FINAL REPORT, OIT EAST CAMPUS ENERGY AUDIT

OIT Department of Renewable Energy Engineering

prepared for

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March 20, 2009

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REE 439, Winter 2009

Disclaimer

The results of the energy analysis presented in this report cannot be construed to have absolute, predictive accuracy, representing the actual energy use of the building or its individual systems. All reasonable efforts have been taken to ensure the accuracy of the energy model inputs, including verifying that actual details correspond to the building as it is currently proposed. The primary benefit of energy modeling is for comparison of alternative Proposed options to determine their relative energy savings potential.

There a number of factors that will cause the actual energy use of the building to diverge from the projected energy use of the model. Among these are: differences in building Proposed relative to the building modeled; abnormal weather conditions; variations in schedules for equipment, systems, and occupancy; inconsistencies in the application of controls and operations strategies compared to those used in the model; the level of direct loads; and changes in connected loads and electricity and gas rates. In addition, the model results do not necessarily take into account all the energy uses of a facility or building site that would show up as loads on the utility meters.

Nevertheless, refinements of the energy model to reconcile all these differences, when these adjustments are made by a capable energy engineer, can yield model results that are more consistent with actual energy use.

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Summary

Methodology

The EUI of the 56,000 square feet building was determined from data obtained from a two year history of energy bills from utility providers. CBECS statistical end-use data for a high school was utilized to determine the energy use profile of the building with some adjustments.

A walk-through audit was then performed to find potential areas of improvement and energy savings. As-found equipment is described, energy end use is characterized, and recommendations are made for energy saving measures.

Results

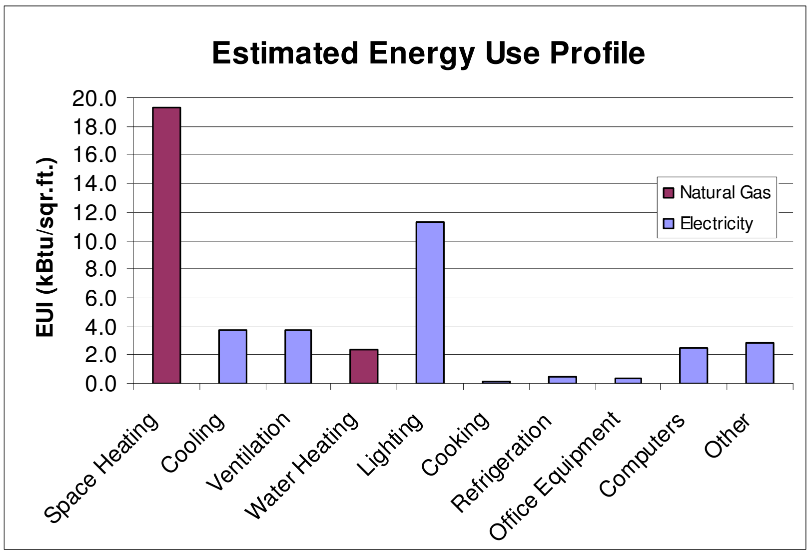

Figure 1: Estimated Energy End Use Profile

Figure 1 details the energy use profile of the building. The total EUI is 47.9 kBtu per square foot per year. Areas of potential savings include lighting, hot water, HVAC, building envelope, and miscellaneous plug loads. If all recommended energy efficiency measures are implemented the EUI would be reduced to approximately 36.7 kBtu per square foot per year.

Recommendations

Table 1: Recommended energy efficiency measures

Model ID	Initial Costs	Annual Energy Use and Cost After EEM		Annual Savings per EEM				Simple Payback
		(10^3kBtu)	($)	kWh	therms	($)	(%)	(years)
Baseline	NA	2616	$45,780	-	-	-	-	-
EEM1	$0	2509	$43,280	31,000	-	$2,500	4.08%	0
EEM2	$1,800	2414	$42,196	-	950	$1,000	3.64%	1.7
EEM3	$6,400	2310	$39,761	30,400	-	$2,500	3.97%	2.6
EEM4	$4,600	2282	$39,425	-	280	$336	1.07%	13.7
EEM5	$200	2268	$39,593	-	140	$168	0.54%	1.2
EEM6	$225	2268	$39,733	-	-	$28	0.00%	7.9
EEM7	$200	2267	$39,741	-	17	$20	0.06%	10
EEM8	$6,111	2056	$37,242	-	2103	$2,519	8.04%	2.4
Total	$19,536	2056	$37,242	61,400	3,490	$9,071	21.4%	2.153736

EEM 1: Computer energy management
EEM 2: Install on-demand hot water heaters
EEM 3: Install lighting system occupancy sensors
EEM 4: Perform maintenance on HVAC equipment
EEM 5: Install weather stripping on exterior doors
EEM 6: Upsize HVAC units to eliminate slip-in duct heaters
EEM 7: Up charge to replace single pane windows with double pane, as needed
EEM 8: Thermostats

a. Replace older models with new programmable models
b. Program all thermostats to match schedules and lock set points
c. Train staff on thermostat operation

Introduction

The students of the 2009 Energy Systems Management and Auditing class at Oregon Institute of Technology (OIT) prepared this report based on our energy audit of the OIT Portland East building. In this report, we discuss our findings from this audit and recommend energy efficiencies measures that will reduce utility costs at OIT Portland East. Energy efficiency measures (EEMs) vary from inexpensive and mundane changes in scheduling (turning off lights or computers at night) to expensive and complex system upgrades (replacing heating, ventilation, and cooling systems). To help prioritize the use of the limited dollars available for building upgrades, we used payback analysis to compare the cost-effectiveness of the EEMs presented. We hope to see some of these EEMs implemented not only to reduce operating costs for the school and increase the comfort of future students, but also to demonstrate the leadership and innovation that OIT is known for.

Background

Building Description

OIT Portland East was built as a high school in 1953. Today, after several remodels, the 56,000 ft^2 building houses classrooms and offices for OIT, and several tenants: Clackamas Community College (CCC), Eastern Oregon University (EOU), and the North Clackamas County Chamber of Commerce (Chamber). The building has 22 classrooms and labs, offices, a library, student and staff lounges, six restrooms, and a gym. The building is a single story and has a central courtyard that increases the glazing and external wall area.

The primary tenants of the East Campus building are OIT in the southwest and north classrooms and CCC in the southeast classrooms. The remainder of the southeast wing of classrooms is now leased to EOU and the Chamber. The gym is rented-out and used regularly, but was excluded from this audit due to plans for renovation: OIT hopes to replace the gym and locker room area with new classrooms and labs. Ideally, this two-story addition will feature energy-conscious design.

Energy Use Analysis

Building EUI

An analysis of OIT utility data for 2007 and 2008 generated the data seen in table 2 and figures 2 and 3 below. At first glance some conclusions can be made about the patterns of energy use. Since the domestic water heating is the only natural gas load during the summer months and this load is relatively constant throughout the year, we assume the summer natural gas load of 120 therms/month is the average hot water load. Because

Electricity use is fairly constant at around 3,000 kWh/month, it is not possible to determine the individual electricity loads without comparing them to statistical data.

