Energy Audit Report

for

**Oregon State University
Kerr Administration Building**

**1500 SW Jefferson Avenue.
Corvallis, OR 97331**

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TABLE OF CONTENTS

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Introduction

Facility Profile

This report presents the results of an ASHRAE level II audit energy analysis conducted for the Oregon State University Kerr Administration Building located on the Oregon State University campus in Corvallis, OR. The building consists of portion "A" and portion "B". Portion "A" total has six floors including a telecom room in the basement. Portion "B" has three floors, including a large data center on second floor. Total conditioned space area is approximately 122,000 sf, which includes administration offices, conference rooms, café room, data center and telecom etc.

Methodology

This audit is per ASHRAE Level II requirements. This audit includes two site visits, review existing drawings and billing information and energy analysis based on DOE2 energy model and engineer hand calculation.

David Gilles conducted two site visits, first one on 05/12/2011, the second one on 06/13/2011. For the 1st visit, Larrie Easterly, Greg Smith and Brandon Trelstad from Oregon State University were present. Greg Smith was present for both audits.

The energy analysis was performed using standard engineering calculation procedures and the building energy simulation program eQuest, an hour by-hour energy usage modeling program evolved from DOE2 which was jointly developed by Lawrence Berkeley and Los Alamos National Laboratories for the U.S. Department of Energy. While eQuest is generally accepted as one of the most accurate building energy simulation programs, the estimated energy usage should not be interpreted as an absolute prediction. The actual energy usage may differ from the prediction due to variables beyond the energy analyst's control. These may include changes in occupancy, schedules, final equipment selection, installation and operation, weather variations from typical year data used, and other unforeseen circumstances.

A baseline building energy performance model was first developed based on the existing building conditions. Energy efficiency measures (EEMs) were identified and analyzed by modifying the baseline building to reflect the impact of each EEM on the building's energy performance. An interactive model was created to simulate net effect of all EEMs. The cost-effectiveness of each EEM was evaluated using a simple payback analysis, which yields a time required to recover the cost for implementing the EEM by its annual energy cost savings. The EEM cost estimates are either obtained from RSMeans 2009 or provided by the local equipment vendors.

Recommended Package

This energy analysis was conducted to identify energy efficiency measures (EEM), which could be implemented to reduce building energy consumption. One modeled interactive package of EEMs (EEM1, EEM2 and EEM4 is recommended, which is estimated to save 29.5% of baseline building energy usage (903,796 kWh/yr of electricity, 16,640 therms/yr of steam) and 29.5% energy cost savings ($77,638/yr). At an estimated cost of $1,250,106, the simple payback is 16.1 years.

A hand calculation was done for replacing all building steam pipes and traps insulation(EEM5), the total cost for this measure is $96,391, total energy saving is 17,169 therms, simple payback is 2.9 years. This measure is recommended.

A lighting fixture count survey was done by owner, total 1,201 T-12 lighting fixtures were found from this survey, all lighting fixtures will be replaced by high efficiency T-8 lighting fixture, and it's expected to get 67% lighting power savings due to the fixture replacement, this measure is recommended. Due to the owner conducting the lighting audit & replacement EEM recommendations, this measure cost savings were determined using simplified engineering calculations and are not including as part of packaged savings.
Total savings including lighting & recommended package are 1,210,582 kWh/yr 16,440 therms/yr of steam and 34.7% of energy savings.

			ENERGY EFFICIENCY MEASURES SUMMARY												
EEM #	Description	Incremental Cost	ANNUAL CONSUMPTION						ENERGY AND COST SAVINGS COMPARED TO PROPOSED BASELINE						Simple Pay Back	% Cost Savings from Baseline
			Electric		Steam		Total		Electric		Steam		Total			
		$	KWH	Cost, $[1]	therms	Cost, $[1]	10^6 Btu	Cost, $	KWH	Cost, $	therms	Cost, $	10^6 Btu	Cost, $	YR[2]	
	Existing baseline	----	3,747,871	$187,394	39,030	$76,109	16,694	$263,502								
1	ASU and TU DDC Upgrades	$1,042,200	2,895,564	$144,778	23,720	$46,254	12,255	$191,032	852,306	$42,615	15,310	$29,855	4,440	$72,470	14.4	27.5%
2	DCV in conference room	$25,000	3,740,715	$187,036	38,620	$75,309	16,629	$262,345	7,156	$358	410	$800	65	$1,157	21.6	0.4%
3	Daylighting (not recommended)	$16,767	3,725,639	$186,282	39,540	$77,103	16,670	$263,385	22,231	$1,112	-510	-$995	25	$117	143.2	0.0%
4	Heat Recovery Chiller	$182,906	3,694,158	$184,708	36,280	$70,746	16,236	$255,454	53,713	$2,686	2,750	$5,363	458	$8,048	22.7	3.1%
	Modeled Recommended Package(EEM1,2,4)	$1,250,106	2,844,074	$142,204	22,390	$43,661	11,946	$185,864	903,796	$45,190	16,640	$32,448	4,749	$77,638	16.1	29.5%
5	Replace insulation for all steam pipes, replace leaking valves and traps	$96,391	3,747,871	$187,394	21,861	$42,629	14,978	$230,022	0	$0	17,169	$33,480	1,717	$33,480	2.9	12.7%

Detailed Baseline Building Description

General Description

- Building located at 1500 SW Jefferson Avenue. Corvallis, OR 97331, building was originally designed and built in 1967 has been continuously occupied by OSU.
- Building typical occupancy schedule is 4:30 A.M. to 5:00 P.M. weekdays, closed during weekends and holidays.
- Building portion "A" has six floors; portion "B" has three floors; the total building condition area is about 122,000sq.ft. Computer data center is about 2800 sq.ft, telecom room is about 1700 sq.ft. All the rest areas are offices or office support areas about 117,500 sq.ft..
- Several remodels and additions have been completed since building was occupied in 1967.

Building Envelope and Internal Loads

Item	Description	Remarks
Opaque Construction	**1.** Existing exterior wall: Brick veneer wall with building paper and 8in CMU, assembly U=0.202; **2.** Built-up roof with R-13 cellulose insulation and 4in CMU, assembly U=0.065.	Per record drawings
Windows	Single pane tinted glass, assembly U=1.25; SHGC=0.94; VLT=0.58.	Per site visit
Misc Equipment	0.5w/sf for most spaces; Computer room data center on building "B" 2nd floor: 211kW; Telecom room in building "A" basement: 42.8kW.	Estimated based on similar facilities and cooling equipment tonnage
Lighting	Corridor-0.5W/sf; Stair-0.6W/sf; bathroom: 0.9W/sf; all rest: 1.2W/sf. (Owner survey conducted separately).	Estimated based on similar facilities.
People	Typical office building, 100 sf/person	Estimated based on similar facilities.

