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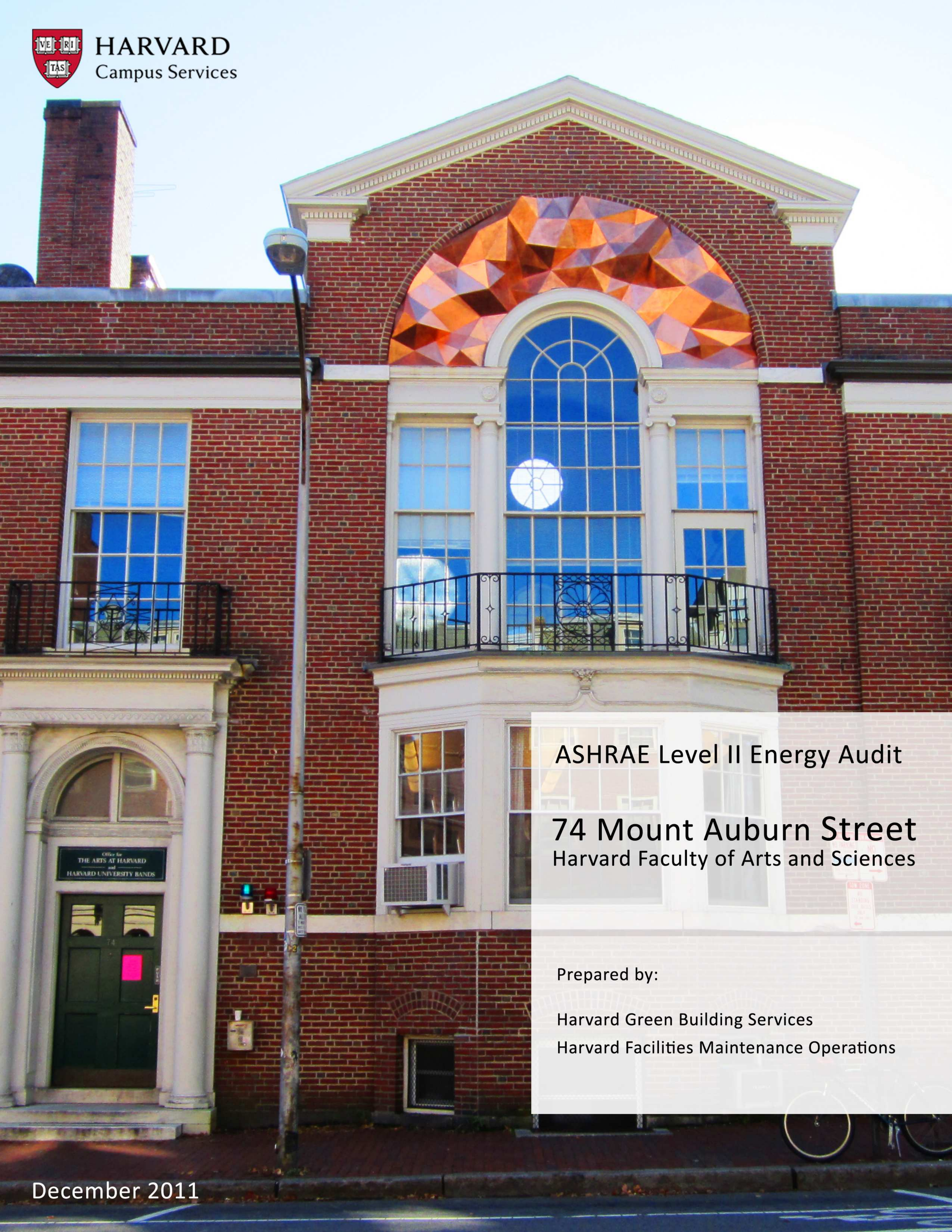

ASHRAE Level II Energy Audit

74 Mount Auburn Street
Harvard Faculty of Arts and Sciences

Prepared by:

Harvard Green Building Services
Harvard Facilities Maintenance Operations

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1.0 EXECUTIVE SUMMARY

At the request of the Faculty of Arts and Sciences (FAS), Green Building Services (GBS) and Facilities Maintenance Operations (FMO) jointly performed a comprehensive energy audit of 74 Mount Auburn Street (MAS) to identify opportunities to save money and energy, while reducing the University's greenhouse gas emissions. We thank the building management team from FAS for supporting this audit, and in particular, Ray Traietti for his assistance in providing the operations and maintenance history along with other information helpful to these efforts.

This audit meets or exceeds the Level II requirements established by ASHRAE[1] and adopted in 2009 by the Harvard Greenhouse Gas (GHG) Working Group for Building Efficiency and Demand Management as the standard for all campus energy audits. As a result, this report includes the following: an historical analysis of all building utility consumption (electricity, district steam, natural gas, and city water); specific efficiency improvement recommendations for each of the primary building systems (HVAC equipment and distribution, lighting, plug loads, and domestic water heating); and a detailed financial analysis of each recommendation, which includes the Savings to Investment Ratio (SIR) based on life cycle costs and using contractor-provided pricing for full installation. This comprehensive approach uses structured techniques to provide a valuable framework for substantial and measurable utilities savings.

In addition, the Audit Team performed a wide range of measurements and calculations that exceed ASHRAE Level II requirements, including: planned completion of a full infrared thermographic scan of the building envelope to identify opportunities to reduce leakage of tempered air; a detailed review of building automation controls and equipment sequence of operations; and calculation of current and projected greenhouse gas emissions to support each energy conservation recommendation.

Key Audit Findings:

- In fiscal year 2011, MAS spent $16,928 on all utilities.
- Eighteen (18) separate low cost Energy Conservation Recommendations (ECRs) identified.
- Annualized savings for of all low cost ECRs totals $4,193, a 25% reduction at current energy prices.
- Potential to reduce total GHG emissions by 14% from the FY06 baseline and 26% from FY11.
- Potential to reduce Energy Use Index[2] by 25% from FY11.
- **Estimated payback period from building budget energy savings for recommended low cost ECRs is forty-five (45) months.** (The table on Page 4 summarizes specific recommendations and payback periods with expected utility savings for the building.)

This audit demonstrates the potential for MAS to serve as a model of sustainable building operations and resource conservation at Harvard. To that end, the Audit Team hopes this report proves to be a useful decision-making tool in considering sustainable building operation strategies. We also believe the value of this report can be further enhanced with a presentation by the Audit Team that encourages direct dialogue with key decision makers. **To initiate those discussions, we will be in contact during the coming weeks to schedule a meeting with the building management team to review audit findings and help guide ECR implementation.** We strongly believe that with continued collaboration, FAS can

[1] American Society of Heating Refrigeration and Air Conditioning Engineers

[2] EUI is a measurement value used to compare one building's energy consumption to another. When making comparisons between buildings, it is important to ensure their schedule, occupancy, climate, and space types are similar.

make significant progress towards the goal of ensuring a sustainable, healthy, and energy-efficient building environment at MAS.

74 Mount Auburn Street Low Cost Energy Conservation Recommendations							
ECR #	ECR Title	Reason for Evaluation	Approx. Annual Building Savings	Approx. Annual University Savings	Net Costs	SIR	Simple Payback Years
1	Replace 75-watt incandescent lamps with LED alternative	Inefficient lighting	$969	$831	$825	22.5	0.9
2	Replace 32-watt T8 lamps with 25-watt alternative	Inefficient lighting	$231	$198	$180	12.1	0.8
3	Replace 17-watt 2' T8 lamps with 15-watt alternative	Inefficient lighting	$1	$1	$3	5.6	2.6
4	Replace incandescent task and overhead lamps with CFL alternative	Inefficient lighting	$47	$41	$175	4.0	3.7
5	Install occupancy sensor to operate bathroom exhaust fan and lights	Inefficient lighting control	$210	$99	$450	8.1	2.1
6	Install Ecostrips to shut down peripherals during unoccupied periods	Inefficient receptacle control	$28	$24	$180	2.3	6.3
7	Replace toilet with low flow alternative	Inefficient flush fixtures	$43	$30	$400	1.7	9.2
8	Replace urinal flushometer with 0.5 gallon per flush alternative	Inefficient flush fixtures	$22	$15	$170	2.0	7.8
9	Replace existing heating hot water pumps with automatic speed controlled alternative	Inefficient HVAC control	$283	$243	$2,200	1.9	7.8
10	Repair economizer function of studio space AHUs	Inefficient HVAC control	$418	$359	$2,000	3.1	4.8
11	Install CO2 sensor and occupancy sensor to control operation of basement AHU	Inefficient HVAC control	$1,008	$580	$3,000	5.6	3.0
12	Install valve for heating hot water coil in basement AHU to decrease steam consumption in building	Inefficient HVAC control	$321	$67	$2,000	3.1	6.2
13	Install programmable thermostats to control operation of FCUs	Inefficient HVAC control	$96	$83	$800	1.8	8.3
14	Install programmable thermostats to control operation of baseboard radiation	Inefficient HVAC control	$149	$31	$200	14.2	1.3
15	Program outdoor air temperature reset for HHW system	Inefficient HVAC control	$190	$40	$1,200	3.0	6.3
16	Insulate domestic hot water piping in basement mechanical room	Uninsulated piping	$22	$0	$250	0.7	11.3
17	Insulate outdoor air intake for open office space AHU	Compromised envelope	$1	$0	$10	1.0	19.5
18	Install interior storm windows for studio space	Compromised envelope	$153	$32	$1,600	1.8	10.4
		Total	**$4,193**	**$2,676**	**$15,643**	**-**	**3.7**

2.0 BACKGROUND

74 Mount Auburn Street (MAS) houses the Office for the Arts at Harvard University. Purchased by the University in 1971, the building is owned and operated by the FAS. The building was originally constructed in 1916. MAS has a total of fifteen (15) offices, houses the University band and includes studio space for a number of dance groups. The building has two (2) floors above grade and an occupied basement level encompassing a total of 8,438 square feet of space.

2.1 Space Types

The two main levels at MAS are used as office and conference space for the Office of the Arts. The basement level houses the band equipment and office space for band personnel. The basement level also houses the building mechanical equipment.

74 Mount Auburn Street Space Types (Sq. Ft.)					
Floor	**Office Space**	**Common Area**	**Corridor**	**Mechanical/ Storage**	**Total**
Basement	300	1,200	400	1,100	3,000
First Floor	2,400	300	300	0	3,000
Second Floor	1,438	800	200	0	2,438
Totals	**4,138**	**2,300**	**900**	**1,100**	**8,438**

2.2 Occupancy and Use Schedules

The office space and common areas at MAS are typical occupied during work hours (8 a.m. – 5 p.m.) by the staff of the building. The basement band area is typically occupied by band members after 5 p.m. and on the weekends. While summer sees lower total occupancy of the building, many rooms are still used by staff. Payback calculations for conservation projects included twenty-four (24) full-time occupants and a visitor average of seventy (70) per day. These occupancy patterns are leveraged in the energy conservation strategies included in this report.

The chart below represents the typical occupancy by space type.

74 Mount Auburn Street Occupancy Schedules			
Space Type	**Monday through Friday**	**Sat**	**Sun**
Band Space	5 p.m. – 12 p.m.	All times	
Office Space	8 a.m. – 5 p.m.	Closed	

2.3 Recent Building System Upgrades and Existing Conditions

In recent years, the MAS building systems have benefited from a variety of resource efficiency improvements. To save water, many its plumbing fixtures and fittings have been replaced, including the aerators and toilets with low flow alternatives. Additionally, the heating system efficiency has been improved by fitting the hot water radiators with Braukman® control valves and installing local thermostats for limited control of the fan coil units. Overall, the building mechanical equipment is older but still in good working order.

The following describes the existing primary building systems.

Heating

MAS is served by the University's district heating loop with steam produced from the Blackstone Steam Plant. The steam supply enters the basement on the southwest side of the building feeding a shell and tube steam-to-hot water heat exchanger. Heating hot water is circulated throughout building via two (2) pumps, operating in a lead/lag configuration. The end devices are a mix of hot water radiators and fan coil units. The radiators are each equipped with a thermostatic control valves to allow for individual temperature control of the spaces. The fan coil units are equipped with a local thermostat to control fan operation but do not have control valves to control the flow of hot water to individual units. The larger basement social area is heated by a heating and ventilation unit located in the basement mechanical room. The operating schedule for that unit is currently 24/7.

