B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Packaged Terminal Heat Pumps and Room-Based Occupancy Sensors M&V

Best Western Peppertree Airport Inn

Spokane, WA

June 11, 2010

Funded by:

Bonneville Power Administration
Contact: Erik Boyer

Prepared by:

EMP2, Inc.

David Frank, PE

Contents

Executive Summary

The purpose of this analysis is to perform measurement and verification (M&V) on several standard hotel energy conservation measures (ECMs), which include packaged terminal heat pumps (PTHPs) and room-based occupancy sensors (OCS). Data was collected over a six month period at the Best Western Peppertree Airport Inn in Spokane, WA, to determine electrical savings by replacing a packaged terminal air conditioner (PTAC) (electric heat) with a PTHP with room-based occupancy sensors. Savings result from improved heating efficiency of the PTHP over the electric resistance PTAC unit, and savings also result from temperature setback during unoccupied periods using the occupancy sensors. The savings for both of these measures were found to be lower than expected due to current staff operating procedures. The main contributor to low ECM savings was that the staff manually turns the units off after each room cleaning. This analysis is unique in that energy savings vary based on the outside air temperature (OSA) rather than assuming a constant unit load based on operating mode throughout various OSA temperature ranges. Due to limited cooling data collection, minimal cooling energy usage and use of standard efficiency PTHP's the calculated cooling savings from the PTHP were found to be insignificant. Table 1.0 shows the verified yearly savings, based on metered data, for the Best Western Peppertree Airport Inn in Spokane, WA, by implementing the ECMs. The savings percentage from the baseline is estimated from the cooling and heating baseline load only, not the entire building energy consumption.

Table 1.0 Summary of Findings Best Western Peppertree Inn, Spokane, WA

Savings Analysis	Savings per Room per Year (kWh)	Total Savings for Hotel (kWh)	Savings Percentage from PTAC/PTHP Baseline (%)	Savings Percentage from Entire Hotel Baseline (%)
Savings from PTAC to PTHP	86	8,641	8%	1%
Savings from PTHP to PTHP w OCS	138	13,781	12%	2%
Savings from PTAC to PTHP w OCS	224	22,422	20%	4%

1.0 Background

BPA is interested in developing a deemed savings value for high efficiency PTHPs and room-based occupancy sensors. This is one of several hotels that will be used as a pilot project to verify energy savings through long term measurements. Long term measurements are needed to verify typical occupant behavior and staff operating procedures. The Best Western Peppertree Airport Inn (the Inn) is an 85,000 square foot (approximated), three story facility and has 100 guest rooms. Amana, the heating and air conditioning unit manufacturer, in conjunction with BPA and EMP2, was able to divide the facility into three groups. Each group consists of a specific type of heating and air conditioning equipment (PTAC or PTHP), and controls (manual controls or OCS). It was originally intended that each group would consist of 33 similar rooms, in order to compare room groups with similar orientation and amount of exterior areas.

After several months of data collection and review, it was apparent that some units were not installed as originally specified. EMP2 and BPA performed a room by room survey to verify the equipment installed in each room. It was found that the installation did not meet the intended distribution.

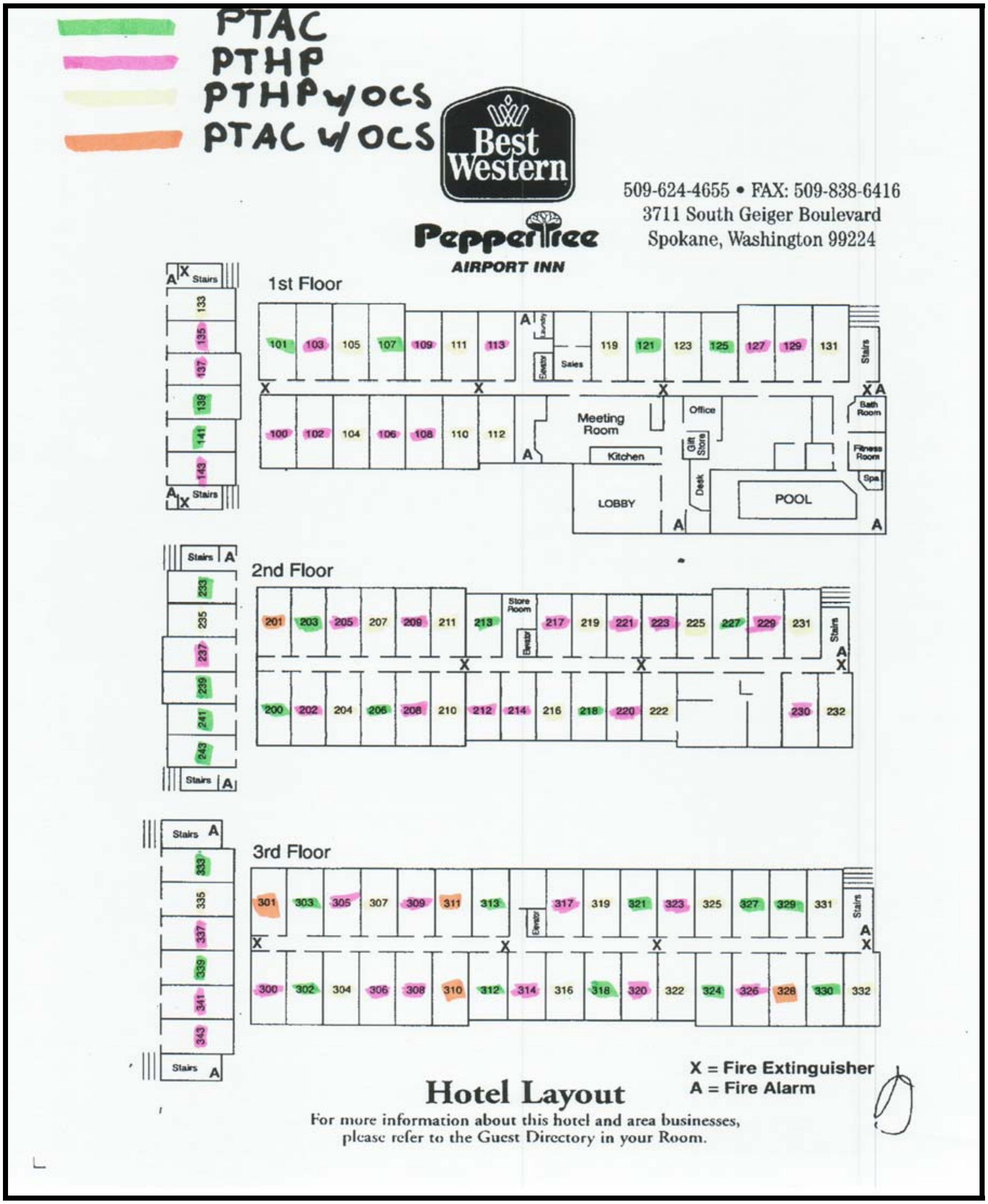
Below is a table of the intended and actual Group installations:

Table 1.1 Installed Group Descriptions

Group #	Equipment	Intended Installation	Actual Installation
Group #1	PTACs Units with Electric Heat and manual controls	33	28
Group #2	PTHPs Units with manual controls	33	38
Group #3	PTHPs Units with Occupancy Sensors	33	29

Although the number of units in each Group and distribution is not uniform, the results did demonstrate consistency once normalized to monthly energy consumption. It was also found that a new Group was installed, which includes PTAC units with occupancy sensors, called Group #4. Group #4 was not included in the analysis of this report due to only 5 rooms with this type of equipment and control strategy. EMP2 evaluated Group #4 but found that the data did not provide reasonable results due to lack of data points. Diagram 1.0 shows the hotel and Group equipment layout as installed at the Inn.

Diagram 1.0 Hotel and Group Layout



EMP2 collected information on similar studies done on room based occupancy sensors. It was found that the energy savings vary significantly from location to location and study to study. Based on EMP2's analysis of the Best Western Peppertree, it was found that the staff operating procedures has a significant impact on energy savings. Table 1.2 displays energy savings ranging from 252kWh/room/yr to 2,641kWh/room/yr. EMP2 believes that one of the primary variables affecting the energy savings is based on current hotel operating procedures, whether or not the cleaning staff turns the units off after cleaning the room. This is why EMP2 believes the savings have such a large variance. When comparing the savings from this report to others it can be seen that the verified savings are lower than any presented in Table 1.2. EMP2 contributes this mainly due to the hotel's operating procedure of turning the PTAC/PTHP units off after the cleaning staff leaves the room. It should also be noted that the studies performed in Table 1.2 all used an average power consumption for each operating mode, this study accounts for varying energy consumption as weather conditions change.

