Energy Efficiency Improvements for the Inn at Otter Crest

June 5, 2015

Lee Ha

ME 493 FINAL REPORT – YEAR 2015

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Executive Summary

The objective of this Capstone project is to reduce the annual energy utility bill for the Inn at Otter Crest (IOC), an Oregon Coast resort hotel and condominium built in 1972. The IOC homeowners association set the project design specification (PDS) of a 20% reduction in the annual IOC energy bill, with a simple payback of six years or less for any purchase.

Unique challenges to the final design included the mixed use of IOC condo units (private ownership vs. hotel use), difficult occupancy schedule prediction, and unavailability of fossil fuel. Of the eight cost-saving measures researched, only two were found to be feasible and satisfy the PDS payback criteria: air source heat pumps and LED exterior lighting.

Replacing resistance heaters with mini-split ductless heat pumps was found to reduce the annual electricity bill by 13.4%, with a payback period of 4.5 years when combined with available incentives. Changing exterior lighting to LED from CFL was found to reduce the annual electricity bill by 0.7%, with a payback period of 3.2 years. The combined annual utility savings for kWh consumption alone is 14%, below the PDS target of 20%. Additional savings are possible with heat pumps due to a reduced peak demand. A detailed eQUEST energy model of an eight unit IOC condo predicts a 30-35% reduction in the peak demand with heat pump space heating.

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1
Introduction

The Inn at Otter Crest (IOC) is an oceanfront resort built in 1972 on the Oregon Coast, where electricity is the only available source of energy. The IOC association of owners is a representative group who make property management decisions based on the collective interests of all IOC owners. The association is concerned about the mounting electricity bills, which totaled $135,000 in 2014. The Capstone team has been tasked with reducing the electricity bill for the condo buildings on the property, excluding the heated pool and restaurant. The mild to cool Oregon Coast weather leads to a combined majority energy end-use of heating for domestic water and spaces. Electric resistance is the current method of space and water heating due to the lack of fossil fuel availability.

Figure 1. Ocean view condo buildings on the grounds of the Inn at Otter Crest

The IOC condo buildings are divided into either four or eight condo units. Figure 1 shows the four and eight unit buildings, as well as the general property layout. IOC condo electricity usage is metered to groups of eight condo units, either per single eight unit building or per pair of adjacent four unit buildings. The utility charges for the property are divided evenly among condo owners, based on the total annual energy expenditure for the previous fiscal year.

Condo units vary in use and ownership. Some units are used as permanent residences while others are used periodically when the owner is visiting. Other units are divided into two sub-units and rented out through the IOC hotel service. Condo owners have complete control over all appliances, heaters, and thermostats within each condo, making blanket implementation of interior energy efficient improvements difficult. With the aforementioned limitations in mind, the Capstone team set out to identify feasible energy saving measures which satisfy the customer's criteria. This report contains proposed saving energy measures, evaluation of proposed energy saving measures, and the final design solution.

2
Mission Statement

The Capstone team will recommend energy efficiency and cost saving improvements to reduce the energy bill for the Otter Crest community. Energy savings will be evaluated through research and energy audit modeling. The metric for success is a reduction of the IOC energy bill by 20%, with the stipulation of a six year payback for any purchase. The project will be completed by June 5, 2015.

3
Main Design Requirements

The PDS criteria were established by the project sponsor, the IOC association of owners. The goal for project success is a net total 20% reduction in the electrical utility annual expenditure associated with property lodging buildings. The constraint for individual energy efficient improvements is a simple payback of 6 years or less. All energy efficiency considerations were measured against the PDS requirements and the feasibility of implementation.

4

Top Level Energy Efficiency Considerations

Domestic hot water, space heating, and a portion of lighting (exterior) were all investigated for potential energy savings. Figure 2 shows the energy consumption by end-use of an eight unit condo modeled by eQUEST. Miscellaneous equipment represents the so called ‘plug load’ electricity use, in other words all of the equipment and appliances which are plugged into a wall socket. All appliances and equipment internal to IOC condos are property of the respective condo owners, and as such miscellaneous equipment energy use would be difficult to reduce.

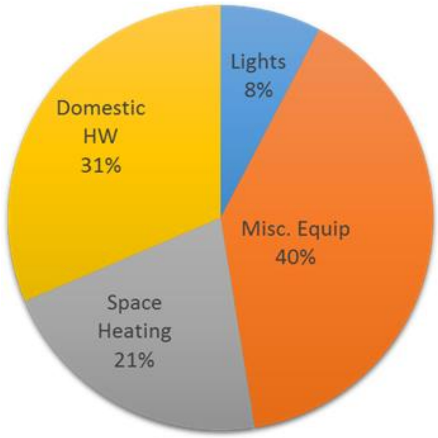


Figure 2. Energy consumption by end-use for an 8 unit condo, as modeled by eQUEST.

The energy efficiency measures which were considered may be split into two categories: exterior improvements (external to the privately owned space) and interior condo improvements. Exterior energy efficiency improvements have the advantage of being implemented by IOC management, whereas interior condo improvements require the consent of the respective private owner. For this reason, the Capstone team initially focused on exterior measures.

4.1 Exterior Considerations

Building Envelope

The Capstone team calculated the effective R value of exterior condo walls using a thermal imager to accurately obtain differential wall temperature measurements. The effective R value was determined to be approximately 12.5, a sufficient R value for a wood framed structure. The effective R value will be lower than the in-wall insulation R value due to thermal bridging of the wood frame. The windows had been upgraded in the early 2000’s from the original 1970’s construction. The Capstone team determined that building envelope properties are sufficient such that any further improvements would require a payback period in excess of the PDS criteria.

Exterior Lighting

The price of LED lighting has decreased in recent years due to advancements in manufacturing processes. Given the large number of exterior lighting fixtures on the IOC property, and the recent drop in LED bulb prices, exterior lighting was selected as a viable option for the final design.

Solar Panels

Climate information for the Oregon Coast revealed a total annual solar collection of 687.72 kWh per square meter. Including tax incentives and utility rebates, the initial cost of a photovoltaic (PV) system is estimated at $3,617,310. The high cost of the system coupled with the low solar collection gives a payback of 23 years, well outside the target payback period.

4.2 Interior Considerations

Air Source Heat Pumps

Without natural gas availability, all IOC space heating is currently performed by way of electric resistance. Primary space heating is performed by thermostat controlled electric baseboard heaters, with secondary heating by electric fan-forced wall heaters. Heat pumps offer a higher ratio of heating to electrical energy consumed than simple resistance heaters, and operate best in climates which rarely experience freezing weather such as the Oregon Coast. A heat pump's efficiency is discussed in terms of its coefficient of performance (COP) to help compare heat pumps with electrical resistance heaters. The COP is defined as the ratio of heating (or cooling) to the electrical energy consumed. It is true that electrical resistance heaters are 100% electrically efficient, in that all electricity is converted into heat. Electrical resistance heaters therefore have a COP of 1.0 (1 part heat produced for every 1 part of electric energy consumed). Heat pumps use electricity to power a refrigerant cycle which extracts heat from ambient air to produce more heat energy than electricity consumed. Typical COP values for heat pumps are 2.5 to 3.0 (2.5 parts heat produced for every 1 part of electric energy consumed). Heat pumps were considered for the final design.

Hybrid Water Heaters

Hybrid water heaters normally operate as a heat pump, but they also have backup resistance heating for instances of high hot water demand. Units are usually installed in garage sized areas as they require an installation space with at least 1,000 ft^3 of air around the water heater [1]. This means they cannot currently be used as direct replacements for IOC water heaters which are located in small hallway closets and lack air circulation.

Hot Water Recirculation System

Hot water recirculation saves water and energy by recirculating the standing water in hot water piping back to the heater until hot water reaches the point of use. The Capstone team decided against this option due to OSHA's hot-water system operating guidelines, which require that recirculation pumps be run continuously and be excluded from energy conservation measures [2]. The OSHA guideline is concerned with the growth of Legionella in hot water loops and is directed towards larger hot-water systems, however any hot water recirculation method may be subject to OSHA guidelines.

Tankless Water Heaters

Tankless heaters eliminate the stand-by loss associated with traditional tank water heaters. Eliminating stand-by loss would lower the electricity consumption for IOC domestic hot water. Tankless heaters were not considered for the final design due to a pay-back period well outside the PDS criteria. The payback period estimate is longest for meters which are charged for peak demand, such as the majority of IOC meters. Tankless heaters draw a large amount of electric current which would result in significant demand charges [3].