Cooling

MAS is not on the University's district chilled water. Some of the basement, first and second floor spaces are cooled during the summer months with window air-conditioning units. Two packaged air-conditioning units located on the roof provide cooling for the dance studio area. These units have economizer functionality to allow for free cooling when outdoor air temperature and humidity conditions permit.

Ventilation

The basement and second floor studio space of MAS have centralized ventilation. However, the Team noted that the outside air dampers of the dance studio packaged air-conditioner units did not appear to operate correctly. Therefore, it is not clear that ventilation air is being provided to this space. In the basement, the AHU runs continuously in order to ventilate and condition the basement common space. The bathrooms located in the basement and first floors are equipped with exhaust fans that vent at the roof of the building. The exhaust fans for the basement bathrooms are controlled with a timer that does not appear to be working based on field test conducted in the filed by the Team. The first floor bathroom exhaust fans are controlled with the wall mounted switch located in each bathroom. The windows throughout the building are operable with screens and can be used to provide outside air to the spaces when the climate allows for natural ventilation.

Building Automation Controls

MAS has limited building automation controls and is not part of the Siemens® DDC building control network. Heating for the building is controlled with a single thermostat which measures outside air temperature and modulates the steam valve based on the readings. The thermostat is currently set to allow the building to enter its heating mode when ambient temperatures are below 50°F. The basement AHU is equipped with only basic controls used to maintain temperature set points in the basement common space. The AHU also has a face and bypass arrangement so that it can continuously ventilate the basement space regardless of whether the building is calling for heating. This arrangement was installed because the AHU heating coil is not fitted with a valve to prevent the flow of heating hot water through it. Radiators throughout the building are all equipped with thermostatic valves which control HHW flow to each radiator. The fin tube radiant pipe in the basement social room is controlled with a non-programmable thermostat. The rooftop packaged units serving the dance studio are controlled with programmable thermostats located in the studio space and are programmed for unoccupied setbacks.

Lighting

The lighting throughout the building is primarily provided by T8 linear fluorescent overhead fixtures. Overhead fixtures in the offices typically use two (2) 32-watt linear fluorescent lamps. In a few of the conference rooms and in the studio space on the second floor, 75 watt R30 lamps are used. All lighting throughout the building is manually controlled by wall mounted switches.

Plumbing

The majority of the toilet fixtures in MAS are dual flush units equipped with a 1.6 gallons per flush (gpf) / 1.1 gpf flushometer. There are also a few 1.6 gpf tank type toilets in the building. The bathroom sinks are fitted with 0.5 gallon per minute (gpm) faucet aerators.

Electrical Metering

The electrical supply is 120/240 volt single phase three-wire service. The building has a single utility meter.

Building Envelope

MAS is a two-story brick structure equipped with old single pane, double hung operable windows and newly installed storm windows on the first floor. Wood sashes throughout fit poorly and do not make a tight seal.

The roof is a black rubber membrane with approximately 2" of board insulation. An aerial thermal image of MAS was taken during the winter months and identified a minimal heat loss from an abandoned AHU which serves the first floor open office area. This image is included in Appendix E.

The exterior walls are assumed to have the following composition: two layers of brick, vapor barrier, wood studs, and drywall. A full thermal scan of MAS will be completed during the winter months to help identify heat loss opportunities.

Domestic Hot Water

Domestic hot water (DHW) is supplied by one (1) A.O Smith® 40-gallon free-standing natural gas-fired water heaters. DHW in the tanks is maintained at 125°F and used for bathroom and kitchen sink faucets.

> Safety Concern: There is no combustion air provided for the natural gas-fired water heater. Although there is a louver installed in the door to the entrance of the mechanical room, the heater should be provided with a dedicated makeup air duct. Without makeup air, there is the possibility of allowing the trespass of carbon monoxide into occupied areas.

2.4 Renewable Energy Assessment

As part of the auditing process the Team examined the possibility of adding renewable energy technologies at MAS including: solar photovoltaic (PV), solar hot water, small scale wind, and cogeneration systems. This analysis is meant to provide general information regarding existing conditions at MAS and is not meant to serve as a guarantee regarding the feasibility of installing any of these systems.

Solar PV: MAS contains flat roof sections that could possibility be used to install solar panels. The open roof will allow for panels to be oriented in the southern directions to maximize the exposure to the southern sun. Surrounding buildings are slightly taller than MAS and they could shade portions of the roof, reducing the amount of usable sunlight.

Solar Hot Water: The flat roof at MAS would make it a possible candidate for a solar hot water installation. Some shading constraints due to surrounding buildings could potentially limit the usable roof space. Additionally, the domestic hot water load at MAS is relatively minimal, creating a longer payback for this system.

Small Scale Wind: Due to the urban location of MAS small scale wind turbines would likely not be feasible due to inconsistent wind flows and high population density. The wind turbines generate a fair amount of noise which may be disruptive to the people in the area. Additionally, the flickering shading effect caused by the spinning blades may also be a disturbance to people in the area.

Cogeneration: The Team does not see any opportunities for cogeneration at the building due to its relatively small heat load.

2.5 Energy Use Index and Benchmarks

The chart below summarizes the current, as well as the historical energy use indexes and utility costs of MAS. Since city water is not considered an energy use, it is not included in the calculation of the EUI and is not included in the total energy cost per square foot calculation.

Energy Use Indices for 74 Mount Auburn Street					
Metric	**2006 (baseline used for 30% GHG Reduction Goal)**	**Current EUI based on FY2011 Data**	**Annualized with all ECRs**	**Savings Potential from FY2011**	**Equivalent to meet 30% GHG reduction goal**
kBtu per sq. ft.	47.08	65.63	48.67	25%	32.96*
Total Energy Cost per sq. ft	$1.68	$1.88	$1.39	$0.49	-
* The University-wide 30% GHG reduction goal is not intended to be interpreted as a strictly school or building-based target					

Since the baseline year of 2006, total energy use for MAS increased by 39%. **<u>The recommendations identified in this report have the potential to reduce the EUI by 25% from FY11.</u>**

ENERGY STAR Rating

MAS's office space is recognized by the ENERGY STAR Portfolio Manager Program[3] and thus eligible for an ENERGY STAR rating. A minimum rating of 75 is necessary to receive ENERGY STAR certification. The current ENERGY STAR rating for MAS is 82, indicating the building is performing in the 82th percentile of buildings of comparable size and in similar climates. By implementing the recommendations in this report it is possible to achieve certification with an even greater ENERGY STAR rating.

3.0 GENERAL INFORMATION

3.1 Audit Team

The Harvard University Energy Auditing Services is collaboration between Facilities Maintenance Operations (FMO) and Green Building Services (GBS). Tony Ragucci, Associate Director of FMO, served as the audit program manager. Kevin Sheehan, FMO Supervisor of Technical Maintenance Services, led the technical equipment review. Eric Potkin, GBS Project Coordinator and Kevin Bright, GBS Assistant Program Manager performed ECR identification and drafted primary findings.

3.2 Audit Process

Prior to starting field visits, the Audit Team collected historical energy data for MAS.

The Team visited MAS in the summer of 2011 and collected detailed information on the mechanical, lighting, and plumbing systems as well as occupancy, building use patterns, and equipment operating schedules. Additionally, the building management staff provided valuable information regarding equipment maintenance. Ultimately, each recommendation was fully priced and energy savings and payback estimates calculated.

The enhanced utility monitoring and greenhouse gas reduction reporting included in this report exceeds the ASHRAE Level II Energy Audit requirements. More information regarding the data collection and analysis requirements of an ASHRAE Level II Energy Audit can be found in Appendix B.

3.3 Financial Analysis – Methodologies and Assumptions

All financial analyses included in this report were derived using the Harvard Life Cycle Cost (LCC) Calculator. The calculator was created by Office for Sustainability in collaboration with the Greenhouse Gas Finance Working Group. In this audit, the LCC calculator was used to perform an analysis of each recommendation. Using the initial project cost, annual savings, life of the equipment, and the equipment's replacement cost, the LLC develops a variety of useful financial, energy savings, and greenhouse gas reduction metrics.

The LCC calculator uses the following four assumptions to estimate the potential energy conservation and financial savings:

1. **Maintenance Escalation** – This variable represents the annual increase in maintenance costs. In the calculator, it is assumed that these costs will increase by 2.2% each year.

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[3] ENERGY STAR is a government program that provides efficiency information to consumers and facility managers. For more information visit: http://www.energystar.gov/

2. **Discount Rate** – Also known as the rate of interest, this variable is used to convert or discount future cash flows to a common time. The default value of 8.0% is used for all of Harvard's proposed energy conservation projects in order to ensure results are comparable across the University.
3. **Time Period** - The calculator computes savings for each project over a period of 20 years.
4. **Utility Escalation Rate** – This variable represents the annual increase in utilities cost; in the calculator, it is assumed these costs will increase by 3.05% each year.
5. **Utility Rates** – The rates used in the LLC calculator reflect the average University rate for utilities provided to all buildings on campus. The building specific rates used throughout this report only reflect the utility rate for the individual building. Therefore, the savings and payback times reported in the LLC calculator may differ from values throughout the rest of the report.

The LCC calculator also reports five different metrics to determine the financial effectiveness of each project as well as its potential impact on greenhouse gases emissions.

1. **20 Year Net Present Value (NPV)** – Current total value of all annual savings and one-time costs, minus the initial cost.
2. **Savings to Investment Ratio (SIR)** – 20 year net present value divided by the initial investment. This is a unitless measure of performance where if the SIR is greater than one, the project is cost effective. If greater than one, this means that for each extra dollar spent, the amount saved will be greater. If the SIR is less than one, for each extra dollar spent, the amount saved will be less.
3. **20 Year Investment Cost / 20 Year MTCDE[4]** – 20 year investment cost[5] of each measure divided by the amount of greenhouse gases the project will mitigate.
4. **Net Present Value / Total GHG Reduction** – 20 year net present value divided by the amount of greenhouse gases the project will mitigate.
5. **Internal Rate of Return** – The annual yield from the project over the 20-year period.

The Team has included a copy of the LCC calculations for each identified energy conservation recommendation in Appendix G of this report. For a copy of Harvard's Life Cycle Cost Calculator and a copy of its guide, please visit Harvard's Green Building Resource.[6]

Building Budget Savings versus Net University Savings -
Utility Expenditures, Recovery Rates, and Impacts from Changes in Consumption

Harvard's utility expenditures include a consumption variable (lower usage results in less money spent) as well as an otherwise fixed cost for infrastructure (Harvard-owned energy plants and distribution systems.) It is important to recognize these differences since the cost of operating and maintaining the university-owned infrastructure is not significantly impacted by incremental reductions in usage such as those identified in this report. All infrastructure costs are allocated as *Care and Operations* expenses to the building budgets based on consumption rate of the previous year.

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[4] MTCDE (Metric Tons of Carbon Dioxide Equivalent): This unit of measure is used to equate the greenhouse gas or warming potential of different substances to carbon dioxide.
[5] 20 year investment cost: Total investment of all costs accrued over the time period.
[6] http://green.harvard.edu/theresource/new-construction/life-cycle-costing/

While the building-level utility expenses will see the full reductions identified in the ECRs, the bottom line savings to the University will be net of the redistributed fixed costs for infrastructure. For example, a building that lowers its annual chilled water bill by $100 (through reduced consumption) saves the University only $25 due to the relatively high fixed costs of producing chilled water. Whereas, the same $100 reduction applied to electricity saves the University $85, because of the lower fixed cost of electric distribution. This information should be considered when prioritizing ECRs and particularly when evaluating building plant alternatives to the existing district energy systems.

The following table reflects the approximate portion of fixed costs for each utility.