Table 1.2 Similar Studies Estimated Room Based Occupancy Savings*

Study/Utility	Occupancy Based Controller Savings (kWh/room/yr)	Baseline (kWh/room/yr)	% Savings
FEMP M&V Study	767	3,212	24%
PG&E	1,767	2,850	62%
BCHydro	252	663	38%
SDG&E (Hampton Inn)	345	1,240	28%
SDG&E (Navy Lodge)	384	3,020	13%
SDG&E (Doubletree)	1,437	2,485	58%
SDG&E (US Grant)	2,641	3,902	68%
Average	**1,085**	**2,482**	**44%**

*See Section 7.0 for Bibliography

1.1 Technology Overview

This analysis investigates the savings by installing PTHPs over PTAC units, and by installing room-based occupancy sensors. The installed PTHPs were selected by the owner and are not high efficiency air conditioning units. Therefore the measured savings for the PTHPs units were from improved heating efficiency, not improved cooling efficiency. Additional electrical savings would be achieved with higher COP and EER ratings. The equipment specifications for the installed PTAC units and PTHPs are given below.

Table 1.3 Equipment Specifications

PTAC and PTHP Equipment Specifications			
Mode of Operation	**Description**	**PTHP**	**PTAC**
	Model Number	123D	123D
Cooling	Voltage	208	208
	Capacity (Btu/hr)	11,500	8,900
	Amps	5	4
	Watts	1,095	1,100
	EER	10.5	10.7
Heating (Electrical Resistance)	Voltage	208	208
	Capacity (Btu/hr)	9,900	9,900
	Amps	15	15
	Watts	3,040	3,040
	Electric Heat Size (kW)	3	3
Heating (Heat Pump)	Voltage	208	N/A
	Capacity (Btu/hr)	10,400	N/A
	Amps	5	N/A
	Watts	1,015	N/A
	COP	3	N/A

The Amana DigiSmart control system allows for automatic temperature setback based on room occupancy. Amana asserts that their DigiSmart controls and energy management software allow for reduced maintenance cost through the automated maintenance notification system, as well as improved equipment life and efficiency.

The Amana brand DigiSmart PTAC or PTHP with antenna, digital control board and occupancy sensor give the property owner control over the equipment settings, which can reduce PTAC or PTHP energy usage. These Amana brand DigiSmart PTACs and PTHPs can be managed through a single interface on a PC. The software provides full PTAC/PTHP unit details, automatic maintenance alarm email, the ability to change all settings and enhanced diagnostics, remotely from the front desk or home office. In order for the DigiSmart system to work properly, each unit must have a digital control board, antenna, and an occupancy sensor and door switch (Diagram 2.0). As an occupant enters the room, the door switch will sense movement in the room; once sensed, the room will be in occupied mode and maintain the room temperature set point. If no movement is sensed for a set period of time, the room will go into unoccupied mode and the temperature setback sequence will be initiated.

Diagram 2.0 DigiSmart Components

Digital Control Board **Antenna** **Door Sensor**

When the room is rented and no movement is sensed for a designated period of time, the room temperature is set back based on a pre-programmed schedule, as shown in Table 1.4. The temperature setback sequence is programmed as a step function over an hour. If an occupant is not sensed within 10 minutes then the temperature is allowed to drift 2°F, and if an occupant is not sensed for an hour, the temperature allowed to drift 6°F from set point, within minimum and maximum temperature limits, as shown in Table 1.4. This control sequence results in energy savings, but the low and high temperature limit savings were not included in Table 1.0 because all units at the Pepper Tree were controlled according to this control sequence.

Table 1.4 Energy Management Control Set points

Setback	Temperature	Time
1st	2°F	10 minutes
2nd	4°F	30 minutes
3rd	6°F	1 hour
Cooling Temperature Lower Limit		60°F
Heating temperature Higher Limit		80°F

The Digismart program also allows for additional energy management configurations and mode override settings that would allow for additional savings. The list below demonstrates the settings that have the largest impact on energy consumption in addition to the control points shown in Table 1.4:

- Unrented Temperature Limit (limits the room temperature to a maximum and minimum which limits heating/cooling energy)

- Hi Speed Temperature Delta T (reduces high fan speed fan use based on temperature difference between set point and room temperature which reduces fan energy)
- Electric Heat Temperature Delta T (reduces electric heat use based on temperature difference between set point and room temperature)
- Fan Operation Setting (Allows for variations in fan cycling to occur which reduces fan energy)
- Front Desk Mode (if applicable) allows the front desk to turn units on/off (reduce unit usage during non-rented periods)

The DigiSmart control system provides additional features to manage energy consumption, verify operation, and as maintenance tools, but, this analysis focused on the energy savings associated with occupancy control.

1.2 Technology Cost

Data was collected from Amana to verify the cost of installing a standard PTHP over a PTAC unit and room based occupancy sensors. Typically, the equipment is sold and shipped to the hotel and the maintenance staff is usually responsible for installing the equipment with some oversight from the supplier. For the Peppertree, Amana provided technical support in programming and verifying that all the rooms were communicating with a central controller, typically the Amana agent assists the site with developing a standard energy management configuration. It appears that once the system settings and configuration is set, it is typically not modified unless the occupant's comfort level drops. The cost of a new standard PTHP over a PTAC unit is estimated at $450/unit. A room based occupancy controller is estimated at $195/unit. The energy management platform was estimated at $2,800.

2.0 Savings Methodology (Field Evaluation)

The savings methodology is based on collecting data from the Amana system that stores instantaneous and state data for a variety of parameters. Data is collected approximately every 5 minutes and 30 seconds. Based on this data, EMP2 was able to determine the current operating mode of the unit and runtime for each mode of operation. The Amana system data did not include power measurements; therefore EMP2 used a separate power meter to verify each unit's power draw at varying outside air temperatures. Actual power measurements for one PTAC and one PTHP were collected for a one month period. EMP2 and BPA collected several months of amperage measurements but needed to verify power factor and voltage readings. EMP2 compared the amperage measurements to the actual power measurements for a one month period. A correction factor was calculated and used to adjust the amperage measurements to the actual power measurements during the same time period. A correction factor of 207.76 demonstrated the best correlation between amperage measurements and power measurements. EMP2 also collected room rental information from the property owner.

The Amana system collected runtime and operating mode. EMP2 was able to determine the length of time for each operating mode. The operating modes consisted of the following:

- Low Fan
- High Fan
- Cooling with Low Fan
- Cooling with High Fan
- Heat Pump Heating Low Fan
- Heat Pump Heating High Fan
- Electric Heat Low Fan
- Electric Heat High Fan

In order to determine the actual power consumption in each operating mode, the actual power consumption for each operating mode was determined. It is understood that PTAC and PTHP power consumption varies based on indoor and outdoor air temperature. Due to a relatively constant indoor air temperature during equipment runtime it was determined that the parameter with the largest impact on unit power draw is outside air temperature. Therefore, power measurements on several PTAC and PTHP units were performed over a three month period to verify how power consumption varied with outside air temperature for each operating mode.