The Commercial Buildings Energy Consumption Survey (CBECS) published by the U.S Department of Energy, provides statistical data of energy end use for various building types. CBECS data of educational buildings was used to delineate an estimate of the energy associated with each end use electricity load. Some modifications had to be made in comparing CBECS data to OIT's energy use. For example, it is known that OIT provides space heat and hot water solely with natural gas; therefore, we negated electricity in the analysis of hot water and the other sectors were assigned a greater percentage. The data from CBECS and the correlated end use for OIT can be seen in tables A-1 and A-2 of Appendix A. Figure 1 shows the results of the correlation of OIT's energy use to the CBECS data.

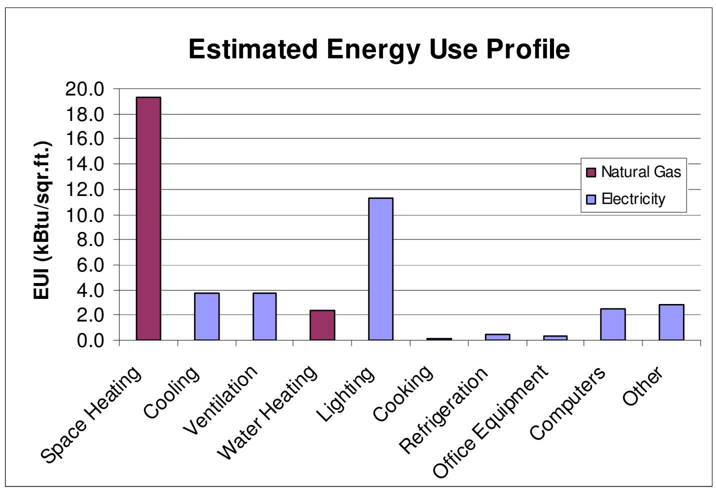

Figure 1: Estimated Energy End Use Profile

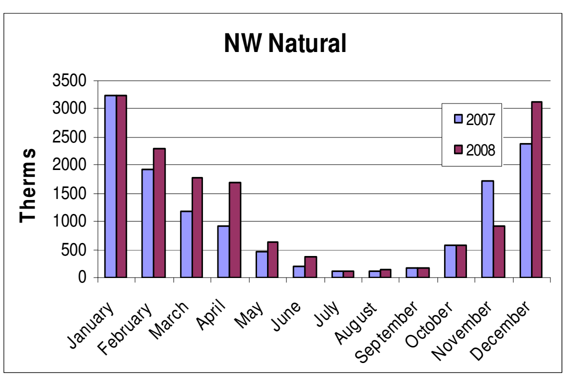

Figure 2: NW Natural Energy End Use Profile

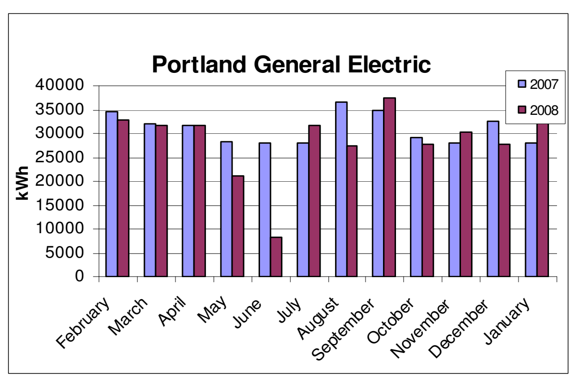

Figure 3: PGE Energy Profile

With a total of 2,680 MBtu consumed annually and a conditioned area of 56,000 ft^2, the EUI for the building is 47.9 kBU/ft^2-yr. The annual gas cost at $1.30 per therm is $18,200 and electricity at $0.08 per kWh is $30,000 per year. This results in an annual energy cost for the building of approximately $48,200.

Table 2: Energy Use Data for 2007 and 2008

NW Natural						
Year 1		Year 2		Average		
Bill Date	Therms	Bill Date	Therms	Month	Therms	kBtu
12/27/2007	2370.2	12/31/2008	3116.6	DEC	2743.4	274340.0
11/28/2007	1707.5	11/24/2008	930.2	NOV	1318.85	131885.0
10/25/2007	575.4	10/27/2008	583.7	OCT	579.55	57955.0
9/26/2007	177.9	9/25/2008	159.9	SEP	168.9	16890.0
8/28/2007	111.0	8/26/2008	146.6	AUG	128.8	12880.0
7/27/2007	115.3	7/25/2008	105.3	JUL	110.3	11030.0
6/26/2007	203.6	6/25/2008	383.1	JUN	293.35	29335.0
5/25/2007	449.9	5/27/2008	628.7	MAY	539.3	53930.0
4/26/2007	910.8	4/25/2008	1695.2	APR	1303	130300.0
3/28/2007	1168.1	3/27/2008	1779.1	MAR	1473.6	147360.0
2/28/2007	1918.4	2/26/2008	2300.7	FEB	2109.55	210955.0
1/31/2007	3251.6	1/30/2008	3253.7	JAN	3252.65	325265.0
PGE						
Year 1		Year 2		Average		
Bill Date	kWh	Bill Date	kWh	Month	kWh	kBtu
12/17/2007	32600	12/16/2008	27600	DEC	30100	102705.4
11/15/2007	28000	11/14/2008	30400	NOV	29200	99634.5
10/16/2007	29200	10/15/2008	27800	OCT	28500	97246.0
9/17/2007	34800	9/16/2008	37400	SEP	36100	123178.3
8/15/2007	36600	8/14/2008	37200	AUG	36900	125908.0
7/17/2007	31800	7/16/2008	27400	JUL	29600	100999.3
6/15/2007	28000	6/16/2008	31600	JUN	29800	101681.8
5/16/2007	28000	5/15/2008	29400	MAY	28700	97928.4
4/17/2007	28400	4/16/2008	31600	APR	30000	102364.2
3/19/2007	32000	3/17/2008	31800	MAR	31900	108847.3
2/15/2007	34800	2/14/2008	33000	FEB	33900	115671.5
1/26/2007	32400	1/17/2008	28000	JAN	30200	103046.6
Total kBtu	2,680,000			EUI (kBtu/sqr.ft.)	47.9	

Audit Findings

Occupancy Area

This building has about 56,000 sf of occupied (heated) space. There are several categories of areas.

