NYSERDA Benchmarking Pilot Operational Assessment

Month - Year

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1.0 Executive Summary *1.1.*

Introduction

As part of a NYSERDA funded effort to identify opportunities for energy conservation, X Solutions was contracted to perform an operational assessment on select facilities at the [redacted]. The buildings assessed are the following and include major research, administrative and residential facilities:

- Research Building 1
- [redacted] Educational Center [redacted]
- Office Building
- Conjoined Research Buildings
- Medical Research Building
- [redacted] Residential Complex (3 Buildings)
- Advanced Research/Office Building
- Educational Building

Additionally, this FlexTech initiative allowed our team to provide benchmarking services through the U.S. Environmental Protection Agency's (EPA) Portfolio Manager.

1.2. Project Background

The purpose of this work was to study how the existing building systems work together and to identify no-cost or low-cost operational and maintenance improvements. Energy Conservation Measure (ECM) recommendations are centered on building system adjustments to achieve performance as intended in the original design, as well as to optimize or improve upon daily & seasonal operations. The primary objective is to identify measures that reduce energy consumption without significant capital investment. Any energy efficient capital improvements that may be effective are also discussed.

In order to achieve the goals of this project, our team conducted the following tasks:

(Task 1: Pre-Site Documentation Review – As the goal of this program is to identify operational improvements that will yield energy savings in a cost-effective manner, review of customer-provided facility system documentation and utility data prior to the onsite assessment was an essential activity that occurred.

(Task 2: Site Visit – Site visits were conducted on several occasions during September - November 2012. During the site visits, our team conducted kickoff meetings with each of the building managers, interviewed the facility staff, conducted a detailed facility walkthrough and reviewed all systems & data points visible on the Building Management System (BMS) with a focus on operational improvements and optimization of existing systems. Through this data collection process, a Current Facility Requirement (CFR) was generated to capture all major equipment, and an Issues Database was developed to capture all energy, indoor air quality and O&M measures identified during the site visit.

(Task 3: Post - Site Visit Analysis – Upon completion of the site visit, the initial evaluation of facility's EUI was refined/completed and all utility information and necessary space use attributes were entered into EPA's ENERGY STAR® Portfolio Manager. The issues identified with energy efficiency impacts were further analyzed as ECM recommendations to provide energy savings, estimated implementation costs and simple payback period. This draft report presents X's developed documentation and findings.

- Task 4: Project Close Out – This report was revised and reissued once facility staff provided comments. The X team and operations staff collaborated to develop an Action Plan out of the measures detailed in the Issues Database and Master List of ECMs that have been selected by the team.

1.3. Summary of Findings

After a brief review of the air handling units, air distribution, heating and cooling systems, our findings indicate the systems were properly installed and are functioning adequately considering the age of the units. The facility staff has already made significant operational improvements designed to conserve energy. As such, the recommendations identified during this assessment are intended to further improve and enhance the current energy strategies already in place.

This project uncovered a total of 210 operational issues and 34 energy conservation measures (ECMs) recommended for further study or implementation. There were also 5 potential capital projects uncovered that were beyond the scope of the current assessment. At this time, X estimates approximately $621,023 in annual cost savings can be realized as a result of implementing the measures explained in this report. The estimated payback for implementing these improvements is 1 year.

While the majority of strategies presented are relatively easy to implement and can most likely be completed through the expertise of in-house operations staff and qualified contractors, there are some ECMs that require further study to fully determine the economic benefits and feasibility of ECM implementation. Furthermore, based on observed operating and system conditions, we highly recommended three future initiatives:

- Control System Master Plan
- Pneumatic to DDC Control Upgrade for Research Building 1, Science Building, and Education Building
- Campus-wide Laboratory Air Optimization

The remainder of this report will support the summary below with details on the conducted survey & quantitative analysis to further substantiate the itemized recommendations.

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Research Building 1	AC-9, 8th floor night setback.	O&M	$ 29,244	$ 45,000	1.5	77,984	1,755
	Raise Precool temp set points to 60F	O&M	$ 80,505	$ 1,000	0.0	214,679	4,830
	Change economizer lockouts from 55F-60F to 45F to 65F	O&M	$ 1,632	$ 200	0.1	4,352	98
	Repair Leaking Control Valves	O&M	$ 4,967	$ 4,500	0.9	13,244	298
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 9,398	$ 2,500	0.3	25,061	564
	Repair / Install Missing Pipe Insulation	O&M	$ 7,962	$ 20,706	2.6	21,233	478
	Cage Wash AHU ToD Scheduling	O&M	$ 9,885	$ 200	0.0	26,359	593
	Night Setback for new AHU's 2, 5, 6, 8, and 10) Need	Capital	$ 140,957	$ 243,400	1.7	375,886	8,457
	Stairwell Lighting Retro-fit	Capital	$ 3,188	$ 13,376	4.2	8,501	191
	VFDs on Glycol Pumps (2)	Capital	$ 9,032	$ 20,600	2.3	24,085	542
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this				-	-
	Damper controls to allow better economizer	Capital -Beyond scope of this				-	-
	Cage wash chiller -> House Chilled water	Capital - Screened Out	$ 1,203	$ 10,000	8.3	-	-

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Research Building 2	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 967	$ 500	0.5	2,579	58
	Implement existing night setback feature	O&M, no equipment needed. Engineering and TAB	$ 65,574	$ 40,000	0.6	174,865	3,934
	Chiller plant variable volume scheme does not work. Recommend abandoning it. Upsize system bypass or replace 2-	O&M / Capital	$ 20,373	$ 15,000	0.7	54,329	1,222

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Science Building	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 3,156	$ 1,750	0.6	8,416	189
	Repair Leaking Control Valves	O&M	$ 10,615	$ 15,000	1.4	28,307	637
	Repair / Install Missing Pipe Insulation	O&M	$ 902	$ 2,119	2.3	2,406	54
	Install VFDs on glycol pumps (2)	Capital	$ 13,548	$ 23,600	1.7	36,128	813
	Possible Night Setback	O&M - Beyond the scope of				-	-
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this				-	-
	Improve Economizer Operation - Switch From Fixed to Active Damper Control	Future Capital Improvement - Not recommended as a	$ 8,043			-	-

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Medical Research Building	Repair / Install Missing Pipe Insulation	O&M	$ 1,117	$ 4,429	4.0	2,978	67
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 967	$ 250	0.3	2,579	58
	Install Static Pressure Sensor, put AC-1 into Active SP	O&M - Put AC-1 SAF on active static pressure	$ 24,083	$ 10,000	0.4	64,223	1,445
	Nighttime ToD Setback for Renovated Spaces / Boxes	Capital - Part of Long Term Planning and Renovations. Savings based on 2004 analysis	$ 72,638	$ -		-	-

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Educational Center	Repair / Install Missing Pipe Insulation	O&M	$ 1,194	$ 5,186	4.3	3,183	72
	Implement Night Setback on AHU-1, AHU-2 and AHU-3	O&M	$ 64,151	$ 9,000	0.1	171,070	3,849
	Night Setback For Fan Coil Units	O&M	$ 10,242	$ 1,000	0.1	27,313	615
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 583	$ 750	1.3	1,555	35
	Repair Leaking Control Valves	O&M	$ 899	$ 1,500	1.7	2,398	54
	1st Floor Lighting Retro-fit	Capital	$ 2,028	$ 10,967	5.4	5,407	122
	Install VFD on Penthouse HW Pump - Convert 3-way	Capital	$ 6,774	$ 16,300	2.4	18,064	406
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this				-	-
	Lighting Occupancy Sensors	Capital - Screened out	$ 2,416	$ 16,730	6.9		

	ECM	Note	Savings	Cost	Payback	Annual kwh Savings	Annual klbs Saved
Office Building	Space Sensor Calibration Issues	O&M	$ 12,654	$ 1,250	0.1	33,744	759
	Stairwell Lighting Retro-fit	Capital	$ 669	$ 3,145.80	4.7	1,784	40

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Educational Building	Repair / Install Missing Pipe Insulation	O&M	$ 661	$ 691	1.0	1,762	40
	Repair Leaking Control Valves	O&M	$ 1,581	$ 3,000	1.9	4,216	95

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Staff Housing	None	None	None	None	-	0	0

	ECM	Note	Savings	Cost	Payback	Annual kwh Savings	Annual klbs Saved
Adv. Research/ Office Building	Repair Heat Wheels	O&M	$ 72,466	$ 24,000	0.3	193,242	4,348
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 9,318	$ 3,750	0.4	24,847	559
	Repair Leaking Control Valves	O&M	$ 699	$ 1,500	2.1	1,865	42

Total Savings	**Implementation Costs**	**Payback**	**Annual kwh Savings**	**Annual klbs Saved**
$ **621,023**	$ **617,027**	**1.0**	**1,432,709**	**32,236**

**Savings that are highlighted in orange are not included in recommended summary total as estimating capital costs exceed current scope or project payback appears excessive.*

2.0 Building Information

[redacted]

[redacted]

[redacted]

[redacted]

The square footage breakdown per building is as follows:

	Total
Research Building 1	198,150 ft²
Educational Center	148,170ft²
Office Building	73,000 ft²
Medical Science/Research Building 2	290,338 ft²
Staff Housing	630,000 ft²
Adv. Research/ Office Building	223,000 ft²
Educational Building	350,000 ft²

2.1. System Narrative

Utilities & Central Building Management System Overview

[redacted] **Steam Plant**
[redacted] main steam plant serves the most of the [redacted] campus. The buildings supplied include Medical Science, Medical Research, Research Building 1, Educational Center, Research Building 2, Library, Office Building, [redacted], Advanced Research/Office Building, Educational Building, [redacted] Staff Housing, [redacted] Athletic Center, [redacted]. Four (4) boilers, two (2) 90,000 pounds and two (2) 70,000 pounds, generate roughly 50 million pounds of steam per month. The boilers take Con Edison natural gas and in turn supply steam to the buildings throughout the campus.

[redacted] **Building Management System (BMS)**
Typical of an older campus which has expanded over time, the HVAC and utility systems are served by several control systems varying in age and sophistication. The control systems range from original, antiquated, stand-alone pneumatic controls to DDC systems of varying vintage. The DDC systems include Honeywell Excel 5000, Excel Supervisor, Environet, Siebe and Siemens.

This complexity is further compounded in that some buildings have different systems served by different control systems. For example, the Research Building 1 has air handlers controlled by the Excel Building Supervisor system, Excel 5000, Siemens, as well as standalone pneumatic systems. The Current Facilities Requirement (CFR) in the appendix lists which systems control each piece of equipment.

The multiple systems and varying user interfaces make the control system complicated and not very user friendly. There is no uniform method of presenting data, as all of the systems are slightly different. Despite this complexity, the condition and operation of the DDC systems appear satisfactory. Deficiencies were identified, but in no greater frequency than is to be expected in a campus of this size.

2.1.1. Research Building 1

[redacted] approximately 198,150 sq ft and is primarily used for research. It contains a mix of students and researchers that occupy the building on a 24/7 basis.

Building Management System

The majority of the HVAC components are controlled by local pneumatic control systems with a few systems tied into the Honeywell BMS system for alarm purposes. The newest pieces of equipment, air handler nine (9) and the two new chillers are on the Seimens BMS and Enviornet, respectively.

Air Distribution Systems

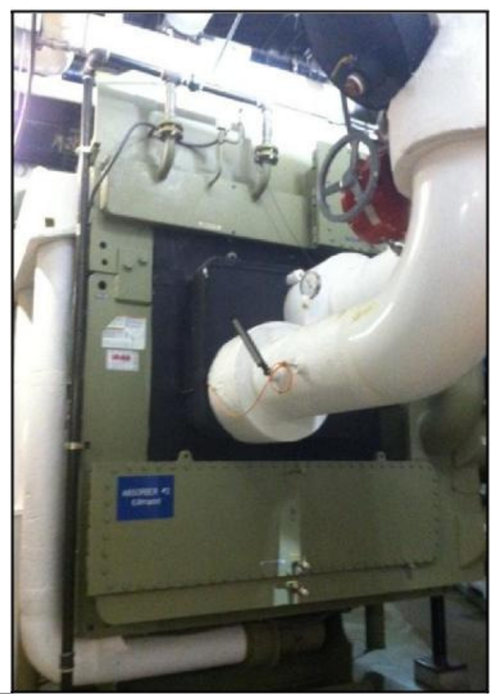
There are fourteen (14) air handling units located throughout the building; eleven (11) units use mixed air and the remaining three (3) utilize 100% outside air. All of the units have hot deck and cold deck air distribution systems. All of the units utilize chilled water and steam. Supply fans are constant volume with the exception of AC-9, which is fitted with a variable frequency drive and controlled by static pressure set points. There are multiple exhaust fan systems for toilets and general exhaust, as well as fume hoods serving research labs. All exhausts are constant volume with the exception of the ^{8th} floor return.

Chilled/Condenser Water System

[redacted] chilled water needs are supplied through two (2) 1650 ton high pressure steam absorption chillers. A three (3) cell cooling tower and associated chilled water and condenser water pumps serve the chillers. The system is arranged in a primary / secondary chilled water system. The secondary pumps are fitted with VFDs. There are also three (3) smaller 60 ton TRANE chillers in the penthouse that serve the AHU-01 cage wash and the Laser Lab.

Heating System

Steam is provided by the campus' central steam plant. Steam is utilized at the air handlers for preheat and hot deck coils. There are no perimeter units or reheats in the building.