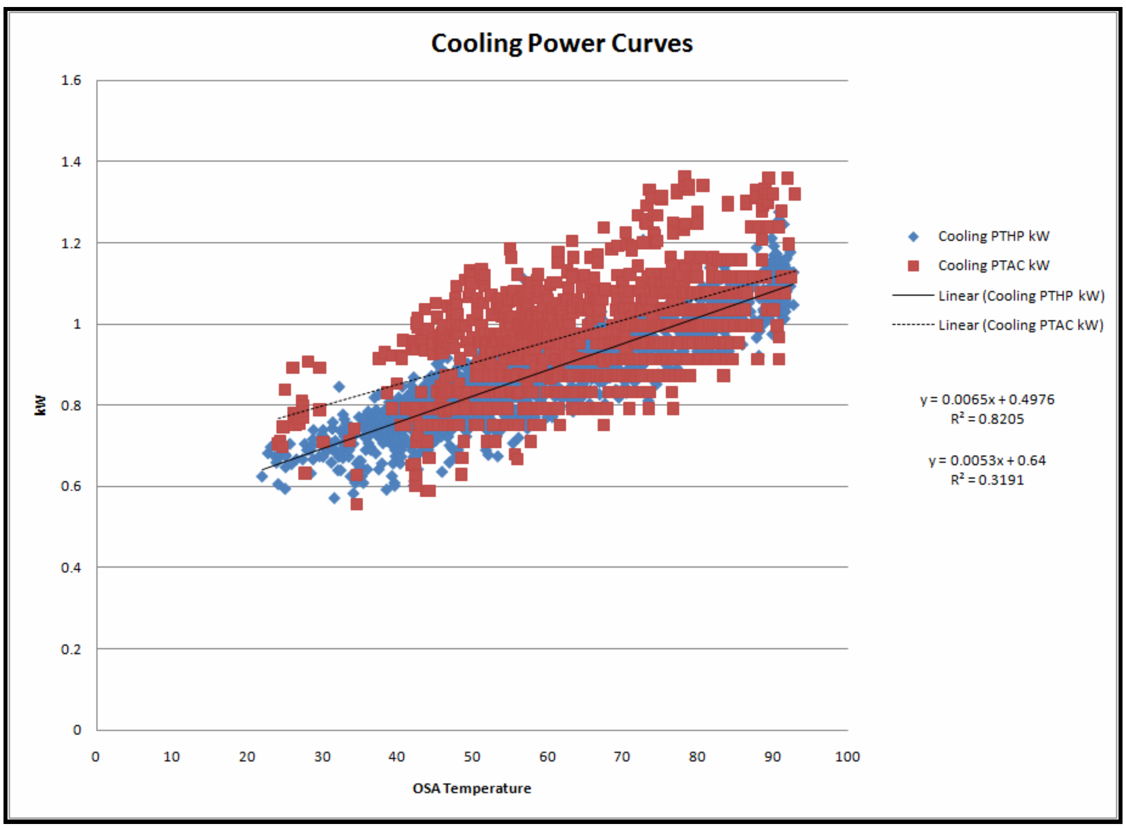
Fan Mode

The supply and condensing fans run at a one speed and the power draw does not vary based on outside air temperature. Several spot measurements were taken to verify power draw in low and high fan speeds. It was found that there was only a slight increase in power consumption from low to high fan speed. It was found that the power factor dropped on the high fan speed setting which reduced power consumption. With only a slight increase in power consumption from low to high fan speeds and a relatively low wattage draw when compared to the electric or compressor wattage it was decided that the energy consumption between the high and low fan speed would be insignificant. Therefore the analysis used the same power draw for both fan speeds. The fan power for either fan speed was calculated to be 0.1 kW or 100 watts, with a 212 voltage reading, 0.6 amperage draw and an average power factor of 0.8.

Cooling Mode

For both the PTAC and PTHP units the actual power information was collected for a one month period and amperage information was collected for over a three month period. EMP2 used the short-term power measurements to verify the power factor and voltage. Based on the collected data EMP2 developed a power curve based on outdoor temperature. EMP2 had long term amperage measurements but needed some verification of power factor and voltage to develop the power curve. The collected power measurements verified that EMP2's developed power curve using a correction factor of 207.76 which yielded the best correlation to power draw. The correction factor is a combination of voltage and power factor. The power curve was plotted against OSA temperature for both the existing PTAC units and PTHPs. The data shown in Plot 1.0 is from three PTHPs in cooling mode and one PTAC unit in cooling mode. A linear regression line was used to fit the data. The trend line equations given in the graph below were slightly modified to subtract fan power energy by dropping the y intersects value by 0.1 kW. This demonstrated a purely cooling compressor and condenser fan power curve. It can be seen that the PTAC unit consumes approximately 100 watts more on average than the PTHP at various outdoor temperatures. Even though the PTHP was found to consume less energy than the PTAC mode the analysis assumed no savings from installing a PTHP over a PTAC unit. This was due to limited cooling data collected. It is also interesting to see that the both the PTAC and PTHP are in cooling mode during low (below °55F) ambient temperatures. It was found that the PTAC/PTHP would both operate in cooling mode during low ambient temperatures, but typically for only short time durations. Overall, the cooling energy consumption in the heating months was minimal.

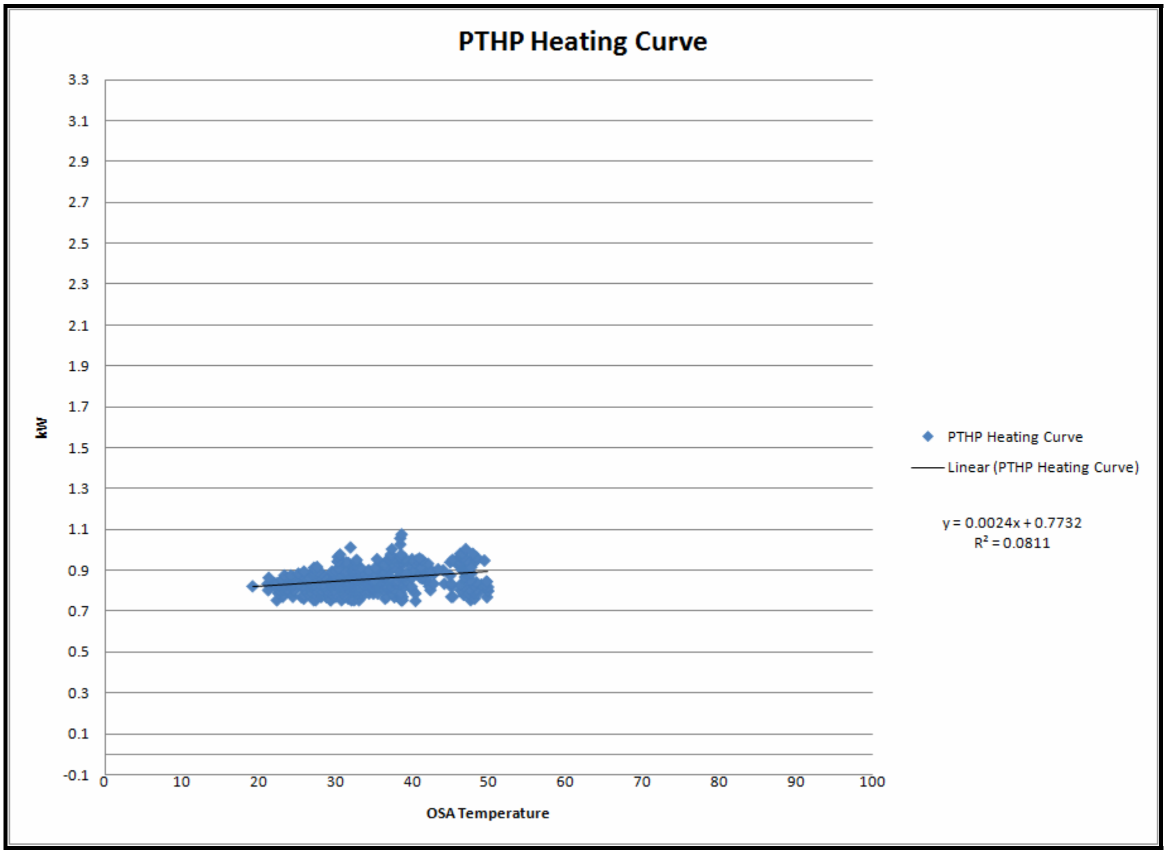
Plot 1.0 Cooling Power Curves



Heating Mode (Heat Pump)

A similar approach as the cooling curve was developed for the heat pump heating curve from data collected from three units. Based on the collected data EMP2 developed a power curve that varies based on outdoor temperature. EMP2 had long term amperage measurements but needed some verification of power factor and voltage to develop the power curve. The collected power measurements verified that EMP2's developed power curve using correction factor of 207.76 yielded the best correlation to power draw. The power curve was plotted against OSA temperature for the PTHP during heating mode. A linear regression line was used to fit the data. The trend line equations given in the graph below were slightly modified to subtract fan power energy by dropping the y intersects value by 0.1 kW. This demonstrated a purely heating compressor and evaporator fan power curve.

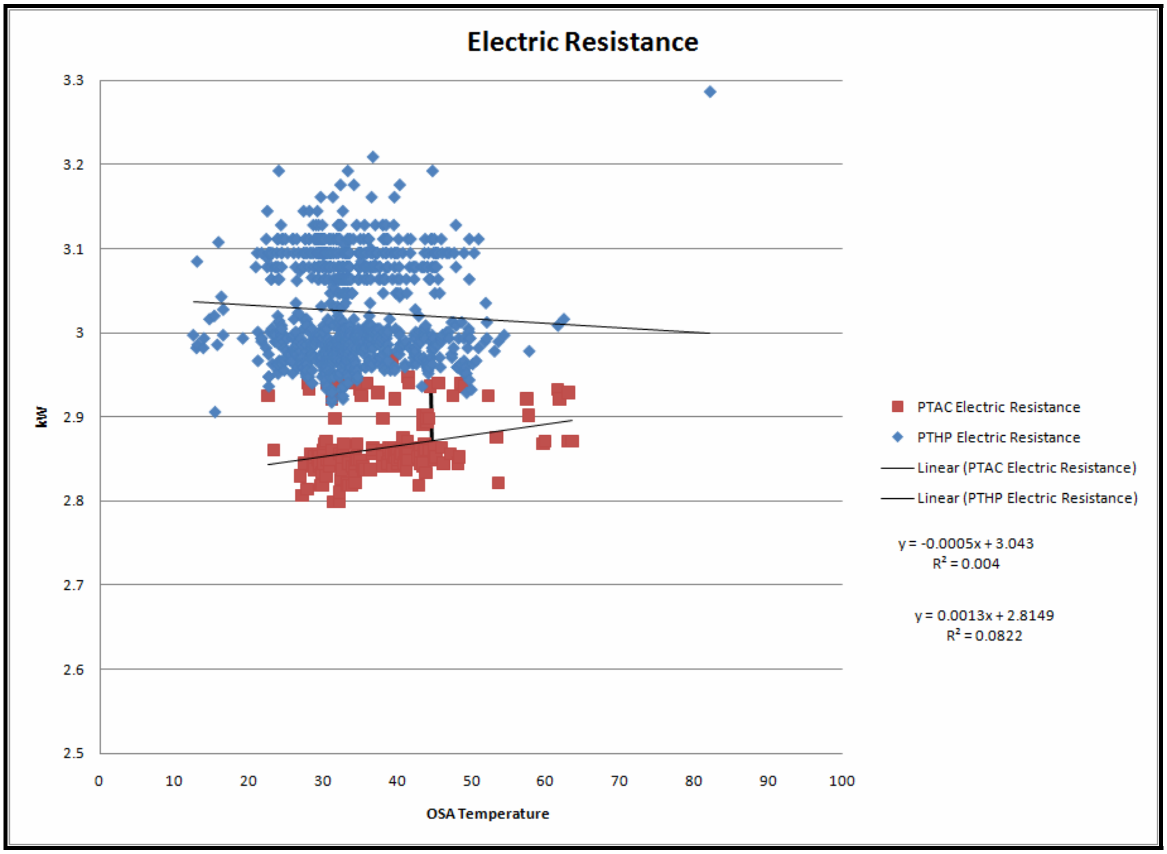
Plot 2.0 Heating Power Curve (Heat Pump Mode)