- Continuously occupied areas. This includes the main offices (OIT, CCC, EOU, Clackamas Chamber of Commerce) and the student lounge and library. These places will be constantly occupied during open hours.
- Sporadically occupied areas. These are areas that are only occupied on an occasional basis. They include faculty and staff offices, maintenance and storage areas, conference rooms, and the staff lounge.
- Classrooms and Labs. These are occupied on a varied schedule, although a few are occupied on an almost continuous basis (rooms 129/127, 151.)
- Restrooms. These are occupied on an occasional basis
- Hallways. Occupied on an occasional basis.
- Gym. This was not included in the survey since extensive renovation is already being planned.

Table 3 shows the approximate square footage and percentage of the total area occupied by each type of area, as estimated from available plans. Extensive remodeling has occurred so these figures cannot be taken as highly accurate, but are close enough to be a good representation of usage.

Table 3: Occupation type for space in OIT

Area Type	Square Footage	Percent of Total
Continuously Occupied Areas	6,980	12
Sporadically Occupied Areas	5,680	10
Classrooms and Labs	22,300	40
Restrooms	1,500	3
Hallways	11,650	21
Gym	8,090	14
Total	**56,200**	**100**

Figure 4 shows the percent usage, by type, of the building. It shows clearly that the teaching areas consume the greatest building space. Since these are sporadically occupied, they therefore have the greatest potential for improvement in energy efficiency. Hallways occupy the second largest amount of space, and would be the next most likely area of energy savings.

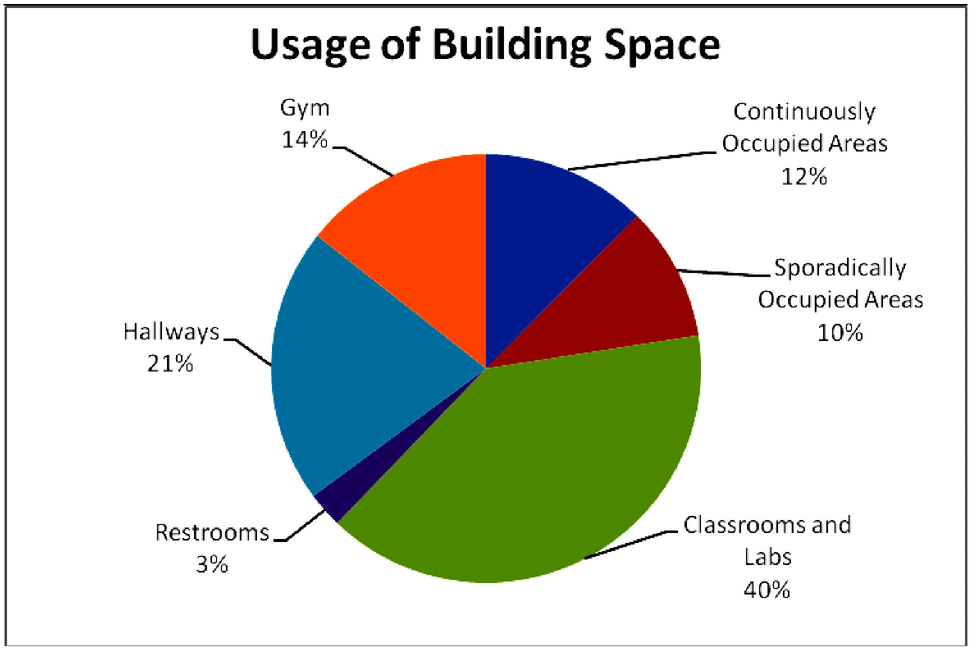

Figure 4: Percentage of usage of building space

Classroom Occupancy Schedule

In order to estimate classroom usage, the scheduled occupancy was tabulated for the week of February 2-8, 2009. (See Table 4 below) The classes are scheduled for occupation only 20% of the available time. Assuming that the classes are also used at other times for studying still only brings the occupied time up to 25%. It is therefore important to ensure that during the unoccupied time there is little to no energy usage.

Table 4. Percent classroom occupation time

Hours of Occupation	Hours	Percent
Total Possible	1800	100
Scheduled	362.5	20
Scheduled and Study Time	442.5	25

Lighting

Except where noted, the lighting systems consist primarily of GE F32 T8 XL SP41 fluorescent lamps with electronic ballast and GE F26 DBX 841 ECO compact fluorescent lamps. The longer fluorescent lamps consume 32W and produce light at 4100K. The compact fluorescent lights consume 26W. Lighting codes specify required light levels for hallways, and hallway lights generally remain on during hours of operation to meet the requirements. Classroom lights have switches, and a cursory inspection indicates that students and staff turn off the lights in unoccupied rooms, in most cases. Bathroom lights, on the other hand, frequently remain on throughout the day.

A recent exception to lights being turned off when rooms are not in use is the library, room 130. Because of security concerns, a security camera has been installed in the room. Operation of the camera requires that lights be left on 24 hours per day.

Existing ASHRAE design guidelines for schools and universities call for a lighting power density (LPD) of 1.2 W/ft^2. The LPD is the maximum amount of consumed power allowed per area, for example: Rm. 193 has 23 light fixtures containing two 32 Watt bulbs. This amounts to 1472W of power being consumed by the lighting load. Divide this by the room area of 1428 ft^2 and the result is 1.03 W/ft^2, which is within the guidelines.

ASHRAE also recommends a light source system efficacy of 75 lm/W, which is the minimum requirement for the ratio of light output (in lumens) to power consumed in order to produce that light. Again looking at Rm. 193, an illuminance meter reading taken at the center of the room was 620 lx. Multiply by the area of the room, 132.6 m^2, to get 82212 lm. Divide this by the total Wattage of the 23 lights, 1472W, and the result is an efficacy of 55.9 lm/W, which is below the recommended level of 75 lm/W.

Using the same procedures for rooms 127 and 129 (Area = 832ft^2/77.3m^2, 470 lx, 16 32W bulbs) the results were: LPD = 0.62 W/ft^2 and efficacy = 71 lm/W. In this case, the LPD is acceptable, but the efficacy is still below recommended levels, although very close. Most of the rooms in the school are the same area, 832ft^2/77.3m^2, however, the light levels are higher on the eastern half of the building averaging around 600 lx with 24 light bulbs per room. With these numbers the LPD is 0.92 W/ft^2 and the efficacy is 90.6 lm/W, which are both acceptable numbers.

An investigation of the light fixtures, lamps, and ballasts attempted to get a complete description of the lighting systems. The plans for the renovation in 1992 provided the starting point for the investigation. The number and type of lamp in each room and each zone were compiled in Appendix F. The renovation plans did not include changes made during a retrofit ten years ago. For example, an inspection of the building located some 26W compact fluorescents which had replaced T8 lamps indicated in the lighting plans.