Occupancy-Responsive Adaptive Thermostat Control

So-called 'smart thermostats' offer a range of functions and leaning algorithms which attempt to reduce HVAC system energy use. One feature which may reduce space heating cost for IOC hotel units is a thermostat web network control which allows instant management of multiple thermostats from the front desk [4]. This system may be coupled with electronic room access, a feature not currently available at IOC. The IOC hotel staff are already in the practice of turning off space heating for vacant rooms to mitigate heating of unoccupied hotel spaces, therefore smart thermostats were not included in the final design.

5
Final Design

The mixed use of IOC condo units, property layout, and unavailability of fossil fuel each provided unique challenges to the final design. Only two of the energy efficiency considerations were found to be feasible and satisfy the PDS payback requirement: air source heat pumps and LED exterior lighting. Replacing resistance heaters with mini-split ductless heat pumps was found to reduce the annual electricity bill by 13.4%, with a payback period of 4.5 years when combined with available incentives, not including installation cost. Changing exterior lighting to LED from CFL was found to reduce the annual electricity bill by 0.7% with a payback period of 3.2 years. The combined annual utility savings for kWh consumption alone is 14%, 6% below the PDS target of a 20% reduced annual utility bill. Additional savings are possible with the reduced peak electricity demand of heat pumps. Energy modeling with eQUEST showed a 30-35% reduction in peak kW demand using heat pumps for space heating. A more detailed description of the final design measures is discussed in the following sections.

5.1 Mini-Split Ductless Heat Pumps

Research and client interviews revealed The IOC's heating system to be a vital consideration in the site's high energy use. We ultimately selected ductless mini-split heat pumps due to their high efficiency, low cost, and ease of installation. Further research indicated that mini-splits have the added benefit of distributing heat more efficiently than the currently installed electric baseboard heaters [5]. The heat-pump system consists of an exterior condenser connected, via a refrigerant line, to a number of evaporator units fixed to interior walls, as seen in Figure 3.

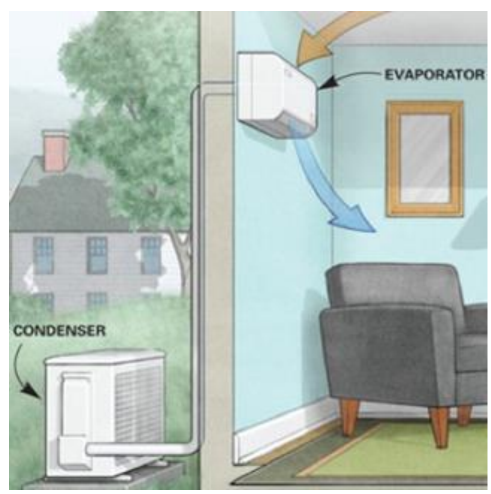


Figure 3: A typical mini-split ductless heat pump installation, shown with one evaporator.

The heating system was sized on the basis of peak heat loss, as outlined in 2013 ASHRAE Fundamentals. Under the “worst-case” assumption of no internal heat generation or solar gain, the peak heat loss (Q_H) is calculated as follows [6];

$$Q_H = U * A * \Delta T$$

where **U** is the thermal transmittance of the building envelope, **A** is the heat transfer area, and **∆T** is defined by the internal set-point temperature and the external design condition temperature. The UA value for the calculation was obtained from an energy signature inverse model of the worst-case building on the property. Worst-case, for this purpose, was defined by the 8-unit building with the highest heat-loss, or the highest UA value. The sloped-line of the inverse model, when multiplied by the average hours in a month (730 hrs) gives the UA for the heat loss calculation. For the internal-external temperature difference, the internal set-point was assumed to be 70^{o}F and the 99% heating dry-bulb temperature of 34.4^{o}F was used for the external temperature. The design heating load was calculated at 25kW, or 85,303 Btu/hr. We decided to be conservative and oversize the system slightly for a 100,000 BTU/hr. We recommend the installation of two 50,000 Btu/hr heat pumps per eight unit building, and one per 4 unit building.

5.2 LED Lighting

Light emitting diode (LED) bulbs provide an increase in savings, when compared to compact fluorescent bulbs (CFL), through increased efficiency and a longer life expectancy. A nine watt LED bulb will produce as much light as a 60-watt incandescent bulb, while a 14-watt CFL bulb is needed to produce the same amount of light. Although LED bulbs cost approximately three times as much as CFL, their average life expectancy is five times longer. One additional advantage for the use of LED bulbs is that they are more environmentally friendly than CFL bulbs which contain mercury.

6

Energy Modeling

The design process involved generating two different building energy models. The models identified potential energy savings and addressed the more complicated problem of utility demand charges. The first of these issues was addressed with an inverse modeling process, referred to as an energy signature model. The appeal of this modeling process is that it utilizes data which was readily available: average dry bulb temperature and utility bill data.

The process involves the plotting of monthly consumption data against monthly temperature data, and applying a piece-wise line fit. The model allowed us to separate the temperature independent base load from the temperature dependent load. The slope of the temperature dependent line fit, when multiplied by time, represents the UA portion of the heating equipment sizing calculation. The slope value is dependent upon the efficiency of the building's heating system. A new slope value is calculated from the efficiency of a new proposed heating system. We used the difference between the existing heating slope and the proposed heating slope to calculate the savings from heat pump installation. For more information regarding the inverse model, please see Appendix B.

The second model used was a detailed building simulation of an eight unit condo building in eQUEST. EQUEST energy simulations require a great deal of inputs, and for our purposes, a great deal of assumptions. By comparing the actual energy use of the building, obtained from Central Lincoln MyMeter data, to the eQUEST model energy simulation, we were able to calibrate the model to minimize error. One of the purposes of performing a detailed simulation was to evaluate the impact of the proposed heat pumps on the peak demand of the building. The IOC experiences considerable demand charges and interest in reducing them was expressly stated by our client. Peak demand was difficult to address outside of a building simulation on due to its dependence on occupant behavior, a variable for which data is limited. Through the eQuest model we were able to evaluate the demand-reducing potential of our proposed heating system. Please see the Appendix E for the detailed output from the eQUEST model energy simulation.

7
Cost Analysis

The first step in performing an effective utility cost analysis is to understand how utility charges are structured, information that is found in the utility rate schedule. The IOC property is considered a commercial residential site with two different metered rate schedules, 190 and 200. Utility rate schedules consists of up to three parts: basic charge, energy charge (kWh consumption), and demand charge (kW peak demand). The majority of IOC meters fall under schedule 200 and include a demand charge, while schedule 190 consists of only basic and consumption charges.

The basic charge is the flat monthly fee which is independent of electricity use. The energy charge is based on total electricity consumed, measured in kilowatt-hours (kWh), for a given rate. Schedule 200 has two different energy charge rates based on the consumption. For conservative estimates, we based our calculations on the higher rate of $0.0875/kWh. The demand charge, sometimes referred to as peak demand, is based on the highest average 15 minute interval of electrical power delivered during a billing period, measured in kilowatts (kW). Schedule 200 demand charges are incurred when peak demand exceeds 30 kW within a billing period. Each kW in excess of 30 kW for a given billing period is billed at $8.96/kW. A summary of the utility bill charges for all condo building meters is shown in Table 1.

Table 1. Summary of utility bill charges for 2014

Utility Bill Distribution 2014 (20 Meters)		
Category	**Total Charge**	**Percent of Total Bill**
Base Charge	$8,881.92	6.62%
Demand Charge	$19,157.91	14.27%
Energy Charge	$106,202.70	79.11%
Total	$134,242.53	100%

7.1 LED Lighting Cost Analysis

There were three main factors for the cost benefit of LED vs. CFL lighting: price, efficiency (watts per bulb), and life expectancy. To make the calculation straight forward, cost analysis was performed for 450 exterior light bulbs. A comparison of LED and CFL bulbs Is shown in Table 2.

Table 2. Summary of LED and CLF bulbs

Light Bulb Information				
Bulb Type	$/bulb	Watts/bulb	Life Expectancy (year)	Utility Cost (year)
CFL	$3.00	14	2.5	$6.18
LED	$10.00	9	7.5	$3.97

The initial investment is $4,500 to change all 450 bulbs assuming $10 per LED bulb. The energy charge savings for a complete changeover to LED lighting would be $994 annually (0.7% of the total), resulting in a simple payback of 3.2 years. With life expectancy five times that of CFL, LED's would continue to save more in subsequent years of operation. Figure 5 shows the simple payback of LED's in a 14 year investment period. The drop in savings in the seventh year accounts for the replacement for all 450 LED bulbs.