Heating Mode (Electric Heat)

The electric heating elements within the PTAC and PTHP are single stage; therefore the power draw does not vary with OSA temperatures. Based on the data in Plot 3.0 it can be seen that the electric resistance heater runs in warm-up mode prior to the fan operating. Therefore by assuming the lower end of the power draw as the power consumption it was assumed that the PTAC unit would consume 2.9 kW when the electrical resistance heater is operating and for the PTHP the electrical resistance heater would consume 3.0 kW.

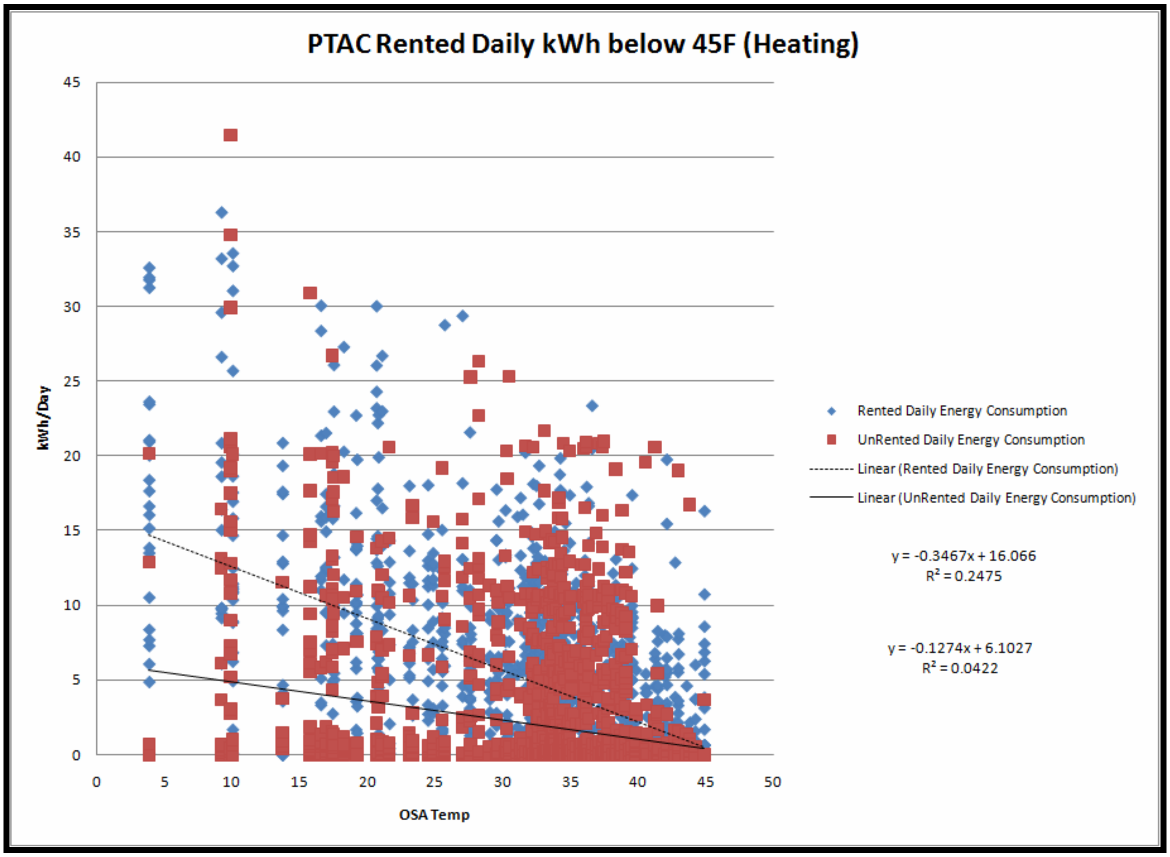
Plot 3.0 PTAC vs. PTHP Electric Resistance Heating



Once the power curves were developed, EMP2 was able to determine the actual unit's power draw at various outdoor air temperatures. The Amana system was used to determine the mode of operation and mode runtime. The Amana system would collect and record data approximately every 5 minutes and 30 seconds, however the OSA weather sensor for the Amana system was not working or programmed incorrectly. EMP2 collected local weather data from AgriMet, The Pacific Northwest Cooperative Agricultural Weather Network, weather station that was within 20 miles of Spokane. The weather data was collected in 15-minute increments and was paired with the closest time stamped 5-minute Amana data set. This didn't provide the exact weather condition at every 5 minute data collection point but gave reasonable OSA data. EMP2 also collected room rent rates from the Inn staff. EMP2 collected and matched the hotel rent rates to the 5 minute recorded Amana data. If the room was rented then EMP2 estimated that the room was rented for the entire day, as it is difficult to estimate when occupants arrive and depart. By knowing the equipment operating mode, equipment mode runtime, OSA weather data, room rent status, and developed power curves based on OSA temperature, EMP2 was able to determine the power consumption approximately every 5 minutes and categorize the energy consumption as rented or unrented for 100 rooms over a six month period.

In order to normalize the data for an entire year EMP2 developed another curve that summarized each Group's energy consumption based on OSA temperature. Due to the large amount of data and limitations with the current software the 5 minute data was not plotted against OSA temperature, however EMP2 summarized the data into daily averages to determine if a regression analysis was reasonable. EMP2 developed four curve fits for each Group in the hopes of normalizing daily energy consumption vs. OSA weather. EMP2 developed two curves, one for rented rooms and the other for un-rented rooms for temperatures below 45°F, and another two curves for temperatures above 45°F. The 45°F temperature was estimated to be the balance point when operating mode changes from heating to cooling.

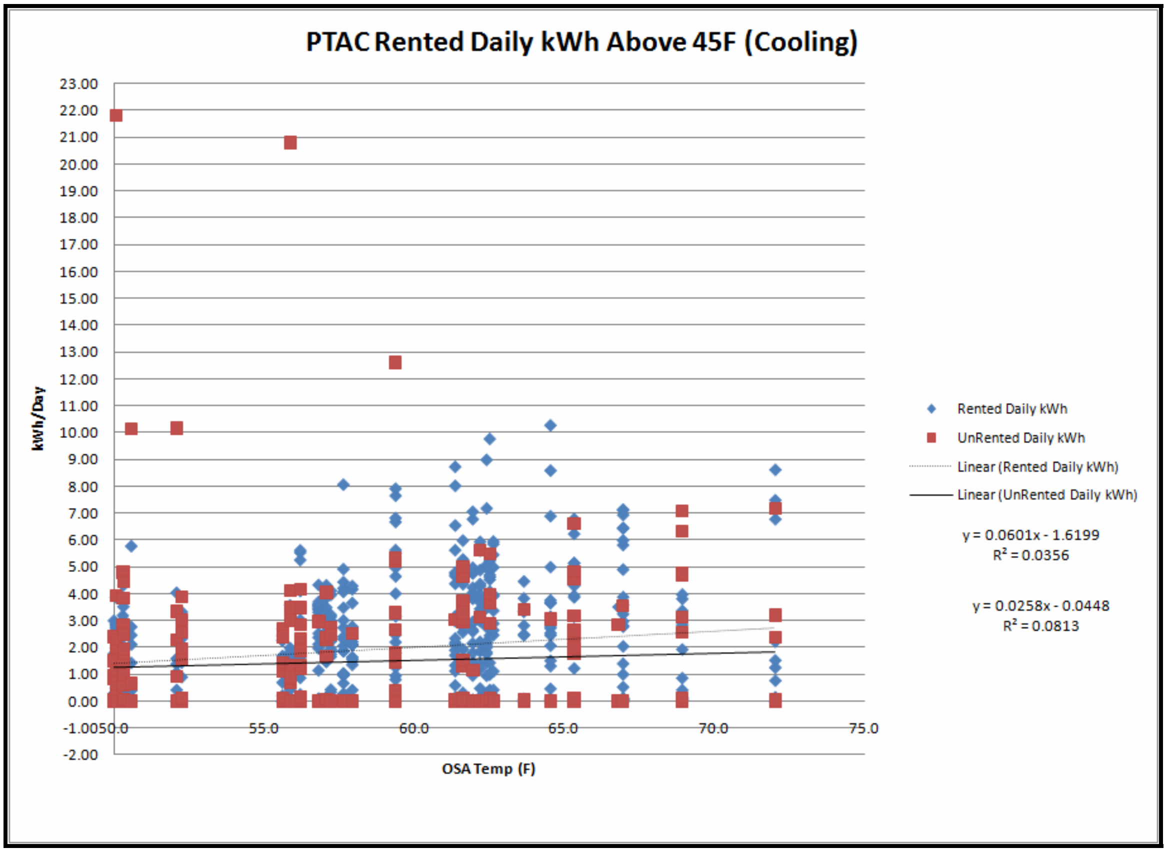
Plot 4.0 PTAC Rented/Un-Rented Normalized Curves for Heating