Lighting – EEM (Not part of scope – owner provided audit)

Determining lighting power savings was excluded from the scope of this analysis per proposal agreement on scope of work. The owner completed survey on lighting fixture count, total 1,201 T-12 existing fixtures were found from this survey. Per the owner, all of them are recommended to be replaced with T-8 high efficiency lighting fixture. Retrofitting lamps from T12 bulbs to T8 bulbs is typically cost-effective and easy to do. Transitioning from T12 to T8 is estimated to cost $100 per fixture, parts and labor included. See table below for the lighting fixtures information from survey and simplified calculation of energy saving if replace existing T12 bulbs with high efficiency T8 bulbs. The power saving is estimated at 67% over existing lighting. No interactive effects were considered.

| Lamp Quantity | Existing System F34T12 Lamp | | | High Efficiency eletronic system F32T8 Lamp | | | |

Lamp Quantity	Power(Watts)	Number of installations	Total Power(Watts)	Power(Watts)	Number of installations	Total Power(Watts)	Power Savings(%)
1	44	17	748	25	401	10025	
2	74	384	28416	48	800	38400	
3	118	27	3186	73			
4	148	773	114404	96			
		1201	146754		1201	48425	67

Assuming: 12 hours per day, 5 days per week assumed = 3,120 hours/yr
98.329 kW x 3,120 hrs = 306,786kWh/yr savings or $15,339 /yr savings.
Estimated cost = $120,100; Simple payback = 7.8 yr

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Table lighting fixture count from Owner Survey

Date surveyed	Building	Location	Space Type	Desc. Of Existing	Desc. Of Replacement	Surveyed by	Work to be done by	# existing	# of installations
2/20/2007	Kerr	Entire Bldg	OFFICE	4 lamp, T-12	2 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	684	684
2/20/2007	Kerr	Entire Bldg	HALL/STAIR	4 lamp, T-12	2 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	32	32
2/20/2007	Kerr	Entire Bldg	COMMON	4 lamp, T-12	2 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	53	53
2/20/2007	Kerr	Entire Bldg	RESTROOM	4 lamp, T-12	2 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	4	4
2/20/2007	Kerr	Entire Bldg	OFFICE	3 lamp, T-12	2 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	27	27
2/20/2007	Kerr	Entire Bldg	OFFICE	2 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	197	197
2/20/2007	Kerr	Entire Bldg	HALL/STAIR	2 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	125	125
2/20/2007	Kerr	Entire Bldg	COMMON	2 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	36	36
2/20/2007	Kerr	Entire Bldg	RESTROOM	2 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	26	26
2/20/2007	Kerr	Entire Bldg	OFFICE	1 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	10	10
2/20/2007	Kerr	Entire Bldg	HALL/STAIR	1 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	6	6
2/20/2007	Kerr	Entire Bldg	COMMON	1 lamp, T-12	1 lamp, T-8 (retrofit)	SMITH	OUTSIDE CONTRACTOR	1	1
	Kerr Total							1201	1201

Description of Existing Conditions

The following sections document the existing HVAC per site visit and record drawings.

Water Side HVAC System

Cooling Equipment:

Item	Description	Remarks
Water Cooled Hermetic centrifugal Water Chiller	1. 450 tons, 650 gpm, 58.6F/42F, 8.4FT pressure drop; kw/ton: 0.505 2.Chiller was installed in 2005	Carrier 19xrv
Cooling Tower	1. 1,350 gpm, 85F/75F, 2*20hp fan with VFD 2. New motor and VFD was installed in 2005.	BAC
CHWP-006	1. Chiller loop pump for building A, 250gpm, 45FT.WG. head; 5hp motor 2. Pump was installed in 2005. 90.2% motor efficiency.	B & G 1510 2-1/2 BB
CHWP-007	1. Chiller primary pump, 650gpm, 45FT.WG. head; 10hp motor 2. Pump was installed in 2005. 91.7% motor efficiency.	B & G 1510 4 BC
CHWP-008	1. Chiller loop pump for building B, 404 gpm, 60FT.WG. head; 10hp motor 2. Pump was installed in 2005. 91.7% motor efficiency.	B & G 1510 3 BC
CDP-009	1. Cooling Tower pump, 1350gpm, 80FT.WG. head; 40hp motor with VFD 2. Pump was installed in 2005. 94.5% motor efficiency.	B & G 1510 6E

Figure 1 CWHP - 006

Figure 2 CHWP- 007

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Figure 3 CHWP-008	**Figure 4 Chiller**
Figure 5 Cooling Tower	**Figure 6 CDP-009**
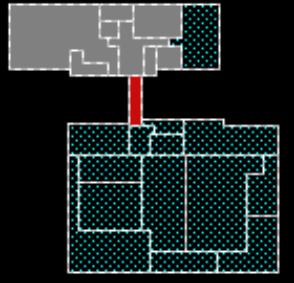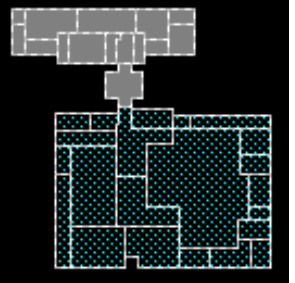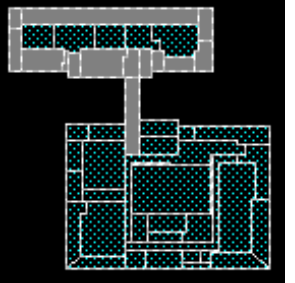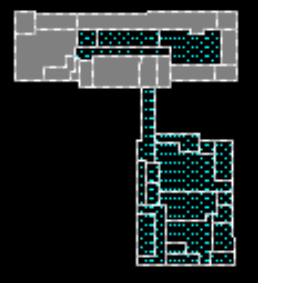
Heating Plant Equipment:
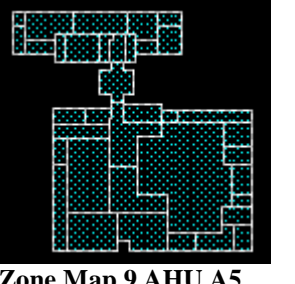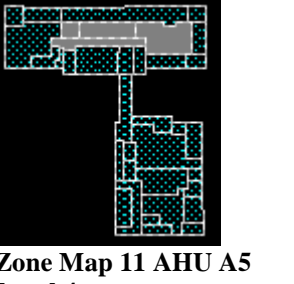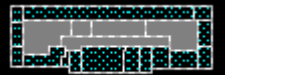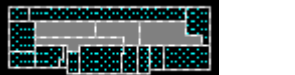
Building heating is provided by a mix of low pressure steam and hot water generated by a steam to hot water exchanger within the building. The campus heating plant was modeled as steam meter in energy model. The zone reheat coils are a mix of hot water and electric. The hot water reheat zones are served by three zones reheat pumps (A-15, A-16 and A-10) as show in the images below. All AHU central heating coils are steam. The steam piping within the facility is insulated for major straight sections, but shows signs of old age. In addition, nearly all steam pipe fittings, valves and devices are un-insulated. An example of the existing steam piping conditions is depicted in the following images. No steam trap replacement schedule is implemented by building maintenance staff. Visible steam leaks were observed at some valve locations (Figure 13).

Steam/hot water heating zone map breakdown:
1. "A" portion exterior zones served by AHU-A1/2 with central steam heat coil and HW zone reheat via steam-HW exchanger located in basement mechanical room. Zones served by AHU indicated by grey or red areas in model zone maps below.
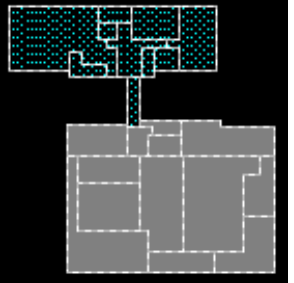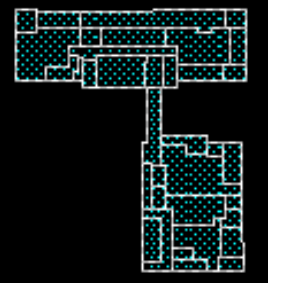
Zone Map 1 AHU A1/2 Level 1	**Zone Map 2 AHU A1/2 Level 2**	**Zone Map 3 AHU A1/2Level A-3**	**Zone Map 4 AHU A1/2 Level 4**
Zone Map 5 AHU A1/2 Level 4	**Zone Map 6 AHU A1/2 Level 5**	**Zone Map 7 AHU A1/2 Level 6**	

2. AHU-A5 serves "A" portion interior zones, steam heating central coil none/electric reheat. Zones served by AHU indicated by grey or red areas in model zone maps below.