Fixed Costs of Utilities Supplied through Harvard E&U Infrastructure (FY11 Rates)				
	Steam	**Chilled Water**	**Electricity**	**Water**
Unit Rate	$29.92 per MMBTU	$10.39 per Ton-Day	$0.154 per kWh	$14.31 per CCF
Approximate Infrastructure Component	53%	75%	13%	24%

4.0 ENERGY CONSERVATION RECOMMENDATIONS

4.1 Energy Conservation Recommendation Summary

ECR Collective
Faculty of Arts and Sciences - 74 Mt. Auburn Street

ECR	Measure Type	Energy Conservation Recommendation	Electricity	Steam	Natural Gas	Water	GHG Reduction	Total Building Savings	Total University Savings	Total Costs	Utility Rebate	Net Costs	Cost / MTCDE	Payback (years)	SIR
			kWh	MMBtu	Therms	CCF	MTCDE								
1	Lighting	Replace 75-watt incandescent lamps with LED alternative	6,820	0	0	0	2.7	$969	$831	$2,750	$1,925	$825	$1,034	0.9	22.5
2	Lighting	Replace 32-watt T8 lamps with 25-watt alternative	1,624	0	0	0	0.6	$231	$198	$180	$0	$180	$284	0.8	12.1
3	Lighting	Replace 17-watt 2' T8 lamps with 15-watt alternative	8	0	0	0	0.0	$1	$1	$3	$0	$3	$962	2.6	5.6
4	Lighting	Replace incandescent task and overhead lamps with CFL alternative	334	0	0	0	0.1	$47	$41	$175	$0	$175	$1,343	3.7	4.0
5	Lighting Control	Install occupancy sensor to operate bathroom exhaust fan and lights	591	6	0	0	0.7	$210	$99	$450	$0	$450	$682	2.1	8.1
6	Receptacles	Install Ecostrips to shut down peripherals during unoccupied periods	200	0	0	0	0.1	$28	$24	$180	$0	$180	$2,312	6.3	2.3
7	Water Conservation	Replace toilet with low flow alternative	0	0	0	4	0.0	$43	$30	$400	$0	$400	-	9.2	1.7
8	Water Conservation	Replace urinal flushometer with 0.5 gallon per flush alternative	0	0	0	2	0.0	$22	$15	$170	$0	$170	-	7.8	2.0
9	HVAC Control	Replace existing heating hot water pumps with automatic speed controlled alternative	1,996	0	0	0	0.8	$283	$243	$2,200	$0	$2,200	$2,828	7.8	1.9
10	HVAC Control	Repair economizer function of studio space AHUs	2,945	0	0	0	1.1	$418	$359	$2,000	$0	$2,000	$1,742	4.8	3.1
11	HVAC Control	Install CO2 sensor and occupancy sensor to control operation of basement AHU	4,003	22	0	0	3.1	$1,008	$580	$3,000	$0	$3,000	$981	3.0	5.6
12	HVAC Control	Install valve for heating hot water coil in basement AHU to decrease steam consumption	0	16	0	0	1.1	$321	$67	$2,000	$0	$2,000	$1,827	6.2	3.1
13	HVAC Control	Install programmable thermostats to control operation of FCUs	678	0	0	0	0.3	$96	$83	$800	$0	$800	$3,027	8.3	1.8
14	HVAC Control	Install programmable thermostats to control operation of baseboard radiation	0	7	0	0	0.5	$149	$31	$200	$0	$200	$393	1.3	14.2
15	HVAC Control	Program outdoor air temperature reset for HHW system	0	9	0	0	0.6	$190	$40	$1,200	$0	$1,200	$1,855	6.3	3.0
16	Insulation	Insulate domestic hot water piping in basement mechanical room	0	0	7	0	0.0	$22	$0	$250	$0	$250	$6,523	11.3	0.7
17	Insulation	Insulate outdoor air intake for open office space AHU	0	0	0	0	0.0	$1	$0	$10	$0	$10	$5,727	19.5	1.0
18	Envelope	Install interior storm windows for studio space	0	8	0	0	0.5	$153	$32	$1,600	$0	$1,600	$3,061	10.4	1.8

	Electricity	Steam	Natural Gas	Water	GHG Reduction	Total Building Savings	Total University Savings	Total Costs	Utility Rebate	Net Costs	Cost / MTCDE	Payback (years)
Total Savings from Recommendations	**19,198**	**68**	**7**	**6**	**12**	**$4,193**	**$2,676**	**$17,568**	**$1,925**	**$15,643**	**$1,280**	**3.7**
Percentage Reduction in Utility Consumption	**29%**	**22%**	**7%**	**6%**	**26%**	**25%**	-	-	-	-	-	-
TOTAL FY11 Utility Consumption	65,400	314	99	94	47	$16,928	-	-	-	-	-	-

4.2 Low Cost Energy Conservation Recommendations

Note: Savings calculations reflect savings from individual measures only and do not assume that other recommendations have been implemented. Calculations and assumptions used are solely based on the existing equipment and usage schedules.

Lighting (ECR 1 – ECR 5)

ECR 1 *(implemented as part of the student weatherization)*

Replace 75-watt incandescent lamps with LED alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$2,750	6,820				2.7	$969	$1,925	0.9	2.8

Existing Condition: *Inefficient Lighting*
Lighting in a portion of the offices, conference areas and second floor studio space is provided with recessed can fixtures fitted with 75 watt R30 lamps. Other lamps can be used to reduce wattage consumption.

Recommendation: Replace the existing 75-watt R30 lamps with a 13-watt Philips® R30 LED alternative to reduce electric consumption. The new lamps will be a direct replacement for the existing incandescent lamps and will maintain dimming functionality. The replacement LEDs also have a rated lifespan of 45,000 hours versus 2,000 for the existing incandescent lamps, which will help reduce maintenance costs associated with replacing burn outs.

Implementation: Estimate includes the cost to furnish fifty-five (55) Phillips® BR30 LED lamps. In order to estimate the electric savings assumptions for daily usage were made based on space type. NSTAR offers a $35 incentive for each of these lamps installed and these incentives are included in the price calculations. Further information regarding assumptions and the calculations made for this ECR can be found in Appendix C.

ECR 2 *(implemented as part of the student weatherization)*

Replace 32-watt T8 lamps with 25-watt alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$180	1,624				0.6	$231	$0	0.8	0.8

Existing Condition: *Inefficient Lighting*
Lighting for the basement and office spaces is provided by 32-watt T8 fluorescent fixtures. There are newer T8 lamps available which provide comparable lighting output at greatly reduced wattages.

Recommendation: Replace the lamps in the existing T8 fixtures with 25-watt T8 bulbs. The new lamps will produce approximately 10% less light than the current lamps; however, most people cannot notice a lighting reduction of 10% or less. Additionally, reducing the lighting output will still maintain adequate lighting levels in all spaces. The existing ballasts can remain and will be compatible with the reduced wattage, helping to keep installation costs down.

Implementation: Estimate includes the cost to furnish one-hundred and sixteen (116) 25-watt T8 lamps. In order to estimate savings yearly runtime estimates were made for each existing T8 fixture. Further information regarding assumptions and calculations are included in Appendix C.

ECR 3 *(implemented as part of the student weatherization)*

Replace 17-watt 2' T8 lamps with 15-watt alternative										
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$3	8				0.0	$1	$0	2.6	2.6

Existing Condition: *Inefficient Lighting*

Lighting for the bathrooms located on the first floor is provided by 17-watt T8 fluorescent fixtures. There are newer T8 lamps available that provide comparable lighting output at greatly reduced wattages.

Recommendation: Replace the lamps in the existing T8 fixtures with 15-watt T8 lamps. Lowering the wattage of the linear fluorescent lamps will help the building reduce its electric consumption throughout the year. The existing ballasts can remain and will be compatible with the reduced wattage, helping to keep installation costs down.

Implementation: Estimate includes the cost to furnish two (2) 15-watt T8 lamps. In order to estimate savings yearly runtime estimates were made for each existing T8 fixture. Further information regarding assumptions and calculations are included in Appendix C.

ECR 4 *(implemented as part of the student weatherization)*

Replace incandescent task and overhead lamps with CFL alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$175	334				0.1	$47	$0	3.7	3.7

Existing Condition: *Inefficient Lighting*

Within the offices of MAS, task lights and a portion of the overhead lights are fitted with incandescent lamps. There are compact fluorescent lamp (CFL) alternatives available which provide comparable lighting output at greatly reduced wattages.

Recommendation: Replace the incandescent lamps in the task lights and overhead fixtures with reduced wattage CFL alternatives. Lowering the wattage of the task lights and overhead fixtures will help the building reduce its electric consumption throughout the year.

Implementation: Estimate includes the cost to furnish eight (8) CFL lamps. In order to estimate savings yearly runtime estimates were made for each existing task light and overhead fixture. Further information regarding assumptions and calculations are included in Appendix C.

ECR 5 *(implemented as part of the student weatherization)*

Install occupancy sensor to operate bathroom exhaust fan and lights									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$450	591	6			0.7	$210	$0	2.1	2.1

Existing Condition: *Inefficient Lighting Controls*

There are four bathrooms located at MAS. On the first floor there are two bathrooms that contain local exhaust fans and lighting simultaneously controlled by a wall switch. In one bathroom, a single 32-watt lamp provides lighting, in the other; two (2) 17 watt lamps are used for lighting. The wattage of the exhaust fans in the first floor bathrooms is 50 watts. Each fan exhausts approximately 50 CFM from the bathroom. In the basement level, there are two larger bathrooms containing three toilet fixtures each. In these spaces lighting is provided with two (2) 32-watt T8 lamps and controlled with a local wall switch. Each bathroom has its own fan that uses 75 watts of power to exhaust 150 CFM from the bathroom. The exhaust fans are controlled with a time clock that is not functioning correctly.

Recommendation: Replace the manual wall switches in the basement and first floor bathrooms with occupancy sensors. The sensors should have two relays so that they can be used to operate both the lights and exhaust fans. Installing the sensors will significantly reduce the runtime of the lights and fans in all four locations resulting in significant lighting and heating savings.

Implementation: The estimate includes the cost to furnish and install the four occupancy sensors in the bathrooms. The sensors should be programmed to minimize the length of time between the space being unoccupied and the lights and fan shutting down. In order to estimate savings yearly runtime estimates were made for each bathroom. Further information regarding assumptions and calculations are included in Appendix A.

Receptacles (ECR 6)

ECR 6 *(implemented as part of the student weatherization)*

Install Ecostrips to shut down peripherals during unoccupied periods									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$180	200				0.1	$28	$0	6.3	6.3

Existing Condition: *Inefficient Receptacle Control*

During a walkthrough, the Team noted that six (6) workstations at MAS had a number of peripheral equipment including speakers and printers that were left on despite the computer being shut down and the office unoccupied. Despite being inactive, the speakers and printer consume electricity in their standby mode.

Recommendation: Install Ecostrip® power strips in order to better control the operation of the peripheral receptacle equipment. The power strip provides a lead plug that will operate the other ports of the strip. When the equipment plugged into the lead port is turned off, the other equipment using the power strip will shut off automatically. In an office scenario, once the computer is shut down for the evening, the speakers and printer will also shut down. This control sequence will help MAS reduce its electric consumption throughout the year.

Implementation: The estimate includes the cost to furnish and install six (6) Ecostrip® power strips at MAS. In order to estimate savings, yearly runtime estimates were made for each workstation. Further information regarding assumptions and calculations are included in Appendix A.

Water Conservation (ECR 7 – ECR 8)

ECR 7 *(implemented as part of the student weatherization)*

Replace 1.6 gpf toilet with low flow alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$400				4	0.0	$43	$0	9.2	9.2

Existing Condition: *Inefficient Flush Fixtures*
There is one (1) gravity fed tank type toilet located in a first floor bathroom at MAS. These toilets use 1.6 gallons per flush (gpf) each time the fixture is used.

Recommendation: Replace the existing tank toilet with a low flow WaterSense® labeled alternative. The low flow toilet will use 1.28 gpf which will help to reduce overall water consumption at the building. WaterSense® labeled toilets are tested to ensure superior flush power and will perform as well if not better than the existing 1.6 gpf toilet.

Implementation: The estimate includes the cost to furnish and install one (1) low flow toilet at MAS. Estimates of the number of occupants and visitors to MAS were provided by building management staff. Assumptions regarding fixture usage were drawn from standards published in the LEED**Error! Bookmark not defined.** for Existing Buildings: Operations and Maintenance 2009 reference guide. Further information regarding assumptions and the calculations made for this ECR are included in Appendix C.

ECR 8 *(implemented as part of the student weatherization)*

Replace urinal flushometer with 0.5 gallon per flush alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$170				2	0.0	$22	$0	7.8	7.8

Existing Condition: *Inefficient Flush Fixtures*
There is one (1) 1.0 gpf urinal located in the basement bathroom of MAS. This urinal has an excessive flush rate and contributes to unnecessary water consumption at MAS throughout the year.

Recommendation: Replace the flushometer of the urinal in order to lower its flush rate from 1.0 gpf to 0.5 gpf. By simply replacing the flush valve of the urinal, MAS can reduce its water consumption considerably.