In Plot 4.0, it can be seen that even during rented days, that in some cases, the energy consumption can be zero. This is believed to be due to the cleaning staff's operating procedure of turning the units off after cleaning. It can also be seen that during unrented periods the number of days the energy consumption is at zero is more frequent. This demonstrates a potential reason that the savings for the ECMs was found to be low when compared to other facilities. The zero energy usage during rented and unrented periods reduces energy consumption, and consequent energy savings, significantly.

Plot 5.0 shows the average daily kWh consumption per room for temperatures above 45°F. It can be seen in Plot 5.0 that the cooling data is limited and the regression analysis does not provide a favorable correlation.

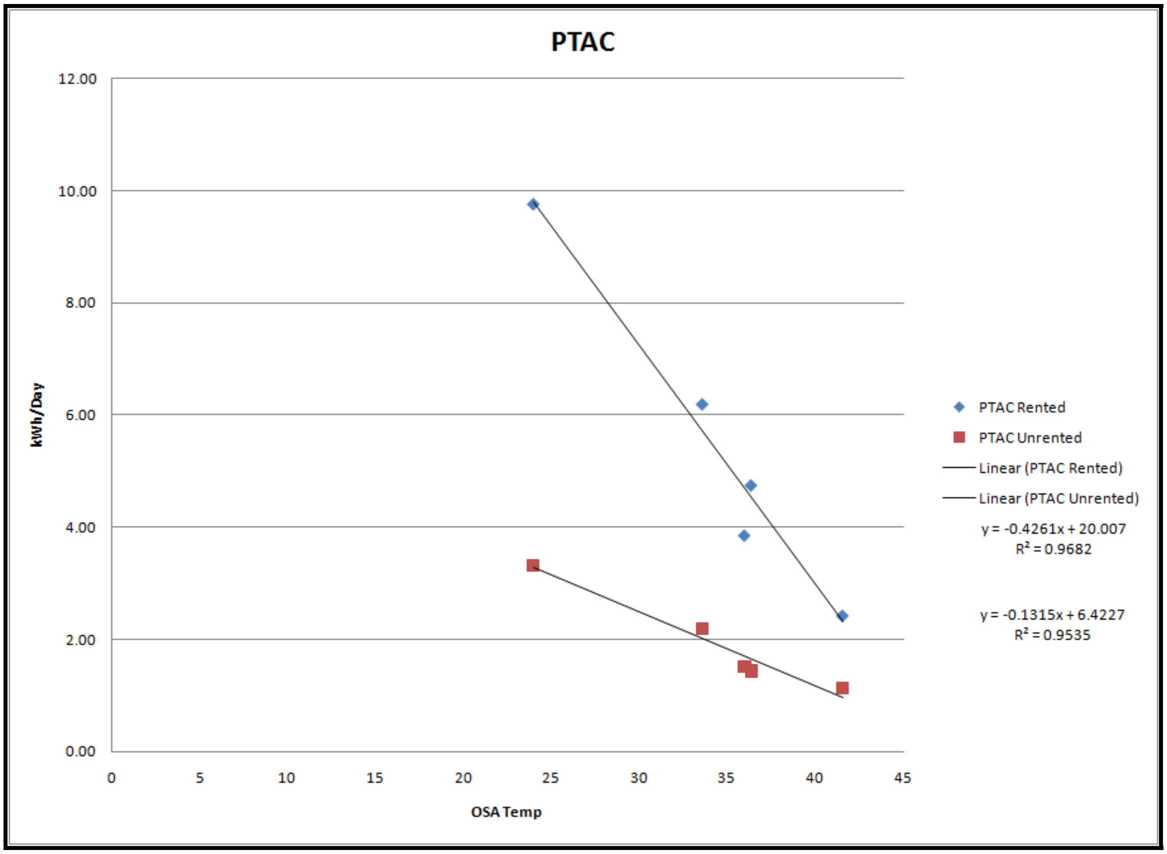
Plot 5.0 Rented/Un-Rented Normalized Curves for Cooling



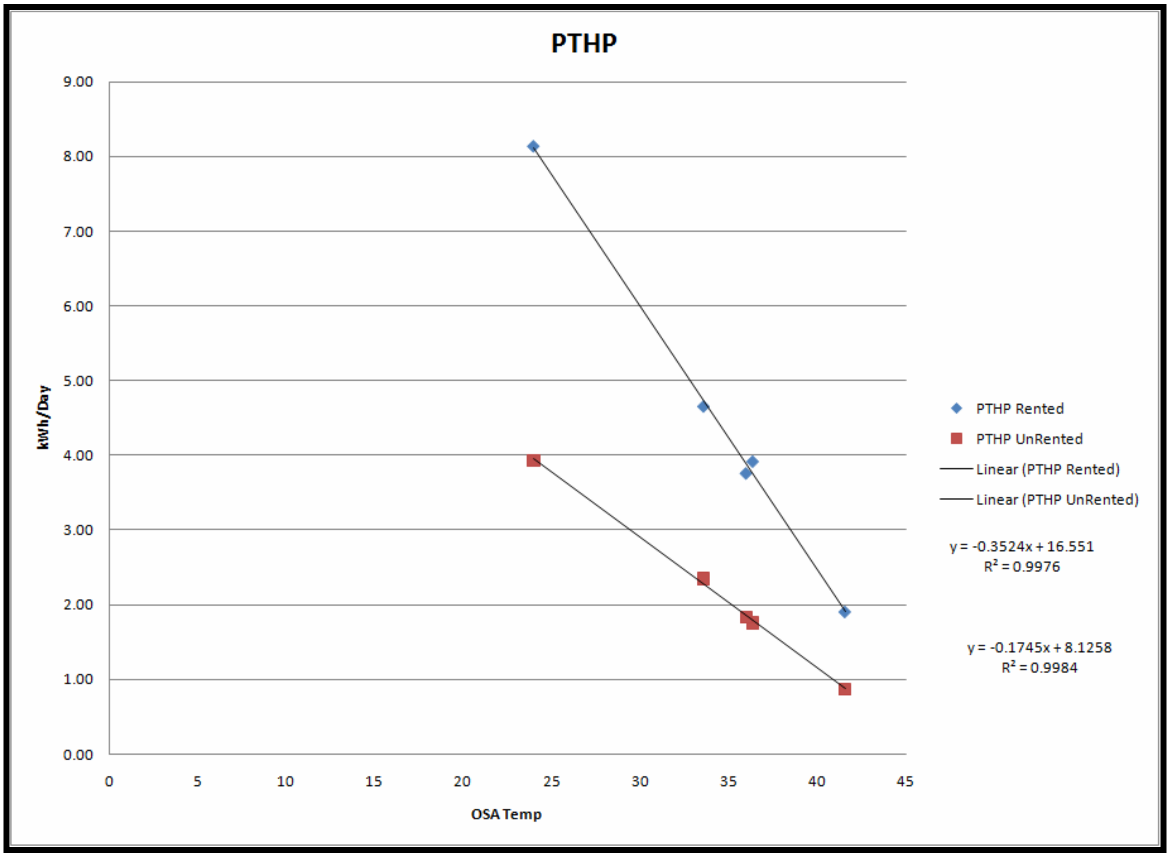
It can be seen from Plot 4.0 and Plot 5.0 that the R^2 values are demonstrating a poor correlation between average daily temperatures and average daily energy use especially for the cooling curves due to limited data collected during the cooling season. The data demonstrates the same findings for the other two Groups analyzed. The poor R^2 values are somewhat expected due to the staff operating procedures and occupant behavior. It can be seen in the data that energy consumption at a given OSA temperature varies significantly from zero to the maximum energy consumption at that OSA temperature. There are multiple factors that effect energy consumption regardless of temperature, but a big driver is understood to be staff operating procedures. Based on discussions with the staff and the facility manager, the cleaning staff manually turns each unit off after cleaning the room. This was adopted as a facility policy in order to conserve energy. This policy is theorized to develop a large scatter in the data due to some rooms whether rented or unrented to consume zero energy. If the staff was to leave each unit on, then an improved R^2 value would be expected since the units would consume a more consistent energy consumption as OSA temperature varies.