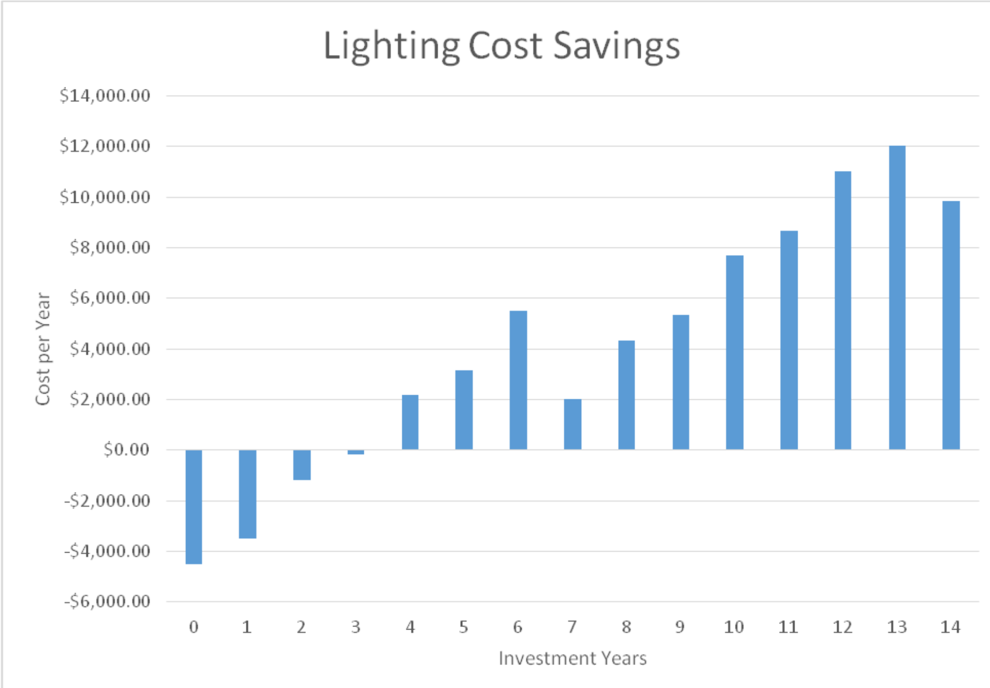


Figure 5. 14 year investment period for conversion of 450 CFL bulbs to LED.

7.2 Mini-Split Ductless Heat Pump Cost Analysis

The heat pump cost analysis focused on the 16 buildings with eight condo units. These buildings were selected for the cost analysis because all 16 buildings have a demand charge under rate schedule 200. The more efficient heating per kW of power offered by heat pumps would lower peak demand. Additionally, Central Lincoln PUD offers a $500 incentive per heat pump when installed to replace baseboard and fan-forced wall heaters. This would result in $16,000 saved for an installation of 32 heat pumps (16 buildings w/ 8 units, 1 50,000 BTU heat pump per 4 units). However, this incentive is only available if a pre-approved contractor performs the heat pump installation. All of the Central Lincoln PUD approved contractors have been screened to ensure they meet the district's requirements. Approved contractors know Central Lincoln will inspect heat pump systems installed under their program. Approved contractors also agree they will make any corrections necessary if installation problems are found during Central Lincoln’s inspection process. Please see the Central Lincoln PUD website for the heat pump rebate brochure.

Table 3 shows the initial investment to install 32 heat pumps is $80,000, not including the cost of installation by a Central Lincoln approved contractor. Heat pump energy savings was calculated using an energy signature model. Annual saving in energy consumption (kWh). The energy consumption applied to the flat utility rate gives the annual average saving of $1,121.12 per building and $17,937.92 for all 16 buildings. In comparing the amount saved to the 2014 utility bill the heat pump managed to save an annual of only 14.1 %. The simple payback was calculated from the initial investment divided by the annual saving of 4.5 year investment.

Table 3. Summary of heat pump initial investment

Summary of Heat Pump Cost				
Cost per Unit	Units per Building	16 building total cost	Incentive Value	Total Capital Cost
$3,000	2	$96,000.00	-$16,000.00	$80,000.00, plus installation*

*Installation must be performed by a Central Lincoln approved contractor to qualify for the rebate incentive.

8
Conclusion and Recommendations

The Capstone team was unable to prove through modeling and calculations that the final design will achieve the PDS goal of a 20% utility bill reduction annually. However, sufficient evidence was shown to suggest that additional peak demand savings are possible with heat pump space heating. Specifically, a 30-35% reduction in peak demand was shown by the eQUEST detailed model. Please see Appendix D for the modeled resistance heating and heat pump peak demand. Due to the peak demand charge criteria, not all of the reduced demand will be realized in the form of a lower utility bill, but it is a step in the right direction.

The ultimate goal of IOC energy efficiency upgrades should be to qualify as many buildings as possible for the lower rate schedule 190. If all IOC condo meters were charged under rate schedule 190 for the 2014 year, the Capstone team calculated the annual utility bill would be $87,000, a savings of 35% ($48,000) from the actual $135,000 annual bill. To qualify for rate schedule 190, a given meter must have a monthly billing demand of less than 31 kW for any 9 months out of a 12 month billing period.

Depending on occupant behavior, it may be possible for some condo meters to qualify for rate schedule 190 from a changeover to heat pump heating alone. Unfortunately, the Capstone team was unable to predict or model occupant behavior with enough certainty to quantify post heat pump installation peak demand.

8.1 Recommendations

Backup Heat

Heat pumps may experience difficulty generating sufficient heat during the rare times when outside temperatures drop to near freezing or below. During these times the heat pumps may rely on the built in baseboard heaters to provide backup heat. For this reason, it is recommended that the currently existing resistance heating remain installed in the condo buildings. This may present some efficiency loss if the residents and guests continue to use resistance heaters in lieu of the heat pumps, even under normal conditions. One possible method of mitigating this is to inform customers and residents that the IOC is attempting to be as green and sustainable as possible, and to please use the more efficient heat pumps for space heating before using electric heating.

Cooling

Heat pumps provide both heating and cooling capabilities. Energy savings and thus payback period were calculated based on the use of heat pumps for space heating only, and not summer cooling. It is recommended that heat pumps be disabled in the summer months to minimize the payback period. Even with cooling, eQUEST model results predict that heat pumps would use less energy annually than resistance heating alone, but the payback period is greatly increased if cooling energy is accounted for. Please see Appendix E for the eQUEST modeled annual energy comparison between current resistance heating, heat pump heating, and heat pump heating and cooling.

Hybrid Water Heaters and Future Peak Demand Reduction

Hybrid heat pump water heaters offer another avenue for reducing peak demand further. Hybrid heaters were not considered for the final design due to potential for significant structural changes to the water heater storage closets. As stated in the top level design considerations section, hybrid water heaters require a surrounding air volume of 1,000 ft^3. Depending on the recommendation from hybrid water heater manufacturers, it may be possible to modify the existing storage closets with the installation of a screen door and ventilation louvers.

With the proven savings and payback period of heat pumps, given the occupant behavior considerations, the Capstone team recommends first installing heat pumps for space heating. After a full year of heat pump operation, enough peak demand data would exist to make an informed decision regarding hybrid water heats. If heat pump space heating reduces peak demand sufficiently, it would be a safe assumption that hybrid water heaters would reduce peak demand even further, with the eventual goal of reducing the rate schedule for as many condo meters as possible.

References

[1] https://smartwaterheat.org/sites/default/files/hpwh_utility-customer-handout.pdf

[2] https://www.osha.gov/dts/osta/otm/legionnaires/hotwater.html

[3] https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/ElectricTanklessCompetitiveAssessment.pdf

[4] J.Woolley, M. Pritoni, and M. Modera.“Why Occupancy-Responsive Adaptive Thermostats Do Not Always Save -and the Limits for When They Should.” (2014).

[5] Engelmann, P., K. Roth, and V. Tiefenbeck. "Comfort, Indoor Air Quality, and Energy Consumption in Low Energy Homes." (2013): 20. Web. 3 June 2015

[6] Kissock, Franc Sever Kelly, PE Dan Brown, and PE Steve Mulqueen. "Estimating Industrial Building Energy Savings using Inverse Simulation." (2011).

Appendix A. Central Lincoln PUN rate schedules

CENTRAL LINCOLN PEOPLE'S UTILITY DISTRICT

SCHEDULE 200 - GENERAL SERVICE (LARGE)

AVAILABLE:
Throughout our service area in Lincoln, Lane, Douglas and Coos Counties.

APPLICABLE TO:
Commercial/Industrial uses having a monthly billing demand of 31 kilowatts or larger during at least 4 months of the most recent 12-month billing period.