Implementation: Estimate includes the cost to furnish and install the 0.5 gpf urinal flushometer. Estimates of the number of occupants and visitors to MAS were provided by building management staff. Assumptions regarding fixture usage were drawn from standards published in the LEED**Error!**

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HVAC (ECR 9 – ECR 16)

ECR 9

Replace existing heating hot water pumps with automatic speed controlled alternative									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$2,200	1,996				0.8	$283	$0	7.8	7.8

Existing Condition: *Inefficient HVAC Control*
There are two (2) 1 HP heating hot water (HHW) circulating pumps located in the basement mechanical room of MAS. The pumps operate in a lead/lag configuration and are used to distribute HHW to the building's radiators, AHU and fan coil units (FCUs) during the heating season. The pumps currently operate at a constant speed regardless of the heating demand in the building. Since the radiators are equipped with thermostatic valves that modulate based on ambient temperature, there are opportunities to reduce the electric consumption of the hot water pumps by modulating their speed based on the building's heating demand.

Recommendation: Replace the existing HHW circulation pumps with Grundfos Magna® variable speed circulation pumps. The recommended pump has built-in controls that automatically control motor speed in order to precisely meet the demand and maintain a consistent head pressure. Additionally, the new pump employs a permanent magnet motor that allows for greater efficiencies at reduced motor loads than AC induction motors. The pump is also self lubricating which reduces wear on its components and prolonging equipment life span. Only one (1) of the pumps should be replaced and the second pump should be left as a backup in the event the new pump fails.

Implementation: Estimate includes the cost to furnish and install the new variable speed pump. In order to quantify energy savings the Team made an assumption for the current pump runtime and estimated that the new pumps would reduce total energy consumption by 55% (based on manufacturer data). Further assumptions and the calculations made for this ECR are included in Appendix C.

ECR 10

Repair economizer function of studio space AHUs									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$2,000	2,945				1.1	$418	$0	4.8	4.8

Existing Condition: *Inefficient HVAC Control*
The studio space located on the second floor of MAS is served by two (2) Carrier® mixed air units used to ventilate and condition the interior space. The Team noted that the outside air dampers of both units were not functioning properly and therefore were not adequately ventilating the interior studio space. Moreover, there is an opportunity for the units to activate an economizer mode to take advantage of free cooling opportunities when outside air conditions are favorable. However, in its current configuration, the units are unable to provide free cooling and therefore are operating their

compressors unnecessarily during the swing season months. Correcting the operation of the outside air dampers in both units would allow the free cooling feature to help reduce electrical consumption.

Recommendation: Repair the outside air dampers of each AHU in order to allow them to ventilate and provide free cooling to the studio spaces when outside air conditions are favorable. Repairing the dampers will decrease the runtime of the cooling compressors in the units and reduce the building's electrical consumption throughout the year.

Implementation: Estimate includes the cost to repair the AHU outside air dampers. The Team estimates that the economizer control of the units will result in the reduction of the compressor's runtime by 934 hours each year based on local weather data. Further information regarding assumptions and the calculations made for this ECR are included in Appendix C.

ECR 11

Install CO2 sensor and occupancy sensor to control operation of basement AHU									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$3,000	4,003	22			3.1	$1,008	$0	3.0	3.0

Existing Condition: *Inefficient HVAC Control*

In the basement of MAS, there is a mixed air unit located in the basement mechanical room equipped with a 1.5 HP supply fan that serves the basement common area. The fan currently ventilates and conditions the space 24/7 regardless of temperature or occupancy. The basement common area is typically only used by Harvard Band members after 5 p.m. The basement AHU does have some level of control where its face and bypass arrangement modulates based on space temperature. There are offices located in the basement as well, but ventilation to these spaces is provided by a separate system.

Recommendation: Install a carbon dioxide sensor and occupancy sensor to better control the operation and ventilation of the basement AHU. The carbon dioxide sensor will communicate with the outside air damper of the system and modulate the volume of outside air to the space based on carbon dioxide concentrations. This control sequence will allow the unit to reduce its steam consumption by decreasing the volume of outside air it needs to condition throughout the year. The occupancy sensor will be used to operate the AHU based on space occupancy. This will allow the unit to shut down during the day, when the space is sparsely occupied in order to conserve electricity. In tandem, these two control schemes will allow the basement AHU to conserve a significant amount of steam and electricity throughout the year.

Implementation: The cost estimate includes the price to furnish, install and program the carbon dioxide and occupancy sensor. It was assumed that the basement unit provides 500 CFM of outside air to the basement space and that the area is typically occupied 10 hours a day. Further information regarding assumptions and the calculations made for this ECR are included in Appendix C.

ECR 12

Install valve for heating hot water coil in basement AHU to decrease steam consumption in building									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$2,000		16			1.1	$321	$0	6.2	6.2

Existing Condition: *Inefficient HVAC control*

The basement AHU has a heating coil that is fed HHW from the building's heating hot water heat exchanger. The AHU has a face and bypass damper arrangement in order to control the temperature in the basement space. When the thermostat in the basement reaches its set point, the damper arrangement with the AHU directs airflow around the heating coil rather than through it to prevent the space from overheating. While this control sequence keeps the space at a comfortable temperature, there are other means to control the hot water flow through the AHU that would conserve steam energy.

Recommendation: Install a heating hot water valve for the AHU's heating hot water coil. A thermostat in the space will monitor space temperature and modulate the valve position based on the space heating demand. This measure, in order to reduce steam consumption, will prevent the flow of water through the coil. In its current state, HHW is flowing through the coil and transferring energy like a radiator would regardless of air flow. This recommendation is targeted to prevent the flow of water and heat transfer unless there is a heating demand in the space. As a result, a significant amount of steam can be conserved throughout the heating season.

Implementation: The estimate includes the cost to furnish and install the heating hot water valve in the AHU. In order to estimate steam savings, the Team assumed that the volume of heating hot water flow would be reduced depending on outside air conditions. Further information regarding assumptions and the calculations made for this ECR are included in Appendix C.

ECR 13 *(implemented as part of the student weatherization)*

Install programmable thermostats to control operation of FCUs									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$800	678				0.3	$96	$0	8.3	8.3

Existing Condition: *Inefficient HVAC control*

There are ten (10) heating only fan coil units (FCUs) installed at MAS. The FCUs are equipped with a thermostat installed on the side of its cabinet which controls the fan operation. The thermostats are manually-operated dials where the room occupants determine the appropriate temperature set point for the space. As a result, the FCUs maintain a particular temperature set point in the space regardless of time of day or occupancy.

Recommendation: Replace the manually operated dial thermostats with programmable thermostats for the FCUs. With appropriate scheduling, the programmable thermostats will depress the temperature set points during occupied hours by shutting off the fans, which will save a considerable amount of electricity during the heating season.

Implementation: The estimate includes the cost to furnish and install the programmable thermostats for the ten (10) FCUs. In order to estimate savings, the Team assumed the programmable thermostats would reduce the runtime of the FCU by varying amounts depending on outside air temperature. Further information regarding assumptions and calculations made for this ECR are included in Appendix C.

ECR 14

Install programmable thermostats to control operation of baseboard radiation									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$200		7			0.5	$149	$0	1.3	1.3

Existing Condition: *Inefficient HVAC Control*
In the basement common area, there is 20 feet of heating hot water baseboard installed. The baseboard is controlled with a local manually operated thermostat. The occupants of the space select a temperature set point which the baseboard maintains in the room regardless of schedule or occupancy.

Recommendation: Replace the manually operated dial thermostat with a programmable thermostat. With the appropriate settings, the programmable thermostat will depress the temperature set point in the space, allowing MAS to reduce its steam consumption during the winter months.

Implementation: The estimate includes the cost to furnish and install the programmable thermostat for the baseboard radiation. In order to predict savings, the Team assumed that the programmable thermostat would prevent the flow of water through the radiator by varying amounts depending on outside air temperatures. Further information regarding assumptions and calculations for this ECR are included in Appendix C.

ECR 15

Program outdoor air temperature reset for HHW system									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$1,200		9			0.6	$190	$0	6.3	6.3

Existing Condition: *Inefficient HVAC control*
The heating hot water system at MAS is supplied from the University's central steam distribution system. The steam is converted to heating hot water (HHW) in the basement of MAS via a shell and tube steam-to-hot water heat exchanger. Heating hot water is created at 170°F and distributed to the building's AHU, radiators, and FCUs. The temperature set point of the HHW remains static regardless of outside air temperature or heating demand within the building. Energy is lost as a result of heating the water to 170°F due to pipe distribution losses and overheating interior spaces.

Recommendation: Install an outside air temperature sensor that will modulate the temperature of the heating hot water system throughout the year. By modulating the temperature of the heating hot water based on outside air temperature, MAS can avoid heating losses through the hot water pipe distribution system and overheating its interior spaces. Over the course of the year, the outside air temperature reset will allow the building to reduce its steam consumption.

Implementation: The estimate includes the cost to implement the necessary controls for an outside air reset for the heating hot water system. An existing outside air temperature sensor is already in place and should be used as part of the controls scheme. It was estimated that this measure would save 3% of the total steam consumption at the building. Further information regarding the assumptions and calculations for this ECR can be found in Appendix C.

Insulation (ECR 16 – ECR 17)

ECR 16 *(implemented as part of the student weatherization)*

Insulate domestic hot water piping in basement mechanical room									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$250			7		0.0	$22	$0	11.3	11.3

Existing Condition: *Uninsulated piping*
MAS has some uninsulated domestic hot water piping located in the basement mechanical room. The uninsulated pipes allow heat to radiate from the pipes before reaching its final destination as well as result in basement areas overheating. Uninsulated piping includes:

- 3 feet of 1” pipe;
- 10 feet of 0.75” pipe;
- 15 feet of 0.5” pipe.

Recommendation: Insulate the exposed pipes throughout the basement. Insulating the pipe will conserve natural gas (used to fire the water heater) by allowing less heat to radiate from the pipe as the domestic hot water is distributed throughout MAS.

Implementation: The estimate includes the price to furnish and install the insulation for the pipes. In order to calculate heat loss from the uninsulated piping the Team assumed the average temperature differential between the pipe and the surround air is 40°F. Further information regarding assumptions and the calculations made for this ECR are included in Appendix C.

Envelope (ECR 17 – 18)

ECR 17

Insulate outdoor air intake for open office space AHU									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$10		0.03			0.0	$1	$0	19.5	19.5

Existing Condition: *Uninsulated Ductwork*
An abandoned rooftop unit (RTU) was used to ventilate and condition the first floor open office space of MAS. Over time, FCUs were installed in the space to provide conditioning; however, the ductwork and roof penetrations remained. While the penetrations have been covered they are not insulated and as a result heat from the interior space is being transferred to the exterior adding to the heating load of the space.

Recommendation: Insulate the outside air duct of the abandoned RTU in order to prevent the transfer of heat from the office space to the exterior. Reducing the heat transfer will decrease the heating demand of the space, and allow MAS to reduce its steam consumption.

Implementation: Estimate includes the cost to insulate the outside air duct opening of the abandoned RTU. In order to calculate the steam savings, the Team measured the duct opening and estimated its current U-value. Further information regarding the calculations and assumptions made for this ECR are included in Appendix C.

ECR 18

Install interior storm windows for studio space									
Budgetary Cost	Annual Utility Savings				MTCDE	Annual Savings	Available Incentives	Payback with Incentives	Payback without Incentives
	Electricity	Steam	Natural Gas	Water					
$	kWh	MMBtu	Therms	CCF	Metric Tons	$	$	Years	Years
$1,600		8			0.5	$153	$0	10.4	10.4

Existing Condition: *Poor Window Insulation*
studio space on the second floor of MAS has a substantial amount of single pane glazing. As a result, the space's insulative value is low which increases the heating and cooling demand of the space throughout the year.

Recommendation: Increase the insulative value of the glazing by installing interior storm windows. The storm windows will essentially add another pane of glass to the window arrangement which will help the space retain conditioned air for a longer period of time. By adding this additional pane of glass the heating demand of the space will decrease, reducing the building's steam consumption.

Implementation: Estimate includes the cost to furnish and install the storm windows for the second floor studio space. In order to estimate savings, the Team measured the area of the single pane windows and calculated the heating losses based on local climate data. Further information regarding the calculations and assumptions made for this ECR are included in Appendix C.