Zone Map 8 AHU A5 Level 1	**Zone Map 9 AHU A5 Level 2**	**Zone Map 10 AHU A5 Level 3**	**Zone Map 11 AHU A5 Level 4**
Zone Map 12 AHU A5 Level 4	**Zone Map 13 AHU A5 Level 5**	**Zone Map 14 AHU A5 Level 6**	

3. AHU-B1 serves "B" portion zones, steam heating central coil none/electric reheat. Zones served by AHU indicated by grey or red areas in model zone maps below. (no service above level 3)

|			
Zone Map 15 AHU B1 Level 1	**Zone Map 16 AHU B1 Level 2**	**Zone Map 17 AHU B1 Level 3**	**Zone Map 18 AHU B1 Level 4**

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4. AHU-B4 serves "B" portion perimeter zones, steam heating central coil none/electric reheat. Zones served by AHU indicated by grey or red areas in model zone maps below. (no service above level 3)

Zone Map 19 AHU B4 Level 1	Zone Map 20 AHU B4 Level 2	Zone Map 21 AHU B4 Level 3	Zone Map 22 AHU B4 Level 4
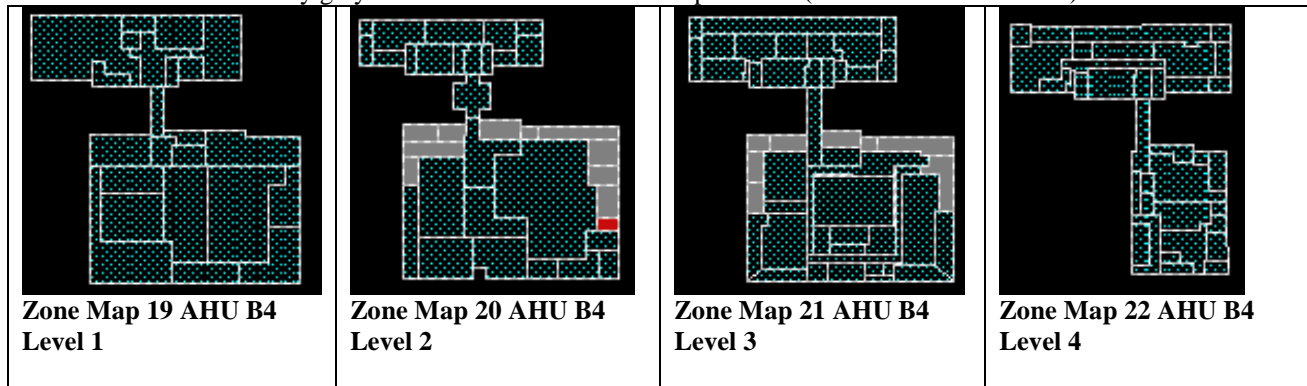
5. AH-1 serves "B" portion top floor dual duct zones (hot deck only, cold deck from AHU-B1), hot water central coil. Zones served by AHU indicated by grey or red areas in model zone maps below.

| Zone Map 23 AH-1 Level 1	Zone Map 24 AH-1 Level 2	Zone Map 25 AH-1 Level 3	Zone Map 26 AH-1 Level 4
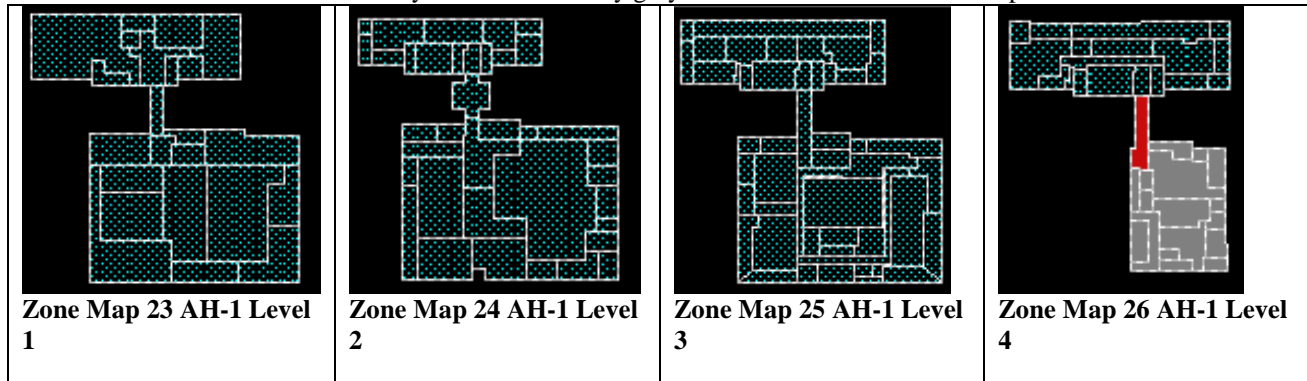
Figure 7 Zone reheat pump for zone A-15

Figure 8 Zone reheat pump for zone A-16

Figure 9 Zone reheat pump for zone A-10

Figure 10 Three zone reheat pumps and pipes

Figure 11 Existing steam system.

**Figure 12 Steam pipes and trap – existing insulation with deteriorated conditions.**

Figure 13 Leaking steam valve

Air Side HVAC System

Unit	Description	Remarks
A-1,2 Figure 14 A-1 supply fan motor	• System type: VAV with chiller water coil for cooling, hot water coil for heating and zone hot water reheat. • Fan control: VFD. Fixed static pressure setpoint control. • A-1 supply fan: 26,000cfm, 6in TSP,40HP motor with VFD, 94.5% motor efficiency; • A-2 supply fan: 26,000cfm, 6in TSP,40HP motor with VFD, 94.5% motor efficiency; • Heating coil for A-1&A-2, steam coil, 40,800cfm;heat air from 55F to 80F; • Cooling coil for A-1&A-2, Chiller Water, cooling capacity: 1,215MBH; 40,800cfm; 162gpm total chilled water from 42F to 57F. • Economizer is enabled whenever the outside air temperature is less than the return air temperature.	Serves building portion "A" exterior spaces

A-5	• System type: VAV with chiller water coil for cooling and hot water coil for heating. • Fan control: VFD. Fixed static pressure setpoint control. • Cooling coil: Chiller Water, 21,120cfm total air flow; 83.6gpm total chilled water from 42F to 57F; • Heating coil: 21,120cfm total air flow; heat air from 55F to 80F; • Supply fan: 28,000cfm, 6in TSP,40HP motor with VFD, 94.5% motor efficiency; • Economizer is enabled whenever the outside air temperature is less than the return air temperature.	Serves building portion "A" interior zones
Figure 15 A5 supply fan VFD Figure 16 A5 supply fan motor		
Common Exhaust/Return A-42	Portion "A" is served by a common exhaust/return, 30HP motor with VFD, 94.4% motor efficiency. Fixed static pressure setpoint control.	Common exhaust for building portion "A".

Figure 17 Building A space temperature set point

B-1	• System type: VAV with chiller water coil for cooling, steam coil for heating and zone electrical reheat. • Fan control: VFD. Fixed static pressure setpoint control. • Supply fan: 60,000cfm, 6in TSP, 100HP motor with VFD, 95.4% motor efficiency. • Heating coil for B-1, steam coil, 60,000cfm; heat air from 55F to 95F. • Cooling coil for B-1, Chiller Water, cooling capacity: 1,920MBH; 60,000cfm; 162gpm total chilled water from 42F to 57F; 256gpm chiller water from 42F to 57F. • Economizer is enabled whenever the outside air temperature is less than the return air temperature. • Existing filters for unit B-1 were observed to be in poor condition. Noticeably visible sections were crumpled and out of position. Filters were dirty & could use replacement.	Serves building portion "B" main bldg.
Figure 18 B-1 supply fan motor		

 Figure 19 B-1 supply fan VFD Figure 20 B1 supply fan filter		
B-4 Figure 21 B4 Figure 22 B4 differential pressure manometer	• System type: VAV with chiller water coil for cooling, steamcoil for heating and zone electrical reheat. • supply fan: 11,750cfm, 2.5in TSP,10HP motor; • VFD. Fixed static pressure setpoint control. • Re-heat coil for B-4, steam coil, 3,000cfm for south; 9,000cfm for N,W &E reheat air from 50F to 100F; • Cooling coil for B-1, Chiller Water, cooling capacity: MBH; 11,750; 162gpm total chilled water from 42F to 57F; 256gpm chiller water from 42F to 57F. • Economizer is enabled whenever the outside air temperature is less than the return air temperature. • Manometer indicates filter condition is ok. This unit appears to have had recent filter replacement.	Serves building portion "B" perimeter spaces.
Common Return B-40 Figure 23 B40 Return fan	Common return fan for building portion "B", 30HP motor with VFD.	Common return for building portion "B".
AH-1	• System type: Dual duct system with hot deck only, hot water coil for heating, cold deck from B-1 unit. • supply fan: 6,000cfm, 2.5in TSP,10HP motor, 89.5% motor efficiency; • Economizer is enabled whenever the outside air temperature is less than the return air temperature.	Serves building portion "B' third floor office.