Heating, Ventilation, and Cooling Equipment

Heating, ventilation, and cooling (HVAC) systems represent a large fraction of the energy use in most buildings, and OIT East is no exception. Based on our utility billing analysis, we estimate that HVAC systems represent more than half of the energy used in the building. Rather than a central, ducted heating system, the building has separate roof-mounted packaged HVAC units above every classroom, plus additional units for offices, hallways, and common areas. These thirty-seven units are detailed in Appendix B. The packaged units were purchased in two batches: units AC-1 to AC-23, manufactured by York, were added to the building during the last remodel of the west and north hallways, used primarily by OIT; units AH-1 to AH-12, manufactured by Carrier, were added later during the 199X remodel of the south and east hallways, now used primarily by CCC. These packaged units have 80% efficient gas-fired heating and electric-powered air-conditioning. The older units have a range of Seasonal Energy Efficiency Ratings (SEER) for cooling from 8.4 to 9.9 BTU of cooling per Watt-hour input. The newer units all have an SEER of 10 BTU/Wh.

All of the units feature economizers, a controlled damper that opens to pull in outside air for cooling when the outside temperature is in a desirable range. Economizers increase HVAC efficiency by reducing the building's cooling load. However, the drawback of economizers is they require regular maintenance. A stuck economizer can leak hot air in the winter months or simply stop functioning when needed.

Along with the package units described above, the building has several auxiliary HVAC systems. A single packaged unit, AC-X, provides electric heating and cooling to the OIT main offices in the northeast corner of the building. Ventilation fans draw air out of the restrooms and janitor closets. Duct heaters, DH-1 to DH-5, provide supplemental heat to the CCC offices and meeting room. Finally, three electric resistance wall heaters provide supplemental heat in low-usage areas of the building.

We examined the HVAC units on the roof of the building. Out of the 37 package units on the roof, we found 8 units with potential maintenance problems, as noted in Table 5. Several HVAC units and one of the exhaust fans had loud fan imbalance problems. Two units were leaking warm air out of the economizer, an indication that their dampers are not fully closing. A third unit had an old wasps nest lodged in its economizer; this may or may not affect its functioning, but is a sign that the units have not been recently cleaned or maintained. Finally, unit AC-17 was partially disassembled and turned off. Note that this unit serves the northeast hallway, so units from surrounding hallways may have to compensate by running beyond their design-capacity.

Table 5. HVAC equipment in need of maintenance

System	Description	Manufacturer	Area	Notes
AC-1	A/C Unit with Gas Heat	York	Rm 178	Audible fan imbalance.
AC-2	A/C Unit with Gas Heat	York	Rm 191	Economizer stuck open.
AC-3	A/C Unit with Gas Heat	York	Rm 193	Old wasp nest in economizer.
AC-4	A/C Unit with Gas Heat	York	Rm 195	Condenser on, 50 F weather.
AC-17	A/C Unit with Gas Heat	York	NE Hall	Off, fan disassembled.
AC-18	A/C Unit with Gas Heat	York	Rm 139	Economizer stuck open.
AC-23	A/C Unit with Gas Heat	York	Rm 149	Audible fan imbalance.
EF-1	Ventilation Fan	Greenheck	W RR	Audible fan imbalance.

Thermostats

A thermostat is a control device that regulates the temperature of a building in order to maintain a set point. The thermostat measures the temperature of an area, and as the measured value deviates from the set point, it regulates the output of the heating and cooling systems.

Thermostats allow the occupants to control the set point as well as dictate the heating and cooling systems hours of operation. In this way, thermostats allow occupants to exert control over their energy use.

As part of our energy use analysis, we examined a representative sample of seven thermostats. We found that each thermostat had inefficient control settings that could be characterized by a combination of excessive hours of operation, days of operation, extreme set points, or antiquated thermostats.

In addition, we observed improper use of the thermostats when users wanted to temporarily change the system settings. The thermostats offer a feature that temporarily changes the set point for the temperature in the room, and then reverts to the programmed schedule after a certain amount of time. However, we found that users sometimes reprogrammed the thermostats without sufficient knowledge of the system, causing the system to run longer than necessary or at an excessive set point.

Envelope

Nearly all of the exterior doors in the building have seal issues. Viewing the doors, we could see light shining through several spaces around the doors. This is an indication that air can pass easily through, and heating or cooling energy is wasted.

Other observations concerning the building envelope include the foyer doors near the Clackamas Chamber of Commerce are always open, the windows in the older areas of the building are single pane, and there is no ceiling insulation in most of the building.

Hot Water

The OIT Portland Metro Campus uses almost no hot water. The gymnasium showers are decommissioned and there are only 3 sets of bathrooms (3 men's, 3 women's). None of the bathrooms being utilized contain showers, leaving just 12 lavatories that intermittently use water only for hand washing. The only other hot water use is a dishwasher and sinks in the chemistry lab and the custodial services.

The water heater is located in the middle of the building away from the areas it is actually used. It has 100 gallon capacity and a BTU input rating of 197,000 BTUs. Up to 30 % of the energy consumed by a water heater is used just to keep the water hot while it's not being used. Gas water heaters have higher standby losses than electric due to the uninsulated flue running up the center of the tank. There are other additional large losses due to the fact that this system has a ½ hp recirculating pump to provide hot water at the taps at all times.

Miscellaneous Loads

A large source and waste of electrical consumption is from unattended computers. Many of the computers throughout the building are vacant for the majority of the day, as well as at night and on weekends. During the audit of the building, 130 computers were counted. Of these, only 30 of them were turned off with the monitors left on stand-by. The rest of the computers sat idle, again with the monitors on stand-by. Table 6 shows the energy that is wasted from these machines when the building is vacant during the night and weekends.

Table 6. Computer energy use analysis

Energy used by computers while unoccupied	
Power Consumed (W)	56.4
Hrs/week Unattended	82
kWh/yr per computer	240
Number of Computers	130
Total kWh/yr	31,250

There are several significant “phantom” loads on campus. Printers, photocopiers, and vending machines draw power continuously. A quick count puts the number of printers in the building at 16. There are at least 3 photocopiers and 4 large vending machines. The printers are drawing an average 15 watts each even while in standby mode. That's 5,760 watts per day while not being used. The 3 photocopiers are each using 52 watts in standby mode for a total of 3,700 watts per day. And the 4 vending machines draw 640 watts each or 61,440 watts per day.

Recommendations

Table 1: Recommended energy efficiency measures

Model ID	Initial Costs	Annual Energy Use and Cost After EEM		Annual Savings per EEM				Simple Payback
		(10^3kBtu)	($)	kWh	therms	($)	(%)	(years)
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a. Replace older models with new programmable models
b. Program all thermostats to match schedules and lock set points
c. Train staff on thermostat operation

EEM 1 - Computers

Currently, the majority of the computers in the building are on during off-hours. When added up, this comes to around 82 hours a week that the computers are on while the building is vacant. If they were shut down during this period, approximately $60 per year would be saved for each computer. By putting the computers on a schedule, making sure they shut down at night and weekends, the energy consumption can be reduced drastically. At an average rate of $0.10/kWh, the yearly savings by shutting every computer down at night and on weekends would total over $3000 per year.