CHARACTER OF SERVICE:
Alternating current, sixty-hertz, 120/240 volts nominal, single-phase or if available at the point of delivery, three-phase or other voltages when approved by Central Lincoln.

POINT OF DELIVERY:
Service to a single contiguous property will normally be provided at one point of delivery and through one meter. However, at our option, service may be provided at more than one point of delivery on contiguous property. In such case, each point of delivery will be considered as a separate account and will be individually metered and charged.

MONTHLY RATE

Basic Charge:	$40.01 Per Month, *PLUS*
Demand Charge:	First 30 KW-No Charge Balance: $8.96 per month per KW of Billing Demand,
Energy Charge: *For less than 25 KW*	KW x 200 KWH = Calculated KWH Calculated KWH @ 8.74¢ KWH - Calc. KWH = Balance @ 3.75¢ per KWH, *OR*
Energy Charge: *For 25 KW or more*	First 5,000 KWH @ 8.74¢ Balance KWH @ 3.75¢

BILLING DEMAND:
Billing demand is the highest average kilowatts delivered within any 15-minute period during the billing month.

POWER FACTOR:
Power factor will be measured at the discretion of Central Lincoln. Billing Demand will be increased by one percent (1%) for each percent the customer's power factor is less than 95% lagging.

TAX ADJUSTMENTS:
Bills may be increased in the communities or areas where taxes or assessments are imposed by any governmental authority. *(Such taxes may be assessed on the basis of meters, or customers, or the price of or revenue from electric energy or service sold, or the power or energy generated, transmitted, purchased for sale, or sold.)* Any such increase will continue in effect only for the duration of such taxes and assessments.

MINIMUM CHARGE:
$40.01 per meter per month unless a higher minimum is established by contract.

RULES AND REGULATIONS::
Service under this schedule is subject to the District's Rules, Regulations and Practices on file and available at the offices of Central Lincoln.

Adopted:	September 22, 2010
Effective:	October 1, 2010
Cancels:	Schedule 200 Adopted September 23, 2009 (Res. 853)
Resolution:	861

CENTRAL LINCOLN PEOPLE'S UTILITY DISTRICT

SCHEDULE 190 – SMALL GENERAL SERVICE

AVAILABLE:
Throughout our service area in Lincoln, Lane, Douglas, and Coos Counties.

APPLICABLE TO:
Commercial uses having a monthly billing demand of less than 31 kilowatts during any 9 months of the most recent 12-month billing period.

CHARACTER OF SERVICE:
Alternating current, sixty-hertz 120/240 volts nominal, single-phase or, if available at the point of delivery, three-phase when approved by Central Lincoln.

POINT OF DELIVERY:
Service to a single contiguous property will normally be provided at one point of delivery and through one meter. However, at the option of Central Lincoln, service may be provided at more than one point of delivery on contiguous property. In such case, each point of delivery will be considered as a separate account and will be individually metered and charged.

RATE

Basic Charge:	$25.00 per month, PLUS
Energy Charge:	All kilowatt hours (KWH) at 6.45¢ per KWH

MINIMUM CHARGE:
$25.00 per meter per month unless a higher minimum is established by contract.

TAX ADJUSTMENT:
Bills may be increased in the communities or areas where taxes or assessments are imposed by any governmental authority. *(Such taxes may be assessed on the basis of meter, or customers, or the price of or revenue from electric energy or service sold, or the power or energy generated, transmitted, purchased for sale, or sold.)* Any such increase will continue in effect only for the duration of such taxes and assessments.

RULES AND REGULATIONS:
Service under this schedule is subject to the District's Rules, Regulations and Practices, on file and available at the offices of Central Lincoln.

Adopted:	June 25, 2014
Effective:	July 1, 2014
Cancels:	Schedule 190 Adopted September 22, 2010 (Res. 861)
Resolution:	878

Appendix B. Heat pump modeling

Final Report Heat Pump Section

To understand how we got the paybacks for heat pumps, one needs to understand the scientific method used. Below, there is a quick overview of Inverse modeling.

Inverse Modeling

Inverse modeling is done by estimate the energy savings from retrofitting the existing building systems. This model is accomplished by developing a simulation model which consists of multiple stages, running model with actual weather data, calibrating the model to actual energy use data, modifying the model to include the proposed changes and running the base and proposed models with typical meteorological year weather data to estimate energy savings.

Simulation Model

In order to get a simulation or base model, the energy consumption records for previous year and temperature averages for the same year are obtained. These data are then calibrated and important information is extracted such as the heating slope, weather-independent energy consumption and heating change-point temperature.

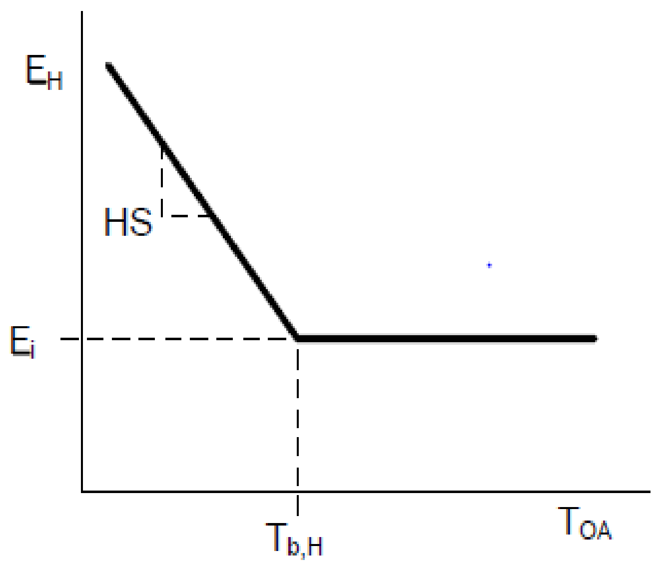


Figure 1. Represents the energy consumption as function of temperature.

The graphical representation of the energy consumption as function of temperature is shown in figure 1, where E_i is weather-independent energy consumption, E_H is heating energy, $T_{b,H}$ is heating change-point temperature, T_{OA} is outside air temperature and HS is heating slope.

The mathematical representation of the inverse model is a piecewise function:

$$E = E_i + HS(T_{b,H} - T_{OA})^+$$

$$\frac{HS_P}{HS_C} = \frac{\eta_C}{\eta_P}$$

Where subscripts p and c show proposed and current.

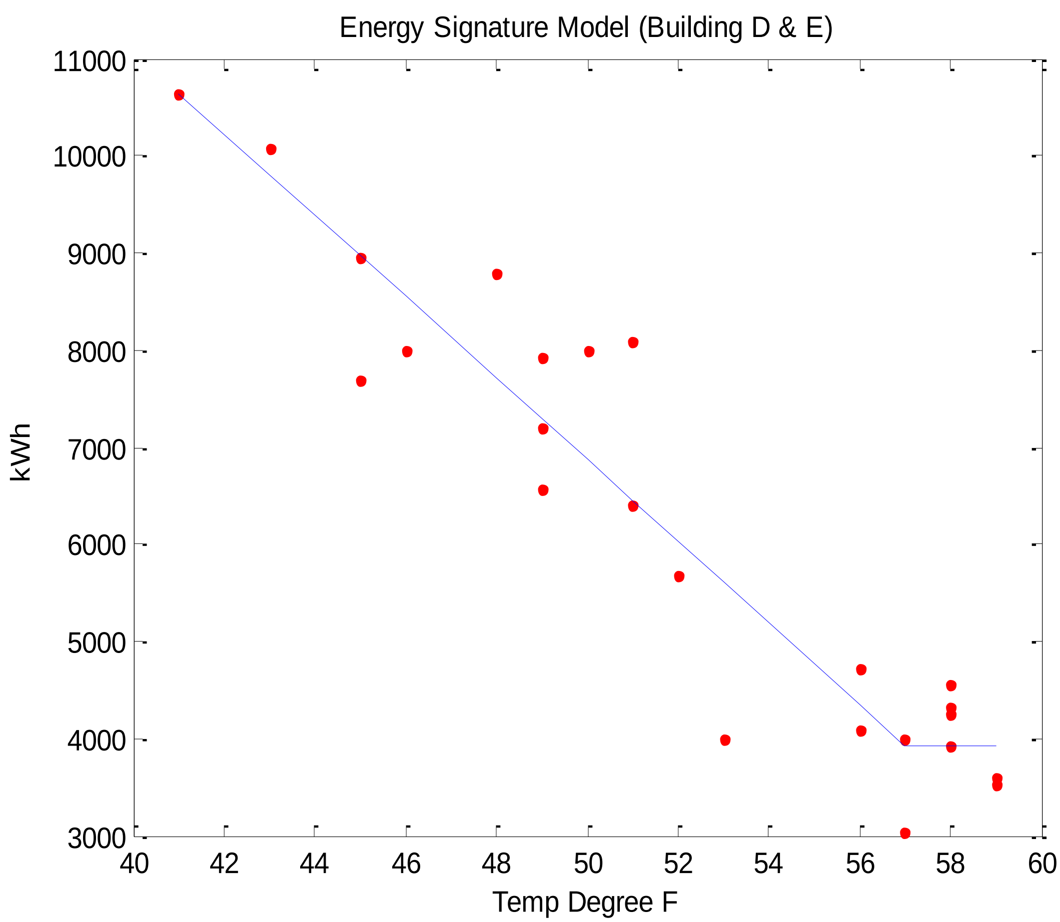


Figure 2. Represents actual energy signature model.