Figure 24 AH-1 Figure 25 AH-1 supply fan motor		
Figure 26 Building B space temperature set point		
Telecom RCU-1, 2/DC1,2 Figure 27 IT Room/FC dry cooler	• RCU-1, 2: Each 15 Ton packaged room cooling units: o 8,400 cfm @1/2" ESP; up flow discharge, front return, min capacities: o 157 MBH sensible cooling at 72F DB and 50% RH room conditions; o 5HP fan motor; o 17.4 LB/HR humidification, o 4-row economizer cooling coil with 157 MBH sensible cooling at 54gpm of 50F, 40% glycol-water solution, o LIBERT LIE-192GU. • DC1, 2: Outdoor dry cooler, capacity matched to RCU-1, 2.	Serves telecom room in building portion "A" basement
Data Center AC-1,2/DC-1,2	• AC-1: Computer room unit, total one unit, temp rise 10F, 54gpm. • AC-2: Computer room unit, total two units,, 12,000cfm per unit @1/2" ESP, 7.5HP motor; entering air WB 60F;	Serves data center on building portion "B" second floor

Figure 28 Pumps for DC1/2 95gpm Figure 29 Pumps for DC1/2 Figure 30 Data center dry cooler Figure 31 Data center AC-2 unit	entering air DB 72F; humidifier: 22lb/hr; temp rise 10F, 67gpm. • DC-1: Packaged outdoor dry cooler, capacity matched to AC-1; • DC-2: Packaged outdoor dry cooler, capacity matched to two AC-2 indoor units.	

Modeled Existing Building Energy Usage

Existing Baseline Building Energy Use Summary*						
Energy End-Use Category	MMBtu per Year			% of Total MMBtu	Annual Energy Cost	% of Total Cost
	Electricity	Steam	Total			
Interior Lights	1611		1611	9.7%	$ 23,607	9.0%
Misc Equipment	5367.1		5367.1	32.1%	$ 78,647	29.8%
Space Heating	1885.2	3705.6	5590.8	33.5%	$ 99,884	37.9%
Space Cooling	1011.5		1011.5	6.1%	$ 14,822	5.6%
Heat Rejection	62.3		62.3	0.4%	$ 913	0.3%
Pumps & Aux.	568.8		568.8	3.4%	$ 8,335	3.2%
Vent Fans	2159.6		2159.6	12.9%	$ 31,646	12.0%
Domestic Hot Water		197.4	197.4	1.2%	$ 3,849	1.5%
Exterior Lighting	125.8		125.8	0.8%	$ 1,843	0.7%
Total	12791.3	3903	16694	100.0%	$ 263,547	100.0%

Gross conditioned floor area in	Energy Use Index (EUI) kBtu per		Energy Cost Index (ECI) $	
122,000	136.8		$	2.16
Electricty virtual cost per kWh: ($)	0.05	Steam virtual cost per therm: ($)		1.95
* Note: Small differences may exist between this summary table and reported results due to rounding of values.				

The modeled results were compared to PGE Energy Use Index or CBECS for similar buildings and were determined to be reasonable.

EUI comparison

EUI	From PGE Use Index Bldg w/elect. Heat) kbtu/sf-ry	From PGE Use Index Bldg w/Fossil fuel heat kbtu/sf-ry
College	95.73	110.86
General office	88.3	106.64
Data center	Variable	Variable

The baseline building energy simulation results were charted to compare against existing bills below. The monthly and yearly building billing histories were used to calibrate the baseline building energy model to be within 10% of the annual average billing history. Note: a factor of 10 multiplier was applied to the owner provided steam billing data as the data appeared to be unrealistically low (only approx 4,000 therms/yr reported) based on the observed operating characteristics of the facility as well as using analyst knowledge for comparable sized buildings heating energy use in this climate. Steam is also used for service hot water generation in the building, which is anticipated to consume nearly 2,000 therms alone.

From owner provided billing history and energy model results, it shows high electricity usage and the electricity usage is constant year around, the high electricity usage might be due to 24/7 running cooling only units for data center and telecom room, high lighting energy usage and electric reheat.

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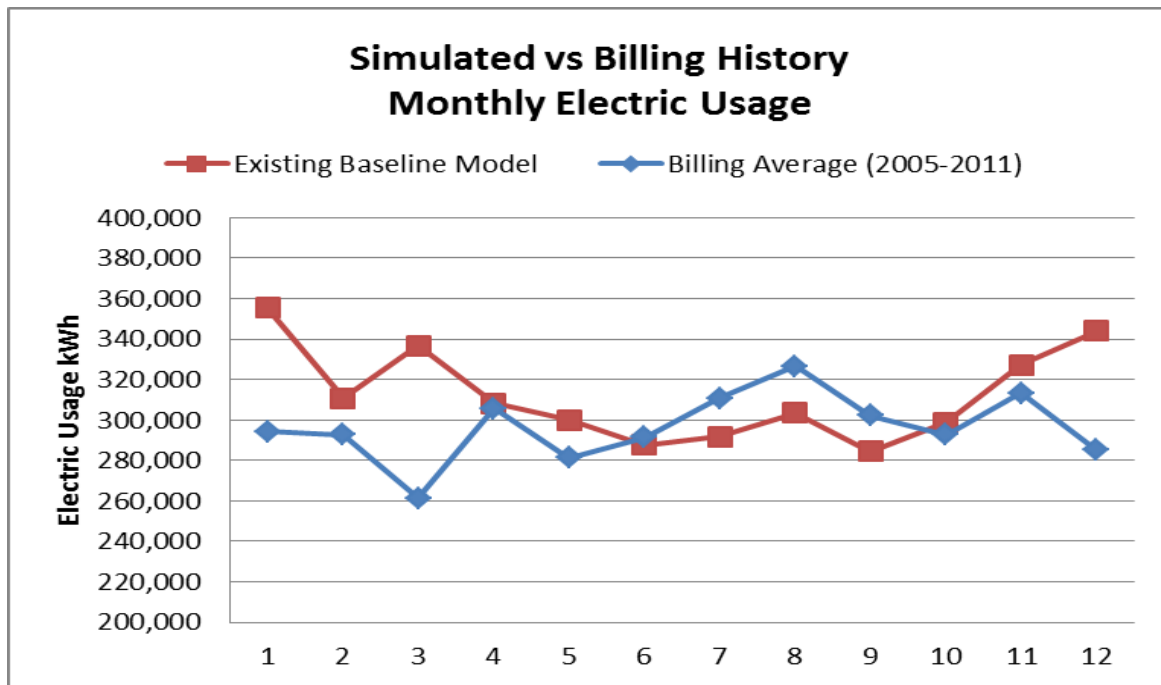
Figure 32 Graph of utility electrical data provided by owner compared to energy simulation "existing baseline" results.
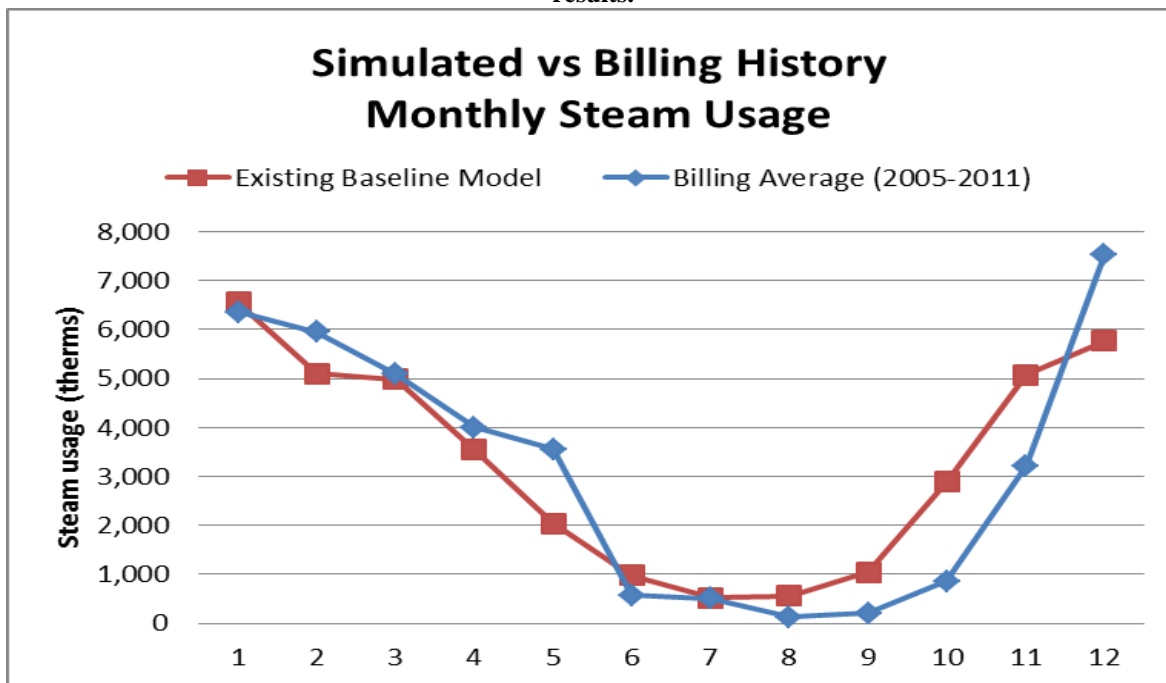