Pumps

There are several pumps used to distribute chilled, hot and domestic water. With the exception of the secondary chilled water system, pumps are constant volume.

Auxiliary Systems

A glycol system is also in place to supply cold rooms used for storing experiments. This closed loop system consists of two (2) glycol towers with two (2) cells in each. All four (4) fans are on variable speed drives.

Lighting

The building is currently utilizing T8 lighting and does not have a lighting control system.

1650 ton High Pressure Absorption

2.1.2. [redacted] Educational Center [redacted]

[redacted]. *Approximately 120,000 sq. ft., with 1500 students and faculty occupying this building on an 8 am to 10 pm schedule. The building is closed on weekends.*

Building Management System

The major HVAC components are controlled by local pneumatic control systems. There is no building automation system to control the equipment with the exception of the chiller and cooling tower. The fan coil units throughout the building can be de-energized via the Honeywell system.

Air Distribution Systems

There are four (4) air handling units, two (2) of which are 100% outside air and two (which are recirculation. The building has a perimeter fan coil unit system in place as well. There are multiple exhaust fans serving individual spaces as well as general exhaust. There are approximately six (6) small packaged DX units dedicated to specific areas.

Chilled/Condenser Water System

The building is fitted with one (1) 680 ton LP steam absorption chiller and associated pumps and cooling tower. The primary pumps circulate chilled water between the chillers and air handlers. Secondary pumps serve to supply chilled and hot water to the building's fan coil units.

Heating System

Steam is provided by the campus' central steam plant. Steam is utilized at the air handlers. Perimeter heating is provided via hot water fan coil units.

Pumps

There are several pumps used to distribute chilled water, condenser water and hot water for heating coils. All pumps are fixed speed.

Lighting

The building utilizes T8 fluorescent type fixtures in the office spaces and LED lighting in the corridors. The first floor is fitted with T-12 lighting fixtures. There is no lighting controls system.

Full details for all [redacted] Building equipment can be found in the CFR located in Appendix C.

2.1.3. Office Building

[redacted]
approximately 60,000 square feet. With about 100 employees, the facility is utilized for office space. Peak building occupancy is from 7am to 10pm, five days a week, and most building systems run 24 hours a day.

Building Management System
The major HVAC components are controlled by Environet control systems and the building heat exchangers are tied into the Honeywell BMS system.

Air Distribution Systems
There are no air handler units in this building. Floors 4-7 HVAC needs are met by recently renovated 2-pipe fan coil units. Floors 1-3 are served by older heating only fan coils and window AC units. Floors 1-3 will be renovated in the near future.

Chilled/Condenser Water System
The building receives chilled water from the Research Building 1chiller plant.

Heating System
Steam is provided by the campus's central steam plant. There are two heat exchangers used for house hot water. Perimeter heating is provided via hot water fan coil units.

Pumps
There are dual temperature pumps used to distribute chilled water and hot water to the fan coil units as well as pumps for domestic and hot water. These pumps have been fitted with VFDs.

Lighting
The majority of the building utilizes T8 fluorescent lighting. Stairwell lighting is currently T-12. There is no lighting controls system.

Full details for all Office Building equipment can be found in the CFR located in Appendix C.

2.1.4. [redacted] Science Building / Research Building 2

[redacted] are 2 conjoined buildings built in [redacted]. Adv. Research is over 240, 000 sq. ft., while Research Building 2 is 50,000 sq. ft. The primary use of the buildings is for research. Peak building occupancy is from 8am to 10pm, seven days a week, and building systems run 24 hours a day.

Building Management System

The major HVAC components in Science Building are controlled by local pneumatic control systems. There is limited interconnected control to the Honeywell BMS System. Research Building 2's major HVAC components (AHUs and VAV Boxes) are controlled by DDC control systems via the Honeywell BMS.

Air Distribution Systems

In Science Building, there are twenty nine (29) air handling units, four (4) 100% outside air, fourteen (14) recirculation, and seven (7) heating ventilation units. There are approximately six (6) water cooled DX systems serving specific critical loads. In this facility, there are numerous fume hoods serviced by twelve (12) exhaust fans and eighteen (18) general and toilet exhaust fans. In Research Building 2, there are three (3) 100 % outside air handling units with VAV air distribution systems. There are four (4) fume hood exhaust fans. A majority of the labs in Advanced Research Building have window AC units to provide additional cooling.

Chilled/Condenser Water System

The Science Building is fitted with one (1) 1150 ton HP steam absorption chiller and its associated pumps and cooling tower. It is arranged as a primary/secondary chilled water system and utilizes VFDs on the secondary pumps. The Research Building 2 is fitted with two (2) 600 ton HP Steam absorption chillers and associated pumps and cooling towers. These chillers are arranged as a primary only system.

Heating System

Steam is provided by the campus' central steam plant and is used by perimeter stream radiators.

Pumps

There are pumps on site for chilled water, condenser water, and domestic hot water. Science Building secondary and Research Building 2 primary chilled water pumps are fitted with VFDs.

Lighting

The building uses T8 type lighting. There is no controls system for lighting.

Full details for all Science Building / Research Building 2 equipment can be found in the CFR located in Appendix C.

2.1.5. Medical Research Building

[redacted] approximately 156,000 sq. ft. The primary use of this building is for research. The building operates on a 24/7 schedule due to the sporadic working hours of the researchers.

Building Management System

The major HVAC components are controlled by DDC control systems. There is a combination of Honeywell, Environet and LCS DDC controls used in this building.

Air Distribution Systems

There are two (2) 100% outside air AHUs serving the building. AC-1, which serves the entire building with the exception of the 6th floor vivarium, is fitted with heat recovery heat wheels, heating and cooling coils. AC-2, which serve the vivarium, is fitted with run-around heat recovery coils, heating and cooling coils. The air distribution systems are dual duct, fitted with a combination of VAV and constant volume terminal units. There are six (6) water cooled packaged DX units serving dedicated areas. There are numerous fume hoods in the building – approximately sixty (60) fume hood exhaust fans and two (2) toilet exhaust fans.

Chilled/Condenser Water System

The building is fitted with two (2) 550 ton LP steam absorption chillers and associated pumps and cooling towers. The chilled water system is a primary only system.

Heating System

Steam is provided by the campus' central steam plant and utilized at the AHUs. There is no perimeter heating in the building.

Pumps

There are several constant volume pumps used to distribute chilled water, house hot water and domestic hot water. All pumping systems utilize constant speed pumps and constant volume distribution systems.

Lighting

The building uses T8 lighting. There is no lighting control system.

Full details for all Medical Research Building equipment can be found in the CFR located in Appendix C.

2.1.6. Advanced Research/Office Building

This state-of-the-art laboratory building is one of the newest campus additions; opening its doors in 2008. This 223,000 sq ft facility contains a mixture of advanced research facilities, office space and a vivarium. It is occupied by over 200 researchers and administrative staff.

Building Management System

Air Distribution Systems
The building has major mechanical rooms in the penthouse and basement. The penthouse houses eleven (11) 100% OA air handling units, eight of which are fitted with heat recovery wheels. The basement MER houses seven 100% OA units, and four recirculating air units. There are numerous fume hoods in the facility. Fume hoods and general exhaust are serviced by 33 general and dedicated exhaust fans. The air distribution systems are all variable air volume systems.

Chilled/Condenser Water System
The building is fitted with three (3) 850 ton HP steam absorption chillers and associated pumps and cooling towers. The chilled water system is a constant volume primary only system utilizing a system bypass. There are six (6) CRAC units serving the buildings data canter.

Heating System
Steam is provided by the campus's central steam plant. Steam is utilized at the air handlers for preheats and at house hot water heat exchangers for use in reheat coils and the perimeter radiation heating systems. The reheat system is variable volume and the pumps are fitted with VFDs. The perimeter system is a constant volume system utilizing a temperature reset strategy.

Pumps
There are several pumps used to distribute chilled water, condenser water, hot water and domestic water. With the exception of the reheat system, the pumps are constant speed.

Lighting
The building uses T8 lighting fixtures. The exterior lighting is operated via a lighting control system. Interior lighting utilizes manual light switches.

Full details for all Advanced Research/Office Building equipment can be found in the CFR located in Appendix C.

2.1.7. Educational Building

[redacted] approximately 350,000 sq. ft. The primary use of this building is for educative purposes. The building operates on a time of day schedule. The building was recently purchased by [redacted] and is under a phased renovation.

The HVAC components are controlled via local pneumatic controls.

Air Distribution Systems
There are twelve (12) 100% OA air handler units which are fitted with heating coils only. There are twelve (12) general exhaust fans. The building and equipment are old and are being systematically renovated and upgraded. Space in original condition utilizes perimeter heating and window air conditioning units, most of these are currently unoccupied. Renovated spaces are utilizing perimeter heating and ceiling mounted chilled water cassettes for air conditioning.

Chilled/Condenser Water System
There are three (3) water cooled CRAC units and an associated cooling tower serving a data center. The building is not yet fitted with a central cooling system. A temporary rental chiller is being utilized during the cooling season until a permanent chiller plant can be installed.

Heating System
Steam is provided by the campus's central seam plant. Steam is utilized at the AHUs and to house hot water heat exchangers for perimeter heating. There are two steam boilers located in the penthouse mechanical room but are not in use.

Pumps
There are several pumps to distribute domestic water and house hot water. All pumps are currently constant speed.

Lighting
The building uses T8 lighting fixtures in the renovated areas. There is no lighting controls system.

Full details for all Educational Building equipment can be found in the CFR located in Appendix C.]

2.1.8. [redacted] Residential Complex

The series of residential buildings were built in 1973. Together, they are a combined 630,000 square foot complex. Each individual building is 210,000 sq ft. The buildings are home to staff researchers and faculty. The complex is operational 24/7.

Building Management System
The major HVAC components are controlled by a mixture of local pneumatic controls and the Honeywell BMS system.

Air Distribution Systems
There are three (3) general exhaust fans and three (3) toilet exhaust fans per building. Heating and cooling are supplied via 2-pipe fan coil units in each room.

Chilled/Condenser Water System
The building complex is fitted with one (1) 1150 ton LP steam absorption chillers and associated
pumps and cooling towers. The pumping systems are all fixed speed primary only systems.

Heating System
Steam is provided by the campus's central steam plant. Steam is converted into domestic and house hot water. House hot water is used for heating purposes at local fan coil units.

Pumps
There are several pumps used to distribute chilled water, condenser water, hot water and domestic water. All are fixed speed.

Lighting
The building uses T8 lighting and does not have a control system. Resident spaces use compact fluorescent technology.

Full details for all [redacted] Housing equipment can be found in the CFR located in Appendix C.

3.0 Operating Parameters

Due to the nature of the research activities and clinical services provided, nearly all of the facilities are made available to the employees, staff and researchers at all times. While peak facility occupancy occurs during typical working hours (7 am – 10 pm Monday through Friday), the HVAC systems run continuously 24 hours a day, 7 days a week.

3.1. Current Facility Requirement (CFR)

As part of this project a Current Facility Requirement (CFR) was generated. The CFR describes each major HVAC component's operational requirements in as much detail as available through data gathered during the BMS reviews and site assessments. Information included in the CFR includes details such as areas served by each AHU, CFM, operating schedules, unit type, location, fan HP, and VFD set points. A copy of the CFR has been included in Appendix C and has been provided digitally to the facility for their use.

** Please note, not all of the AHU data was available; as such, assumptions were made when necessary.*

3.2. Documentation

Overall, the completeness of a building's documentation is important for any successful energy conservation project. Good documentation control can increase the cost effectiveness of any future energy conservation projects by limiting the amount of hours spent gathering required information. [redacted] has historical utility data available, as well as building drawings.

The primary documentation deficiency is the lack of up-to-date equipment schedules; the CFR for this report was generated from BMS reviews, nameplate data and original drawings gathered during the site walkthroughs. It is recommended that a collective effort be taken to create a universal electronic file that has all data readily available for use by building operators, energy managers and any consulting engineers delivering mechanical/energy services onsite.

3.3. Operations & Maintenance

The operating staffs' responsibilities cover the entire HVAC systems operation as well as basic maintenance. The staff maintains extended coverage through the day and evening and personnel have the ability to adjust control schedules and temperature set points. [redacted] found the operations staff to be well versed in the operation of their HVAC systems.