Another option is to program the computers to automatically turn off if they sit idle for a set period of time. As a result, the computers would only waste a small amount of energy before they would automatically shutdown.

EEM 2 - Hot Water

The natural gas used to provide hot water at OIT is estimated to be about 1,300 therms/year and consumes approximately 130 Million Btu/year. This translates into a cost of $1,400/year for hand washing. (This is a conservative estimate that does not include the losses due to the recirculating pump and piping.)

We recommend the installation of four point-of-use water heaters, one for custodial staff and one for each set of bathrooms. This will eliminate the heat loss associated with transferring hot water though piping and the heat that is lost to the environment due to poor insulation on the existing hot water heater. Table 7 details cost, savings, and simple payback of this measure.

Table 7: Savings and Installation Costs for Hot Water Efficiency Measures

Installation Cost	Annual Savings		Simple Payback (yrs)
	MBtu	($)	
$1,800	95	$1,100	1.6

EEM 3 - Lighting

The greatest efficiency gains in lighting can be made by simply turning off lights when they are not needed; however, since this is difficult to enforce, installing occupancy sensors is the best way to ensuring that lights are turned off when the room is not occupied. A joint study by the Lighting Research Center and the Energy Star building program gathered data from several studies on the implementation of occupancy sensors and their effect on energy use as seen in table 8. (http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf)

An average of each of the five studies is listed in table 8 along with an approximation of the potential savings resulting from implementing occupancy sensors at OIT. Table 8 also shows an estimate of the lighting load consumed by each room type. This estimate was calculated by dividing the total lighting load by the relative square footage of each room type.

Installing an occupancy sensor in the library is particularly important because the lights are currently on 24 hours per day. An occupancy sensor would allow the lights to be turned off when the library is closed. In this occupancy mode, the lights would turn on when someone enters the room, thus the security camera will operate as needed. This measure would save over 50% of the lighting energy currently expended in the room.

Table 8: Estimate of potential energy savings for occupancy sensors (in %), US EPA

Space type	CEC	Esource	EPRI	Novitas	Watt Stopper
Private office	25-50	13-50	30	40-55	15-70
Open office	20-25	20-28	15	30-35	5-25
Classroom	-	40-46	20-35	30-40	10-75
Conference	45-65	22-65	35	45-65	20-65
Restroom	30-75	30-90	40	45-65	30-75
Warehouses	50-75	-	55	70-90	50-75
Storage	45-65	45-80	-	-	45-65

Table 9: Potential savings with the implementation of occupancy sensors

	Percent of Lighting Load	Baseline Lighting Energy Use (MWh)	Potential Savings		
			(%)	(MWh)	($)
Class Rooms	40%	64.4	37%	23.8	$1,905
Offices	12%	19.3	22%	4.2	$337
Restrooms	3%	4.8	50%	2.4	$193
Hall Ways	21%	33.8	0%	0.0	-
Other	24%	38.6	0%	0.0	-
Total	100%	160.912	19%	30.4	$2,435

Dual technology occupancy sensors use both passive infrared and ultrasonic technologies to sense occupancy. For this reason they are recommended for areas of low traffic such as classrooms and offices. We recommend ceiling mounted models with panoramic view, such as the PDT-CM model made by Sensor Switch, Inc. outlined in the National Lighting Product Information Program. (http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SROS2.pdf)

Infrared sensors are less expensive and are sufficient for restrooms where the occupants will pass the sensor while they enter the room. In this case switch-plate mounted sensors are sufficient.

Table 10 gives a breakdown of the cost of installation for occupancy sensors. We estimate that installing occupancy sensors in each classroom, office and bathroom with give a simple payback of 2.6 years.

Table 10: Installation costs for Occupancy Sensors

Occupancy Sensor Installation Costs		
Technology	Number of Units	Cost/Unit
Dual	27	$150
Infrared	8	$75
Labor	35	$50
Total Cost		$6,400

Since the East half of the building meets both the LPD and efficacy recommendations, no lighting improvements are needed in this area. The Western side of the building, including all OIT classrooms, meets the LPD requirements but is deficient of the efficacy recommendation. While this means there is not the recommended amount of emitted light for the amount of power being consumed, it would be difficult to see any improvement by adding more lights. This would add more consumed power and therefore not change the efficacy.

Some improvement in efficiency could be made by replacing T8 lamps with T5s. This change would help to meet ASHRAE lighting efficacy standards. However, T5 lamps require swapping out ballasts and fixtures. At an approximate cost of $300 per luminaire, replacements are cost effective only for those parts of the building that are being renovated.

However, cost effective energy saving measures can be applied to some lights immediately. The lights which are currently installed in the hallways are very directional, that is: the lights have baffles which direct the light straight down to the ground. As a result the lighting is uneven, as illustrated in Figure 5. If the fixtures were of a type which diffused the light in all directions, the light would be more even. It would also make it possible to use less light fixtures to get the same amount of light that is currently being produced. (See Figure 6.) This would result in a considerable energy savings.

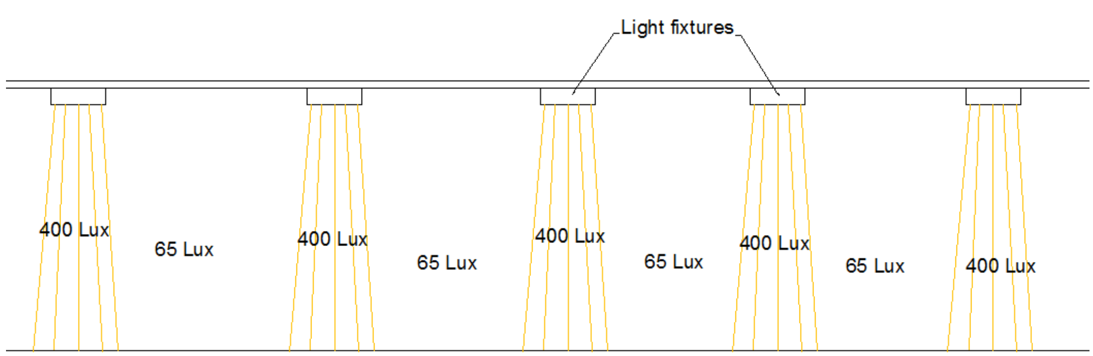

Figure 5: Current hallway lighting pattern.