Figure 33 Graph of steam utility data provided by the owner compared to energy simulation "existing baseline" results. Note: owner provided steam usage has been adjusted by increasing by a factor of 10 to account for the anticipated heating energy usage for the facility served by steam heating. The DOE2 simulation results are in line with anticipated usage.

Energy Efficiency Measure Summary

EEM were identified through site inspections and conversations with the owner & facility operators. A final package model was created to show the interactive effects of all recommended EEMs and the total projected savings. Measures not simulated in DOE2 included separately. The cost-effectiveness of each EEM was evaluated using a simple payback analysis. This simple payback represents the time required to recover the cost for implementing the EEM by its annual energy cost savings. The EEM costs are based on local contractor estimates & data from RSMeans cost estimating resources.

The utility rates used for energy model:
- $0.05/kWh electric rate
- $19.5 per 1000LBs steam (equivalent $1.95/therm rate used for simple payback)

Costs estimates based on RSMeans have been increased by 35% to account for the buy American requirements of this project.

EEM1: HVAC system DDC upgrades and AHUs Supply Air Temperature and Static Pressure Reset

EEM1 description
This measure consists of
1. Upgrade existing AHU from pneumatic control to a full DDC system, includes convert both AHU and zone terminal units control to DDC. Terminal units DDC control includes retrofitting terminal units, adding room occupancy sensors to control temperature and ventilation setback. DDC can deliver more accurate signals, faster response from controlled devices and additional scheduling & reset capabilities, which were modeled by increasing 1F for cooling setpoint and decreasing 1F for heating setpoint. Zone terminal units are modeled to be shut off during unoccupied hours.
2. Base on AHU DDC control upgrade, the system can reset AHUs supply air temperature and static pressure.
   2.1 Reset AHUs A-1, A-2, B-1, and B-4 cooling control supply air temperature according to the zone with the largest cooling demand, setpoint will vary from 55F to 65F. Reset AHUs A-1, A-2, B-1, B-4 and AH-1 heating control supply air temperature according to the zone with the largest heating demand, temperature will vary from 75F to 105F.
   2.2 Reset static pressure for AHUs A-1, A-2, B-1, B-4 and AH-1 according to polling of each zone reset static pressure to satisfy the zone with the largest load. Existing VFD control is by a fixed static pressure setting. The reset proposed will track the zone airflow loads dynamically to reset the static pressure setpoint for the VFD drive. Resetting the static pressure will further reduce fan power consumption. This measure was simulated within eQuest by a modification of the fan VFD curve. See image below for comparison of typical VFD curve and modified static pressure curve from BSUG meeting 09/16/2009- VFD fan energy use more than the system curve, presented by Reid Hart from PECI. Curves used are ccc_Base for the existing condition, with ccc_ResetSP for the simulated reset VFD operation.

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FAN-EIR-FPLR Curves
CCC FanSysCalc vs. eQuest defaults
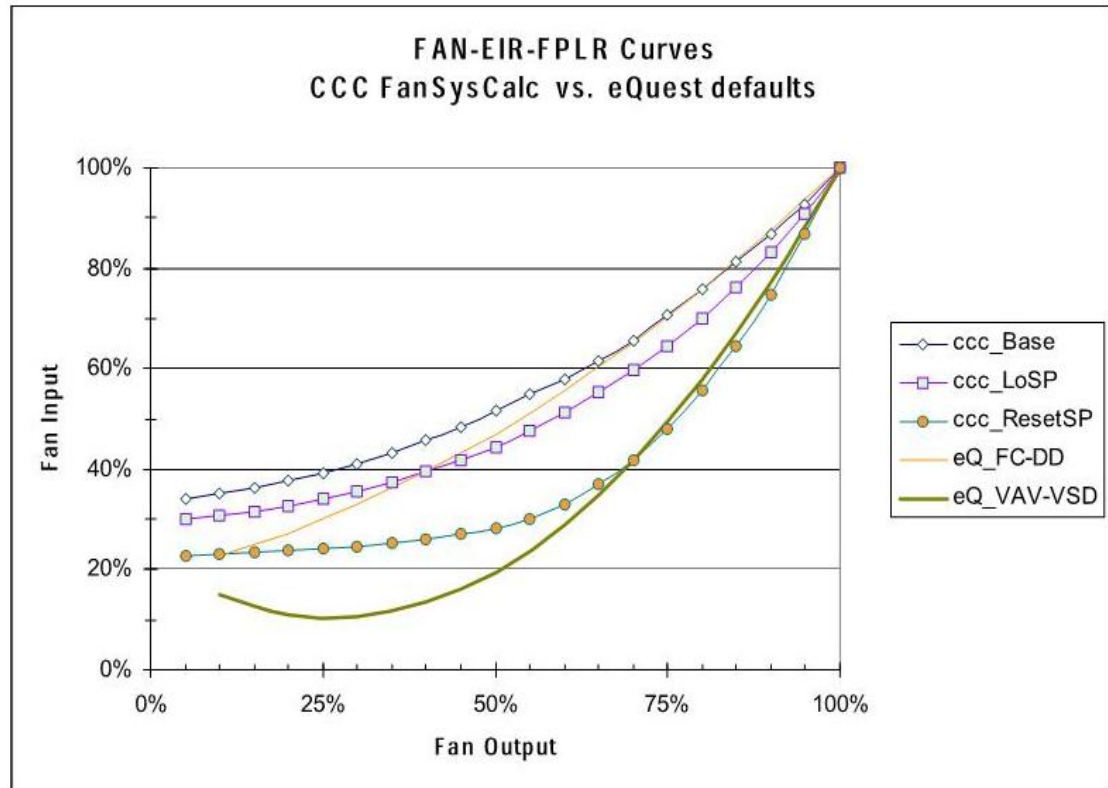
Incremental Installation Cost

Costs for this measure are the cost for full HVAC system DDC upgrade. The cost includes all AHU unit controllers. In addition approximately 261 terminal units and zone sensors will be included in this DDC retrofit. Total cost for this measure is estimated at $1,042,200 (see Appendix C for details).