5.0 UTILITY ANALYSIS

5.1 Utility Rate Schedules

Utility Rate Schedule – FY 11 (July 2010 through June 2011)		
Utility	**Unit**	**Rate**
Electricity	kWh	$0.14
Natural Gas	Therms	$3.07
District Steam	MMBtu	$20.15
Water	CCF	$11.21

5.2 CO_2 Equivalents for Utilities

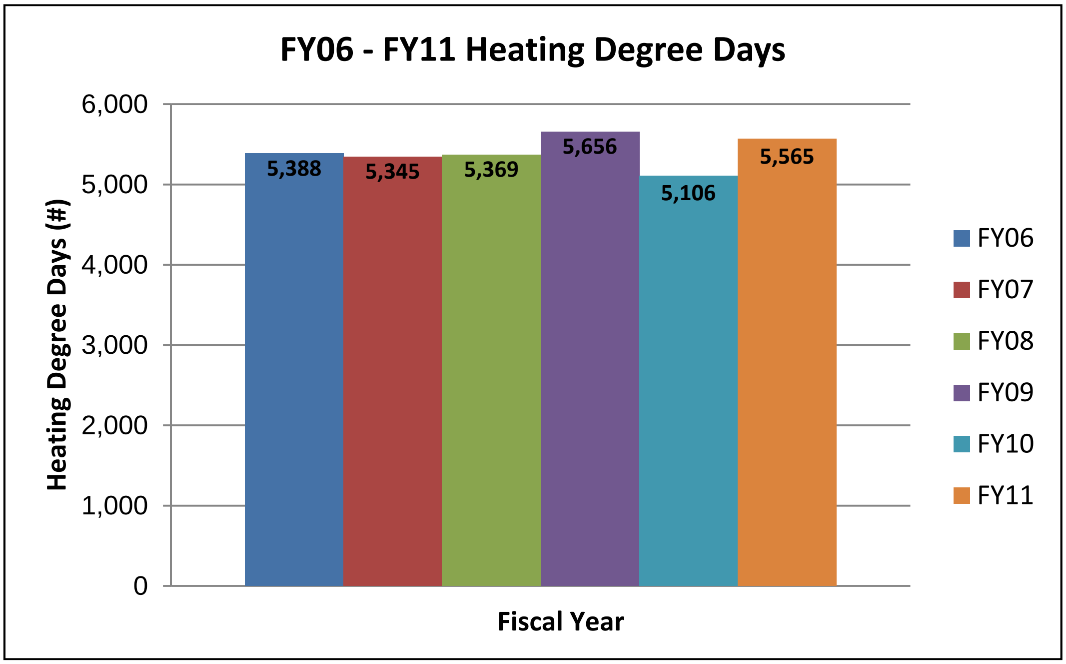
The table below lists the metric ton of carbon dioxide equivalents (MTCDE) for each utility consumed by MAS. The conversion factors were calculated by the Greenhouse Gas Inventory and Measurement Working Group. These factors were used to estimate the greenhouse gas reductions for each energy conservation recommendation at MAS.

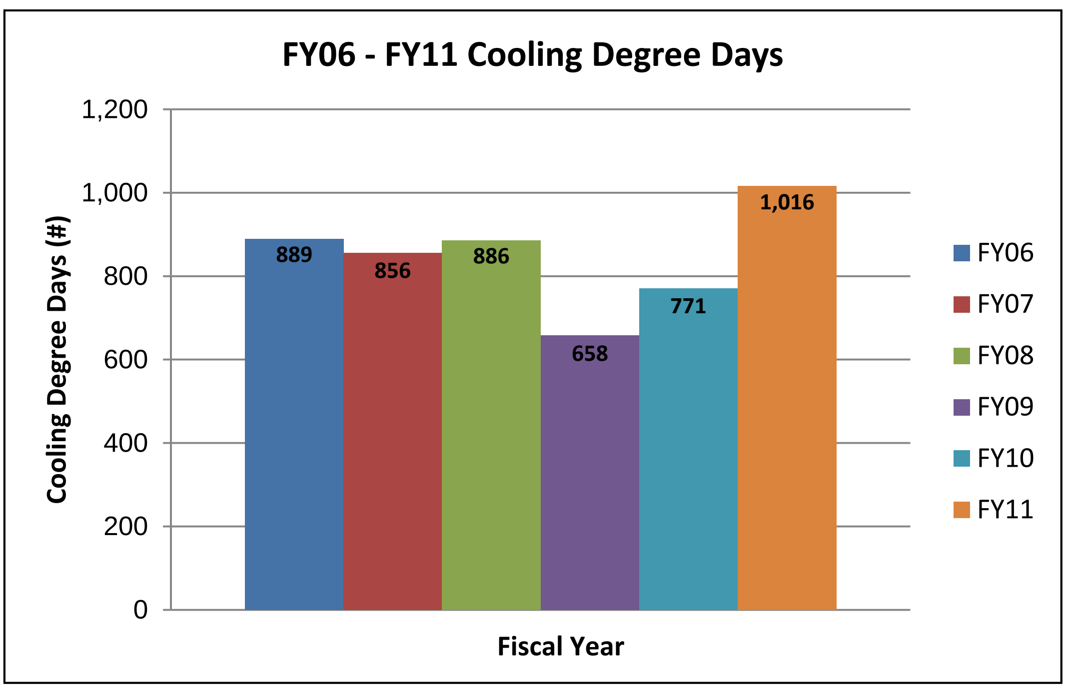
Carbon Dioxide Equivalents by Utility Type		
District Steam (MTCDE/MMBtu)	**Natural Gas** (MTCDE/therm)	**Electricity** (MTCDE/kWh)
0.068680	0.005318	0.000390

5.3 Annual Degree Days FY06 – FY11

The graphs below provide the number of heating and cooling degree-days for Cambridge, Massachusetts for the past six fiscal years.

A heating degree-day (HDD) is the number of degrees that a day's average outside air temperature is below 65°F and a building's interior is typically heated. A cooling degree-day (CDD) is the number of degrees that a day's average outside air temperature is above 65°F and air conditioning is typically used to cool a building's interior spaces.

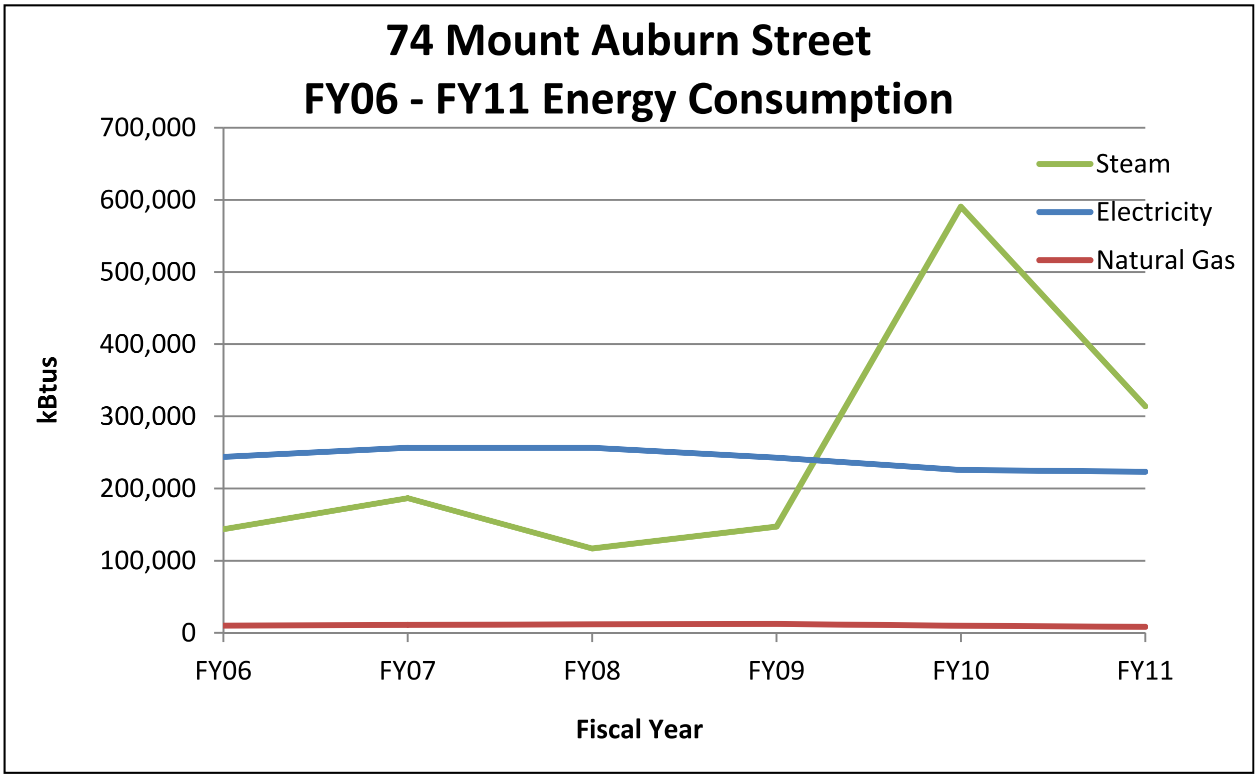




5.4 Utility Performance Summary by Fiscal Year

Examining the historical utility data of the building is a requirement of an ASHRAE Level II audit. The table below shows the energy performance of MAS from fiscal years (FY) 2006 through 2011. The graph below visually represents the trend in energy consumption over these years.

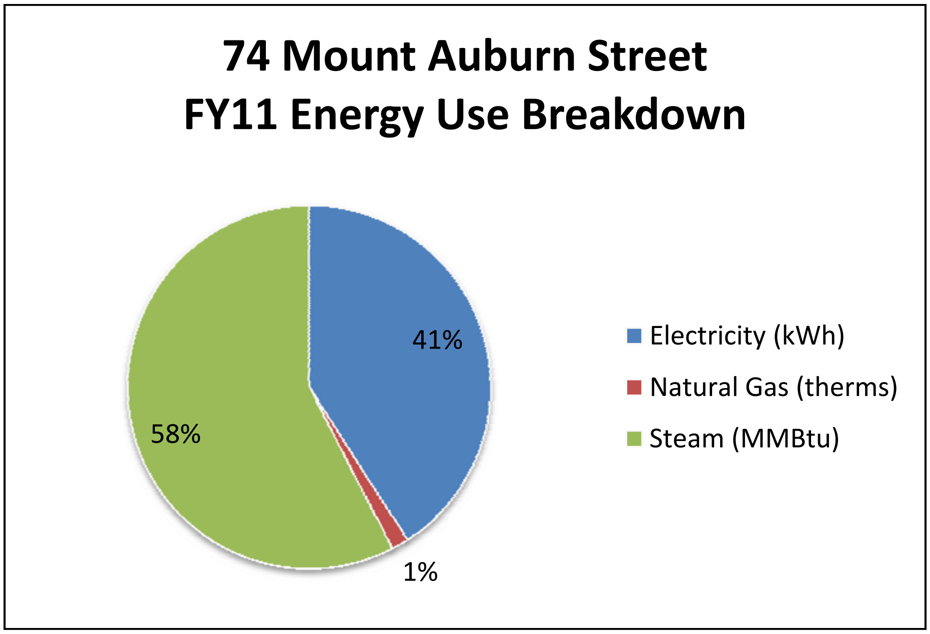
Total energy consumption at MAS has increased between FY06 and FY11 with the most noticeable increase occurring in the past two fiscal years. Total usage dropped from FY07 to FY08 then remained fairly constant through FY09 before increasing in FY10. As displayed by the graph below, the increase in total building energy consumption between FY09 and FY11 is fueled by the increase in steam consumption. Overall, total utility consumption at MAS has increased by 26% between FY06 and FY11.