4.0 Energy Accounting

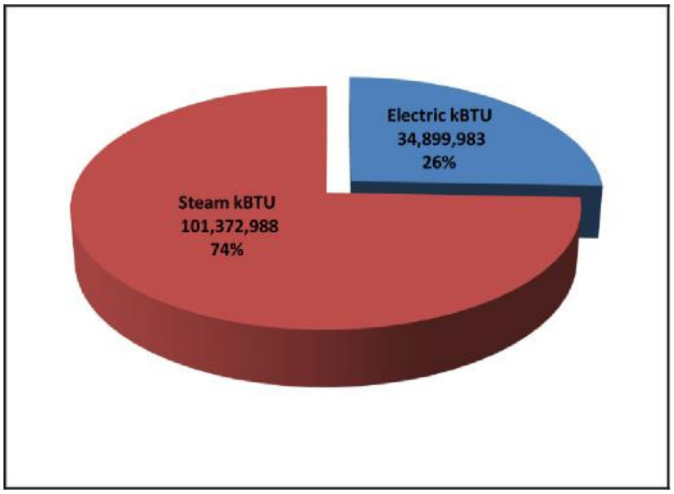
4.1. Overall Energy Performance

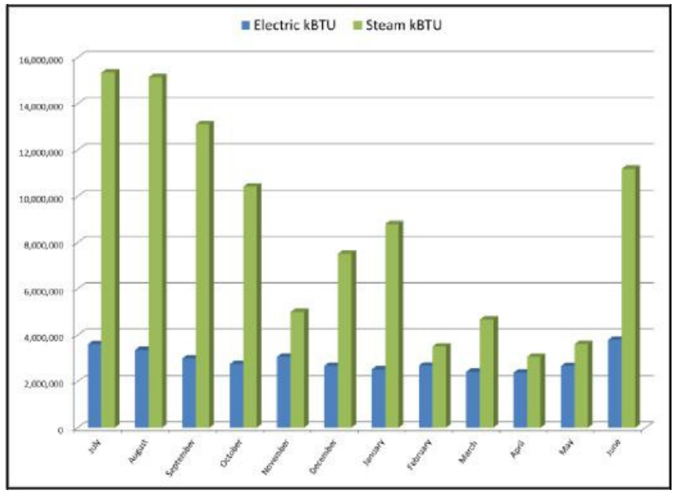
4.1.1. All Buildings

2011 – 2012 energy consumption (kBTU) data was tabulated and charted for the facilities included in the scope of work (July 2011 – June 2012). [redacted]. Out of this building set, the largest energy consumer is Science Building/Research Building 2, accounting for 25% of the total energy used. The next largest consumers are Medical Research Building at 22% and Research Building 1 at 19%.

4.1.2. Research Building 1

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.





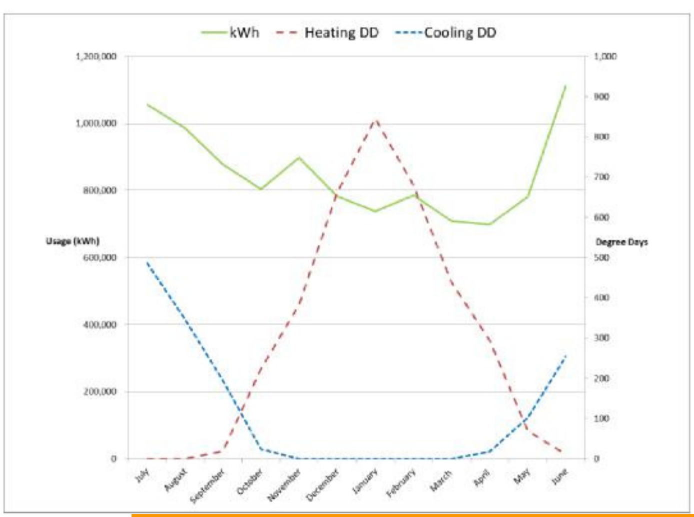
Utility Breakdown **12 Month Profile**

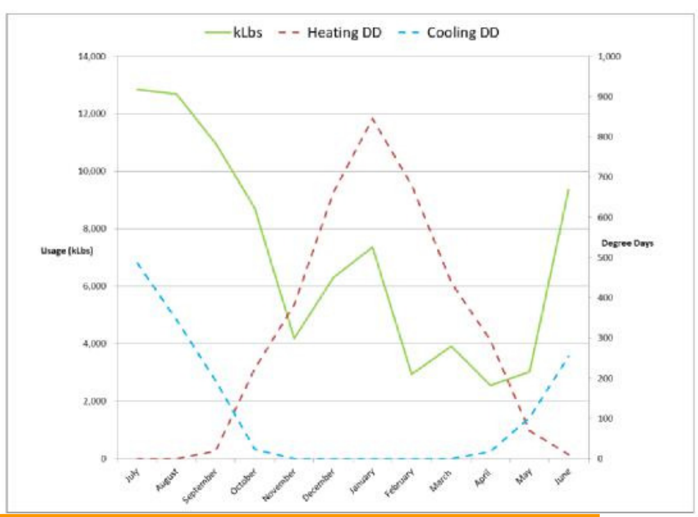
Steam is the major consumer in Research Building 1 at 74% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers.

Additionally, the two main energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Overall, electric usage remains fairly constant throughout the year while steam consumption fluctuates with seasonal loading patterns.

Degree Day Comparison

Each main utility was also plotted versus degree days to illustrate usage as a function of seasonal temperature fluctuations.





Steam consumption generally follows degree day trends as steam is used for both heating and cooling. Electric consumption peaks slightly in the summer (20%) but is fairly consistent throughout the year.

Historical Energy Performance

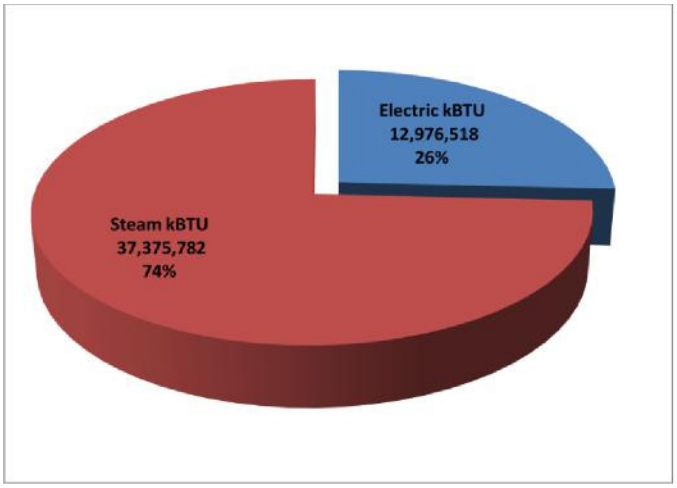
Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2011 and 2012 can point to changes in building space use, operational issues or equipment malfunction/replacement.

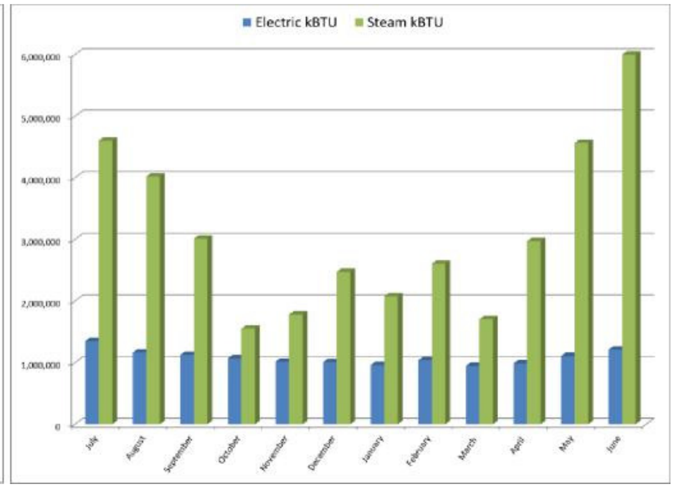
FY10/11	6098 DD	**FY11/12**	5050 DD	**Performance Comparison**	
Steam		**Steam**			
101,232,000	Lbs	84,902,000	Lbs		
16,601	Lbs/DD	16,800	Lbs/DD	199 Lbs/DD	1% increase
Electric		**Electric**			
10,238,400	kWh	10,228,600	kWh		
1,679	kWh/DD	2,205	kWh/DD	526 kWh/DD	31% increase

The usage per degree day comparison for steam year over year is within 1%. The 31% increase in kwh/DD is due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page.

4.1.3. [redacted] Educational Center [redacted]

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.





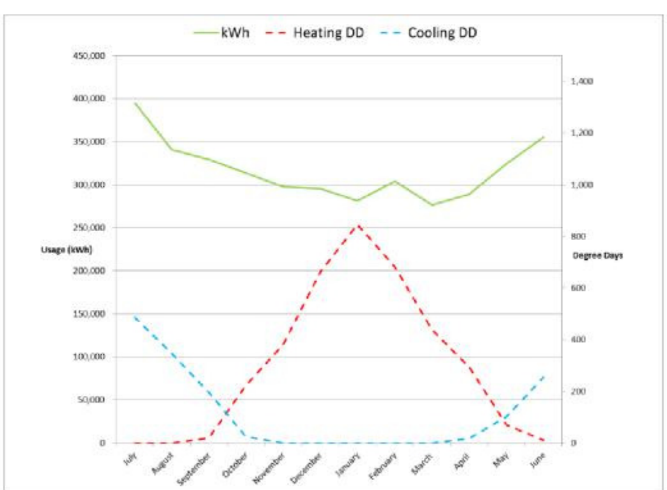
Utility Breakdown **12 Month Profile**

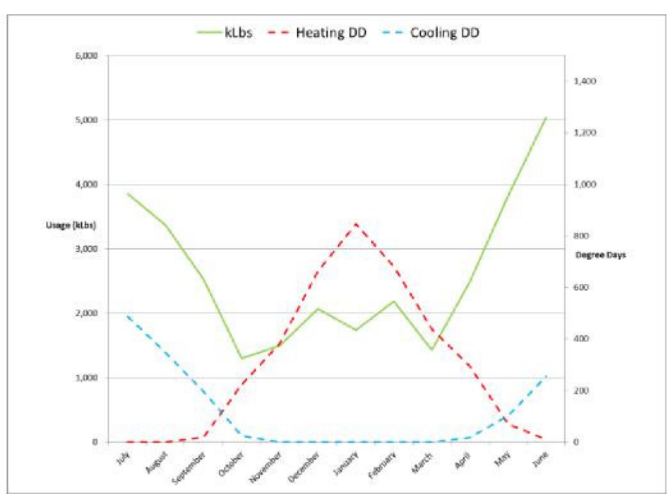
Steam is the major consumer in Educational Center at 74% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers.

Additionally, the two main energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Overall, electric usage remains fairly constant throughout the year while steam consumption fluctuates with seasonal loading patterns.

Degree Day Comparison

Each main utility was plotted versus degree days to illustrate usage as a function of seasonal temperature fluctuations.





Steam consumption generally follows degree day trends as steam is used for both heating and cooling. Electric consumption peaks slightly in the summer (20%) but is fairly consistent throughout the year.

Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2011 and 2012 can point to changes in building space use, operational issues or equipment malfunction/replacement.

FY10/11	6098 DD	**FY11/12**	5050 DD	**Performance Comparison**	
Steam		**Steam**			
31,513,000	lbs	31,303,000	lbs		
5,168	lbs/DD	6,199	lbs/DD	1031 lbs/DD	20% increase
Electric		**Electric**			
3,968,800	kWh	3,803,200	kWh		
651	kWh/DD	753	kWh/DD	102 kWh/DD	16% increase

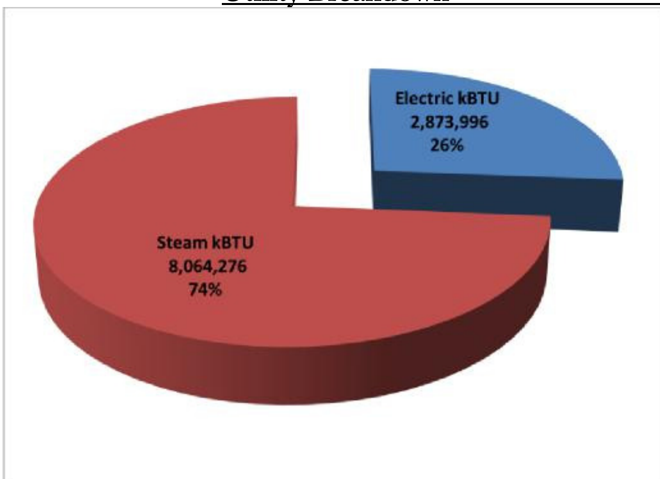
The reduction in total degree days (6098 for FY10/11, 5050 for FY11/12) should have led to a reduction in steam usage; however there is a moderate increase. The usage increase is most likely due to changes in equipment operation. Since the building is using predominantly local pneumatic controls, it is hard to maintain consistent operation year over year.

The 16% increase in kwh/DD is due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page

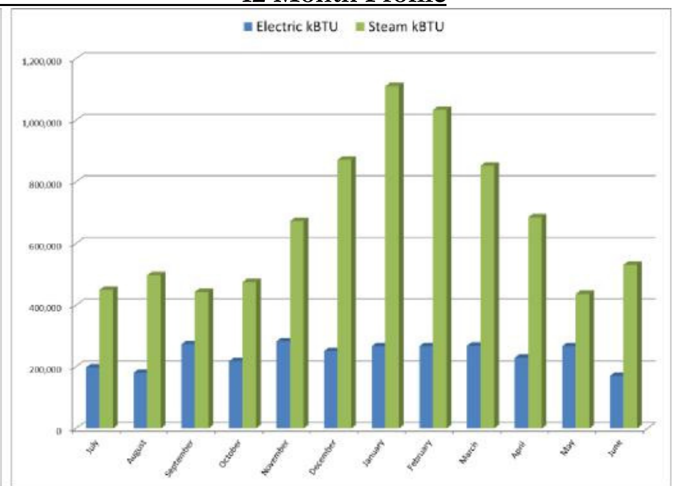
4.1.4. Office Building

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.