Savings Summary

The energy savings are primarily a result of the reduced cooling, heating, fan and pump energy. See Appendix C for input & output reports.

Annual Saving				Cost ($)	Simple payback (Yrs)
Electricity (kWh/yr)	Steam (therms/yr)	Energy (MBtu)	Energy Cost Savings ($)		
852,306	15,310	4,440	$72,470	$1,042,200	14.4

EEM2: DCV control at conference room

EEM2 description

This measure determines the energy savings from adding demand control ventilation control at high occupancy conference rooms. When the conference is empty, the CO_2 sensor will shut the TU box to zero air flow, reducing the minimum airflow. Conference room is designed for large number of people with high outside air requirements. However, the spaces are frequently only partially occupied or unoccupied. In addition, system level CO_2 sensors will lower outside air quantity during low occupancy periods based on return air CO_2. See table below for the room which CO_2 sensors will be installed.

Room numbers are per the archive drawings and may not reflect current room numbering.

Room number	CO2 sensor
Meeting room A110B	1
Conference room A202	1
Conference room A420	1
Meeting room A522	1
Conference room A622B	1
Conference room A300A	1
Meeting room A507	1
Conference room B124	1
Conference room B214	1
Conference room B100A	1
Conference room B204E	1
Conference room B306L	1
Conference room B308B	1

Incremental Installation Cost

Costs for this measure are the cost for installing 13 CO_2 sensors at high occupancy spaces to control zone outside air. In addition, 6 return air CO_2 sensors at the return air damper of each unit. Total cost for this measure is $25,000 (see Appendix D for details).

Savings Summary

The energy savings are primarily a result of the reduced heating and fan energy. See Appendix D for input & output reports.

Annual Saving				Cost	Simple payback
Electricity (kWh/yr)	Steam (therms/yr)	Energy (MBtu)	Energy Cost Savings ($)	($)	(Yrs)
7,156	410	65	$1,157	$25,000	21.6

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EEM3: Daylighting Control at Common Area

EEM3 description

This measure determines the energy savings from using continuous dimming ballasts and daylighting sensors in the building exterior common areas. The maximum daylighting zone depth is 2.5 times the window height. The fraction of lighting controlled by the daylighting sensor is an area weighted percentage of the lighting power of the entire space with some exceptions for assumed lighting design layout.

Sensors are placed within the middle of daylighting zones at a height of ten feet to match a typical ceiling mounted sensor. The daylighting control lighting set point of 35 footcandles was determined based on the associated space's use and luminance values from the IES Lighting Handbook. See table for the rooms where daylighting sensors will be installed.

Room numbers are per the archive drawings and may not reflect current room numbering.

Room number	Daylighting sensor
Clerical recep A100	1
Entry lobby Lo101	1
Info center A110	1
Meeting rm A110B	1
Entry lobby Lo103	1
Conference rm B100a	1
Conference rm B124	1
Conference rm A202	1
Work rm A220C	1
Corr Ho202	1
Conference B204E	1
work rm A302	1
Corr H301C	1
Corr H301	1
Mail mach A400	1
Vest V401	1
Elevator Lobby L401	1
Conference A420	1
Recep A416	1
Vest V501	1
Elevator lobby L501	1
Meeting Rm A522	1
Work rm A600A	1
Vest V601	1
Elevator lobby L601	1
Work rm A622A	1
Conference rm A622b	1

Incremental Installation Cost

Costs for this measure include the cost of the daylighting sensors, controls, ballast and wiring. Costs are from RS Means' Building Electrical Cost Data 2009 and adjusted for year and location. . Costs used include labor, overhead, and profit.

EEM Quantity	Sensors		Total Cost
	$400 sensor, wiring,CX	Dimming Ballast, Additional $60/ballast	
27 single zone controls	$14,580	$2,187	$16,767

Savings Summary

The energy savings are primarily a result of the reduced cooling and lighting energy, but heating energy increased. See Appendix E for input & output reports.

Annual Saving				Cost ($)	Simple payback (Yrs)
Electricity (kWh/yr)	Steam (therms/yr)	Energy (MBtu)	Energy Cost Savings ($)		
22,231	-510	25	$117	$16,767	143.3

Due to very long time payback for this measure, this measure will not be recommended.

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EEM4: Heat Recovery Chiller

EEM4 description

This measure consists of adding an energy efficient heat recovery chiller and utilizing its condenser water for Building portion "B" third floor space heating (served by AH-1 unit) to reduce the heating demand currently met by the campus steam loop. Previous attempts were made at data center heat recovery. The previous heat recovery utilized return condenser water direct to AH-1 hot water coil. With this arrangement, the condenser water temperatures were insufficient to meet the heating demands of the hot water coil in AH-1.

This measure proposes to utilize a heat recovery chiller, which can provide up to 130F condensing water for heat recovery. Since AH-1 already has a hot water coil & is located in the same mechanical room as the condenser water pumps it is ideal for heat recovery. The data center cooling equipment is near the end of its useful life. It is recommended that the system be replaced with the following components:

- Retrofit/provide data center room AHU with chilled water coils.
- Dedicated heat recovery chillers (60-ton) located in the existing mechanical room with AH-1
- New system pumps & motors
    o Small HP pumps & constant load –VFD not anticipated to achieve much savings at this time.
- New dry coolers – replace outdated equipment with new dry coolers utilizing non- HCFC/CFC refrigerants (alternative is a new cooling tower) located where existing data center drycoolers currently are.
- Utilize existing HW coil in AH-1

Incremental Installation Cost

Costs for this measure are the cost of installing an 80-ton high efficiency heat recovery chiller and an 80-ton dry-cooler, retrofit data center room AHU with chilled water coil

	Cost per Unit	# of Unit	Costs
High efficiency heat recovery chiller(60 tons)	$80,000	1	$80,000
Dry cooler (60 ton)	$30,000	1	$30,000
Computer room cooling units	$15,660	3	$46,980
Pumps and motor	$25,926		$25,926
Total			$182,906

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Savings Summary

The energy savings are primarily a result of the reduced cooling energy. See Appendix F for input & output reports.

Annual Saving				Cost	Simple payback
Electricity (kWh/yr)	Steam (therms/yr)	Energy (MBtu)	Energy Cost Savings ($)	($)	(Yrs)
53,713	2,750	458	$8,048	$182,906	22.7

EEM5: Re-insulate Steam Pipe and replace faulty valves and traps

EEM5 description

This measure consists of replacing insulation to all existing steam pipe as well as to replace all leaking and faulty steam valves and traps. Per site visit, estimate that 25% of existing steam pipe and trap insulation was damaged, missing or in poor condition, that's a big waste of steam energy. Existing steam pipe length was taken from record drawings, and only length of steam piping from the main junction box to the mechanical rooms was considered in this measure. Small diameter steam pipes that may be behind enclosed walls were not considered.