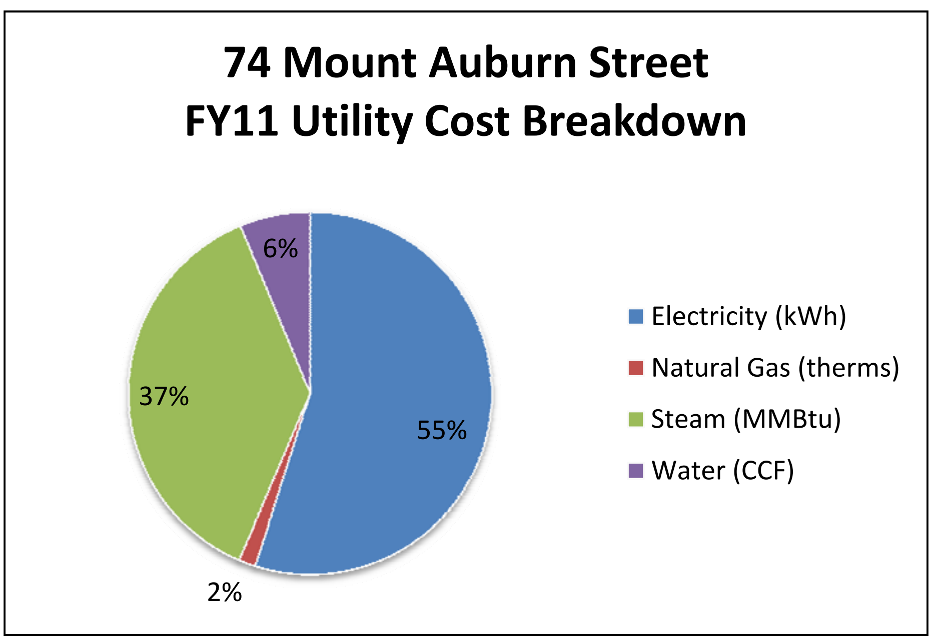
Energy Performance Summary by Fiscal Year						
Year	Energy Type	Metric Tons of CO2 Equivalent	Total Annual Use	Conversion Multiplier	Thousand BTU (kBtu)	Total Annual Cost
FY11	Electricity (kWh)	25	65,400	3.41	223,145	$9,288
	Natural Gas (Therms)	0	83	100	8,300	$255
	Steam (MMBtu)	22	314	1,000	313,910	$6,325
	Water (CCF)	-	94	-	-	$1,059
	Totals	**47**	**-**	**-**	**545,355**	**$16,928**
FY10	Electricity (kWh)	26	66,160	3.41	225,738	$8,956
	Natural Gas (Therms)	1	99	100	9,900	$262
	Steam (MMBtu)	41	591	1,000	590,530	$12,582
	Water (CCF)	-	87	-	-	$923
	Totals	**67**	**-**	**-**	**826,168**	**$22,722**
FY09	Electricity (kWh)	27	71,120	3.41	242,661	$10,654
	Natural Gas (Therms)	1	122	100	12,200	$343
	Steam (MMBtu)	12	147	1,000	147,320	$3,880
	Water (CCF)	-	85	-	-	$848
	Totals	**39**	**-**	**-**	**402,181**	**$15,725**
FY08	Electricity (kWh)	28	75,160	3.41	256,446	$11,321
	Natural Gas (Therms)	1	119	100	11,900	$326
	Steam (MMBtu)	10	117	1,000	116,930	$2,835
	Water (CCF)	-	96	-	-	$924
	Totals	**38**	**-**	**-**	**385,276**	**$15,406**
FY07	Electricity (kWh)	29	75,120	3.41	256,309	$12,259
	Natural Gas (Therms)	1	109	100	10,900	$333
	Steam (MMBtu)	16	187	1,000	186,590	$4,317
	Water (CCF)	-	101	-	-	$973
	Totals	**45**	**-**	**-**	**453,799**	**$17,882**
FY06	Electricity (kWh)	26	71,440	3.41	243,753	$10,741
	Natural Gas (Therms)	1	99	100	9,900	$318
	Steam (MMBtu)	14	144	1,000	143,640	$3,107
	Water (CCF)	-	101	-	-	$912
	Totals	**41**	**-**	**-**	**397,293**	**$15,078**

5.5 Utility Component Breakdown

In FY11, MAS used a total of 545,355 kBtus of energy including electricity, natural gas, and district steam. The chart below proportionally illustrates energy use breakdown by utility category. Steam represents 58% of the total energy consumption while electricity represents 41%. Natural gas represents 1% of the total energy consumption at MAS.



In FY11, MAS spent a total of $16,928 on all utilities including electricity, natural gas, district steam, and city water. The chart below proportionally illustrates the cost breakdown by utility category. 55% of the total utility cost was comprised of electricity while 37% of the total cost was steam. City water accounted for 6% of all utility cost and natural gas accounted for only 2%. This chart is inconsistent with the energy use breakdown and shows that while steam represented the highest consumption electricity represented the highest percentage of total cost.



5.6 End Use Component Energy Usage Breakdown

The table below provides energy consumption end use breakdowns for MAS based on FY11 data. Since there are no sub meters to continuously measure electrical loads within MAS, the Team used some assumptions in order to estimate and then extrapolate annual distribution loads. The lighting load is based on a count of all the lighting fixtures and estimates yearly runtime per fixture. The space cooling load is based on the ratings of the window air-conditioning units and the two rooftop unit at MAS and estimates of annual runtime. The other equipment load is equal to the total electrical consumption minus that used for lighting. The space heating consumption is equal to the steam consumption at the building. The domestic hot water consumption is equal to the natural gas consumption at the building.

City water was not included in this analysis since it is strictly a utility cost and is not considered a component of energy consumption by the building.

Space heating consumes the most energy and comprises 58% of MAS's annual energy budget and 40% of the building's annual energy cost. Domestic hot water consumes 2% of total use and equals 2% of the building's annual energy cost. Lighting accounts for 7% of the total energy budget and comprises 11% of the total energy cost. Other equipment consumes 28% of MAS's annual energy budget and represents 40% of the total annual cost.

Annual Energy Consumption by End Use Components FY 2011							
End Use	**Electricity**	**Natural Gas**	**Steam**	**Total**	**% of Total Use**	**Total Cost ($)**	**% of Total Cost**
	kWh	**Therms**	**MMBtu**	**kBtu**			
Space Heating			314	314,000	58%	$6,327	40%
Space Cooling	8,430			28,700	5%	$1,197	8%
Domestic Hot Water		83		8,300	2%	$255	2%
Lights	11,791			40,243	7%	$1,675	11%
Other Equipment*	45,179			154,198	28%	$6,416	40%
Total	**65,400**	**314**	**83**	**545,540**	**100%**	**$15,870**	**100%**
*Includes: Plug loads, fan motors, condensate pumps, exterior lights, AHUs, and miscellaneous equipment.							

5.7 Energy Use and Cost Indices by Fiscal Year

Calculating historical energy usage on a square footage basis is a requirement of an ASHRAE Level II audit. The EUI information can be helpful in comparing energy intensity in buildings of similar space types in similar geographical locations on a per square footage basis. Additionally, the cost index can be helpful in comparing one buildings operation costs to that of similar buildings.

The table below displays the energy performance data in consumption and cost per square foot. The annual utility cost indices for MAS, in dollars per square foot, are highlighted in red.

Energy Use and Cost Indices by Fiscal Year		
Year	**Metric**	**Utility Data**
FY 11	Energy Utilization Index (kBtu/ft^2/year)	64.63
	Energy Cost Index ($/ft2/year)	$1.88
	Utility Cost Index (Including City Water) ($/ft^2/year)	$2.01
FY 10	Energy Utilization Index (kBtu/ft^2/year)	97.91
	Energy Cost Index ($/ft2/year)	$2.58
	Utility Cost Index (Including City Water) ($/ft^2/year)	$2.69
FY09	Energy Utilization Index (kBtu/ft^2/year)	47.66
	Energy Cost Index ($/ft2/year)	$1.76
	Utility Cost Index (Including City Water) ($/ft^2/year)	$1.86
FY08	Energy Utilization Index (kBtu/ft^2/year)	45.66
	Energy Cost Index ($/ft2/year)	$1.72
	Utility Cost Index (Including City Water) ($/ft^2/year)	$1.83
FY07	Energy Utilization Index (kBtu/ft^2/year)	53.78
	Energy Cost Index ($/ft2/year)	$2.00
	Utility Cost Index (Including City Water) ($/ft^2/year)	$2.12
FY06	Energy Utilization Index (kBtu/ft^2/year)	47.08
	Energy Cost Index ($/ft2/year)	$1.68
	Utility Cost Index (Including City Water) ($/ft^2/year)	$1.79

5.8 Electrical Demand

Review of electrical demand data is a requirement of an ASHRAE Level II audit. The table below illustrates the maximum electrical demand as well as demand per square foot.

Demand has remained fairly constant over the past five years. The maximum demand for FY11 was slightly higher than previous years possibly due to occupant behavioral changes and increased building usage. Demand remains fairly constant throughout the year indicating that seasonal changes in equipment usage do not significantly affect the electricity demand.

Electrical Demand FY06 through FY11		
Years	**Metric**	**Electrical Data**
FY11	Maximum Demand (kW)	29.2
	Maximum Demand (watts/ft2)	3.5
FY10	Maximum Demand (kW)	26.8
	Maximum Demand (watts/ft2)	3.2
FY09	Maximum Demand (kW)	25.0
	Maximum Demand (watts/ft2)	3.0
FY08	Maximum Demand (kW)	25.0
	Maximum Demand (watts/ft2)	3.0
FY07	Maximum Demand (kW)	25.0
	Maximum Demand (watts/ft2)	3.0
FY06	Maximum Demand (kW)	24.0
	Maximum Demand (watts/ft2)	2.8

6.0 LEED FOR EXISTING BUILDINGS: Operations and Maintenance

6.1 Certification

This U.S Green Building Council (USGBC) rating system recognizes buildings that meet their green operations and maintenance standards. Similar to the programs for New Construction or Commercial Interiors, LEED EBOM provides credits to buildings who meet their standards in the following categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation in Operations.

6.2 EPA Portfolio Manager

As part of the energy audit process, the Team created an EPA Portfolio Manager® account for AC, approximated the building's current credit total, and estimated its certification level. After compiling utility bills, square footages, and other basic building information, the Team concluded that AC would be a good candidate for achieving certification under the LEED® for Existing Buildings: Operations and Maintenance rating system (EBOM).

EPA Portfolio Manager is a database organized by ENERGY STAR® to allow buildings to benchmark their energy performance against similar buildings across the United States. In order to achieve EBOM certification the building needs to meet a minimum energy performance threshold defined by LEED® and calculated using Portfolio Manager®. The specific performance requirements, reported in thousands of Btu's per square foot, vary based on the type of spaces and functions of the building.

To meet the prerequisites for minimum energy performance, MAS needs to demonstrate a reduction in its current energy usage of approximately 19% when compared to its historical energy use baseline. The Team chose a baseline period of July 2011.

As of July 2011, MAS has a EUI of 64.63 kBtu per square foot. The goal for the EUI prerequisite is 52.4 kBtu/sf. Instituting all of the energy conservation recommendations identified by the Team would reduce the EUI to 48.67 kBtu/sf, a 25% reduction.

6.3 Credit Totals

In order to satisfy other prerequisites for LEED® EBOM certification, MAS would need to meet Minimum Energy Performance levels, and verify that the building's ventilation systems meet ASHRAE 62.1-2007 Guidelines. The current credit total, estimated by the Team is 48. (A minimum of 40 credits are required for certification.) There are 31 additional credits identified as 'maybes' and depend on decisions made by the operations staff and management. The credit template prepared by GBS is included in Appendix F. Assuming all prerequisites are met, the Team is confident that with relatively minor adjustments to the operations and maintenance procedures, a rating of *Gold* is achievable for MAS.

APPENDICES

A. Measured Electrical Data

B. ASHRAE Level II Report Guidelines

Source: Procedures for Commercial Building Energy Audits, (2004). American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. www.ashrae.org.

A. General The deliverables from the Level II audit should include a written report detailing the findings from the analysis.

B. Deliverables Consistent with the ASHRAE Procedures for Commercial Building Energy Audits, the Level II – Energy Survey and Engineering Analysis will include but not be limited to the following criteria:

1. Review mechanical and electrical system design, installed condition, maintenance practices, and operating methods.
2. Review existing operating and maintenance problems. Determine planned building changes.
3. Measure key operating parameters and compare to design levels, for example, operating schedules, heating/cooling water temperature, supply air temperature, space temperature and humidity, ventilation quantities, and light level at the task. Such measurements may be taken on a spot basis, or logged, manually or electronically. Determine the sufficiency of ventilation as required by ASHRAE 62.1 and thermal comfort bandwidth based on ASHRAE 55. There should be a survey of tenant comfort.
4. Prepare a breakdown of the total annual energy use into end-use components, including plug loads, as illustrated in the 2007 ASHRAE Handbook—Applications, Chapter 34. Baseline loads should be broken out separately.
5. List all possible modifications to equipment and operations that would save energy and reduce GHG emissions. List preliminary cost and savings estimates.
6. Review the list of practical modifications with the owner/operator and select those that will be analyzed further. Prioritize the modifications in the anticipated order of implementation.
7. For each practical measure, estimate the potential savings in energy cost, GHG offset and its energy index. To account for interaction between modifications, assume that modifications with the highest operational priority and/or best return on investment will be implemented first.
8. Estimate the cost of each practical measure. Identify factors that may significantly affect the cost estimate.
9. Estimate the impact of each practical measure on building operations, maintenance costs, and non-energy operating costs.