Utility Breakdown



12 Month Profile

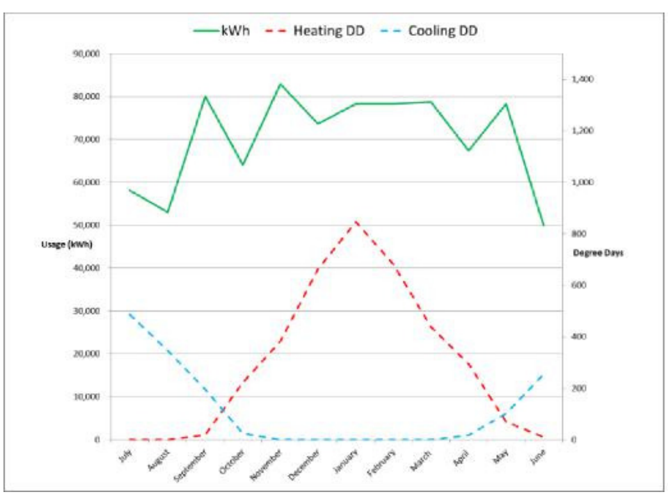


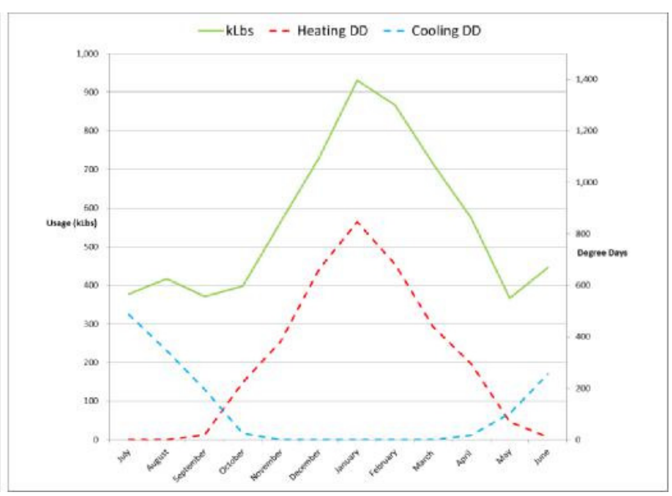
Steam is the major consumer in Office Building at 74% of total usage. The two energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Electric consumption maintains a steady consumption level throughout the year. Steam consumption exhibits a winter peak.

This building profile is a result of the building utilizing steam to generate house heating water but receiving its chilled water, unmetered, from the Research Building 1 chiller plant.

Degree Day Comparison

Each main utility was plotted versus degree days to illustrate usage as a function of





seasonal temperature fluctuations.

Steam consumption follows the heating degree day trends as it is used space heating. Electric consumption does not correspond to degree day fluctuations and varies throughout the year by as much as 30%.

Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2010 and 2011 can point to changes in building space use, operational issues or equipment malfunction/replacement.

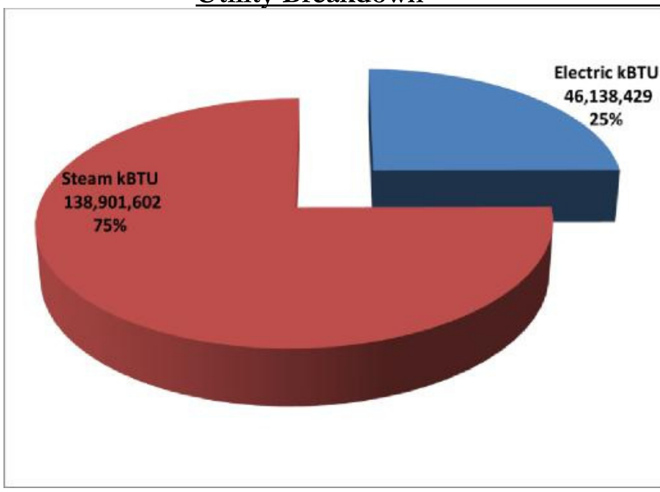
FY10/11 Steam	6098 DD	FY11/12 Steam	5050 DD	Performance Comparison	
7,372,000	lbs	6,754,000	Lbs		
1,209	lbs/DD	1,337	lbs/DD	128	10% increase
Electric		**Electric**			
867,002	kWh	842,320	kWh		
142	kWh/DD	167	kWh/DD	25	17% increase

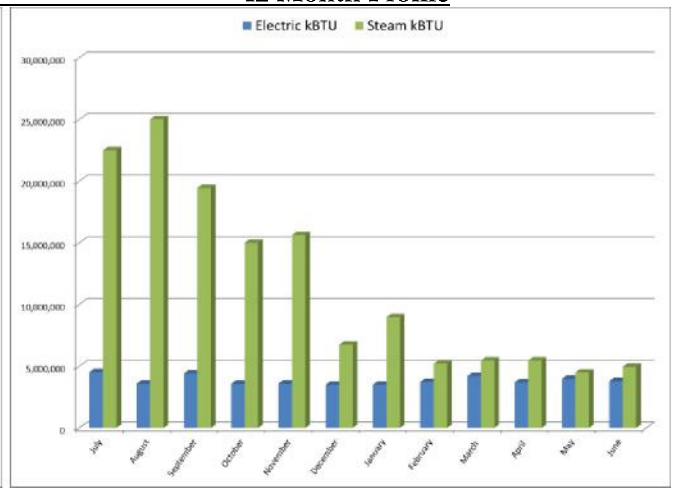
Weather normalized utilization rates for both steam and electric increased slightly from 2011 to 2012. The usage per degree day comparison for steam year over year is within 10%. The 17% increase in kwh/DD is due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page.

4.1.5. Science Building / Research Building 2

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012. The presented profile is not as expected and we suspect metering or allocation errors as the most likely reasons. The data presented is our best approximations, based on what was provided. Commentary on the energy consumption and usage profiles has therefore been omitted.

Utility Breakdown **12 Month Profile**

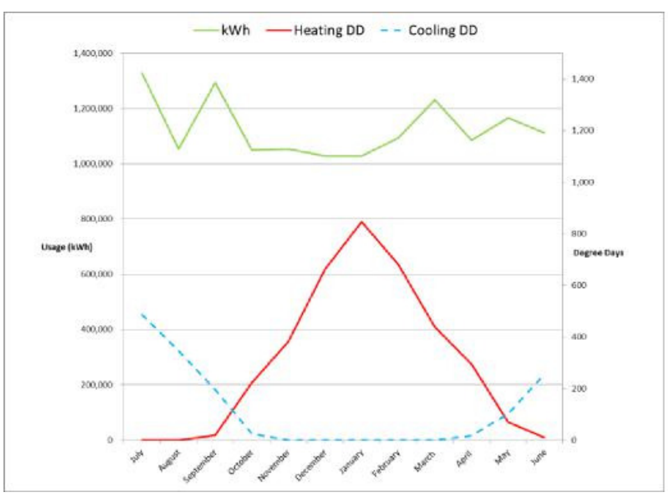


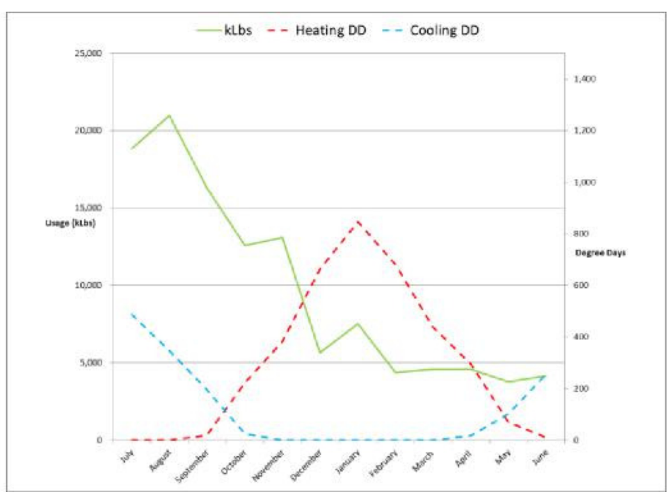


Steam is the major consumer in Science Building at 75% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers.

Degree Day Comparison

Each main utility was plotted versus degree days to illustrate usage as a function of





seasonal temperature fluctuations.

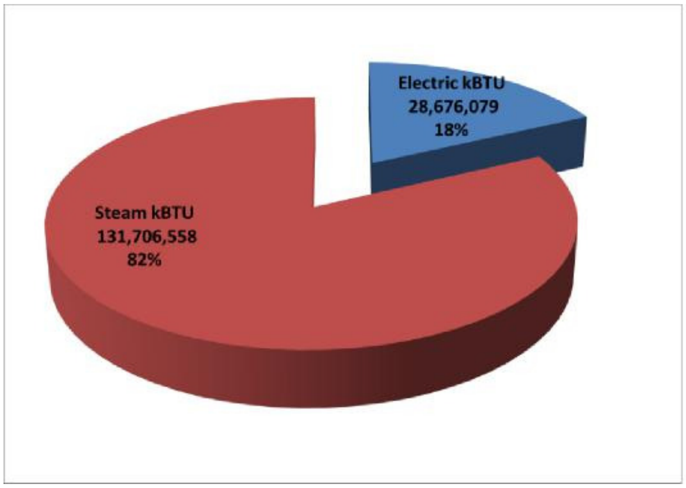
Historical Energy Performance

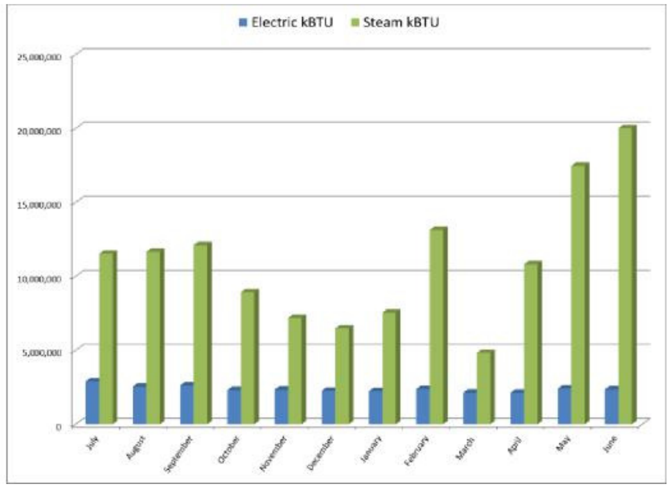
Historical energy performance was tabulated to demonstrate changes in *weather normalized* energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2010 and 2011 can point to changes in building space use, operational issues or equipment malfunction/replacement.

FY10/11	6098 DD	FY11/12	5050 DD	Performance Comparison	
Steam		Steam			
142,038,000	Lbs	116,333,000	lbs		
2,074	Lbs/DD	2,677	lbs/DD	603 lbs/DD	29% increase
Electric		Electric			
12,648,000	kWh	13,522,400	kWh		
2,074	kWh/DD	2,678	kWh/DD	-256 kWh/DD	1% decrease

4.1.6. Medical Research Building

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.





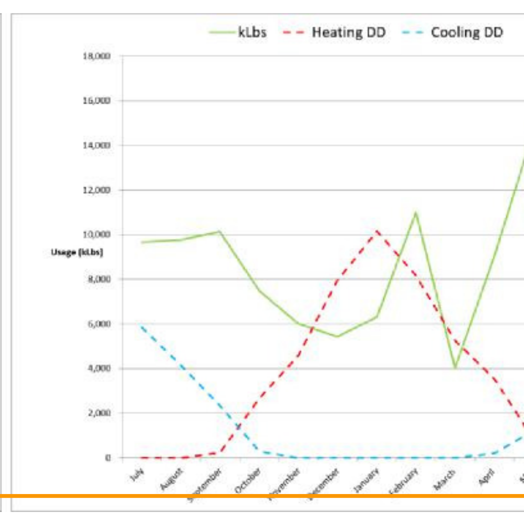
Utility Breakdown **12 Month Profile**

Steam is the major consumer in Medical Research Building at 82% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers. Additionally, the two main energy streams (electric and steam) are presented side-by-side over the same 12-month period to compare each utility's peak and seasonal variations.

The electric consumption remains relatively steady throughout the year due to the 24/7 operation of the building. Steam consumption peaks during the summer months due to the steam absorption chillers in the building.

Degree Day Comparison

Each main utility was plotted versus degree days to illustrate usage as a function of seasonal temperature fluctuations.



Electric consumption remains relatively steady throughout the year as the utility is not utilized for heating or cooling processes. Steam usage fluctuates with seasons. The abnormal spikes are attributed to metering issues.

Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2010 and 2011 can point to changes in building space use, operational issues or equipment malfunction/replacement.

FY10/11 Steam	6098 DD	**FY11/12** Steam	5050 DD	**Performance Comparison**	
78,080,000	lbs	110,307,000	lbs		
12,804	lbs/DD	21,843	lbs/DD	9,039 lbs/DD	71% increase
Electric		**Electric**			
8,575,200	kWh	8,404,478	kWh		
1,406	kWh/DD	1,664	kWh/DD	258 kWh/DD	18% increase

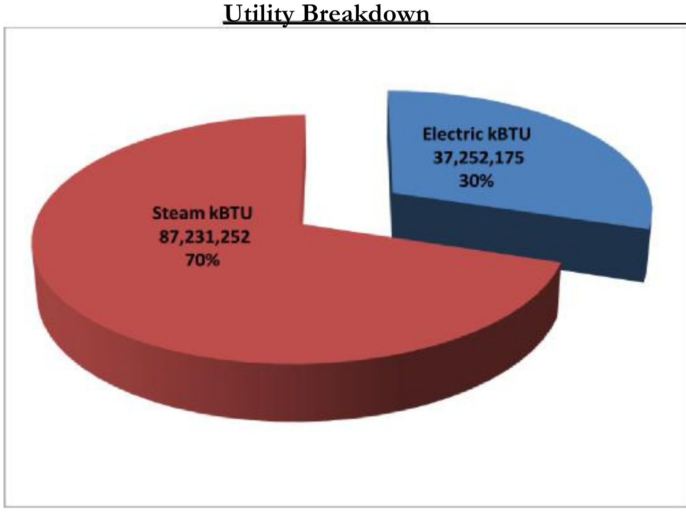
Both steam and electric usage increased in use per degree day. This could be the result of metering issues or possibly due to changes in equipment operation. Since the building is using predominantly local pneumatic controls, it is hard to maintain consistent operation year over year.