Visible leaks were observed in at least one valve and should be replaced (located in the exhaust plenum of "B" portion mechanical room). No steam trap replacement program is evident based on site visit interviews of staff. Steam trap counts were taken by site visit survey's and cross referenced with archive drawings when establishing approximate quantity of traps in the facility. Typical steam trap failure rates (per the DOE Federal Energy Management Program – FTA Steam Trap Performance Assessment DOE/EE-0193 document) were used to estimate anticipated failure of existing traps in the facility. Cost estimates assume trap replacement program

This measure determines the energy savings from replacing all insulation for existing steam pipe and traps and replacing traps and valves which are leaking. This steam calculation considers all length of steam pipe entering the facility from the main junction vault just outside the facility, not necessarily the same length as would be captured on the steam meter serving this facility. The breakdown for building steam savings vs. campus plant savings due to this measure will depend on the actual location of the steam meter.

Incremental Installation Cost

Costs for this measure are the cost of new insulation for all existing steam pipes and traps, as well as implementing a steam trap inspection and replacement program. Total costs are estimated at $71,400. See Appendix G for detail cost estimates.

Savings Summary

The energy savings are primarily a result of the reduced steam system losses. See Appendix G for input & output reports.

Annual Saving				Cost	Simple payback
Electricity (kWh/yr)	Steam (therms/yr)	Energy (MBtu)	Energy Cost Savings ($)	($)	(Yrs)
0	17,169	1,717	33,480	71,400	2.1

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Recommended Modeled Interactive Package

The recommended energy model only EEM package includes all EEM1- HVAC system DDC upgrades, AHUs Supply Air Temperature and Static Pressure Reset, EEM2-DCV controls in all conference rooms and EEM4-Heat recovery chiller. It is also recommended that EEM5 – steam system improvements be implemented, but energy savings results are excluded from the figure below. The results below include only simulation modeling results, accounting for interactive effects of recommended measures.

Packaged Building Energy Use Summary*						
Energy End-Use Category	MMBtu per Year			% of Total MMBtu	Annual Energy Cost	% of Total Cost
	Electricity	Steam	Total			
Lights	1611	0	1611	13.5%	$ 23,607	12.7%
Misc Equipment	5367.1	0	5367.1	44.9%	$ 78,647	42.3%
Space Heating	416.6	2042.1	2458.7	20.6%	$ 45,926	24.7%
Space Cooling	437.9	0	437.9	3.7%	$ 6,417	3.5%
Heat Rejection	17.4	0	17.4	0.1%	$ 255	0.1%
Pumps & Aux.	471.1	0	471.1	3.9%	$ 6,903	3.7%
Vent Fans	1259.8	0	1259.8	10.5%	$ 18,461	9.9%
Domestic Hot Water	0	197.4	197.4	1.7%	$ 3,849	2.1%
Exterior Lighting	125.8	0	125.8	0.8%	$ 1,843	0.7%
Total	9706.7	2239.5	11946	100.0%	$ 185,908	100.0%

Gross conditioned floor area in	Energy Use Index (EUI) kBtu per	Energy Cost Index (ECI) $
122,000	97.9	$ 1.52
Electricty virtual cost per kWh: ($)	0.0500	Steam virtual cost per therm: ($) 1.9500
* Note: Small differences may exist between this summary table and reported results due to rounding of values.		

Appendix A
Building information

Include:

- Original M-drawings(Attach separately due to the file size)

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Appendix B

Existing Baseline – Supporting Documents

Supporting model file names:

- Baseline
  - OSU Kerr – Existing Baseline.pd2
  - OSU Kerr – Existing Baseline.inp

BEPS & ES-D Reports

Appendix C
EEM 1 – Supporting Documents

BEPS & ES-D Reports

Model files
- o OSU Kerr – EEM1.pd2
- o OSU Kerr – EEM1.inp
- o

Cost Estimates

Cost Estimates						
Project : OSU Kerr Admin Building						
Date : August 16, 2011						
EEM	Description	$/SF	SF	qty	Unit Cost	TOTAL
1	ASUs DDC Upgrades					$ 337,500
	TUs DDC Upgrades			261	$ 2,700	$ 704,700
	Total cost					$ 1,042,200

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Appendix D
EEM 2 – Supporting Documents

BEPS & ES-D Reports

Model files
- o OSU Kerr – EEM2.pd2
- o OSU Kerr– EEM2.inp

Cost Estimates

Cost Estimates						
Project :	OSU Kerr Admin Building					
Date :	August 16, 2011					
EEM	Description	$/SF	SF	qty	Unit Cost	TOTAL
2	DCV control in conference room					
	Zone CO2 sensors for DCV controls			13	$ 1,000	$ 13,000
	Return duct sensors			6	$ 2,000	$ 12,000
	Total					$ 25,000

Appendix E
EEM 3 – Supporting Documents

BEPS & ES-D Reports

Model files:
- o OSU Kerr – EEM3.pd2
- o OSU Kerr – EEM3.inp

Cost Estimates

Cost Estimates						
Project : OSU Kerr Admin Building				INTERFACE ENGINEERING		
Date : August 16, 2011						
EEM	**Description**	**$/SF**	**SF**	**qty**	**Unit Cost**	**TOTAL**
3	Daylighting					
	Daylighting sensor			27	$ 540	$ 14,580
	Dimming ballast			27	$ 81	$ 2,187
	Total					$ 16,767

Appendix F
EEM 4 – Supporting Documents

BEPS & ES-D Reports
Model files:
- o   OSU Kerr – EEM4.pd2
- o   OSU Kerr – EEM4.inp
- o

Cost Estimates								INTERFACE ENGINEERING
Project :	OSU Kerr Admin Building							
Date :	August 16, 2011							
EEM	Description		$/SF	SF	qty	Unit Cost	TOTAL	
4	High efficiency Heat reovery water cooled chiller							
	High efficiency water cooled heat recovery chiller (60 tons)				1	$ 80,000	$ 80,000	
	Dry cooler(60-ton)				1	$ 30,000	$ 30,000	
	New data center compuer room cooling unit with chilled water coil				3	$ 15,660	$ 46,980	
	Pump and motor						$ 25,926	
	Total incremental cost						$ 182,906	

Appendix G
EEM 5 – Supporting Documents

Calculation
1. Pipe re-insulation calculation

	Item:	Existing	Proposed	Savings
ECM Summary	**therms/yr**	20,192	4,383	**15,810**
	Cost ($/yr)	$ 39,375	$ 8,547	**$30,829**
	Pipe Insul & Install Cost	$ 60,278		
	Simple Payback (yrs)	2.0		

Length of Pipe	Feet	temp:
Steam	1000	230
Condensate	1000	175

Annual Operating Hours	4784	
Natural Gas Cost ($/therm)	1.95	
Existing Boiler Seasonal Efficiency	65.0%	

Uninsulated/Existing Old Insul. Pipe Heat Loss			Length	Btu/hr	Losses Btu/yr	Boiler Therms/yr	$/year
Uninsulated Steam	249.7	Btu/hr-ft	333	83233	398,188,267	6,125.97	$ 11,946
Uninsulated Cond.	174.9	Btu/hr-ft	333	58300	278,907,200	4,290.88	$ 8,367
Old Insulated Steam	160	Btu/hr-ft	667	106667	510,293,333	7,850.67	$ 15,309
Old Insulated Cond.	39.23	Btu/hr-ft	667	26153	125,117,547	1,924.89	$ 3,754
					Total:	20,192.41	$ 39,375

Proposed 2.5" Insul. Pipe Heat Loss			Length	Btu/hr	Losses Btu/yr	Boiler Therms/yr	$/year
6" insulated Steam	44.79	Btu/hr-ft	1000	44790	214,275,360	3,296.54	$ 6,428
4" insulated Cond.	14.76	Btu/hr-ft	1000	14760	70,611,840	1,086.34	$ 2,118
					Total:	4,382.88	$ 8,547
					Savings	15,809.53	$ 30,829

Removal of existing asbestos insl	$5.20/LF	$	10,400
Re-insulate all Steam lines	$21/LF	$	21,000
Re-insulated all Cond. Lines	$13.25/LF	$	13,250
	Total:	$	60,278
	Simple payback:		2.0