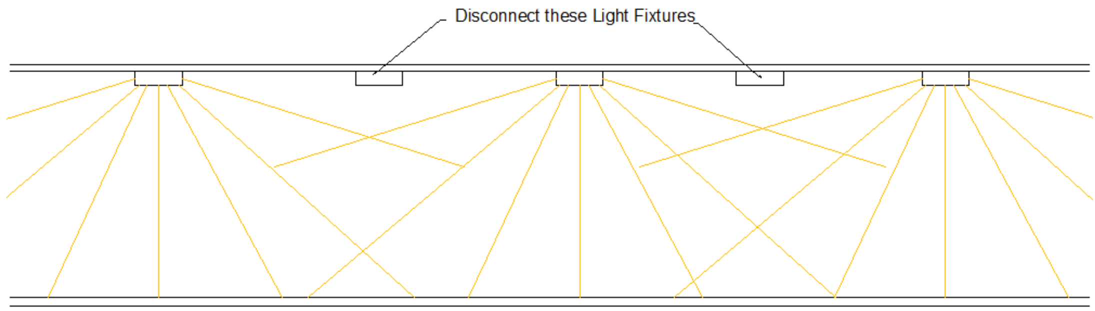

Figure 6: Proposed lighting scheme

Each hall light is on during occupied hours, 7:00 am to 11:00 pm, Monday through Saturday, for a total of 4992 hours per year (Appendix C, Eq. 1). Each light fixture has two 32W bulbs in it, and assuming that electricity costs $0.08/kWh we find that each fixture costs $25.56 per year to run (Appendix C, Eq. 2).

There are a total of 68 hallway fixtures, 30 of which could be disconnected. (See Appendix D and F for specifics.) Replacement covers of a type that would diffuse the light over 180 degrees (See Appendix E for example) could be installed on the 38 remaining fixtures. It should take about 30 minutes each to install the new covers on the 38 lights to be retained, and about 15 minutes each to disconnect the 30 unnecessary lights. At $50/hour for labor it would cost $1,325.00 to do the alterations necessary (See Appendix D.) Assuming a materials cost of $20.00 per replacement cover the total cost of the improvements would be $2,085. (Appendix C, Eq. 3)

With the 30 fixtures disconnected $766.80 will be saved per year (Appendix C, Eq. 4). That means that within 2.7 years this project will be paid for, and the $766.80 annual saving will begin (Appendix C, Eq. 5). Since it is likely that electricity costs will rise, payoff time will probably be less and saving will be greater than calculated.

Some gains in efficiency can also be reached by replacing lighting fixtures. It is often the case that the lenses absorb a large fraction of the light output of the lamps. However, the relatively long payback period for this measure makes this option less attractive than other improvements.

Instant Start (IS) electronic ballasts heat the lamp as it is turned on. This requires more power at start up and can decrease the lifespan of the lamp. Rapid Start (RS) ballasts continuously heat the lamp, improving the lifespan of the lamp, but requiring more power overall than the IS ballast (www.ace-ballast.com). Economic modeling for replacing RS ballasts with IS would need to account for more frequent lamp replacement. At this time, no definite recommendation can be made, regarding IS and RS ballasts.

EEM 4 – HVAC Equipment Maintenance

This measure involves maintenance on the existing HVAC equipment. This will require the hiring of an outside contractor to evaluate the equipment and make repairs as necessary. The maintenance would likely include: filters, fans, coils, sensors, economizers and vibration analysis.

Filters could be upgraded with extended-surface-area filters. These filters have a lower initial pressure drop, higher dust-holding capability, and higher structural ratings. Benefits include longer change cycles and lower pressure drops (which conserve fan energy).

Fan maintenance includes cleaning housings and fan blades, lubricating and checking seals, adjusting belts, checking bearings and structural members, and tracking vibration. Coils should be checked for cleanliness and cleaned if necessary.

Coil cleanliness directly affects the efficiency of heat transfer to and from the air stream, and the performance of the entire HVAC system. A clean coil has a lower pressure drop, and thus lowers fan and pump energy consumption. Lower fan and pump energy consumption also means reduced fan and pump heat which represent a parasitic load for cooling processes.

Sensors should be cleaned and calibrated. Trying to control an HVAC system based on false input values from poorly calibrated sensors is futile.

Economizers should be checked for functionality. If an economizer is not functioning properly, excessive outside air causes increased heating and/or mechanical cooling, and too little air compromises indoor air quality.

An additional maintenance procedure would be a vibration analysis of large fans and motors. Vibration signatures are compared with previous readings for indications of component degradation such as worn bearings, shaft alignment, or fan-blade imbalance.

We estimate that performing these maintenance procedures could save up to 2% of the percent of the natural gas usage per year. The cost of this measure was estimated at $150-$200 per packaged rooftop unit, as obtained from a local HVAC contractor.

EEM 5 – Weather-stripping

This measure requires installation of weather-stripping on the exterior doors where visible gaps were identified in the audit. This is a very low cost measure to reduce infiltration and subsequent heating and cooling loads. We expect that the total natural gas usage to serve these loads could be reduced by 1% if this infiltration was eliminated completely. The cost of the materials is very low and the labor required is limited. The cost of this measure is estimated at $200.

An additional improvement to the building envelope would be achieved by closing the foyer doors near the Clackamas Chamber of Commerce. This would add a significant insulation layer to the exterior doors in that area, and decrease outside air infiltration.

EEM 6 – Upsize HVAC Units

This measure recommends increasing the capacity of existing HVAC units that are currently supplemented by slip-in type electric duct heater. This upsizing would only occur when the unit requires replacement. As such, we will use the incremental cost of purchasing a larger unit for estimating the cost of this measure. If the HVAC unit was large enough to eliminate the need for these auxiliary heating systems the load could be serviced by natural gas rather than electricity. There will be no energy savings from shifting the load, but there will be cost savings from implementing this measure. Natural gas has approximately one half the price for heating as electricity. This measure will shift 8 kW of load from electricity to natural gas. This is equivalent to increasing the HVAC equipment size by 27 kBtu/hr. Assuming that the supplemental heaters have a 1% duty cycle, this will shift 696 kWh of energy usage to gas. The incremental cost of this upsizing was estimated from www.budgetheating.com to cost $75/unit, for a total cost of $225.

EEM 7 – Windows

This measure calls for the installation of double pane windows when the existing single pane windows require replacement. Retrofitting a building with high- performance windows can produce significant energy savings and improved comfort. Since the replacement will be required, again we will use the incremental cost of upgrading the window rather than the total cost. The cost and savings estimates shown in table 1 are stated on a per window basis. The prices were based on a 6x4 foot window and were obtained from www.homeenergy.org. The method of installation is important as the choice of window. When the right window is installed incorrectly, energy savings will be few, structures may be damaged, and the occupants' safety may be jeopardized.

EEM 8 – Thermostats

This energy efficiency measure involves thermostats. The first step is to replace older model thermostats with newer programmable models with lockouts. Programmable thermostats allow one to heat/cool the space according to occupancy schedules. According to the National Association of Homebuilders, this can reduce the energy requirements of a space by 10 to 15 percent without compromising comfort if programmed correctly. We also recommend that the thermostats have a lockout feature, which would not allow users to reprogram the schedule, only change the set point for a short time before reverting to the programmed schedule. The quoted cost of the new thermostats is $257 each for a total equipment cost of $5911. This will also require labor costs to program all thermostats to match the buildings occupancy schedule. The programming of these thermostats will only increase efficiency if the programming is not altered or tampered with. This will require staff training on the operation of the thermostats to ensure that programming overrides are appropriate. We estimate the costs of labor for installation and time for staff training to be worth $200.