Using MatLab and calibrating the model to actual energy use data for previous year and temperature averages for the same year, the base models for all buildings are obtained. Figure 2 show as an example the base model for buildings D and E, very similar graphs were obtained for other buildings.

Modified Model

The modified model is based on changing the heating system, where baseboard heaters were proposed to replace with heat pumps which are well known to have high efficiency.

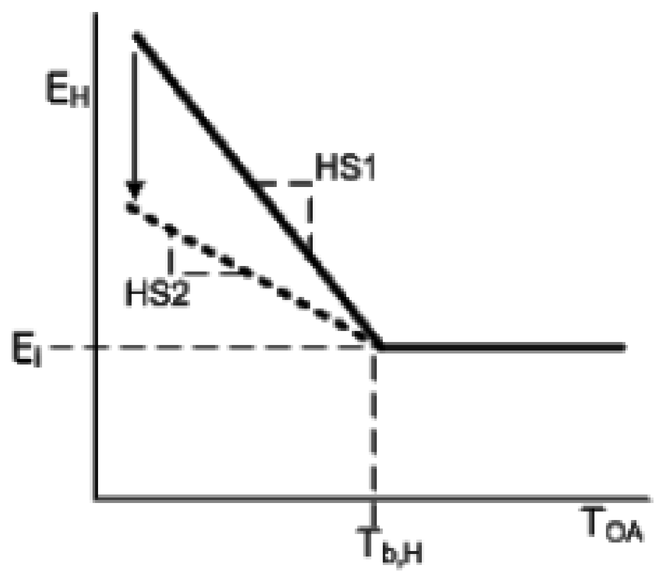


Figure 3. Represents the effects of the heating system modification.

Changing the heating system to more efficient one will cause the slope of the model to decrease as is shown in figure 3, where it can be seen that with the drop of the outdoor temperature the energy consumption is not going to jump as before.

$$E_P = E_i + HS_P(T_{b,H} - T_{TMY})^+$$

$$HS_P = HS_C \frac{\eta_C}{\eta_P}$$

This is the modified energy consumption model based on the change of the heating system, where E_P is proposed energy consumption and T_{TMY} is the typical meteorological year, which is basically a collation of selected weather data for a specific location, generated from a data bank much longer than a year in duration.

Energy Savings

The energy savings are calculated as the monthly sum of the differences between baseline model and modified or proposed model.

$$E_{Savings} = \sum [HS_{Base}(T_{b,H} - T_{OA}) - HS_{Proposed}(T_{b,H} - T_{TMY})]$$

Results

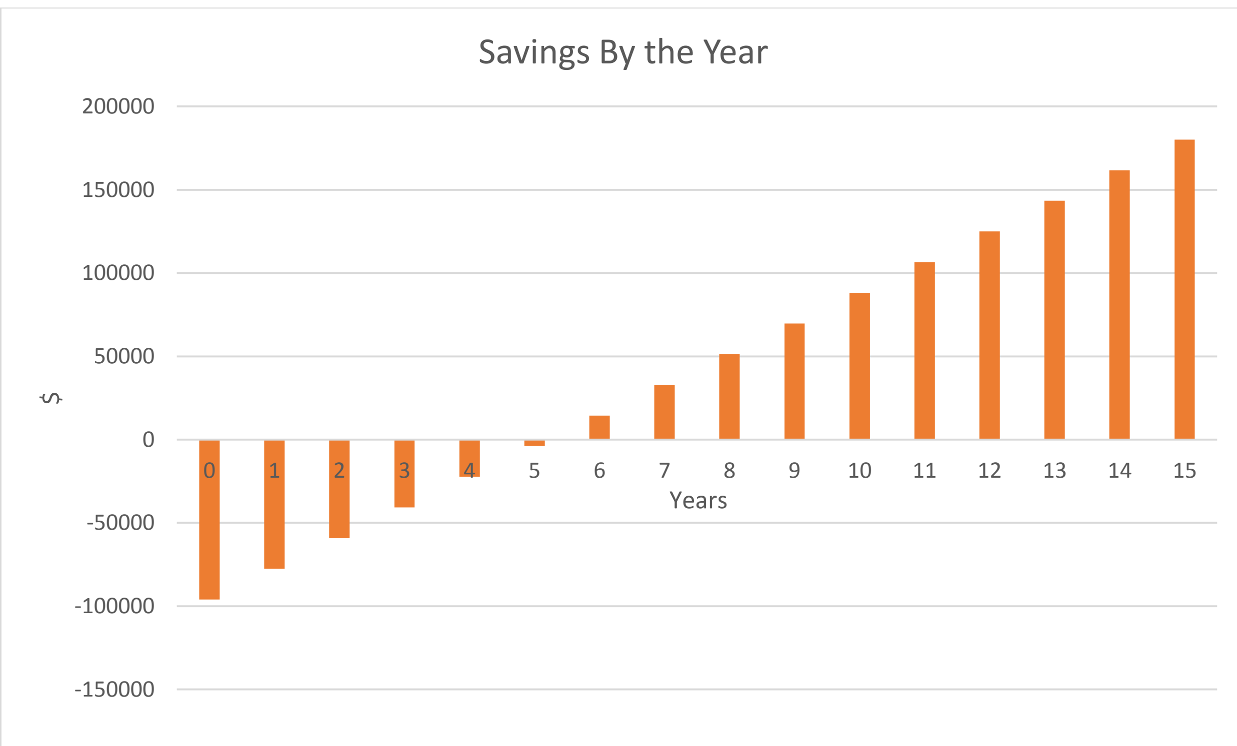
Here is the final results with the following inputs and assumptions;

1. Efficiency: 3.1 (COP)
2. Energy Price: $0.1/kWh
3. Capital Costs: $6000/per 8 unit
4. Simple Payback does not factor in Present Value, Interest etc.

Results for All Buildings:

Simple Payback (Years)	Energy Reduction in a Year (%)	Energy Savings in a Year ($)
5.21	16.3	18411

Years	Savings By the Year ($)
0	-96000
1	-77589
2	-59177
3	-40766
4	-22355
5	-3943
6	14468
7	32880
8	51291
9	69702
10	88114
11	106525
12	124936
13	143348
14	161759
15	180170



Results for Individual Buildings:

	Buildings	Simple Payback (Years)	Energy Savings in a Year ($)
Residental	K	4.40	1363
	B	4.62	1298
	H&G	4.77	1258
	O&P	4.99	1203
	F	4.53	1325
	R&Q	5.59	1073
Mixed	I	6.36	944
	A	6.14	977
	M	5.82	1032
	U	5.34	1123
	S&T	6.18	972
	Y&Z	6.26	959
Hotel	W&X	5.79	1036
	C	4.09	1469
	J	6.45	931
	D&E	4.14	1451

	Buildings	Energy Reduction in a Year (%)
Residental	K	17.3
	B	21.2
	H&G	16.0
	O&P	18.0
	F	13.7
	R&Q	17.4
Mixed	I	13.4
	A	15.4
	M	16.1
	U	15.0
	S&T	15.1
	Y&Z	15.4
Hotel	W&X	15.6
	C	18.6
	J	14.5
	D&E	19.7

