23
33	$42,169.08	$402,606.48	$4,592.79	$449,368.35
34	$42,169.08	$410,915.27	$4,644.21	$457,728.56
35	$42,169.08	$419,065.80	$4,693.18	$465,928.06
36	$42,169.08	$427,061.08	$4,739.82	$473,969.99
37	$42,169.08	$434,904.08	$4,784.24	$481,857.40

38	$42,169.08	$442,597.68	$4,826.54	$489,593.30
39	$42,169.08	$450,144.73	$4,866.83	$497,180.65
40	$42,169.08	$457,548.04	$4,905.20	$504,622.32
41	$42,169.08	$464,810.33	$4,941.74	$511,921.15
42	$42,169.08	$471,934.28	$4,976.55	$519,079.91
43	$42,169.08	$478,922.55	$5,009.69	$526,101.32
44	$42,169.08	$485,777.70	$5,041.26	$532,988.04
45	$42,169.08	$492,502.28	$5,071.32	$539,742.69
46	$42,169.08	$499,098.78	$5,099.96	$546,367.81
47	$42,169.08	$505,569.62	$5,127.22	$552,865.93
48	$42,169.08	$511,917.21	$5,153.19	$559,239.49
49	$42,169.08	$518,143.90	$5,177.93	$565,490.91

Natural Gas Hydronic Heating				
Year	**Capital**	**Operating**	**Environmental**	**Total**
0	$467,223.33	$17,942.89	$323.26	$485,489.48
1	$467,223.33	$33,770.07	$601.07	$501,594.47
2	$467,223.33	$50,054.48	$880.32	$518,158.13
3	$467,223.33	$65,951.18	$1,146.26	$534,320.77
4	$467,223.33	$81,469.38	$1,399.55	$550,092.25
5	$467,223.33	$96,618.10	$1,640.77	$565,482.19
6	$467,223.33	$111,406.13	$1,870.50	$580,499.96
7	$467,223.33	$125,842.07	$2,089.30	$595,154.70
8	$467,223.33	$139,934.30	$2,297.67	$609,455.30
9	$467,223.33	$153,691.00	$2,496.13	$623,410.45
10	$467,223.33	$167,120.15	$2,685.13	$637,028.61
11	$467,223.33	$180,229.57	$2,865.13	$650,318.03
12	$467,223.33	$193,026.86	$3,036.57	$663,286.75
13	$467,223.33	$205,519.44	$3,199.83	$675,942.61
14	$467,223.33	$217,714.59	$3,355.33	$688,293.25
15	$467,223.33	$229,619.38	$3,503.42	$700,346.12
16	$467,223.33	$241,240.72	$3,644.45	$712,108.50
17	$467,223.33	$252,585.36	$3,778.78	$723,587.46
18	$467,223.33	$263,659.89	$3,906.70	$734,789.92
19	$467,223.33	$274,470.74	$4,028.53	$745,722.60
20	$467,223.33	$285,024.18	$4,144.57	$756,392.08
21	$467,223.33	$295,326.36	$4,255.07	$766,804.76
22	$467,223.33	$305,383.25	$4,360.32	$776,966.89
23	$467,223.33	$315,200.68	$4,460.55	$786,884.56
24	$467,223.33	$324,784.37	$4,556.01	$796,563.71

25	$467,223.33	$334,139.88	$4,646.92	$806,010.13
26	$467,223.33	$343,272.63	$4,733.51	$815,229.47
27	$467,223.33	$352,187.94	$4,815.97	$824,227.24
28	$467,223.33	$360,890.98	$4,894.50	$833,008.82
29	$467,223.33	$369,386.81	$4,969.30	$841,579.43
30	$467,223.33	$377,680.35	$5,040.53	$849,944.21
31	$467,223.33	$385,776.43	$5,108.37	$858,108.13
32	$467,223.33	$393,679.74	$5,172.98	$866,076.05
33	$467,223.33	$401,394.88	$5,234.52	$873,852.73
34	$467,223.33	$408,926.33	$5,293.12	$881,442.78
35	$467,223.33	$416,278.45	$5,348.94	$888,850.72
36	$467,223.33	$423,455.53	$5,402.09	$896,080.95
37	$467,223.33	$430,461.72	$5,452.71	$903,137.76
38	$467,223.33	$437,301.10	$5,500.93	$910,025.35
39	$467,223.33	$443,977.63	$5,546.85	$916,747.81
40	$467,223.33	$450,495.20	$5,590.58	$923,309.11
41	$467,223.33	$456,857.59	$5,632.23	$929,713.15
42	$467,223.33	$463,068.50	$5,671.89	$935,963.72
43	$467,223.33	$469,131.52	$5,709.67	$942,064.52
44	$467,223.33	$475,050.19	$5,745.65	$948,019.17
45	$467,223.33	$480,827.94	$5,779.91	$953,831.18
46	$467,223.33	$486,468.12	$5,812.54	$959,504.00
47	$467,223.33	$491,974.02	$5,843.62	$965,040.97
48	$467,223.33	$497,348.81	$5,873.22	$970,445.37
49	$467,223.33	$502,595.64	$5,901.41	$975,720.38