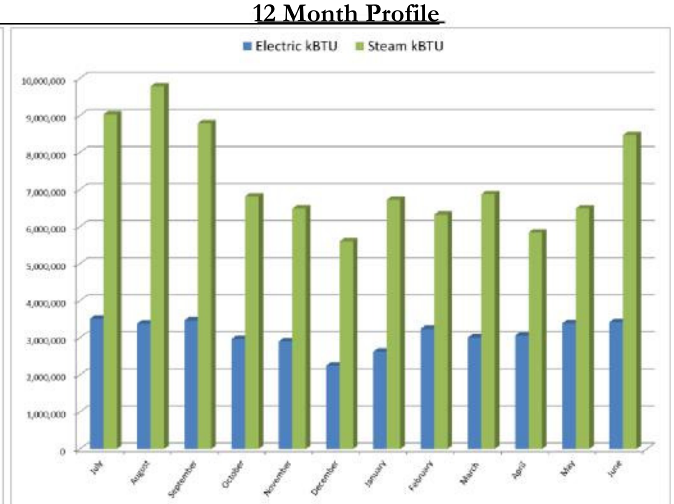
The 18% increase in kwh/DD may also be partly due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page.

4.1.7. Advanced Research/Office Building

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.

Utility Breakdown **12 Month Profile**



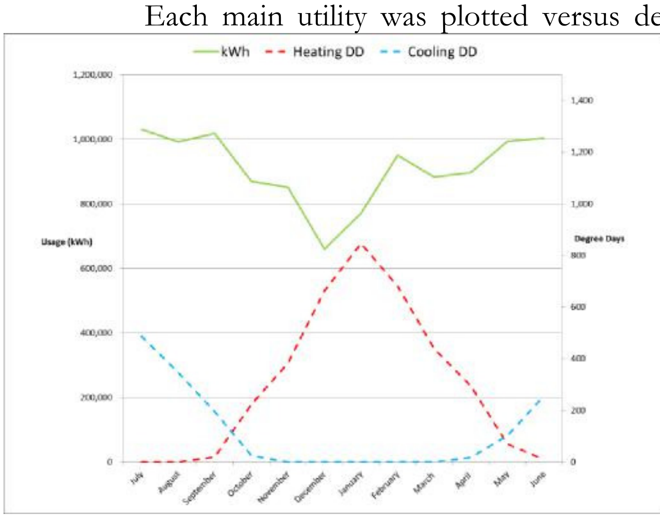


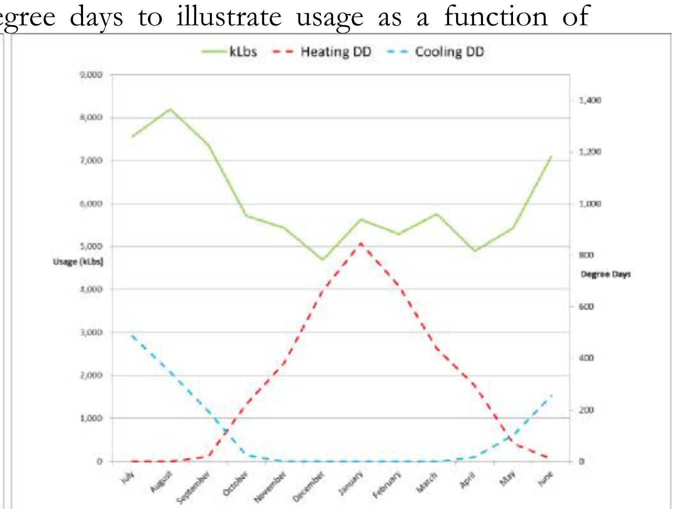
Steam is the major consumer [redacted] at 70% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers.

Additionally, the two main energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Overall, electric usage remains fairly constant throughout the year while steam consumption fluctuates with seasonal loading patterns.

Degree Day Comparison

Each main utility was plotted versus degree days to illustrate usage as a function of





seasonal temperature fluctuations.

Steam date tends to fluctuate with the seasons and peaks in the summer due to the operation of the steam absorption chillers. Electric consumption is fairly consistent with an uncharacteristic winter drop in consumption in November and December, possibly due to reduced occupancy during the holiday season.

Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2010 and 2011 can point to changes in building space use, operational issues or equipment malfunction/replacement.

FY10/11	6098 DD	**FY11/12**	5050 DD	**Performance Comparison**	
Steam		**Steam**			
71,386,000	lbs	73,058,000	Lbs		
11,700	lbs/DD	15,100	lbs/DD	3,400 lbs/DD	34% increase
Electric		**Electric**			
10,940,400	kWh	10,917,988	kWh		
1,794	kWh/DD	2,162	kWh/DD	368 kWh/DD	21% increase

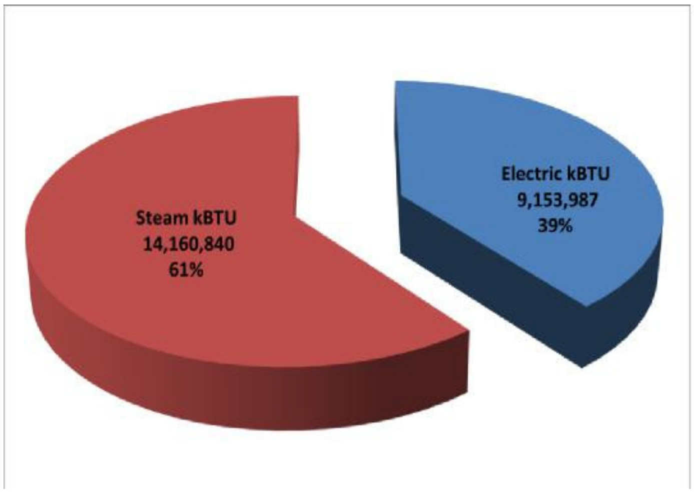
Steam and electrical usage both increase in terms of usage per degree day. This is indicative of changes in operation or worsening system efficiencies.

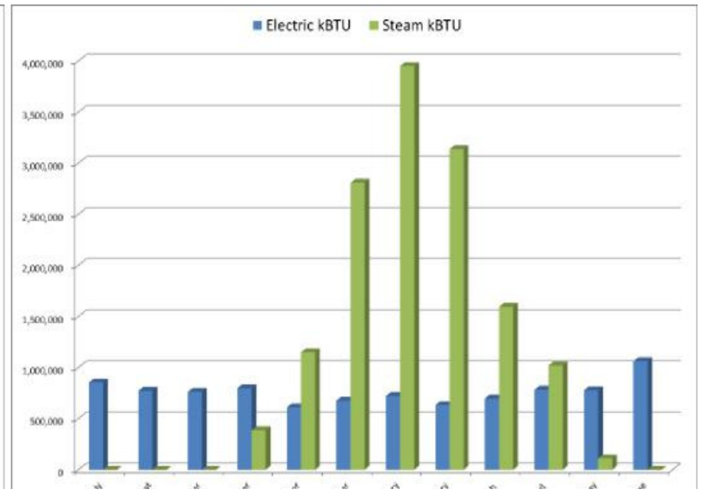
The 21% increase in kwh/DD may also be partly due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page.

4.1.8. Educational Building

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.

Utility Breakdown **12 Month Profile**

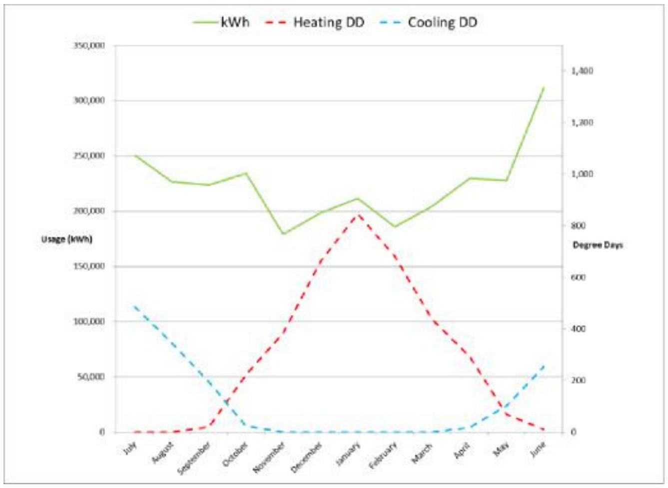


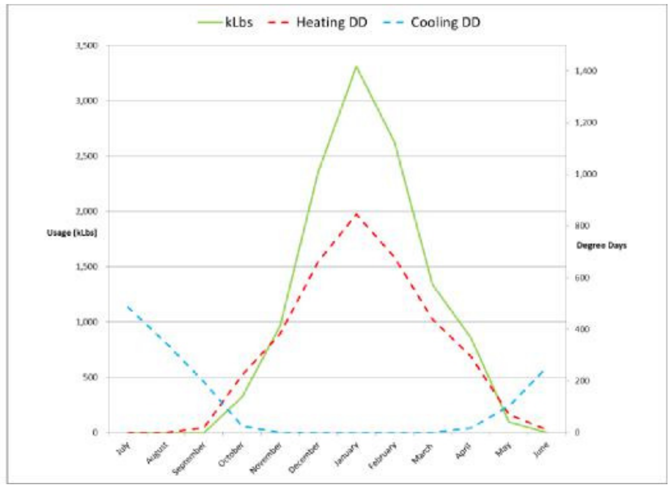


Steam is the major consumer in Educational Building at 61% of total usage. Additionally, the two main energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Overall, electric usage remains fairly constant throughout the year with a moderate increase in the summer months. This is attributed to increased air conditioning loads being provided via the window air conditions and the temporary electric chillers. Steam consumption fluctuates with seasonal heating patterns.

Degree Day Comparison

Electric consumption was plotted versus degree days to illustrate usage as a function of seasonal temperature fluctuations.


kWh
Heating DD
Cooling DD
Usage (kWh)
Degree Days
July
August
September
October
November
December
January
February
March
April
May
June


kLbs
Heating DD
Cooling DD
Usage (kLbs)
Degree Days
July
August
September
October
November
December
January
February
March
April
May
June

Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2011 and 2012 can point to changes in building space use, operational issues or equipment malfunction/replacement.

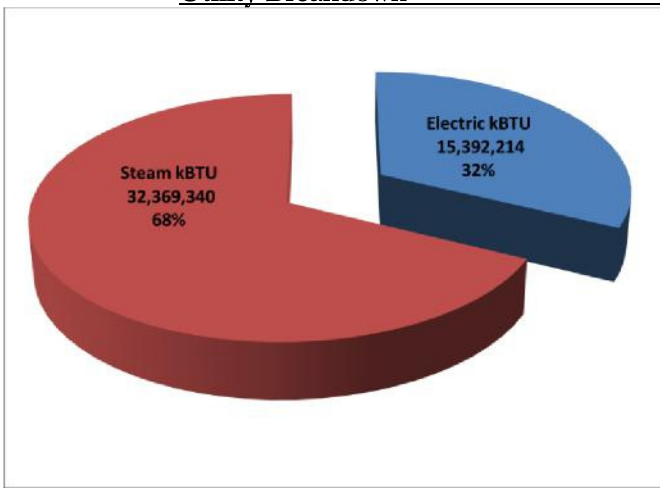
FY10/11	6098 DD	**FY11/12**	5050 DD	**Performance Comparison**	
Steam		**Steam**			
n/a		11,860,000	Lbs		
		2,300	lbs/DD		
Electric		**Electric**			
2,287,796	kWh	2,682,880	kWh		
375	kWh/DD	531	kWh/DD	368 kWh/DD	21% increase

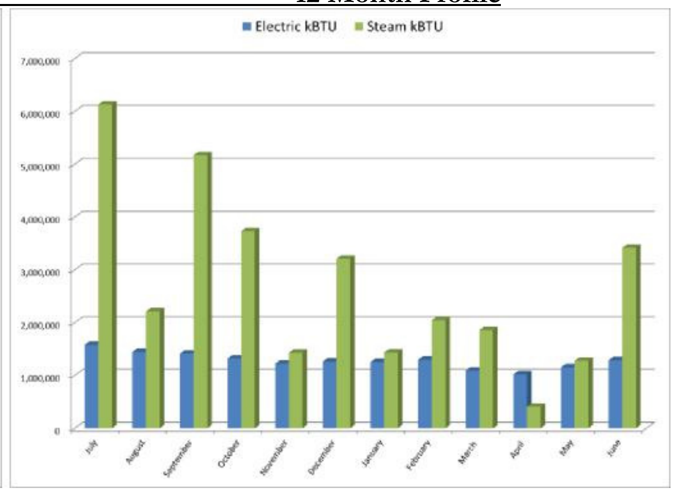
A direct comparison cannot be made for Educational Building that no steam data is available for fiscal year 2010/2011. The increase in electric consumption is probably partly due to the increased occupancy of the building over the past year and should be expected to increase in the future.