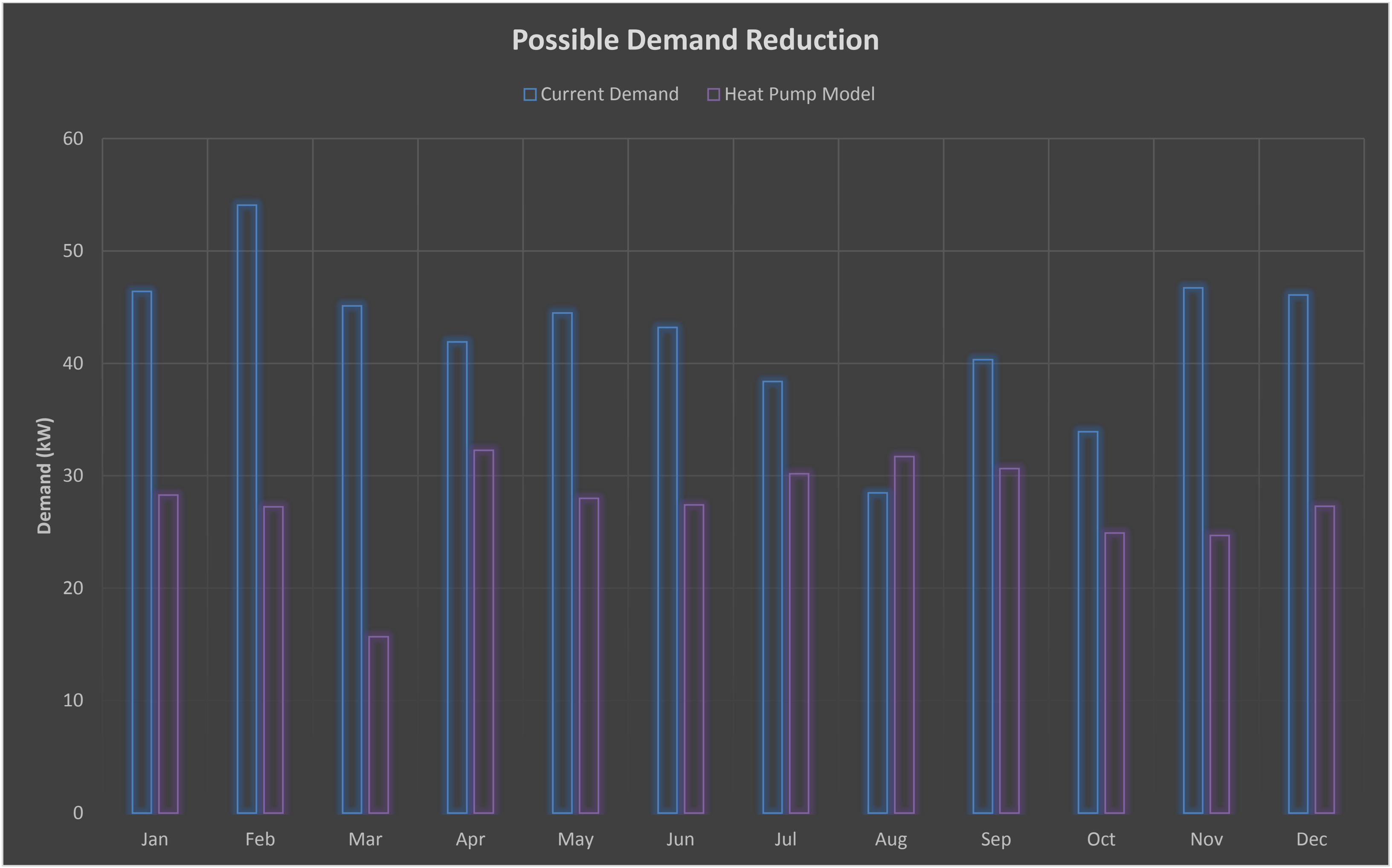
References:

Estimating industrial building energy savings using inverse simulation by Franc Sever, Kelly Kissock Phd, PE, Dan Brown PE, Steve Mulqueen, 2001 ASHRAE.

Appendix C. Annual kWh usage by building.

	Total kWH by meter for 2012 - 2014							
Unit	**BLDG**	2012	2013	2014		Total kWh		Average per unit
4	L	34240	34000	24240		92480		23120
4	V	36800	32880	24080		93760		23440
8	B	69440	73040	50880		193360		24170
8	J	67600	71840	55200		194640		24330
8	M	73440	70400	54000		197840		24730
4&4	S&T	77120	68880	53440		199440		24930
8	A	75040	73680	52560		201280		25160
4&4	Y&Z	74560	76240	51200		202000		25250
4&4	O&P	76560	76960	54400		207920		25990
4&4	R&Q	79440	78160	51200		208800		26100
4&4	W&X	79360	73920	56240		209520		26190
4	N	38480	38240	28240		104960		26240
4&4	D&E	78800	74000	60560		213360		26670
8	I	81200	81120	60000		222320		27790
8	U	81840	86720	62480		231040		28880
8	C	84240	87200	66320		237760		29720
8	K	93120	85600	64720		243440		30430
8	F	96880	96480	75360		268720		33590
4&4	H&G	105120	101120	66320		272560		34070
Model Home	AA	62720	48000	34680		145400		48467

Appendix D. Potential peak demand reduction.



Appendix E. eQuest energy model reports.

Inn at otter crest 2 DOE-2.2-48r 5/31/2015 15:05:10 BDL RUN 4

REPORT- BEPS Building Energy Performance WEATHER FILE- Salem OR TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	24.0	0.0	130.5	69.4	0.0	0.0	0.0	0.9	0.0	0.0	98.4	6.2	329.4
FM1 NATURAL-GAS MBTU	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
MBTU	24.0	0.0	130.5	69.4	0.0	0.0	0.0	0.9	0.0	0.0	98.4	6.2	329.4

TOTAL SITE ENERGY 329.40 MBTU 41.8 KBTU/SQFT-YR GROSS-AREA 41.8 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 988.19 MBTU 125.4 KBTU/SQFT-YR GROSS-AREA 125.4 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.38
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 18

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Figure E1. Baseline BEPS report

Inn at otter crest 2 DOE-2.2-48r 5/31/2015 15:05:10 BDL RUN 4

REPORT- PS-F Energy End-Use Summary for EM1 WEATHER FILE- Salem OR TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
JAN													
KWH	611.	0.	2422.	6343.	0.	0.	0.	82.	0.	0.	1956.	154.	11566.
MAX KW	2.270	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	7.176	0.433	50.979
DAY/HR	3/18	0/ 0	2/18	6/18	0/ 0	0/ 0	0/ 0	6/18	0/ 0	0/ 0	10/15	1/ 1	8/18
PEAK ENDUSE	0.142	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	6.347	0.241	
PEAK PCT	**0.3**	**0.0**	**9.6**	**76.3**	**0.0**	**0.0**	**0.0**	**1.0**	**0.0**	**0.0**	**12.4**	**0.5**	
FEB													
KWH	541.	0.	2195.	3673.	0.	0.	0.	47.	0.	0.	1800.	139.	8394.
MAX KW	2.270	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	7.405	0.433	46.026
DAY/HR	1/18	0/ 0	2/18	5/ 1	0/ 0	0/ 0	0/ 0	5/ 1	0/ 0	0/ 0	8/16	1/ 1	6/18
PEAK ENDUSE	0.000	0.000	4.874	33.934	0.000	0.000	0.000	0.437	0.000	0.000	6.541	0.241	
PEAK PCT	0.0	0.0	10.6	73.7	0.0	0.0	0.0	0.9	0.0	0.0	14.2	0.5	
MAR													
KWH	604.	0.	2425.	1559.	0.	0.	0.	20.	0.	0.	2023.	154.	6784.
MAX KW	2.270	0.000	5.719	16.773	0.000	0.000	0.000	0.216	0.000	0.000	7.419	0.433	24.106
DAY/HR	1/18	0/ 0	31/ 1	14/ 8	0/ 0	0/ 0	0/ 0	14/ 8	0/ 0	0/ 0	21/15	1/ 1	20/ 7
PEAK ENDUSE	1.192	0.000	3.990	11.126	0.000	0.000	0.000	0.143	0.000	0.000	7.414	0.241	
PEAK PCT	4.9	0.0	16.6	46.2	0.0	0.0	0.0	0.6	0.0	0.0	30.8	1.0	
APR													
KWH	551.	0.	3688.	42.	0.	0.	0.	1.	0.	0.	3157.	149.	7586.
MAX KW	2.270	0.000	18.066	5.171	0.000	0.000	0.000	0.067	0.000	0.000	13.017	0.433	31.462
DAY/HR	**4/18**	**0/ 0**	**4/18**	**2/ 6**	**0/ 0**	**0/ 0**	**0/ 0**	**2/ 6**	**0/ 0**	**0/ 0**	**2/ 7**	**1/19**	4/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.886	0.241	
PEAK PCT	7.2	0.0	57.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.6	0.8	
MAY													
KWH	636.	0.	3908.	3.	0.	0.	0.	0.	0.	0.	3120.	154.	7821.
MAX KW	2.270	0.000	18.066	0.937	0.000	0.000	0.000	0.012	0.000	0.000	12.205	0.433	30.757
DAY/HR	2/18	0/ 0	2/18	1/ 5	0/ 0	0/ 0	0/ 0	1/ 5	0/ 0	0/ 0	1/ 7	1/19	2/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.181	0.241	
PEAK PCT	7.4	0.0	58.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	0.8	
JUN													
KWH	564.	0.	3648.	0.	0.	0.	0.	0.	0.	0.	2837.	149.	7199.
MAX KW	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.367	0.433	30.066
DAY/HR	6/18	0/ 0	6/18	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	12/ 7	1/19	13/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.490	0.241	
PEAK PCT	7.6	0.0	60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.6	0.8	
JUL													
KWH	568.	0.	3822.	0.	0.	0.	0.	0.	0.	0.	2642.	154.	**7186.**
MAX KW	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.648	0.433	29.471
DAY/HR	4/18	0/ 0	4/18	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	14/ 7	1/19	11/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.894	0.241	
PEAK PCT	7.7	0.0	61.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.2	0.8	
AUG													
KWH	632.	0.	3867.	0.	0.	0.	0.	0.	0.	0.	2628.	154.	7280.
MAX KW	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.225	0.433	29.099
DAY/HR	1/18	0/ 0	1/18	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	20/ 7	1/19	22/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.523	0.241	
PEAK PCT	7.8	0.0	62.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3	0.8	