10. Following submission of the report of the Level II analysis, meet with the owner to discuss priorities and to help select measures for implementation or further analysis

11. A summary of energy use and cost associated with each end-use. Show calculations performed or quote the name and version of software used and includes both input and output pages. Provide interpretation of differences between actual total energy uses and calculated or simulated end-use totals.

12. A description of the building, including typical floor plans and inventories of major energy-using equipment.

13. A list of measures considered including those with longer paybacks, renewables and those currently impractical with brief reasons for rejecting each.

14. For each practical measure, provide:

    - A discussion of the existing situation and why it is using excess energy.
    - An outline of the measure, including its impact on occupant health, comfort, and safety.
    - A description of repairs which are required for a measure to be effective.
    - The impact on occupant service capabilities, such as ventilation for late occupancy or year-round cooling.
    - An outline of the impact on operating procedures, maintenance procedures, and costs.
    - Expected life of new equipment and the impact on the life of existing equipment.
    - An outline of any new skills required in operating staff and training or hiring recommendations.
    - Calculations performed or provide the name and versions of software used and include both input and output data.

15. A table listing the estimated costs for all practical measures, the savings, the GHG offset and financial performance indicator. For the cost of each measure, show the estimated accuracy of the value quoted.

16. Overall project economic evaluation.

17. Recommended measurement and verification method(s) that will be required to determine the actual effectiveness of the recommended measures.

18. Discussion of feasible capital-intensive measures that may require a Level III analysis.

19. If applicable, electronic files of any energy modeling performed

20. Bid documents and specifications are not required at this level of audit.

C. ECR Assumptions and Calculations

ECR 1 – Replace 75-watt incandescent lamps with LED alternative

Assumptions	
Number of 75w R30 lamps	55
R30 replacement lamp wattage	13
Hours per day (overhead lights)	8
Days per year	250

Equation	
((55*(75-13)*8*250)/1000	Electricity Savings
6,820	kWh

ECR 2 – Replace 32-watt T8 lamps with 25-watt alternative

Assumptions	
Number of T8 lamps	116
Existing lamp wattage	32
Proposed lamp wattage	25
Hours per day (overhead lights)	8
Days per year	250

Equation	
((116*(32-25)*8*250)/1000	Electricity Savings
1,624	kWh

ECR 3 – Replace 17-watt 2' T8 lamps with 15-watt alternative

Assumptions	
Number of T8 lamps	2
Existing lamp wattage	17
Proposed lamp wattage	15
Hours per day (overhead lights)	8
Days per year	250

Equation	
(2*(17-15)*8*250)/1000	Electric Savings
8	kWh

ECR 4 – Replace incandescent task and overhead lamps with CFL alternative

Assumptions	
Number of 75w lamps (task lights)	2
Number of 90w lamps (task lights)	2
Number of 100w lamps (task lights)	1
Number of 75w lamps (overhead lights)	3
Task light replacement wattage	12
Overhead light replacement wattage	23
Hours per day (overhead lights)	8
Hours per day (task lights)	1
Days per year	250

Equation	
(((2*(75-12))+(2*(90-12))+(1*(100-12))*1*250)+(3*(75-23)*8*250))/1000	Electricity Savings
334	kWh

ECR 5 – Install occupancy sensor to operate bathroom exhaust fan and lights

Assumptions	
Four bathrooms need modifications	-
Wattage of lamps in first floor bathroom	66
Wattage of exhaust fan in first floor bathrooms	100
Air volume from first floor exhaust fan (cfm)	100
Wattage of lamps in basement bathrooms	128
Wattage of exhaust fans for basement bathrooms	150
Air volume from basement exhaust fans (cfm)	300
Reduction in lighting and fan operation (hours)	6
Days saved per day	250
Heating degree hours between 9 a.m. and 5 p.m.	19,315

Electric Savings Equation	
((66+50+128+150)*6*250)/1000	Electric Savings
591	kWh

Steam Savings Equation	
((1.08*(100+300)*19315*(6/8))/1000000	Steam savings
6	MMBtu

ECR 6 – Install Ecostrips to shut down peripherals during unoccupied periods

Assumptions	
Number of computers with computer and peripherals that need an Ecostrip left on (assumed)	6
Wattage of speakers in standby	10
Wattage of printer in standby	10
Peripherals are left on 2 nights per week, year-round, for 16 hours per night	-

Equation	
(6*(10+10)*16*2*52)/1000	Electricity Savings
200	kWh

ECR 7 – Replace toilet with low flow alternative

Existing Case Toilet Replacement					
Group	Daily Uses per Employee	Daily Uses per Visitor	Total Daily Uses	Flush Rate (GPF)	Daily Sewage Generation (gal)
All	3	0	36	1.6	58
Total uses by all occupants					**36**
Total Daily Volume (gal)					**58**
Annual Work Days					**250**
Existing - Total Annual Volume (gal)					**14,400**

Design Case Toilet Replacement					
Group	Daily Uses per Employee	Daily Uses per Visitor	Total Daily Uses	Flush Rate (GPF)	Daily Sewage Generation (gal)
All	3	0	36	1.28	**46**
Total uses by all occupants					**36**
Total Daily Volume (gal)					**46**
Annual Work Days					**250**
Design Case - Total Annual Volume (gal)					**11,520**

ECR 8 – Replace urinal flushometer with 0.5 gallon per flush alternative

Existing Urinal					
Group	Daily Uses per Employee	Daily Uses per Visitor**	Total Daily Uses	Flush Rate (GPF)	Sewage Generation (gal)
Males	0	0.33	12	1	12
Annual Usage Days					250
Existing - Total Annual Volume (gal)					2,888

Design Case Urinal Replacement					
Group	Daily Uses per Employee	Daily Uses per Visitor	Total Daily Uses	Flush Rate (GPF)	Sewage Generation (gal)
Males	0	0.33	12	0.5	6
Annual Usage Days					250
Design Case - Total Annual Volume (gal)					1,444

ECR 9 – Replace existing heating hot water pumps with automatic speed controlled alternative

Assumptions	
1. There are currently 2 circulating pumps that are both 1 HP operating in lead lag configuration	-
2. Savings by using Grunfos auto calibrating pumps	55%
3. Approx hrs per year pumps currently operate	4,864

Equation	
(1*.746*4864*.55)	Electricity Savings
1,996	kWh

ECR 10 – Repair economizer function of studio space AHUs

Assumptions	
1. There are two (2) units with compressors rated at 208V, 17.3A, 3 phase	
2. Currently, dance space is being cooled when outside air temperatures range between 45-60 deg F	
3. Enable outside air economizer during these periods	
4. Room is cooled for 10 hours per day	
5. Possible reduction in compressor run-time (5 hrs per day when temps are between 45-60)	473

Equation	
(208*17.3*1.73*473)/1000	Electricity Savings
2,945	kWh

ECR 11 – Install CO2 sensor and occupancy sensor to control operation of basement AHU

Assumptions	
1. OA volume (cfm)	500
2. Unit runs continuously 24/7	-
3. Optimize OA volume based on CO2	-
4. Operate AHU only when room is occupied	-
5. Supply fan motor is 1.5 HP, 5.5A, 208 V	-
6. Occupancy sensor will reduce unit run-time by 14 hours per day	-
7. Heating Degree Hours reduction	40,355
8. AHU SF motor is 70% loaded	-

Electricity Savings Equation	
(1.5*0.746*14*365*0.7)	Electricity Savings
4,003	kWh

Heating Savings Equation	
(1.08*500*40355)/1000000	Steam Savings
22	MMBtu

ECR 12 – Install valve for heating hot water coil in basement AHU to decrease steam consumption in building

Assumptions	
1. HHW system operates when temperatures are below 55 deg F	
2. 2.4 gpm of HHW is directed to AHU coil at all times	
3. In current operation, HHW decrease in temperature by 15 deg F	
4, Current time HHW goes through AHU coil (hours below 55 deg F)	4,864
6. Proposed valve open time:	40 - 55 Deg F operating 10% of time
	20 - 40 Deg F operating 30% of time
	0 - 20 Deg F operating 70% of time
Total Hours	885

Heating Savings Equation	
(2.4*60*15*8.337*885)/1000000	Steam Savings
16	MMBtu

ECR 13 – Install programmable thermostats to control operation of FCUs

Assumptions	
1. Heating only FCUs installed throughout building (10)	
2. Program space temperature setpoints to 60 deg F during unoccupied hours	
3. Thermostats currently set to maintain 75 deg F at all times	
4. FCU fans consume 75 watts each	
5. During nighttime hours, current operation:	40 - 55 Deg F operating 50% of time
	20 - 40 Deg F operating 75% of time
	0 - 20 Deg F operating 100% of time
6. Proposed operation:	40 - 55 Deg F operating 10% of time
	20 - 40 Deg F operating 30% of time
	0 - 20 Deg F operating 70% of time
7. Thermostats only control fan operation	
8. Nighttime Hours (40-55 deg F)	1,350
9. Nighttime Hours (20 - 40 deg F)	751
10. Nighttime Hours (0 - 20 deg F)	87
11. Total run-time reduction	904

Electricity Savings Equation	
(10*75*904)/1000	Electricity Savings
678	kWh

ECR 14 – Install programmable thermostats to control operation of baseboard radiation

Assumptions	
1. Baseboard heat output (Btu/hr/ft)	580
2. In the band room there is 20' of baseboard	
3. During nighttime hours, current operation:	40 - 55 Deg F operating 40% of time
	20 - 40 Deg F operating 60% of time
	0 - 20 Deg F operating 80% of time
4. Proposed operation:	40 - 55 Deg F operating 10% of time
	20 - 40 Deg F operating 30% of time
	0 - 20 Deg F operating 70% of time
5. Baseboard run-time savings (hours)	639
6. Baseboard attempting to heat to 75 deg F at all times	
7. Programmable thermostat will reset temperature set point to 60 deg F during unoccupied periods	

Equation	
(580*20*639)/1000000	Steam Savings
7	MMBtu

ECR 15 – Program outdoor air temperature reset for HHW system

Assumptions
1. HHW delivered to building at 170 deg F regardless of OA temperature
2. Integrate HHW reset so that temperature of water modulates with OA temperature
3. HHW reset typically reduces energy consumption by 3%
4. In FY11, building consumed 314 MMBtu of steam

Equation	
314*0.03	Steam Savings
9	MMBtu

ECR 16 – Insulate domestic hot water piping in basement mechanical room

Assumptions
1. Insulation is 1.0" thick
2. DHW Pipe tube is 40°F difference between pipe and air
3. System is running approximately 1,000 hours per year
4. Boiler is 82% efficient
http://tierling.home.texas.net/PipeHeatLossShell.htm

DHW Pipes				
Pipe Size (in)	Length (ft)	Uninsulated heat loss (BTU/hr.ft)	Insulated heat loss (BTU/hr.ft)	Savings (BTU/hr)
0.5	15	22	4.3	266
0.75	10	29	5.5	235
1	3	36	6.1	90
				591

Equation	
(591*1000)/(100000*.82)	Gas Savings
7	Therms

ECR 17 – Insulate outdoor air intake for open office space AHU

Assumptions	
1. Duct is 10" by 6" in size (sqft)	0.42
2. Damper is closed but heat transfer through conduction of sheet metal	-
3. Insulate with 2" of rigid insulation	-
4. R-value uninsulated	1
5. R-value with 2" of insulation	8
6. Heating Degree Hours	69,180

Equation	
((.42*(1/1)*69180)-(.42*(1/8)*69180))/1000000	Steam Savings
0.03	MMBtu

ECR 18 – Install interior storm windows for studio space

Assumptions	
1. Windows are single pane and do not have storms installed	-
2. Total window area	200
3. U value of windows without storms*	1
4. U value of windows with storms**	0.45
5. HDH	69,180

Area	Total hrs*total delta T	U value	
200	69,180	1	
		Total BTUs (area*total hours*delta T*U valve)	13,836,000

Area	Total hrs*total delta T	U value	
200	69,180	0.45	
		Total BTUs (area*total hours*delta T*U valve)	6,226,200

Saved BTUs	7,609,800

Equation	
7,609,800/1,000,000	Steam Savings
8	MMBtu

D. Building Envelope Thermal Imaging Report (Under Separate Cover)

E. Aerial Thermographic Image

The above aerial thermographic image, taken during the winter months, shows MAS circled in red. White spots on the image are 'hot' areas where heat is being lost through the top of the structures.

The roof appears to be well insulated. A small amount of heat loss can be seen from the abandoned AHU over the open office space on the first floor.