4.1.9. [redacted] Staff Housing Complex

The energy consumption of the building was compiled from Con Edison data as well as sub-metering by the Facilities Department. Data was collected and tabulated for July 2011 – June 2012.

Utility Breakdown **12 Month Profile**



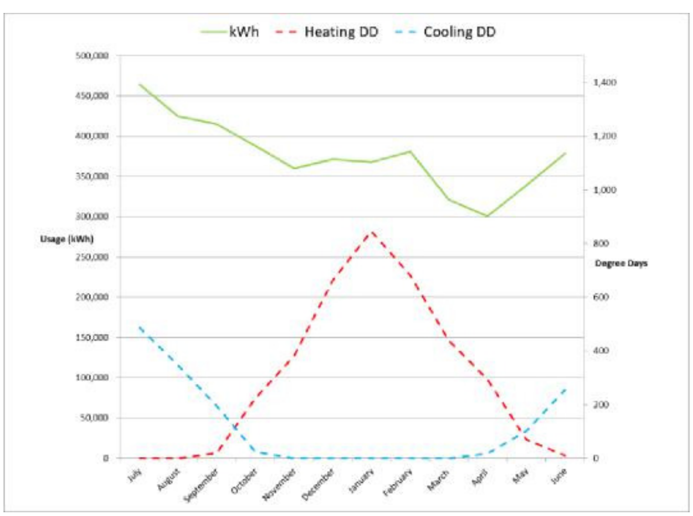


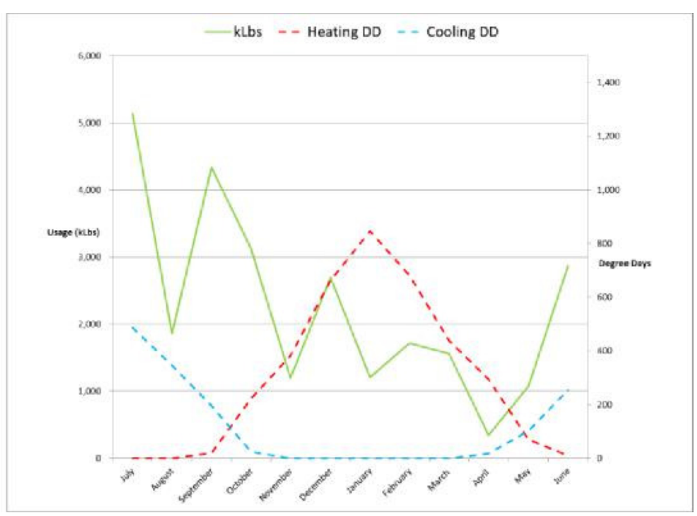
Steam is the major consumer in Staff Housing at 68% of total usage. The reasons for such high steam usage are that it is used for both heating in the winter and air conditioning in the summer via the absorption chillers.

Additionally, the two main energy streams (electric and steam) are presented over the same 12-month period for side by side comparison to demonstrate each utility's peak consumption and seasonal variation. Overall, electric usage remains fairly constant throughout the year while steam consumption fluctuates with seasonal loading patterns. Abnormal drops in August and January are attributed to metering error.

Degree Day Comparison

Electric and steam consumption were plotted versus degree days to illustrate usage as a function of seasonal temperature fluctuations.





Historical Energy Performance

Historical energy performance was tabulated to demonstrate changes in ***weather normalized*** energy use year over year. These data points (consumption/degree day) represent how efficiently each utility is utilized, and the differential between 2011 and 2012 can point to changes in building space use, operational issues or equipment malfunction/replacement.

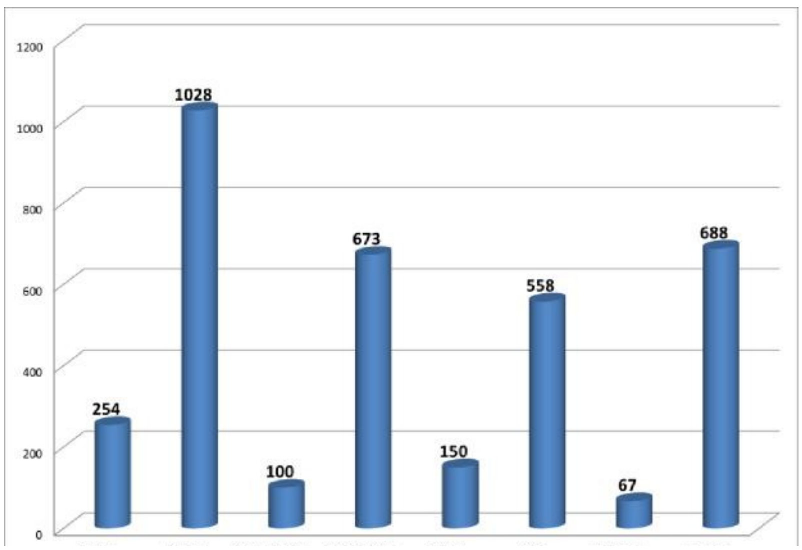
FY10/11	6098 DD	FY11/12	5050 DD	Performance Comparison	
Steam		Steam			
5,981,000	lbs	4,884,000	Lbs		
980	lbs/DD	967	lbs/DD	13 lbs/DD	0% increase
Electric		**Electric**			
4,410,400	kWh	4,511,200	kWh		
723	kWh/DD	893	kWh/DD	170 kWh/DD	24% increase

Year of year steam usage on a degree day basis was flat. The 24% increase in kwh/DD is due to the fact that the building runs 24/7 and the heating and cooling needs are met via steam. As such, the power consumption of the building is consistent, regardless of weather conditions. This is illustrated in the monthly consumption graph on the preceding page.

4.2. Energy Usage Index & Target Indices

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) provides benchmarking data to measure the effectiveness of the building. The Energy Usage Index (EUI) was created by converting the Site energy stream annual totals (kWh and steam Mlb) to KBTU and dividing by building square footage. Site energy usage solely represents energy consumed at the building; this is in contrast to a different method that may be used to present energy consumption, referred to as Source energy. EUI based on Source energy represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses, thereby enabling a complete assessment of energy efficiency in a building. The ENERGY STAR® label, for example, is based on Source energy; please see the following section for additional details.

[redacted] 2012 EUI (kBTU/ft²/year)



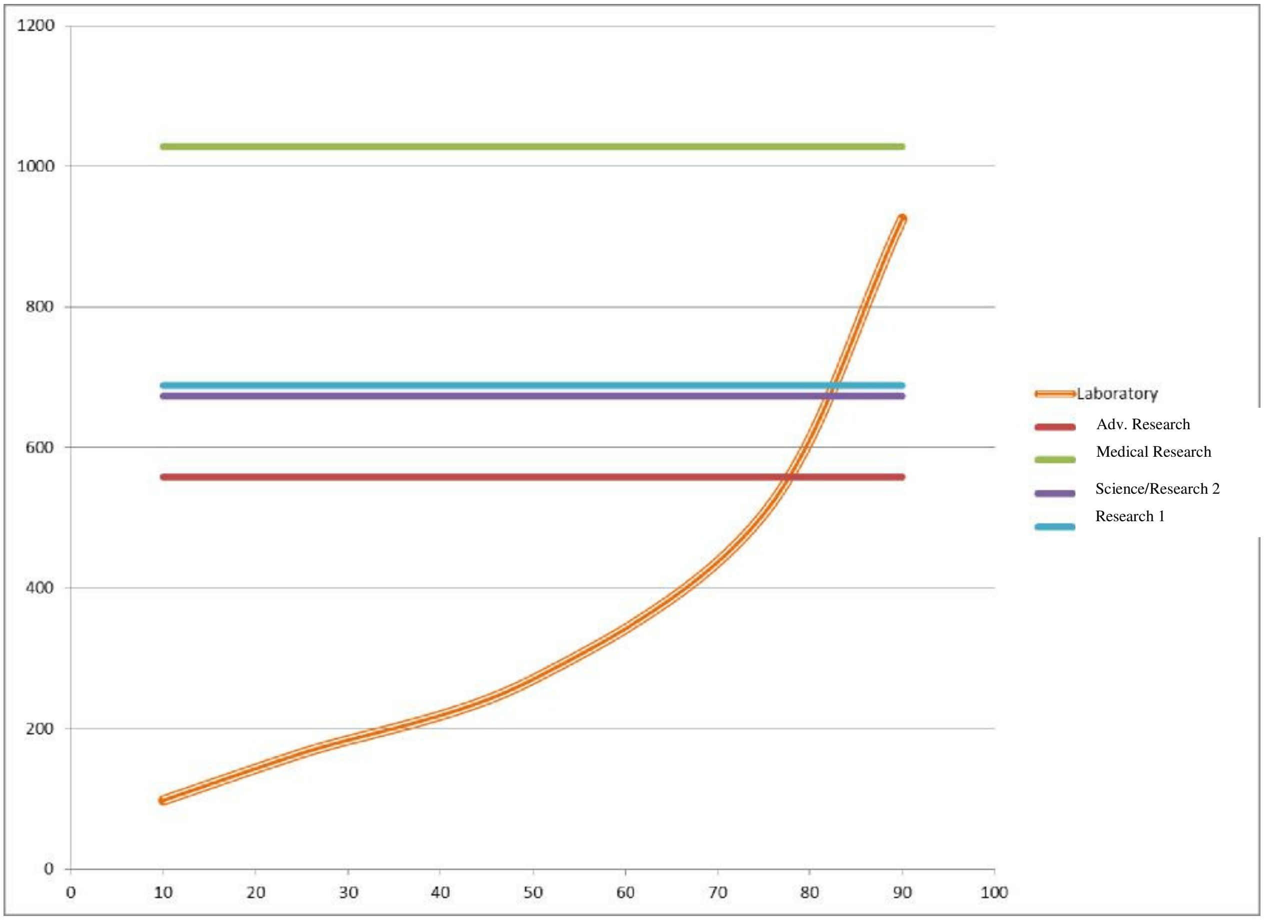
EUI ratings allow site usage comparisons between buildings with the same space type. Through energy consumption and building data surveys submitted by thousands of facilities, EUI ranges and averages have been formulated for many subsets of the existing national building population (offices, warehouses, hotels, etc). [redacted] buildings, however, have unique space-uses and they are difficult to compare to any of the existing building categories directly. As a proxy, [redacted] calculated EUIs were compared to several facility subsets operated in a manner such as these (24/7, high plug load, intense IT equipment use, high conditioning loads):

Building Use	Calculated EUI Values Site Energy, kBtu/year per gross square					
	10th	25th	50th	75th	90th	Mean
Laboratory	98	165	270	505	925	362
College/University	14.1	67	108	178	215	122
Dormitory	36.3	65	74	100	154	76
Professional Office	28.1	41	62	93	138	75

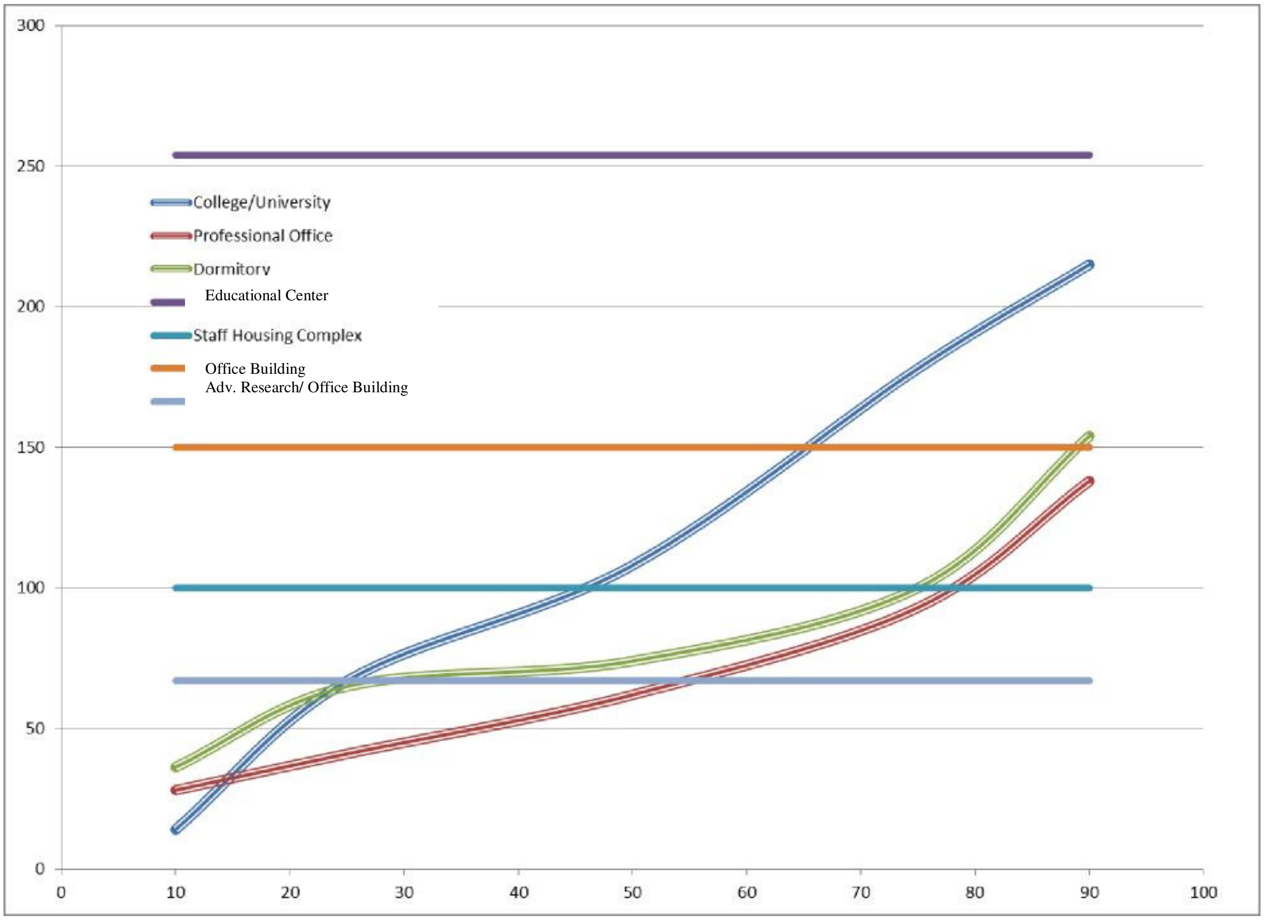
*The EUI date referenced was taken from the 2007 ASHRAE HVAC Applications handbook page 35.8. The data source is calculated based on DOE/EIA preliminary 2003 CBECS microdata.**

The buildings EUI's are shown below in comparison to the aforementioned building categories from ASHRAE 2007 Handbook.