Inn at otter crest 2 DOE-2.2-48r 5/31/2015 15:05:10 BDL RUN 4

REPORT- PS-F Energy End-Use Summary for EM1 WEATHER FILE- Salem OR TMY2

(CONTINUED)--------

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
SEP													
KWH	554.	0.	3726.	0.	0.	0.	0.	0.	0.	0.	2442.	149.	6871.
MAX KW	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.194	0.433	29.100
DAY/HR	5/18	0/ 0	5/18	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	0/ 0	21/ 7	1/19	19/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.523	0.241	
PEAK PCT	7.8	0.0	62.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.3	0.8	
OCT													
KWH	609.	0.	3761.	121.	0.	0.	0.	2.	0.	0.	2706.	154.	7352.
MAX KW	2.270	0.000	18.066	8.683	0.000	0.000	0.000	0.112	0.000	0.000	10.587	0.433	29.423
DAY/HR	3/18	0/ 0	3/18	28/ 1	0/ 0	0/ 0	0/ 0	28/ 1	0/ 0	0/ 0	29/ 7	1/19	24/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.847	0.241	
PEAK PCT	7.7	0.0	61.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.1	0.8	
NOV													
KWH	611.	0.	2325.	3633.	0.	0.	0.	47.	0.	0.	1704.	149.	8468.
MAX KW	2.270	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	6.339	0.433	49.479
DAY/HR	1/18	0/ 0	2/18	19/ 1	0/ 0	0/ 0	0/ 0	19/ 1	0/ 0	0/ 0	29/16	1/ 1	19/18
PEAK ENDUSE	0.142	0.000	4.874	38.126	0.000	0.000	0.000	0.491	0.000	0.000	5.606	0.241	
PEAK PCT	0.3	0.0	9.9	77.1	0.0	0.0	0.0	1.0	0.0	0.0	11.3	0.5	
DEC													
KWH	567.	0.	2442.	4974.	0.	0.	0.	64.	0.	0.	1805.	154.	10005.
MAX KW	2.270	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	6.775	0.433	50.385
DAY/HR	5/18	0/ 0	1/18	31/ 1	0/ 0	0/ 0	0/ 0	31/ 1	0/ 0	0/ 0	12/15	1/ 1	11/18
PEAK ENDUSE	0.000	0.000	4.874	38.783	0.000	0.000	0.000	0.499	0.000	0.000	5.988	0.241	
PEAK PCT	0.0	0.0	9.7	77.0	0.0	0.0	0.0	1.0	0.0	0.0	11.9	0.5	
========	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	
KWH	7047.	0.	38229.	20347.	0.	0.	0.	262.	0.	0.	28820.	1808.	96513.
MAX KW	2.270	0.000	18.066	38.875	0.000	0.000	0.000	0.500	0.000	0.000	13.017	0.433	50.979
MON/DY	1/ 3	0/ 0	4/ 4	1/ 6	0/ 0	0/ 0	0/ 0	1/ 6	0/ 0	0/ 0	4/ 2	1/ 1	1/ 8
PEAK ENDUSE	0.142	0.000	4.874	38.875	0.000	0.000	0.000	0.500	0.000	0.000	6.347	0.241	
PEAK PCT	0.3	0.0	9.6	76.3	0.0	0.0	0.0	1.0	0.0	0.0	12.4	0.5	

YEARLY TRANSFORMER LOSSES = 0.0 KWH

Figure E2. Baseline PS-F Energy End-Use Summary. End-Use monthly energy consumption and demand.

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Inn at otter crest 2                                                    DOE-2.2-48r   5/31/2015    15:31:04  BDL RUN
5

REPORT- BEPS Building Energy Performance                                        WEATHER FILE- Salem       OR TMY2
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                        TASK     MISC    SPACE    SPACE     HEAT    PUMPS     VENT    REFRIG  HT PUMP  DOMEST     EXT
              LIGHTS  LIGHTS    EQUIP  HEATING  COOLING   REJECT    & AUX     FANS   DISPLAY  SUPPLEM  HOT WTR   USAGE
TOTAL
             -------  -------  -------  -------  -------  -------  -------  -------  -------  -------  -------  -------
--------

EM1  ELECTRICITY
    MBTU        24.0      0.0    130.5     16.0     25.6      0.0      0.0      2.8      0.0      0.2     98.6      6.2
304.0

FM1  NATURAL-GAS
    MBTU         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
             ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
========

    MBTU        24.0      0.0    130.5     16.0     25.6      0.0      0.0      2.8      0.0      0.2     98.6      6.2
304.0


                 TOTAL SITE ENERGY      304.02 MBTU     38.6 KBTU/SQFT-YR GROSS-AREA     38.6 KBTU/SQFT-YR NET-AREA
                 TOTAL SOURCE ENERGY    912.06 MBTU    115.7 KBTU/SQFT-YR GROSS-AREA    115.7 KBTU/SQFT-YR NET-AREA

                 PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  1.01
                 PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.00
                 HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE                =    48
                 HOURS ANY ZONE BELOW HEATING THROTTLING RANGE                =     0

                 NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Figure E3. Heat pump model with cooling BEPS report.