F. LEED for Existing Buildings Scorecard

74 Mount Auburn Street LEED EB v.2009

Y	?+	?-	N		Points
17	2	3	4	**SUSTAINABLE SITES**	**26 Points**
			4	SSc1 LEED Certified Design and Construction	4
1				SSc2 Building Exterior and Hardscape Mgmt Plan*	1
1				SSc3 Integrated Pest Mgmt, Erosion Control, and Landscape	1
3				SSc4.1 Alternative Commuting Transportation 10%	3
4				SSc4.2 Alternative Commuting Transportation 25%	7
4				SSc4.3 Alternative Commuting Transportation 50%	11
4				SSc4.4 Alternative Commuting Transportation 75%	15
		1		SSc5 Reduced Site Disturbance - Protect or Restore Open Space	1
	1			SSc6 Stormwater Quality Control*	1
		1		SSc7.1 Heat Island Reduction: Nonroof	1
		1		SSc7.2 Heat Island Reduction : Roof	1
	1			SSc8 Light Pollution Reduction	1
5	1	1	7	**WATER EFFICIENCY**	**14 Points**
	Y			WEp1 Min Indoor Plumbing Fixture and Fitting Efficiency	Required
1				WEc1.1 Water Performance Measurement: Whole Building Metering	1
		1		WEc1.2 Water Performance Measurement: Submetering	1
1				WEc2 Additional Indoor Plumbing Fixture and Fitting Efficiency 10%	1
1				WEc2 Additional Indoor Plumbing Fixture and Fitting Efficiency 15%	1
1				WEc2 Additional Indoor Plumbing Fixture and Fitting Efficiency 20%	1
1				WEc2 Additional Indoor Plumbing Fixture and Fitting Efficiency 25%	1
	1			WEc2 Additional Indoor Plumbing Fixture and Fitting Efficiency 30%	1
			1	WEc3 Water Efficient Landscaping - Reduce Potable Water Use 50%	1
			1	WEc3 Water Efficient Landscaping - Reduce Potable Water Use 62.5%	1
			1	WEc3 Water Efficient Landscaping - Reduce Potable Water Use 75%	1
			1	WEc3 Water Efficient Landscaping - Reduce Potable Water Use 87.5%	1
			1	WEc3 Water Efficient Landscaping - Reduce Potable Water Use 100%	1
			1	WEc4.1 Cooling Tower Water Management - Chemical Management	1
			1	WEc4.2 Cooling Tower Water Management - Non-potable Water Source Use	1
6	20	1	8	**ENERGY & ATMOSPHERE**	**35 Points**
	Y			EAp1 Energy Efficiency Best Mgmt Practices	Required
	Y			EAp2 Minimum Energy Efficiency Performance - ENERGY STAR Rating of 69	Required
	Y			EAp3 Refrigerant Mgmt - Ozone Protection	Required
1	17			EAc1 Optimize Energy Efficiency Performance	18
2				EAc2.1 Existing Building Commissioning - Investigation and Analysis	2
2				EAc2.2 Existing Building Commissioning - Implementation	2
	2			EAc2.3 Existing Building Commissioning - Ongoing Commissioning	2
			1	EAc3.1 Performance Measurement - Building Automation System	1
		1		EAc3.2 Performance Measurement - System-Level Metering 40%	1
			1	EAc3.3 Performance Measurement - System-Level Metering 80%	1
			1	EAc4 Renewable Energy - On-Site 3% / Off-Site 25%*	1
			1	EAc4 Renewable Energy - On-Site 4.5% / Off-Site 37.5%	1
			1	EAc4 Renewable Energy - On-Site 6% / Off-Site 50%	1
			1	EAc4 Renewable Energy - On-Site 7.5% / Off-Site 62.5%	1
			1	EAc4 Renewable Energy - On-Site 9% / Off-Site 75%	1
			1	EAc4 Renewable Energy - On-Site 12% / Off-Site 100%	1
	1			EAc5 Refrigerant Mgmt	1
1				EAc6 Emissions Reduction Reporting	1

3	6	0	1	**MATERIALS & RESOURCES**	**10 Points**
Y				**MRp1 Sustainable Purchasing Policy**	Required
Y				**MRp2 Solid Waste Mgmt Policy**	Required
1				**MRc1.1 Sustainable Purchasing - Ongoing Consumables 40%**	1
	1			**MRc2.1 Sustainable Purchasing - Durable Goods, electric**	1
	1			**MRc2.2 Sustainable Purchasing - Durable Goods, furniture**	1
	1			**MRc3 Sustainable Purchasing - Facility Alterations and Additions**	1
1				**MRc4.1 Sustainable Purchasing - Reduced Mercury in Lamps, 90 pg/lumen-hour**	1
			1	**MRc5 Sustainable Purchasing - Food***	1
1				**MRc6 Solid Waste Mgmt - Waste Stream Audit**	1
	1			**MRc7.1 Solid Waste Mgmt - Ongoing Consumables, 50%***	1
	1			**MRc8 Solid Waste Mgmt - Durable Goods**	1
	1			**MRc9 Solid Waste Mgmt - Facility Alterations and Additions**	1
10	2	3	0	**INDOOR ENVIRONMENTAL QUALITY**	**15 Points**
Y				**EQp1 Outdoor Air Introduction and Exhaust Systems**	Required
Y				**EQp2 ETS Control**	Required
Y				**EQp3 Green Cleaning Policy**	Required
1				**EQc1.1 IAQ Best Mgmt Practices - IAQ Mgmt Program**	1
		1		**EQc1.2 IAQ Best Mgmt Practices - Outdoor Air Delivery Monitoring**	1
		1		**EQc1.3 IAQ Best Mgmt Practices - Increased Ventilation**	1
		1		**EQc1.4 IAQ Best Mgmt Practices - Reduce Particulates in Air Distribution***	1
1				**EQc1.5 IAQ Best Mgmt Practices - IAQ Mgmt During Construction**	1
1				**EQc2.1 Occupant Comfort - Occupant Survey**	1
1				**EQc2.2 Controllability of Systems: Lighting**	1
	1			**EQc2.3 Occupant Comfort - Thermal Comfort Monitoring**	1
1				**EQc2.4 Occupant Comfort - Daylight and Views, 50% Daylight / 45% Views**	1
1				**EQc3.1 Green Cleaning - High Performance Cleaning Program**	1
1				**EQc3.2 Custodial Effectiveness Assessment, <3**	1
1				**EQc3.3 Green Cleaning - Sustainable Cleaning Products, 30%**	1
1				**EQc3.4 Green Cleaning - Sustainable Cleaning Equipment**	1
	1			**EQc3.5 Green Cleaning - Indoor Chemical and Pollutant Source Control**	1
1				**EQc3.6 Green Cleaning - Indoor Integrated Pest Management**	1
6	0	0	0	**INNOVATION AND DESIGN PROCESS**	**6 Points**
1				**IDc1.1: Innovation in Operations**	1
1				**IDc1.2: Innovation in Operations**	1
1				**IDc1.3: Innovation in Operations**	1
1				**IDc1.4: Innovation in Operations**	1
1				**IDc2 LEED AP**	1
1				**IDc3 Documenting Sustainable Building Cost Impacts**	1
1	1	2	0	**Regional Priority Credits**	**4 Points**
1				**RPc1.1: Regional Priority Credit**	1
	1			**RPc1.2: Regional Priority Credit**	1
		1		**RPc1.3: Regional Priority Credit**	1
		1		**RPc1.4: Regional Priority Credit**	1
48	32	10	20	**TOTAL (pre-certification estimates)**	

Certified 40-49 points **Silver** 50-59 points **Gold** 60-79 points **Platinum** 80+ points

G. Life Cycle Cost Calculations for ECRs

74 Mount Auburn Street LCC Summary

School	Building Name	Building Type	Energy Conservation Measure	ECM Category	Total Cost ($)	Rebate ($)	Net Cost ($)	Cambridge Electricity (kWh)	Cambridge Steam (MMBtu)	Cambridge Water (Ccf)	Cambridge Gas (Therms)	20 Yr NPV	20 Yr Cost / 20 Yr MTCDE	NPV / Total GHG Red.	SIR	Simple Payback (years)	IRR
FAS	74 Mount Auburn Street	Office	Replace 75-w att incandescent lamps w ith LED alternative	Lighting	$2,750	1925.00	$825	6,820	0	0	0	$13,791.11	$12.09	$259.35	22.46	0.73	145.32%
FAS	74 Mount Auburn Street	Office	Replace 32-w att T8 lamps w ith 25-w att alternative	Lighting	$180	0.00	$180	1,624	0	0	0	$3,153.68	$22.38	$249.06	12.13	0.67	158.48%
FAS	74 Mount Auburn Street	Office	Replace 17-w att 2' T8 lamps w ith 15-w att alternative	Lighting	$3	0.00	$3	8	0	0	0	$13.93	$48.10	$223.34	5.64	2.27	48.91%
FAS	74 Mount Auburn Street	Office	Replace incandescent task and overhead lamps w ith CFL alternative	Lighting	$175	0.00	$175	334	0	0	0	$532.47	$67.14	$204.29	4.04	3.17	35.79%
FAS	74 Mount Auburn Street	Office	Install occupancy sensor to operate bathroom exhaust fan and lights	Lighting Control	$450	0.00	$450	591	6	0	0	$3,200.34	$34.08	$242.37	8.11	1.58	69.01%
FAS	74 Mount Auburn Street	Office	Install Ecostrips to shut dow n peripherals during unoccupied periods	Receptacles	$180	0.00	$180	200	0	0	0	$242.60	$115.61	$155.82	2.35	5.45	21.42%
FAS	74 Mount Auburn Street	Office	Replace toilet w ith low flow alternative	Water Conservation	$400	0.00	$400	0	0	4	0	$270.93	#DIV/0!	#DIV/0!	1.68	7.60	15.23%
FAS	74 Mount Auburn Street	Office	Replace urinal flushometer w ith 0.5 gallon per flush alternative	Water Conservation	$170	0.00	$170	0	0	2	0	$166.34	#DIV/0!	#DIV/0!	1.98	6.44	18.08%
FAS	74 Mount Auburn Street	Office	Replace existing heating hot w ater pumps w ith automatic speed	HVAC Control	$2,200	0.00	$2,200	1,996	0	0	0	$2,023.67	$141.38	$130.05	1.92	6.66	17.54%
FAS	74 Mount Auburn Street	Office	Repair economizer function of studio space AHUs	HVAC Control	$2,000	0.00	$2,000	2,945	0	0	0	$4,231.77	$87.11	$184.32	3.12	4.11	28.06%
FAS	74 Mount Auburn Street	Office	Install CO2 sensor and occupancy sensor to control operation of	HVAC Control	$3,000	0.00	$3,000	4,003	22	0	0	$13,826.86	$49.07	$226.14	5.61	2.28	48.63%
FAS	74 Mount Auburn Street	Office	Install valve for heating hot w ater coil in basement AHU to decrease steam consumption in building	HVAC Control	$2,000	0.00	$2,000	0	16	0	0	$4,110.79	$91.36	$187.78	3.06	4.20	27.55%
FAS	74 Mount Auburn Street	Office	Install programmable thermostats to control operation of FCUs	HVAC Control	$800	0.00	$800	678	0	0	0	$634.91	$151.33	$120.10	1.79	7.13	16.35%
FAS	74 Mount Auburn Street	Office	Install programmable thermostats to control operation of baseboard radiation	HVAC Control	$200	0.00	$200	0	7	0	0	$2,642.16	$19.64	$259.50	14.21	0.90	118.61%
FAS	74 Mount Auburn Street	Office	Program outdoor air temperature reset for HHW system	HVAC Control	$1,200	0.00	$1,200	0	9	0	0	$2,411.95	$92.74	$186.40	3.01	4.26	27.16%
FAS	74 Mount Auburn Street	Office	Insulate domestic hot w ater piping in basement mechanical room	Insulation	$250	0.00	$250	0	0	0	7	-$83.37	$326.10	-$108.75	0.67	19.38	3.55%
FAS	74 Mount Auburn Street	Office	Insulate outdoor air intake for open office space AHU	Insulation	$10	0.00	$10	0	0	0	0	-$0.25	$286.35	-$7.21	0.97	13.16	7.69%
FAS	74 Mount Auburn Street	Office	Install interior storm w indow s for studio space	Envelope	$1,600	0.00	$1,600	0	8	0	0	$1,317.85	$153.07	$126.08	1.82	7.03	16.63%