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	Condensate	Variable Insulation Thickness	Surface Temp (°F)	Heat Loss (BTU/hr/ft)	Efficiency (%)	
		Bare	174.9	118.5		
	Data Based on 3E Plus software inputs	0.5	99.1	39.23	66.89	
		1	85.2	25.27	78.67	
		1.5	80.4	20.31	82.86	
		2	76.7	16.25	86.28	
		2.5	75.4	14.76	87.54	
		3	74.6	13.66	88.47	
		3.5	73.9	12.8	89.19	
		4	73.3	12.04	89.84	

	Steam	Variable Insulation Thickness	Surface Temp (°F)	Heat Loss (BTU/hr/ft)	Efficiency (%)	
		Bare	249.7	746.8		
	Data Based on 3E Plus software inputs	0.5	118.6	160	78.57	
		1	99.7	92.48	87.62	
		1.5	92	67.13	91.01	
		2	87.5	52.57	92.96	
		2.5	85	44.79	94	
		3	83.3	39.43	94.72	
		3.5	81.8	34.67	95.36	
		4	80.9	31.84	95.74	
		4.5	80.3	29.58	96.04	
		5	79.7	27.72	96.29	
		5.5	79.2	26.18	96.49	
		6	78.8	24.86	96.67	

2. Leaking steam trap replacement/repair program implementation calculation

$$L_{t,y} = \frac{1\ kg}{2.2046\ lbs} \cdot FT_{t,y} \cdot FS_{t,y} \cdot CV_{t,y} \cdot h_{t,y} \cdot \sqrt{(P_{in,t} - P_{out,t}) \cdot (P_{in,t} + P_{out,t})}$$ (1)

where

$L_{t,y}$	Is the loss of steam due to the steam trap t during the period y in kg of steam.
$FT_{t,y}$	Is the failure type factor of steam trap t during the period y.
$FS_{t,y}$	Is the service factor of steam trap t during the period y.
$CV_{t,y}$	Is the flow coefficient of steam trap t during the period y.
$h_{t,y}$	Are the hours steam trap t is operating during the period y in hours.
$P_{in,t}$	Is the pressure of the steam at the inlet of steam trap t in psia.
$P_{out,t}$	Is the pressure of the condensate at the outlet of steam trap t in psia.

Table 2: Failure Type Factor FT

Type of failure	FT
Blow-thru (BT)	1
Leaking (LK)	0.25
Rapid cycling (RC)	0.2

$$FS = 2.1 \cdot \frac{S-1}{S}$$ (2)

where

FS	Is the service factor.
S	Is the capacity safety factor, expressing the ratio between the trap capacity (orifice) and the actual condensate load in an application.

Table 3: Service Factor FS

Application	Capacity safety factor S	Service Factor FS
Process steam traps	1.75	0.9
Drip and tracer steam traps	3.0	1.4
Steam flow (no condensate)	Very large	2.1

$$CV = 22.1 \cdot D^2$$ (3)

where

CV	Is the flow coefficient.
D	Is the diameter of the orifice of the steam trap in inches.

Table 1. Steam trap proactive maintenance program cost estimates.[3]

Cost Element	Minimal Program	Intermediate Program
Trap Identification	$15/trap once	$15/trap once
Equipment and Training	$0 total once	$4000 total once
Trap Testing	$5/trap per year	$10/trap per year
Trap Replacement	$40/trap first year	$40/trap first year
	$15/trap thereafter	$15/trap thereafter
Engineering Management	$5000 + $2/trap/year	$5000 + $4/trap/year
Total Initial Cost	$55/trap	$4000 + $55/trap
Total Annual Cost	$5000 + $22/trap	$5000 + $29/trap

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	Item:	Existing	Proposed	Savings
	therms/yr	2,717	1,359	1,359
	Cost ($/yr)	$ 3,397	$ 1,698	$ 1,698
	Cost	$ 36,113		
	Simple Payback (yrs)	21.3		

ECM Summary

Existing	Distribution System: (1/4in. leak typ.)			Proposed	Distribution System (1/4in. leak typ.)	
# Steam Traps:	14			# Steam Traps:	14	
Expected Failure rate (based on 7yr life):	14.3%			Expected Failure rate (based on bi-annual inspection):	5.0%	
Predicted # Failed Traps:	2			Predicted # Failed Traps:	1	
$L_{t,y} = FT_{t,y}*FS_{t,y}*CV_{t,y}*h_{t,y}*sqrt((P_{in,t}-P_{in,t}/2)*(P_{in,t}+P_{in,t}/2))$				$L_{t,y} = FT_{t,y}*FS_{t,y}*CV_{t,y}*h_{t,y}*sqrt((P_{in,t}-P_{in,t}/2)*(P_{in,t}+P_{in,t}/2))$		
$L_{t,y}/h_{t,y}$ (3/16in leak)	9.21	Steam Losses (lbs/hr)		$L_{t,y}/h_{t,y}$ (3/16in l	9.21	Steam Losses (lbs/hr)
$FT_{t,y}$ (LK)	0.25	Failure type Factor		$FT_{t,y}$ (LK)	0.25	Failure type Factor
$FS_{t,y}$	0.9	Service Factor		$FS_{t,y}$	0.9	Service Factor
$CV_{t,y}$	0.776953125	flow coefficient		$CV_{t,y}$	0.776953125	flow coefficient
D	0.1875	orifice diameter in.		D	0.1875	orifice diameter in.
$h_{t,y}$	1	hr		$h_{t,y}$	1	hr
Pin,t	54.7	psia		Pin,t	54.7	psia
Pout,t	14.7	psia		Pout,t	14.7	psia
$L_{t,y}/h_{t,y}$ (1/4in leak)	16.37	Steam Losses (lbs/hr)		$L_{t,y}/h_{t,y}$ (1/4in le	16.37	Steam Losses (lbs/hr)
$FT_{t,y}$ (LK)	0.25	Failure type Factor		$FT_{t,y}$ (LK)	0.25	Failure type Factor
$FS_{t,y}$	0.9	Service Factor		$FS_{t,y}$	0.9	Service Factor
$CV_{t,y}$	1.38125	flow coefficient		$CV_{t,y}$	1.38125	flow coefficient
D	0.25	orifice diameter in.		D	0.25	orifice diameter in.
$h_{t,y}$	1	hr		$h_{t,y}$	1	hr
Pin,t	54.7	psia		Pin,t	54.7	psia
Pout,t	14.7	psia		Pout,t	14.7	psia
Total steam loss/hr	32.7	(lbs/hr)		Total steam los	16.4	(lbs/hr)
Btu/lb steam	1176	btu/lbs		Btu/lb steam	1176	btu/lbs
Heat Loss	38513	btu/hr		Heat Loss	19256	btu/hr
Hours/yr	4784	btu/yr		Hours/yr	4784	btu/yr
Energy losses @ Boile	2717	therm/yr		Energy losses @	1359	therm/yr
Energy Cost:	$ 3,397			Energy Cost:	$ 1,698	
	1.9%				0.9%	

Cost estimates

Cost Estimates						
Project :	OSU Kerr Admin Building				INTERFACE ENGINEERING	
Date :	August 16, 2011		16			
EEM	Description	$/SF	SF	qty	Unit Cost	TOTAL
5	Re-insulate all existing steam pipes and traps					
	Re-insulate all existing steam pipes				$ 60,278	$ 60,278
	Re-insulate all existing steam traps				$ 36,113	$ 36,113
	Total cost					$ 96,391

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Appendix H

Packaged EEMs – Supporting Documents

BEPS & ES-D Reports

Model files:
- o OSU Kerr – Package.pd2
- o OSU Kerr – Package.inp

Cost estimates
- Total EEM1, EEM2 and EEM4 cost estimate: $1,250,106.