2011-2012 [redacted] EUI vs. ASHRAE EUI



The intersection points of these trend lines and [redacted] building EUIs suggest the performance percentiles of the building within the categories. As indicated, Science Building/Research Building 2, Research Building 1, and Adv. Research/ Office Building all exceed the 75th percentile while Medical Research Building exceeds the 9th percentile. These high values are the result of the 24/7 operation of the buildings and the lack of any night time setback strategies. Additionally, the numbers are skewed high due to the sites' extensive use of absorption chillers for air conditioning purposes.



The intersection points of these trend lines and [redacted] building EUIs suggest the performance percentiles of the building within the categories.

Educational Center is higher than all comparable subsets in that it was originally a laboratory/teaching facility which is now used for office and teaching space. The building is still using the original 100% OA air handlers that are not typically used for office space applications.

Staff Housing's EUI is in the 75th percentile, which is not unexpected given the age of the buildings.

The Office Building's EUI is in the 90th percentile, primarily due to the older fan coil units and window AC's which are currently being renovated. We would expect this to trend downward in the future as the renovations continue.

Major contributing factors to the high EUI's are the 24/7 operation of the buildings and the lack of any night time setback strategies (with the exception of Office Building). Additionally, the numbers are skewed high due to the sites extensive use of absorption chillers for air conditioning purposes.

4.3. Energy Star Label

The U.S. Environmental Protection Agency's ENERGY STAR® Portfolio Manager offers an energy benchmarking tool that compares and ranks buildings against similar buildings, adjusting for climate, space use, and heating and cooling degree days. Buildings are rated on a scale of 1 – 100, with a score of 75 or greater qualifying for the ENERGY STAR® label.

ENERGY STAR® Portfolio Manager only provides ratings for certain building types – on the [redacted] campus, only Staff Housing, Office Building and Educational Center were actually rated. The reasoning for this is Energy Star's lack of samples for laboratory and research facilities.

Outputs from ENERGY STAR® have been included in the appendix and login information provided [redacted] for future use.

5.0 Operational Issues and Energy Conservation Measures

[redacted] investigative process began with a review of the major pieces of equipment on the various BMS systems and then progressed with a site assessment of the buildings included in the project scope. Throughout both phases, all observed operational and physical condition issues were noted in an Issues Database (Appendix D). The Issues Database was developed and continually updated as a central record to categorize each deficiency, the resolution benefit and solutions recommended for implementation. The database also includes other critical pieces of information, such as the associated BMS system, tag number of the system or piece of equipment from the BMS, and a detailed description of the deficiency or problem.

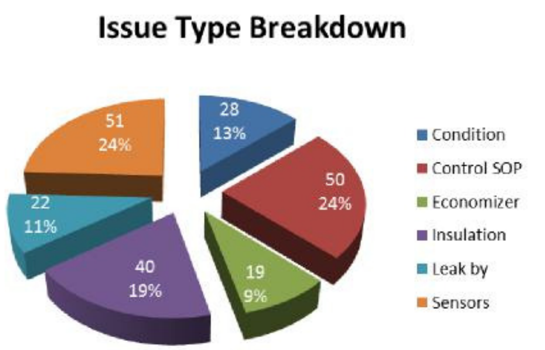
Our review focused on improper set points, potential calibration issues, incorrect control sequences and the general operating condition of the units. The organization of the database was structured such that issues can be reviewed by [redacted] staff in a variety of ways – issues can be sorted by equipment type, building, issue type, etc.

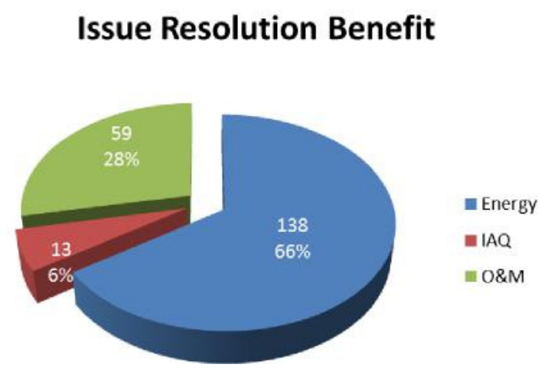
Based on issue frequency and equipment affected, certain issues were developed into an energy conservation measure to correct the deficiency and increase energy efficiency. Examples include leaking steam control valves and sensor calibration issues. Additionally, other energy efficiency measures, both operational and capital, were analyzed separately from Issue Database items. Please see sections below for further Issues Database and ECM details.

Overall, the maintenance and operation of the majority of the equipment is satisfactory. The most significant factors to the sites excessive energy consumption is the age of much of the infrastructure and the 24/7 operation of almost all of the facilities. A concerted effort to evaluate building usage patterns and implementing night setback strategies wherever possible would yield substantial energy reductions. Setbacks can be implemented in some buildings utilizing the existing systems and controls. In others, it will not be possible without substantial capital improvements. We highly recommend setback strategies be evaluated and implemented whenever an AHU, system or space is renovated.

5.1. Issues Database

<u>This project uncovered a total of 210 issues.</u> Over 66% of all issues were related to energy, and their resolution will likely enhance the energy efficiency of the related system and campus overall. More issues would have been uncovered had the entire campus been on the building automation system.





Each issue identified was sorted into one of six issue types: Control (SOP) Sequence of Operation, Sensors, Condition, Leak by, Economizer and Insulation.

The majority of issues are related to building automation system sensors – 51 issues in total are sensor related. The particular issues are related to the values given on the BMS screens. Over 40% of the Sensor issues were identified in Adv. Research/ Office Building.

Out of the 210 issues, over 75% of the deficiencies were uncovered in three buildings: Science Building, Research Building 1, and Adv. Research/ Office Building. As a result of the high volume of issues as well as the intense space use and equipment density, X has identified these buildings are the best candidates for full scale facility retro-commissioning.

5.2. Energy Conservation Measure Summary

Overall, by implementing the energy conservation measures (ECMs) outlined in this report, an estimated $621,023 in annual energy savings can be realized thus improving building operation and sustainability. This would equate to a 5.3% reduction in annual energy costs.

Several of the ECMs can be applied to multiple buildings and systems. While many of the strategies presented are relatively easy to implement and can most likely be completed through the expertise of in-house operations staff and qualified contractors, there are some ECMs that require further study to fully determine the economic benefits and feasibility of ECM implementation.

The following sections outline each potential measure in greater detail. A summary of findings are shown at each building.

5.3. Research Building 1 Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Research Building 1.

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Research Building 1	AC-9, 8th floor night setback.	O&M	$ 29,244	$ 45,000	1.5	77,984	1,755
	Raise Precool temp set points to 60F	O&M	$ 80,505	$ 1,000	0.0	214,679	4,830
	Change economizer lockouts from 55F-60F to 45F to 65F	O&M	$ 1,632	$ 200	0.1	4,352	98
	Repair Leaking Control Valves	O&M	$ 4,967	$ 4,500	0.9	13,244	298
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 9,398	$ 2,500	0.3	25,061	564
	Repair / Install Missing Pipe Insulation	O&M	$ 7,962	$ 20,706	2.6	21,233	478
	Cage Wash AHU ToD Scheduling	O&M	$ 9,885	$ 200	0.0	26,359	593
	Night Setback for new AHU's 2, 5, 6, 8, and 10) Need	Capital	$ 140,957	$ 243,400	1.7	375,886	8,457
	Stairwell Lighting Retro-fit	Capital	$ 3,188	$ 13,376	4.2	8,501	191
	VFDs on Glycol Pumps (2)	Capital	$ 9,032	$ 20,600	2.3	24,085	542
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this				-	-
	Damper controls to allow better economizer	Capital -Beyond scope of this				-	-
	Cage wash chiller -> House Chilled water	Capital - Screened Out	$ 1,203	$ 10,000	8.3	-	-

5.3.1. Nighttime Setback

The most significant factor to the high energy consumption of the Research Building 1 (and most of the campus) is the 24/7 operation of the buildings HVAC systems. This is an industry issue with almost all research facilities, both public and private sector. Most facilities do require off hour airflow to satisfy space conditions, room air change and fume hood requirements. A strategy being broadly implemented is that of a nighttime setback in which the air flows to the spaces are reduced during off hour periods to lower levels when occupancy and HVAC are reduced. Depending on the design of the systems, implementing this type of strategy can range from simple operational changes to large capital undertakings.

Based on the design and layout of the Research Building 1, we believe night setback strategies are viable, on a floor by floor basis. Currently, AC-9, serving the 8th Floor is fitted with VFD's on both its supply and return fans. We estimate that the airflow through the spaces can be reduced by as much as 40% during off hours and still maintain fume hood air flows and air change rates in excess of 8. (Many facilities go as low as 2-4 air changes at night.)

Proper implementation of this strategy on AC-9 will require additional engineering, balancing and controls support. However, there should be no equipment or capital costs. We recommend
evaluate this further and attempt to implement this on a trial basis on the 8th Floor.

In addition to the engineering, balancing and controls costs associated with AC-9, implementation of this strategy on the remaining floors will require the installation of VFD's on the AHU's and represents a sizable capital project (which falls outside the scope of this operational assessment). We recommend [redacted] this opportunity in a future initiative.

This ECM was discussed with operating personnel and caution was raised with respect to maintaining space temperatures in the common equipment rooms. This should not be an issue with the common equipment rooms in Research Building 1 in that most of them are fitted with dedicated spot coolers. If specific problem rooms are identified, they can be addressed via balancing and increasing the airflow to these specific spaces. Alternately, space temp sensors can be used to reset the air handler setback during extreme conditions.

5.3.2. Raise Precool Temperature of Dual Duct Units

During BMS Review and HVAC Inspections, it was noted that the discharge temperature of dual duct units were 55 F prior to entering the hot and cold decks. This temperature is lower than typical for dual duct systems and per the design drawings, the set points should be 63F. A suppressed precool discharge air temperature results in excess simultaneous heating and cooling in the hot decks. This set point may have evolved in response to cooling issues spurred by the aging chiller plant and air handler cooling coils. It may be corrected through the recent chiller plant renovation. As such, we recommend raising the air handler discharge temperatures to at least 60F and observing the operation of each unit.

By increasing the discharge temperature to 60 F, it reduces the amount of energy needed to heat the air for the hot deck. The current calculated $/cfm of the 55 F discharge dual duct is $2.99 for recirculation units and $3.89 for 100% outside air units. By increasing the discharge air temperature, the new $/cfm for recirculation units becomes $2.68 and $3.58 for 100% outside air units. This adds up to over $80,000 is savings and over 9,000,000 kBTUs of steam saved.

The air handlers currently affected are as follows:

Research Building 1 – AC1, AC2, AC3, AC4, AC5, AC6, AC7, AC8, AC9, AC10, AC11, AC12, AC13, MAGLAB

5.3.3. Economizer Lockouts

Economizer settings are designed to allow buildings to utilize free cooling and save on energy costs throughout the year. Typically, economizer cycles are effective between 40F and 65F. [redacted] currently operates with an economizer lockout of 55 F to 60 F, severely limiting the economizers hours of operation. We recommend changing the lockout to 40F and

The air handler units affected are as follows:

Research Building 1 – AC-2, AC-3, AC-4, AC-5, AC-6, AC-7, AC-9

By changing the economizer lockout, the *Research Building 1* building saves an additional $0.06 per cfm. The low change in cost is due to the buildings dual duct operations. Savings were calculated based on the change in $/cfm and the associated air handlers design airflow.

5.3.4. Valve Leak-by Remediation

Several control valves were found to be leaking by while inspecting the AHUs and BMS. These leaking valves unnecessarily increase energy usage and should be corrected. The leak-by can be attributed to a multitude of factors: age, control pressure/signal, internal wear, etc.

The following AHUs were found to have potential leak-by issues:

Research Building 1 – AC-2, AC-6, AC-8

While the exact cause of leak-by could not be determined within the scope of this study, based on our past retro-commissioning experience it is anticipated that the majority of the corrections will require controls/signal repair between the valves and BMS rather than removal or replacement of the existing valves. Though additional troubleshooting will be required by the in house staff we recommend these valves be addressed.