Inn at otter crest 2 DOE-2.2-48r 5/31/2015 15:31:04 BDL RI 5

REPORT- PS-F Energy End-Use Summary for EM1 WEATHER FILE- Salem OR TM

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
JAN													
KWH	611.	0.	2422.	1190.	0.	0.	0.	88.	0.	9.	1955.	154.	6428.
MAX KW	2.270	0.000	4.874	15.299	0.000	0.000	0.000	1.401	0.000	1.197	7.175	0.433	28.293
DAY/HR	3/18	0/ 0	2/18	22/18	0/ 0	0/ 0	0/ 0	22/18	0/ 0	20/18	10/15	1/ 1	22/18
PEAK ENDUSE	0.142	0.000	4.874	15.299	0.000	0.000	0.000	1.401	0.000	0.000	6.337	0.241	
PEAK PCT	0.5	0.0	17.2	54.1	0.0	0.0	0.0	5.0	0.0	0.0	22.4	0.9	
FEB													
KWH	541.	0.	2195.	770.	0.	0.	0.	47.	0.	14.	1800.	139.	5506.
MAX KW	2.270	0.000	4.874	21.556	0.000	0.000	0.000	1.011	0.000	1.964	7.405	0.433	27.250
DAY/HR	1/18	0/ 0	2/18	5/ 1	0/ 0	0/ 0	0/ 0	5/18	0/ 0	5/ 1	8/16	1/ 1	5/ 1
PEAK ENDUSE	0.142	0.000	2.167	21.556	0.000	0.000	0.000	0.261	0.000	1.964	0.728	0.433	
PEAK PCT	0.5	0.0	8.0	79.1	0.0	0.0	0.0	1.0	0.0	7.2	2.7	1.6	
MAR													
KWH	604.	0.	2425.	558.	22.	0.	0.	23.	0.	12.	2023.	154.	5819.
MAX KW	2.270	0.000	5.719	7.932	4.525	0.000	0.000	0.376	0.000	0.550	7.419	0.433	20.214
DAY/HR	1/18	0/ 0	31/ 1	21/ 8	28/19	0/ 0	0/ 0	18/ 1	0/ 0	21/ 8	21/15	1/ 1	12/ 7
PEAK ENDUSE	1.016	0.000	3.990	7.040	0.000	0.000	0.000	0.064	0.000	0.450	7.414	0.241	
PEAK PCT	5.0	0.0	19.7	34.8	0.0	0.0	0.0	0.3	0.0	2.2	36.7	1.2	
APR													
KWH	551.	0.	3690.	9.	217.	0.	0.	13.	0.	0.	3159.	149.	7788.
MAX KW	2.270	0.000	18.066	4.498	12.026	0.000	0.000	0.846	0.000	0.214	13.017	0.433	44.293
DAY/HR	4/18	0/ 0	4/18	2/ 4	18/18	0/ 0	0/ 0	28/18	0/ 0	2/ 4	2/ 7	1/19	18/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	12.026	0.000	0.000	0.832	0.000	0.000	10.859	0.241	
PEAK PCT	5.1	0.0	40.8	0.0	27.1	0.0	0.0	1.9	0.0	0.0	24.5	0.5	
MAY													
KWH	636.	0.	3910.	8.	790.	0.	0.	51.	0.	0.	3127.	154.	8674.
MAX KW	2.270	0.000	18.066	1.990	19.434	0.000	0.000	2.292	0.000	0.000	12.207	0.433	47.717
DAY/HR	2/18	0/ 0	2/18	1/ 5	19/18	0/ 0	0/ 0	19/18	0/ 0	0/ 0	1/ 7	1/19	30/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	15.726	0.000	0.000	1.232	0.000	0.000	10.183	0.241	
PEAK PCT	4.8	0.0	37.9	0.0	33.0	0.0	0.0	2.6	0.0	0.0	21.3	0.5	
JUN													
KWH	564.	0.	3651.	0.	1258.	0.	0.	84.	0.	0.	2851.	149.	8556.
MAX KW	2.270	0.000	18.066	0.000	20.212	0.000	0.000	2.430	0.000	0.000	11.375	0.433	47.628
DAY/HR	6/18	0/ 0	6/18	0/ 0	18/19	0/ 0	0/ 0	16/18	0/ 0	0/ 0	12/ 7	1/19	20/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	16.289	0.000	0.000	1.252	0.000	0.000	9.510	0.241	
PEAK PCT	4.8	0.0	37.9	0.0	34.2	0.0	0.0	2.6	0.0	0.0	20.0	0.5	
JUL													
KWH	568.	0.	3824.	0.	2063.	0.	0.	153.	0.	0.	2665.	154.	9427.
MAX KW	2.270	0.000	18.066	0.000	24.781	0.000	0.000	2.585	0.000	0.000	10.669	0.433	54.966
DAY/HR	4/18	0/ 0	4/18	0/ 0	23/19	0/ 0	0/ 0	9/18	0/ 0	0/ 0	14/ 7	1/19	18/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	23.191	0.000	0.000	2.275	0.000	0.000	8.923	0.241	
PEAK PCT	4.1	0.0	32.9	0.0	42.2	0.0	0.0	4.1	0.0	0.0	16.2	0.4	
AUG													
KWH	632.	0.	3869.	0.	2054.	0.	0.	157.	0.	0.	2651.	154.	9516.
MAX KW	2.270	0.000	18.066	0.000	27.281	0.000	0.000	2.585	0.000	0.000	10.236	0.433	58.985
DAY/HR	1/18	0/ 0	1/18	0/ 0	1/18	0/ 0	0/ 0	3/18	0/ 0	0/ 0	20/ 7	1/19	1/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	27.281	0.000	0.000	2.579	0.000	0.000	8.548	0.241	
PEAK PCT	3.8	0.0	30.6	0.0	46.3	0.0	0.0	4.4	0.0	0.0	14.5	0.4	
(CONTINUED)													
SEP													
KWH	554.	0.	3728.	0.	901.	0.	0.	63.	0.	0.	2453.	149.	7847.
MAX KW	2.270	0.000	18.066	0.000	21.487	0.000	0.000	2.578	0.000	0.000	10.199	0.433	52.130
DAY/HR	5/18	0/ 0	5/18	0/ 0	10/19	0/ 0	0/ 0	5/17	0/ 0	0/ 0	22/ 7	1/19	5/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	20.812	0.000	0.000	2.216	0.000	0.000	8.526	0.241	
PEAK PCT	4.4	0.0	34.7	0.0	39.9	0.0	0.0	4.3	0.0	0.0	16.4	0.5	
OCT													
KWH	609.	0.	3763.	95.	208.	0.	0.	15.	0.	0.	2708.	154.	7552.
MAX KW	2.270	0.000	18.066	5.459	14.462	0.000	0.000	1.395	0.000	0.000	10.587	0.433	39.367
DAY/HR	3/18	0/ 0	3/18	28/ 1	6/18	0/ 0	0/ 0	6/18	0/ 0	0/ 0	29/ 7	1/19	3/18
PEAK ENDUSE	2.270	0.000	18.066	0.000	9.389	0.000	0.000	0.575	0.000	0.000	8.827	0.241	
PEAK PCT	5.8	0.0	45.9	0.0	23.8	0.0	0.0	1.5	0.0	0.0	22.4	0.6	
NOV													
KWH	611.	0.	2325.	956.	0.	0.	0.	51.	0.	12.	1704.	149.	5808.
MAX KW	2.270	0.000	4.874	12.907	0.000	0.000	0.000	1.067	0.000	0.757	6.339	0.433	24.690
DAY/HR	1/18	0/ 0	2/18	20/18	0/ 0	0/ 0	0/ 0	20/18	0/ 0	27/18	29/16	1/ 1	20/18
PEAK ENDUSE	0.000	0.000	4.874	12.907	0.000	0.000	0.000	1.067	0.000	0.000	5.602	0.241	
PEAK PCT	0.0	0.0	19.7	52.3	0.0	0.0	0.0	4.3	0.0	0.0	22.7	1.0	
DEC													
KWH	567.	0.	2442.	1109.	0.	0.	0.	68.	0.	12.	1805.	154.	6155.
MAX KW	2.270	0.000	4.874	14.698	0.000	0.000	0.000	1.353	0.000	0.791	6.775	0.433	27.281
DAY/HR	5/18	0/ 0	1/18	14/18	0/ 0	0/ 0	0/ 0	17/ 1	0/ 0	10/19	12/15	1/ 1	14/18
PEAK ENDUSE	0.142	0.000	4.874	14.698	0.000	0.000	0.000	1.341	0.000	0.000	5.985	0.241	
PEAK PCT	0.5	0.0	17.9	53.9	0.0	0.0	0.0	4.9	0.0	0.0	21.9	0.9	
TOTAL													
KWH	7047.	0.	38243.	4695.	7511.	0.	0.	813.	0.	60.	28900.	1808.	89078.
MAX KW	2.270	0.000	18.066	21.556	27.281	0.000	0.000	2.585	0.000	1.964	13.017	0.433	58.985
MON/DY	1/ 3	0/ 0	4/ 4	2/ 5	8/ 1	0/ 0	0/ 0	7/ 9	0/ 0	2/ 5	4/ 2	1/ 1	8/ 1
PEAK ENDUSE	2.270	0.000	18.066	0.000	27.281	0.000	0.000	2.579	0.000	0.000	8.548	0.241	
PEAK PCT	3.8	0.0	30.6	0.0	46.3	0.0	0.0	4.4	0.0	0.0	14.5	0.4	

YEARLY TRANSFORMER LOSSES = 0.0 KWH

Figure E4. Heat pump model with cooling Energy End-Use Summary. End-Use monthly energy consumption and demand.

Appendix F. Energy Outputs from eQuest model.

Monthly Energy Consumption in kWh				
Total	Actual Avg.	eQuest Baseline	HP with Cooling	HP w/o Cooling
Jan	11262	11566	6428	6428
Feb	8898	8394	5506	5506
Mar	9644	6784	5819	5797
Apr	9413	7586	7788	7571
May	6658	7821	8674	7884
Jun	6382	7199	8556	7298
Jul	5947	7186	9427	7364
Aug	5840	7280	9516	7462
Sep	5822	6871	7847	6946
Oct	5644	7352	7552	7344
Nov	7667	8468	5808	5808
Dec	9227	11718	6155	6155
Total	**92404**	**98225**	**89076**	**81563**

End-Use Energy Consumption		
End-use	Baseline	HP w/o Cooling
Lights	7047	7047
Misc. Equip	36479	36479
Space Heating	19424	3123
Vent Fans	250	1477
DHW	28828	28903
Ext. Usage	1808	1808
Total	93836	78837
Kwh saving	**14999**	**15.98%**