Since the daily energy consumption data was inconsistent, EMP2 then formatted the data to monthly energy consumption and monthly average temperature. Based on the poor R^2 values by looking at daily kWh consumption vs. daily OSA temperature any further break down of time increments was assumed to only further reduce the R^2 values due to additional scatter. This is why EMP2 reduced the time increments to monthly data rather than a breakdown of additional time increments such as hourly or 5 minute data. The monthly energy consumption was plotted for all three Groups for the months of October, November, December, January, and February. September was not included in the plots since, it was found that September is primarily a cooling month and other five remaining months were found to be primarily heating. By including the cooling month of September with the other five predominately heating months the correlation between monthly average OSA temperature and monthly energy consumption was reduced. By plotting the average monthly OSA temperature and monthly average energy consumption for the five months during the heating season it can be seen that a very good correlation exists, typically with an R^2 value above 0.9, which demonstrates a strong correlation, which can be seen in Plots 6.0 thru 8.0.

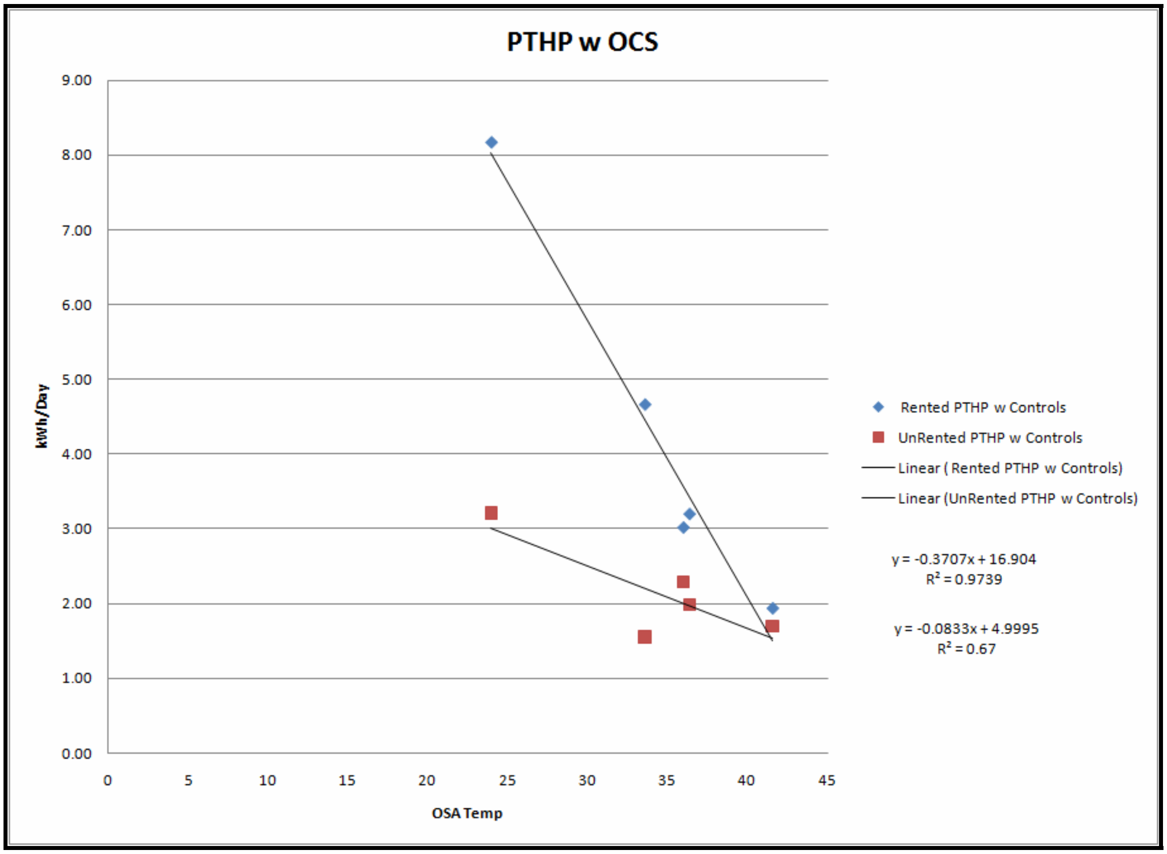
Plot 6.0 Group #1 Regression Analysis during the Heating Season



Plot 7.0 Group #2 Regression Analysis during the Heating Season



Plot 8.0 Group #3 Regression Analysis during the Heating Season



All R^2 values are above 0.9, showing a strong correlation between average monthly room energy consumption and OSA temperature. The only R squared value below 0.9 is the PTHP with OCS for the unrented trend line. A value of .67 is still reasonable but does not show the strongest correlation, this is somewhat expected as kWh consumption is expected to vary more based on room occupancy rather than OSA temperature.

The issue with developing average monthly room energy consumption vs. OSA temperatures in order to normalize energy consumption for the remaining 6 months of the year is that EMP2 has only one month of cooling data. EMP2 compared the average monthly September 2009 weather of 60°F to the average six summer month's temperatures of Spokane using TMY3 data. The difference was only 2.1°F. This demonstrates that on average the weather during the cooling months estimated from April to September is only 2.1°F above the 2009 average monthly September data as shown in Table 1.5. Therefore EMP2 assumed that the average monthly room energy during September could be extrapolated to the other remaining months of April through August. A cooling month was determined to be any month with an average monthly temperature above 45°F, since Plots 6.0 through 8.0 demonstrates the balance point is roughly 45°F. This method isn't as accurate as the heating month's regression analysis, but should provide a good estimate of savings for the summer period.

Table 1.5 Average Monthly Temperature Differences

Cooling Month	Average TMY3 Data (°F)	Difference between 2009 Average Monthly Weather of 60F to TMY3 (°F)
April	48.3	11.6
May	54.6	5.3
June	61.4	-1.4
July	68.8	-8.9
Aug	66.7	-6.7
Sept	61.9	-2.0
6-month Degree Difference		-2.1

By using the heating trend lines and the average monthly room energy consumption for the month of September for the remaining summer months, the data could be normalized to typical occupancy rate and typical weather data for Spokane. Table 1.6 shows the average 30-year weather data for Spokane, WA using TMY3 average monthly data.

Table 1.6 Average Monthly Temperatures

Month	Average Temp TMY3 Data (°F)
Jan	26.7
Feb	31.8
March	39.6
April	48.3
May	54.6
June	61.4
July	68.8
Aug	66.7
Sept	61.9
Oct	46.3
Nov	35.1
Dec	29.7

EMP2 also collected the average monthly occupancy rates from the Spokane Peppertree Inn. As previously discussed the data was separated into two Groups, either rented or un-rented. Therefore, the average monthly occupancy rates will be used to determine the average monthly energy consumption based on weather and occupancy. Table 1.7 shows the average monthly occupancy rates for the Inn.

Table 1.7 Average Monthly Occupancy Rates

Month	# Days	Total (Rooms/ Month)	2006 (Rooms/ Month)	2007 (Rooms/ Month)	2008 (Rooms/ Month)	2009 (Rooms/ Month)	% Occupied
1	31	3100	1927	1895	2038	1468	59%
2	28	2800	2219	1952	2240	2040	75%
3	31	3100	2508	2251	2218	1838	71%
4	30	3000	2260	1884	2034	1513	64%
5	31	3100	2578	2533	2434	1608	74%
6	30	3000	2697	2920	2609	2092	86%
7	31	3100	2901	2837	2622	2395	87%
8	31	3100	2943	2955	2922	2650	93%
9	30	3000	2859	2624	2531	2360	86%
10	31	3100	2321	2300	1960	2056	70%
11	30	3000	1997	2071	1579	1381	59%
12	31	3100	1667	1697	1802	1611	55%

The monthly energy consumption for rented and un-rented rooms was then analyzed for all three Groups as shown in Table 1.8. The equations used to develop the findings as shown in Table 1.8 are given below. It can be seen that some sections of Table 1.8 are highlighted yellow. These sections have been modified from the original data. The highlighted yellow section under PTAC rented data was modified to demonstrate the same energy consumption as the PTHP, as the PTAC was found to consume less energy than the PTHP cooling energy, however based on actual power measurements and similar EER ratings, EMP2 estimated the cooling energy to be the same as the PTHP. The highlighted yellow sections during the month of October for the PTAC w/OCS and PTHP w/OCS were rounded up to zero, since the original data demonstrated negative energy consumption. This demonstrates that the balance point is approximately 45°F and that the energy consumption near 45°F is close to zero. The three bottom rows demonstrate the average daily energy consumption per room, average yearly energy consumption per room, and the average yearly energy consumption if all rooms were specified as one Group.