A representative example of potential savings by utilizing proper scheduling is demonstrated by programming thermostats for a holiday schedule. OIT is closed for classes for four or five weeks at the end of December and the beginning of January every year. The only portion of the building which is occupied is the offices. If the heat was turning off in the unoccupied spaces of the building during this time significant savings could be realized.

Table 11: 2007/2008 heating energy during winter break

	2007/2008 Usage from Utility bills (therms)[4]	Space Heating Usage[1]	Days for this bill	Usage per day (therms)[2]	Days school closed	Usage During Winter Break (therms)[3]
December	2,370	2,250	29	77.6	23	1,784.5
January	3,254	3,134	32	97.9	6	587.6
Total						**2,372.1**

1. Assume hot water usage equals an average of 120 therms/month based on July/August bills, when there would be no heating needed. So Usage for Heating = Total usage minus 120 therms.
2. Adjusted usage divided by days for this bill
3. Usage per day times days school closed.
4. Appendix E tabulates usage for 2007-2008.

Table 11 shows usage for the winter vacation of 2007/2008. The amount used for water heating (120 therms) was deducted from the total to get the amount used for space heating. Fall term ended 12/07/07 and winter term started 01/07/08, so the classrooms were unoccupied for 23 days in December and six days in January.

Table 12: Summary of types of usage

Area Type	square feet	percent
Continuously Occupied Areas	6,980	12
Sporadically Occupied Areas	5,680	10
Classrooms and Labs	22,300	40
Restrooms	1,500	3
Hallways	11,650	21
Gym	8,090	14
Total	**56,200**	**100**

Table 12 shows the types of usage in the building. The classroom, labs and gym comprise 54% of the building, so it is assumed that they also consume 54% of the usage for heating. This means that 54% of the usage during break could be saved if the heat was turned off in the unused spaces, which equates to $1,537.12 saved (Appendix C, Eq. 6).

It should take about a half a day or less to turn off the thermostats, so assuming a labor cost of $25.00 per hour, it would cost $100, and save $1,430.00 per year. (Pay a student to do it and it will cost even less.)

An additional consideration for any HVAC system is upgrading air handler units to more efficient models. The current air handler units include an 80% efficient gas heating and a 9 to 10 seer air conditioner in a single unit. We researched replacing these units with similar higher efficiency packaged units, however, we were unable to find air handler units with increased efficiency gas heating and due to the low level of cooling load experienced by the building, an accelerated replacement schedule with available units with higher efficiency air conditioning is not justified.

Insulation

Insulation plays a very important role in the integrity of the building's envelope. However, although we found almost no insulation in the ceiling, we do not recommend installing it at this time. Retrofitting ceiling insulation could raise fire hazard and other code violation issues that would require hot water, heating, and electrical distribution to be relocated at great expense. Therefore, we conclude that adding ceiling insulation is cost prohibitive. However, all future renovations should include ceiling insulation that meets or exceeds ASHREA standards.

Miscellaneous Loads

16 printers and 3 photocopiers are estimated to consume about 2,312.64 kWh/year, or an annual cost of about $194.00 when not in use (after hours and weekends). Each of these appliances can be automatically switched off during nights and weekends with the implementation of outlet timers. At a cost of $7.99 each, their combined efficiency gain will save $190 annually with a simple payback of less than a year.

OIT currently uses four vending machines provided and maintained by North County Vending (NCV). The machines are estimated to use 22,400kWh/year with an annual cost of $1,800. OIT assumes all of the energy costs associated with these machines. There may be potential for NCV to pay for a portion of the vending machine power use. Also, since none of the items in the vending machines are perishable, timers may be used for the vending machines as is recommended for the printers and photocopiers.

Conclusion

The walk through inspection of the OIT East Campus found many opportunities for potential energy savings, which are outlined in table 1 followed by a detailed description of each measure. Implementing all of the recommended energy saving measures would cost $19,536 resulting in a simple payback period of 2.15 years followed by annual savings of $9,071.

Appendix A – EUI Estimation

Table A-1: EUI from CBECS, (Table E4) and OIT Estimate

	Electricity Energy Intensity (thousand Btu/square foot)										
	Total	Space Heat-ing	Cool-ing	Venti-lation	Water Heat-ing	Light-ing	Cook-ing	Refrig-eration	Office Equip-ment	Com-puters	Other
Average (CBECS)	44.8	1.8	6.4	7.2	0.8	17.5	0.3	3.3	0.7	2.0	5.0
Estimated OIT	25.0	0.0	3.7	3.7	0.0	11.3	0.1	0.5	0.3	2.5	2.9

Table A-2: EUI from CBECS, (Table E4) and OIT Estimete

	Electricity			Natural Gas		
	%	MWh	MBtu	%	kTherms	MBtu
Space Heating	0.0%	0.0	0.0	89.1%	12.5	1081.92
Cooling	14.8%	52.6	206.6	0.0%	0.0	0
Ventilation	14.8%	52.7	207.2	0.0%	0.0	0
Water Heating	0.0%	0.0	0.0	10.9%	1.5	132.16
Lighting	45.2%	161.0	632.8	0.0%	0.0	0
Cooking	0.4%	1.4	5.6	0.0%	0.0	0
Refrigeration	2.0%	7.1	28.0	0.0%	0.0	0
Office Equipment	1.2%	4.3	16.8	0.0%	0.0	0
Computers	10.0%	35.6	140.0	0.0%	0.0	0
Other	11.6%	41.3	162.4	0.0%	0.0	0
Total	100.0%	356.0	1400.0	100.0%	14.0	1214.08