Equations 1 though 4 used in Table 1.8

1.0 Rented Heating Energy Consumption (kWh/Room-Day) = Unit Rented Trend Line based on OSA temperature * Rent Rate (%)

2.0 Un-Rented Heating Energy Consumption (kWh/Room-Day) = Unit Un-Rented Trend Line based on OSA temperature * (1-Rent Rate (%))

3.0 Rented Cooling Energy Consumption (kWh/Room-Day) = September Rented kWh/Room-Day * Rent Rate (%)

4.0 Un-Rented Cooling Energy Consumption (kWh/Room-Day) = September Un-Rented kWh/Room-Day * (1-Rent Rate (%))

Table 1.8 Monthly Energy Savings for Groups #1 through #3

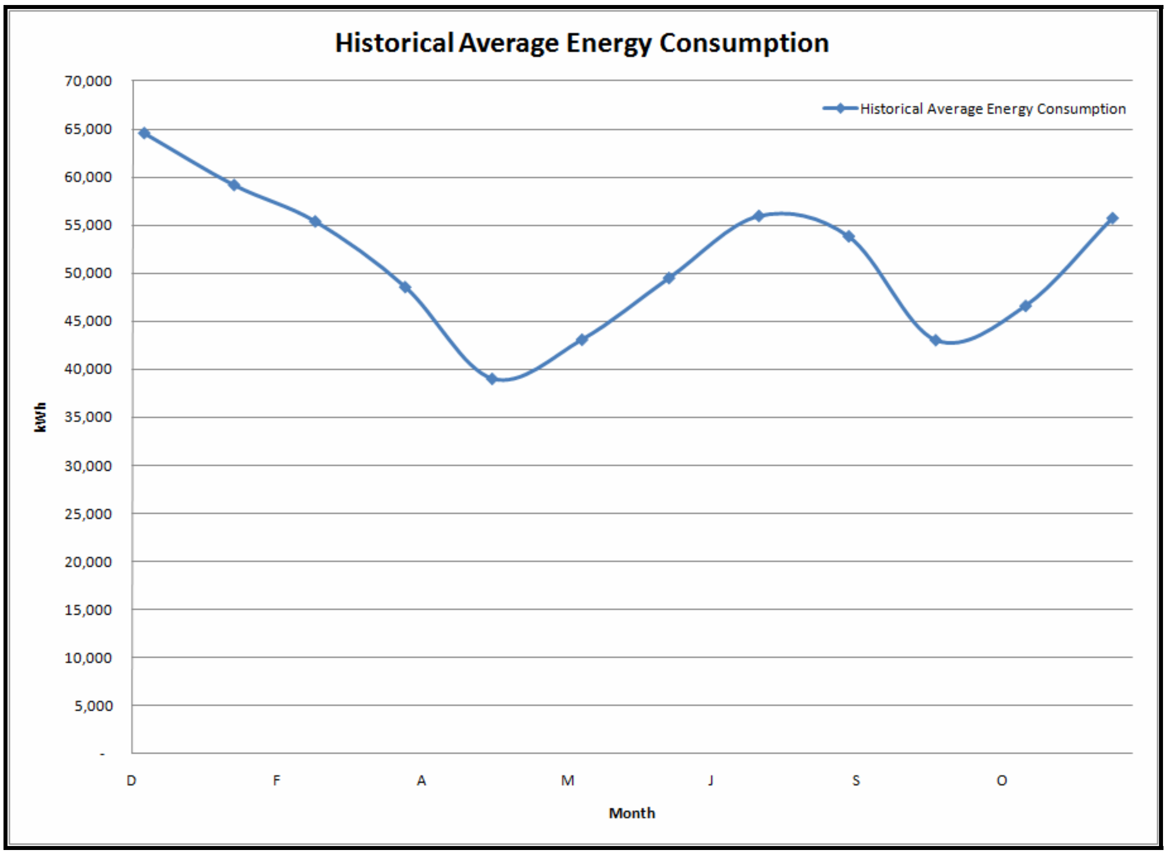
Month	Average Temp	Rent Rate	PTAC Rented (kWh/Room-Day)	PTAC UnRented (kWh/Room-Day)	PTHP Rented (kWh/Room-Day)	PTHP UnRented (kWh/Room-Day)	PTHP w OCS Rented (kWh/Room-Day)	PTHP w OCS UnRented (kWh/Room-Day)
Jan	26.7	59%	5.09	1.19	4.22	1.42	4.14	1.13
Feb	31.8	75%	4.88	0.55	4.04	0.63	3.87	0.58
March	39.6	71%	2.23	0.35	1.85	0.35	1.58	0.49
April	48.3	64%	1.51	0.53	1.51	0.52	1.42	0.52
May	54.6	74%	1.74	0.39	1.74	0.38	1.63	0.38
June	61.4	86%	2.03	0.21	2.03	0.20	1.90	0.20
July	68.8	87%	2.05	0.20	2.05	0.19	1.92	0.19
Aug	66.7	93%	2.18	0.11	2.18	0.11	2.04	0.11
Sept	61.9	86%	2.04	0.20	2.04	0.20	1.91	0.20
Oct	46.3	70%	0.18	0.10	0.16	0.01	0.00	0.34
Nov	35.1	59%	2.95	0.75	2.44	0.83	2.27	0.86
Dec	29.7	55%	4.00	1.14	3.32	1.33	3.21	1.14
Total/Averag	47.6	73%	2.57	0.48	2.30	0.51	2.16	0.28
kWh Consumption per Room Day			3.05		2.81		2.44	
kWh Consumption per Room Year			1,113		1,027		889	
Energy Usage for 100 Rooms			111,310		102,669		88,888	

*The highlighted yellow columns demonstrate a modification of the original data and are explained in the section above.

2.1 Utility Data

The utility data was collected for six years to determine the average monthly kWh consumption contributed towards heating and cooling energy and how the utility energy consumption compared to the metered energy consumption. Based on six years worth of data and plotting the average monthly kWh consumption versus month it can be seen that the winter and cooling months increase in energy consumption. It can be seen in the shoulder months of May and October that the energy consumption is at the minimum. This represents the base load of the facility with minimal heating or cooling requirements. Anything above the base load is estimated as either cooling or heating energy which is contributed by the existing PTAC units. By applying this approach to the utility data it appears that the base load is approximately 39,000 kWh when looking at the low point in Graph 1.0.

Graph 1.0 Historical Average Energy Consumption



When subtracting the estimated base load of 39,000 kWh from the average historical monthly energy consumption, the actual energy contributed from the PTAC units can be estimated from the utility history. By performing this utility analysis it can be seen that the estimated cooling and heating is estimated at 146,813 kWh which is within 25% of the calculated baseline of the PTAC units. Prior to this pilot program, the majority of the rooms were outfitted with PTAC units or Group #1 equipment. This demonstrates that the calculations developed by EMP2 as described in the savings methodology is reasonable when compared to the utility analysis as described in this section. This was done to determine if the analysis approach was reasonable.

Table 1.9 Utility Heating/Cooling Analysis

Month	2003 (kWh)	2004 (kWh)	2005 (kWh)	2006 (kWh)	2007 (kWh)	2008 (kWh)	Averge (kWh)	Heating/Cooling Loads (kWh)
JANUARY	48,880	78,240	56,880	73,440	64,400	65,760	64,600	25,600
FEBRUARY	51,040	54,240	61,040	52,640	66,640	69,600	59,200	20,200
MARCH	55,200	49,840	56,240	63,600	54,880	52,720	55,413	16,413
APRIL	46,720	46,880	42,800	56,560	48,800	49,760	48,587	9,587
MAY	39,360	31,920	36,400	40,560	42,080	44,000	39,053	53
JUNE	36,480	35,120	42,800	47,920	51,440	44,960	43,120	4,120
JULY	41,680	48,560	42,560	51,120	44,640	68,640	49,533	10,533
AUGUST	56,160	59,120	49,440	56,880	77,280	37,040	55,987	16,987
SEPTEMBER	48,080	46,720	52,800	51,200	73,920	50,480	53,867	14,867
OCTOBER	45,840	36,240	44,400	46,960	40,560	44,400	43,067	4,067
NOVEMBER	42,640	41,200	46,880	48,240	55,520	45,280	46,627	7,627
DECEMBER	51,200	49,520	60,320	62,400	60,400	50,720	55,760	16,760
YEARLY TOTAL	563,280	577,600	592,560	651,520	680,560	623,360	614,813	146,813

It appears based on this hotel that during the shoulder months of May and October that the hotel room heating and cooling energy is estimated to be close to zero energy consumption. It was originally estimated that even during the shoulder months that some heating or cooling energy was present. However, based on the verified findings of the this report it can be seen hat little or no cooling/heating energy exists during the shoulder months and only the increased energy consumption from the shoulder months demonstrates cooling/heating energy consumption. In summary, when using utility data, it is difficult to determine hotel room PTAC or PTHP energy consumption. However, investigation of other facilities may show that utility data may be used to estimate hotel room heating/cooling energy usage and should not be ruled out as a possibility at this point in time.