Appendix B – HVAC Equipment Schedule

Table B-1: Installed HVAC Equipent

System	Description	Manufacturer	MBH Out/In	SEER	Area	Notes
AC-1	Packaged Rooftop A/C Unit with Gas Heat	York	194/245	9.0	Rm 178	Audible fan imbalance.
AC-2	Packaged Rooftop A/C Unit with Gas Heat	York	98/125	8.4	Rm 191	Economizer stuck open.
AC-3	Packaged Rooftop A/C Unit with Gas Heat	York	163/204	8.6	Rm 193	Old wasp nest in economizer.
AC-4	Packaged Rooftop A/C Unit with Gas Heat	York	98/125	8.4	Rm 195	Condensor on in 50 F weather.
AC-5	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	W Hall, W RR	
AC-6	Packaged Rooftop A/C Unit with Gas Heat	York	32/40	9.5	Main Office	
AC-7	Packaged Rooftop A/C Unit with Gas Heat	York	32/40	9.5	OREC Office	
AC-8	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.6	Rm 127	
AC-9	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.6	Rm 129	
AC-10	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.6	Rm 131	
AC-11	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.6	Rm 133	
AC-12	Packaged Rooftop A/C Unit with Gas Heat	York	40/50	9.5	Student Lounge	
AC-13	Packaged Rooftop A/C Unit with Gas Heat	York	98/125	9.9	Library	
AC-14	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.8	N Hall	
AC-15	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Server Rm	
AC-16	Packaged Rooftop A/C Unit with Gas Heat	York	60/75	9.8	N RR, Offices	
AC-17	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	NE Hall	Off, fan disassembled.
AC-18	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 139	Economizer stuck open.
AC-19	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 141	
AC-20	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 143	
AC-21	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 145	
AC-22	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 147	
AC-23	Packaged Rooftop A/C Unit with Gas Heat	York	80/100	9.6	Rm 149	Audible fan imbalance.
AC-X	Packaged Rooftop A/C Unit with Electric Heat	<nameplate missing>		n/a	Offices	
AH-1	Packaged Rooftop A/C Unit with Gas Heat	Carrier	90/115	10.0	Rm 176	AH-1 to AH-12 newer units.

System	Description	Manufacturer	MBH Out/In	SEER	Area	Notes
AH-2	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 174	
AH-3	Packaged Rooftop A/C Unit with Gas Heat	Carrier	90/115	10.0	Rm 172	
AH-4	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 170	
AH-5	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	S Hall	
AH-6	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 154	
AH-7	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 152	
AH-8	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 151	
AH-9	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 155	
AH-10	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 157	
AH-11	Packaged Rooftop A/C Unit with Gas Heat	Carrier	92/115	10.0	Rm 159	
AH-12	Packaged Rooftop A/C Unit with Gas Heat	Carrier	59/74	10.0	E Hall, SE RR	
EF-1	Ventilation Fan	Greenheck	n/a	n/a	W RR	Audible fan imbalance.
EF-2	Ventilation Fan	Greenheck	n/a	n/a	N RR	
DH-1	2.5 kW Supplemental Duct Heater	n/a	n/a	n/a	Meeting 108	
DH-2	2.5 kW Supplemental Duct Heater	n/a	n/a	n/a	Office 107	
DH-3	1 kW Supplemental Duct Heater	n/a	n/a	n/a	Office 117	
DH-4	1 kW Supplemental Duct Heater	n/a	n/a	n/a	Office 118	
DH-5	1 kW Supplemental Duct Heater	n/a	n/a	n/a	Office 112	
EWH-1	1.5 kW Electric Wall Heater	n/a	n/a	n/a	Vestibule 101	
EWH-2	1.5 kW Electric Wall Heater	n/a	n/a	n/a	Office 109	
EWH-3	1.5 kW Electric Wall Heater	n/a	n/a	n/a	Mac Lab	

Appendix C – List of Equations

$$16\ hours * 6\ days/week * 52\ weeks/year = 4992\ hours/year$$ (Eq. 1)

$$4992\frac{hours}{year} * \frac{2bulbs}{fixture} * \frac{32W}{bulb} * \frac{\$0.08}{kWh} = \frac{\$25.56}{fixture}each\ year$$ (Eq. 2)

$$\$1{,}325.00\ labor + \frac{\$20.00}{fixture} * 38\ fixtures = \$2{,}085.00\ total\ cost$$ (Eq. 3)

$$30\ fixtures * \$25.56\ savings\ per\ year\ per\ fixture = \$766.80\ saved\ per\ year$$ (Eq. 4)

$$\$2{,}085.00\ total\ cost\ /\ \$766.80\ saved\ per\ year = 2.7\ years\ to\ be\ paid\ off$$ (Eq. 5)

$$2{,}372.1\ therms\ used\ during\ break * 54\%\ unused\ space * \$1.20\ per\ therm\ used = \$1{,}537.12\ saved\ during\ break$$ (Eq. 6)

Appendix D – Lighting Fixture Details

Table D-1: Lighting fixtures observed during walk-through

Hallway	Total lights	Lights to be Disconnected	Lights with New Covers
Northwest entrance to library	13	5	8
Library to northeast entrance	14	7	7
West hallway	10	4	6
East hallway (double fixtures)	18	8	10
south hallway	13	6	7
Total	**68**	**30**	**38**

Appendix E – Lighting Cover Cut Sheet

4ft 2 Lamp 32wt T8 Fluorescent Wrap Around Fixture 120v
[20-WA248E-120]

	$36.38
4+	$32.34
12+	$29.40
20+	$26.95

4ft 2 Lamp 32wt T8 Fluorescent Wrap Around Fixture

enlarge

- Application This surface mounted wrap around unit is designed for use in most commercial, residential and institutional type applications. The unit provides maximum light output with minimum clearance.
- Construction Housing is die formed heavy gauge steel finished in a baked white enamel for maximum reflectivity and durability. Clear acrylic prismatic wrap around diffuser lens hinges from either side and snaps on and off for easy maintenance.
- Electrical Units are furnished with UL listed Class "P" thermally protected, 120v ballast unless stated otherwise. UL Listed and NAECA Compliant.
- Mounting Knockouts are available for both pendant and surface mounting. This unit is designed to be mounted individually or in continuous run.
- **Energy Star Rated**
- High Power Factor Electronic ballast
- Please note Pricing does not include lamps.
- Can Use 2-32 watt T8 Lamps or 2-34 or 40 watt T12 Lamps
- 4 per case

UL LISTED

Figure E-1: Example of 180 degree light cover

Source: Contractors Lighting
http://www.contractorlighting.com/lamp-32wt-fluorescent-wrap-around-fixture-120v-p-170.html?osCsid=1381e831e34ebbd67f7f4afe86752a5e

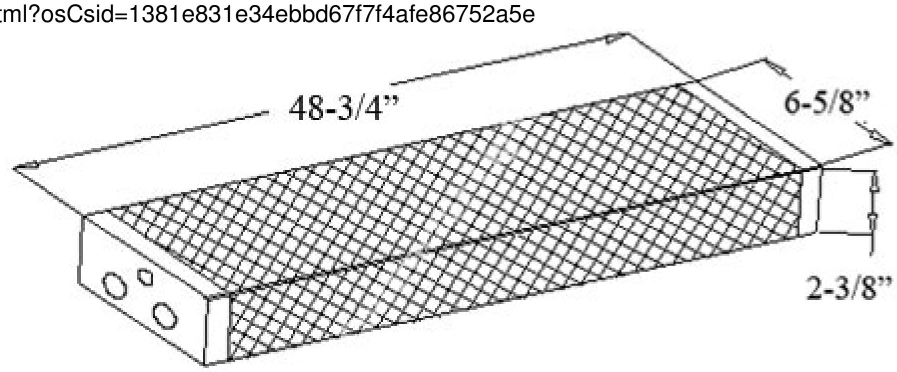

Figure E-2: Example of 180 degree light cover

Appendix F – Lighting Type by Room