2.2 Major Assumptions

- Six months of data collection would normalize occupant behavior and staff operating procedures.
- The distribution of rooms will provide consistent results even though the numbers and orientation is not consistent.
- One month of cooling data would be sufficient to extrapolate energy consumption to the remaining cooling months due to an overall similar average temperature.
- PTAC and PTHP cooling energy is calculated to be the same.
- The developed power curves would apply to all remaining units.
- The setback control and temperature limits were assumed to be constant through out the M&V period.
- The Amana data was assumed to be correct and accurate. (EMP2 and BPA compared a sample set of Amana data to logged data, which demonstrated good correlation.)

3.0 Project M&V Findings

This section will discuss the M&V findings of PTHP and room-based occupancy sensors.

3.1.0 PTHP

This measure proposes installing a packaged terminal heat pump in place of packaged terminal air conditioner with electric strip heat. Savings are found from improved heating efficiency from the heat pump mode during the heating season. The analysis did not demonstrate savings from the PTHP cooling mode over the PTAC cooling mode.

3.1.1 Baseline

The baseline for installing PTHPs is based on a PTAC baseline with electric strip heat. Six months of data was collected for 28 rooms with PTAC units. Data was collected from September 2009 to February 2010. The data was summarized as average daily or yearly energy consumption per room, and categorized as either rented or unrented. A regression analysis was performed to determine the energy consumption in the winter, and the energy consumed in September was used for the remaining cooling months. However, since the data demonstrated that the PTHP consumed more energy than the PTAC for the month of September, EMP2 revised the PTAC cooling baseline to match the PTHP baseline. It is demonstrated that the cooling curve for the PTHPs is more efficient than the PTAC, therefore due to similar EER ratings and limited data collected during the cooling period, the PTHP cooling data was used as the PTAC cooling data. Therefore the analysis did not demonstrate any savings during the cooling mode. The baseline was found to be an average 1,113 kWh per room per year or if all 100 rooms were installed as Group #1, then the baseline would be estimated at 111,310 kWh for the entire year.

3.1.2 Post Condition

The post condition is based on installing PTHPs with heat pump mode during moderate heating temperatures and during low demand periods. The electric resistance heating is programmed to come on when the OSA temperature is below 35°F or when the difference between room temperature and set point temperature is above 5°F during the heating mode. Therefore, even though the OSA temperature may be above 35°F, if the occupant increased the set point temperature 5°F above room temperature then the electric resistance heat would be initiated to heat instead of the heat pump. This provides the occupant with faster warm-up periods. Six months of data was collected for 38 rooms with PTHP units. Data was collected from September 2009 to February 2010. The post condition was found to be an average 1,027 kWh per room per year or if all 100 rooms were installed as Group #2, then the post condition would be estimated at 102,669 kWh for the entire year.

3.1.3 Savings

The savings are estimated by subtracting the baseline from the post condition. The savings are estimated at 86 kWh per room for an entire year based on historical weather and occupancy rates by installing a PTHP unit over a PTAC unit. If the hotel switched all PTAC units to PTHPs without the controls the savings would be estimated at 8,641 kWh per year.

3.2.0 Occupancy Sensors

This measure proposes installing a room-based occupancy sensor that is used in conjunction with control software to setback room temperatures when the room is unoccupied. Savings from this measure is found from the reduced heating and cooling loads during unoccupied periods when the PTAC or PTHP is left in operating mode. Additional savings may also be achieved with the DigiSmart software due to improved maintenance alarms and improved control capabilities, however these were not accounted for within the analysis. This analysis focused on typical expected savings by installing a room-based occupancy sensor used to control room temperatures.

3.2.1 Baseline

There are actually two baselines and two post conditions for the occupancy sensor ECM. The first baseline is assuming Group #1 units are installed throughout the hotel, and the second baseline assumes Group #2 units are installed throughout the hotel. Group #1 is based on 28 PTAC units with measurements from September 2009 to February 2010. Group #2 is based on 38 PTHP units with measurements also from September 2009 to February 2010. The baseline for the Group #1 was found to be 1,113 kWh per room per year, and the baseline for Group #2 t was found to be 1,027 kWh per room per year.

3.2.2 Post Condition

The post condition is based Group #3 equipment, which is a PTHP unit with a room-based occupancy sensor. The post condition data is based on 29 rooms with data collected from September 2009 to February 2010. The post condition energy usage is 889 kWh per room per year or is estimated at 88,888 kWh per year if the hotel installed Group #3 equipment throughout the hotel.

3.2.3 Savings

The energy savings by installing Group #3 equipment above Group #1 equipment is estimated to save approximately 224 kWh per room per year or 22,422 kWh per year if the entire hotel was upgraded from Group #1 to Group #3 equipment.

The savings by installing Group #3 equipment above Group #2 equipment is estimated to save approximately 138 kWh per room per year or 13,781 kWh per year if the entire hotel was upgraded from Group #1 to Group #2 equipment.

4.0 Discussion

EMP2 believes that the energy savings associated with the PTHP and OCS at the Peppertree is lower than what would be expected at most other facilities due to several factors including installation of standard efficient PTHP and current staff operating procedures. The cleaning staff currently turns off the equipment after cleaning the room, leaving the units shutoff until an occupant enters the room and turns the unit on. If a hotel did not have this procedure then the energy savings would be significantly higher. The collected cooling data is also limited but should provide reasonable results due to an overall similar average monthly temperature. If a high efficiency PTHP was installed then additional savings would be found over a standard PTAC unit. EMP2 also believes additional savings can be achieved through the energy management control system that gives status alarm on operation and maintenance items. For example, the alarm system would indicate if a dirty filter was present, this would give the staff an opportunity to quickly replace or clean the filter that would otherwise go without cleaning for a longer time period. A dirty filter would lead to additional energy consumption. This would further reduce maintenance costs and improve equipment performance.

5.0 Conclusion

PTHP Units over PTAC Units

In summary it was found that the installed standard efficient PTHP did not provide any additional cooling benefits over the existing PTAC units, but savings were only found from improved heating efficiency by using the heat pump over the electric resistance heater. Savings were estimated at 8% of the calculated baseline of 111,310 kWh per year, providing a savings of 8,641 kWh. Additional savings could be achieved if the electric resistance heater was disabled from running when the OSA temperature is above 35°F and the room temperature was beyond 5°F above set point temperature. Any time the heat pump could run instead of the electric resistance heater additional savings would be achieved. This would require the staff to simply adjust the dead band from 5°F to a larger dead band of 10°F. Additional savings would also be found by installing a high efficiency PTHP with a higher EER and COP ratings.

Room Based Occupancy Sensors

In summary if Group #3 equipment was installed throughout the hotel over Group #2 equipment then the energy savings would be 12% of the calculated baseline. If Group #3 equipment was installed throughout the hotel over Group #1 equipment the energy savings would be 20% of the calculated baseline.

6.0 Recommendations

For future analysis and studies it is recommended to collect on site weather data with the same time recording interval as the other data collected. This would further improve the power curves which should improve the accuracy of the analysis. It is also recommended to review typical occupant check in and checkout times and maybe averaging a large set of data to estimate the actual check in and checkout times. EMP2 estimated a daily rented status although it is expected that an actual rented day might be a shorter duration than a typical day. This would improve the breakout of rented and un-rented energy use. Additional power measurements for a larger group of equipment in each Group would also be preferred. This would improve each Groups power curves for a more consistent power curve. This analysis allowed for actual equipment runtime in each mode, this is preferred and recommended as the operating time for each operating mode cycles rapidly, typically under 2 minutes. Using a similar approach for data collection equipment is also preferred. This study used data from several sources to determine actual energy consumption; one source is preferred and is predicted to further improve analysis accuracy.

7.0 Bibliography

1. BCHydro, The Blue Horizon Hotel, “Two Passive Infrared Motion Sensor Systems for in Room Energy Hotel Management” November 2007
2. FEMP, The Music Road Hotel, “Demonstration and Evaluation of HVAC Controller for Lodging Facilities” July 2002
3. Pacific Gas and Electric Company, “Occupancy-Based Guestroom Controls” September 2007
4. Sand Diego Gas and Electric, Hampton Inn Del Mar, Navy Lodge, Doubletree Hotel, US Grant Hotel, “Hotel Guest Room Energy Controls”, December 2008