The savings potential is based on eliminating an average of 3 degrees of preheat or chilled water leak-by during the shoulder season. The savings are derived from eliminating the excess heating and cooling loads associated with the leaks. The cost associated with this measure is based on an estimated cost of $2,500 per unit for controls programming and any equipment issue resolution that may be required.

5.3.5. Sensor Calibration

A number of critical HVAC sensors were found out of calibration during the BMS review. Sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following AHUs were found to have sensors out of

calibration: *Research Building 1 – AC-4, AC-5, AC-6, AC-7*

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.3.6. Insulation

During system inspections, several sections of chilled water and steam piping were found to be missing insulation. Properly insulated pipe reduces heat losses and gains by a factor of 10 (approximately). As such, we recommend pipe insulation be installed on the identified locations. Locations where missing insulation has been noted, along with approximate length are presented below:

Building	Location	System	Pipe Size (in)	Temperature of Pipe	Length (ft)	Heat Loss	Heat Loss with	Savings MMBtu	Annual Savings	Cost of Installation
						Btu/hr/ft	Btu/hr/ft			
Research Building 1	Basement Steam Station	Steam	8	200	3	616	62	15	$ 146	$ 387
Research Building 1	Basement Steam Station	Steam	4	200	3	332	38	8	$ 77	$ 378
Research Building 1	AC 8 Mezzanine	Steam	8	200	81	616	62	393	$ 3,931	$ 10,438
Research Building 1	Laser Lab Chiller	Steam	3	260	7	440	51	24	$ 239	$ 883
Research Building 1	AC 10/11	Steam	2.5	260	16	366	44	45	$ 451	$ 2,018
Research Building 1	AC 10/11	Steam	3	260	20	440	51	68	$ 682	$ 2,523
Research Building 1	AC 10	Steam	4	260	20	558	60	87	$ 872	$ 2,523
Research Building 1	AC 12	Steam	2	260	24	307	39	56	$ 563	$ 368
Research Building 1	AC 12	Steam	2	260	40	307	39	94	$ 939	$ 614
Research Building 1	AC 8 Mezzanine	Chilled Water	3	45	6	43	9.8	1	$ 7	$ 90
Research Building 1	AC 8 Mezzanine	Chilled Water	3	45	6	43	9.8	1	$ 7	$ 90
Research Building 1	AC 8 Mezzanine	Chilled Water	8	45	4	100	21	1	$ 12	$ 94
Research Building 1	AC 3 Mezzanine	Chilled Water	4	45	5	54	8	1	$ 8	$ 75
Research Building 1	AC 3 Mezzanine	Chilled Water	6	45	2	78	17	1	$ 4	$ 38
Research Building 1	AC 3 Mezzanine	Chilled Water	8	45	8	100	21	3	$ 23	$ 188

The savings potential is based on the heating loss savings with the associated campus $10.00 per thousand pound of steam generated from the [redacted] central steam plant. Costs were estimated utilizing 2" of pipe insulation on steam pipes and 1" of insulation on chilled water and steam condensate lines.

5.3.7. Cage Wash AHU Time of Day Scheduling

AHU-1 which services the cage wash area is currently operated 24/7. Per operating personnel, cage washing typically occurs during normal working hours and nighttime operation is not necessary. We recommend time of day scheduling be implemented on the unit and it be shut down daily from 10PM to 6 AM. This can be readily implemented via the existing control system.

5.3.8. Stairwell Lighting

The vast majority of the building is fitted with efficient T-8 lighting; however, T-12 lights were identified in the stairwells. As stairwell lighting is currently on 24/7, it is typically a cost effective retro-fit. Recently, LED tubes have been introduced that are direct replacements for T-8 and T12 bulbs, eliminating the need to replace ballasts, greatly reducing installation costs.

As the facility has experience with LED lighting retrofits, we recommend the facility consider upgrading the stairwell lighting.

5.3.9. Glycol Pumps – Install VFD's

The glycol system operates 24/7, servicing the local cooling requirements throughout the building. The system has three constant speed pumps, two of which are in normal operation, with the third acting as a standby pump. Energy could be saved via installing VFD's on the pumps and operating them to maintain system differential pressure. We recommend [redacted] consider this retro-fit.

Energy savings is estimated based on an average 10% speed reduction and an associated reduction in power consumption of 30%.

5.3.10. Evaluate Damper Controls / Economizers for Recirculating Systems

A number of AHU's are fitted with fixed position return air dampers. While this does allow for some energy conservation, a fully modulating economizer cycle would be more efficient. To determine if energy could be saved, each AHU and the spaces it served would need to be evaluated to determine applicability. Control actuators and programming would have to be implemented. This analysis is outside of the scope of this operational assessment. We recommend economizer operation be evaluated along with setback strategies whenever an AHU, system or space is renovated.

5.3.11. Pneumatic to DDC Control

The majority of the equipment in the building utilizes antiquated, local pneumatic controls. We recommend these be upgraded as part of a campus wide master plan. Please refer to the Site Wide Initiatives / Capital Project Discussion

5.4. Research Building 2 Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Research Building 2.

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Research Building 2	Sensor Calibration Issues / Simultaneous heating and	O&M	$ **967**	$ 500	0.5	2,579	**58**
	Implement existing night setback feature	O&M, no equipment needed. Engineering and TAB	$ **65,574**	$ 40,000	0.6	174,865	**3,934**
	Chiller plant variable volume scheme does not work. Recommend abandoning it. Upsize system bypass or replace 2-way control valves	O&M / Capital	$ 20,373	$ 15,000	0.7	**54,329**	1,222

5.4.1. Sensor Calibration

A number of critical HVAC sensors were found out of calibration during the BMS review. Sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following AHUs were found to have sensors out of

calibration: *Research Building 2 – AHU-2*

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.4.2. Implement Nighttime Setback

The most significant factor to the high energy consumption of the Research Building 2 (and most of the campus) is the 24/7 operation of the buildings HVAC systems. This is an industry issue with almost all research facilities, both public and private sector. Most facilities do require, off hour airflow to satisfy space conditions, room air change and fume hood requirements. A strategy being broadly implemented is that of a nighttime setback in which the air flows to the spaces are reduced during off hour periods to lower levels when occupancy and HVAC are reduced. Depending on the design of the systems, implementing this type of strategy can range from simple operational changes to large capital undertakings.

The HVAC systems serving the Research Building 2 were designed and installed with this type of control in mind. The local VAV boxes have setback programming and schedules; they have just not been utilized. We estimate that the airflow through the spaces can be reduced by as much as 40% during off hours and still maintain fume hood air flows and air change rates in excess of 8. (Many facilities go as low as 2-4 air changes at night.)

Proper implementation of this strategy will require additional engineering, balancing and controls support. However, there should be no equipment or capital costs. We recommend evaluate this further and attempt implementation of the night setback schedules.

5.4.3. Chiller Plant Optimization

The chiller plant appears to have been designed with a primary only chilled water pumping system. The pumps are fitted with VFDs, the three air handlers with 2-way valves and the plant with a system bypass valve to prevent low flow conditions at the absorbers. It appears the intent was to have a variable flow distribution system while maintaining constant (or minimum) flows through the absorbers.

Per site personnel, since inception, variable flow operation of the system has not been possible. The system bypass is either too slow, or too small to prevent the absorbers from tripping out under low flow conditions. In response, the chilled water valves on two of the three air handlers have been locked out to have a minimum position of 40%, ensuring sufficient flow through system. The result of this is that during mild weather days, the supply air from these two AHU's is overcooled, resulting in unnecessary reheat, elevating energy consumption.

While theoretically a variable flow system will save energy, this system does not appear to be a good application. The energy saved from variable flow results from the decrease in system frictional losses as the flow reduces. This is a function of the piping system. On large systems, these reductions are considerable and result in substantial energy savings. In the Research Building 2, the entire system resides in the same mechanical room. The piping system is not extensive.

Per in house personnel, substantial effort was made to get the system to run as designed and was unsuccessful. As such, we recommend abandoning this scheme and fitting the air handlers with three way control valves. This will eliminate the overcooling at the air handlers and the low flow condition at the absorbers.

Savings were calculated assuming 1F to 5F over overcooling when OA temperatures are between 82F and 62F.

5.5. Science Building Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Science Building.

	ECM	Note	Savings	Cost	Paybac k	Annual kwh	Annual klbs
Science Building	Sensor Calibration Issues / Simultaneous heating and	O&M	$ **3,156**	$ 1,750	0.6	8,416	**189**
	Repair Leaking Control Valves	O&M	$ 10,615	$ 15,000	1.4	28,307	**637**
	Repair / Install Missing Pipe Insulation	O&M	$ 902	$ 2,119	2.3	2,406	54
	Install VFDs on glycol pumps (2)	Capital	$ **13,548**	$ 23,600	1.7	**36,128**	**813**
	Possible Night Setback	O&M - Beyond the scope of				-	-
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this				-	-
	Improve Economizer Operation - Switch From Fixed to Active Damper Control	Future Capital Improvement - Not recommended as a	$ **8,043**			-	-

5.5.1. Sensor Calibrations

A number of critical HVAC sensors were found out of calibration during the BMS review. Sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following AHUs were found to have sensors out of

calibration: *Science Building - ACS-1, ACS-10, ACS-11, Multi-Zone*

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.5.2. Valve Leak-by Remediations

Several control valves were found to be leaking by while inspecting the AHUs and BMS. These leaking valves unnecessarily increase energy usage and should be corrected. The leak-by can be attributed to a multitude of factors: age, control pressure/signal, internal wear, etc.

The following AHUs were found to have potential leak-by issues:

Science Building – ACS 3, ACS 6, ACS 10, ACS 20, HV 8, HV 9, HV 12, Multi-Zone

While the exact cause of leak-by could not be determine within the scope of this study, based on our past retro-commissioning experience it is anticipated that the majority of the corrections will require controls/signal repair between the valves and BMS rather than removal or replacement of the existing valves. Though additional troubleshooting will be required by the in house staff we recommend these valves be addressed.

The savings potential is based on eliminating an average of 3 degrees of preheat or chilled water leak-by during the shoulder season. The savings are derived from eliminating the excess heating and cooling loads associated with the leaks. The cost associated with this measure is based on an estimated cost of $2,500 per unit for controls programming and any equipment issue resolution that may be required.

5.5.3. Insulation

During system inspections, several sections of chilled water, steam, and condensate piping were found to be missing insulation. Properly insulated pipe reduces heat losses and gains by a factor of 10 (approximately). As such, we recommend pipe insulation be installed on the identified locations. [redacted]

The savings potential is based on the heating loss savings with the associated campus $10.00 per thousand pound of steam generated from the [redacted] steam plant. Costs were estimated utilizing 2” of pipe insulation on steam pipes and 1” of insulation on chilled water and steam condensate lines.

5.5.4. Glycol Pumps - Install VFDs

The glycol system operates 24/7, servicing the local cooling requirements throughout the building. The system has three constant speed pumps, two of which are in normal operation, with the third acting as a standby pump. Energy could be saved via installing VFD's on the pumps and operating them to maintain system differential pressure. We recommend consider this retro-fit.

Energy savings is estimated based on an average 10% speed reduction and an associated reduction in power consumption of 30%.

5.5.5. Night Setback

The majority of the building’s HVAC systems are constant volume and run 24/7. As systems are renovated, we recommend the implementation of VAV/CV boxes and the might setback strategies. We recommend these be upgraded as part of a campus wide master plan. Please refer to the Site Wide Initiatives / Capital Project Discussion

5.5.6. Pneumatic to DDC Control

The majority of the equipment in the building utilizes antiquated, local pneumatic controls. We recommend these be upgraded as part of a campus wide master plan. Please refer to the Site Wide Initiatives / Capital Project Discussion.

5.6. Medical Research Building Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Medical Research Building.

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Medical Research Building	Repair / Install Missing Pipe Insulation	O&M	$ 1,117	$ 4,429	4.0	2,978	67
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ **967**	$ 250	0.3	2,579	**58**
	Install Static Pressure Sensor, put AC-1 into Active SP Control	O&M - Put AC-1 SAF on active static pressure	$ 24,083	$ 10,000	0.4	64,223	1,445
	Nighttime ToD Setback for Renovated Spaces / Boxes	Capital - Part of Long Term Planning and Renovations. Savings based on 2004 analysis	$ **72,638**	$ -		-	-

5.6.1. Insulation

During system inspections, several sections of chilled water, hot water, and steam piping were found to be missing insulation. Properly insulated pipe reduces heat losses and gains by a factor of 10 (approximately). As such, we recommend pipe insulation be installed on the identified locations. [redacted]

The savings potential is based on the heating loss savings with the associated campus $10.00 per thousand pound of steam generated from the [redacted] central steam plant. Costs were estimated utilizing 2" of pipe insulation on steam pipes and 1" of insulation on chilled water and steam condensate lines.

5.6.2. Sensor Calibrations

A number of critical HVAC sensors were found out of calibration during the BMS review – sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following units were found to have sensors out of calibration:

Medical Research Building– AHU-2, FACS room 307A, Mixing Boxes for rooms 634, 637, 638C

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.6.3. Implement Active Static Pressure Control for AC-1

AC-1 is a hot deck/cold deck AHU, approximately 150,000 cfm and supplies air to the majority of the building's spaces. The unit is fitted with dual supply and return air fans, fitted with VFD's. The VFD's are manually set to run at 85% speed.

The majority of the facility is served by the original, dual duct VAV boxes controlled by a DOS based Siebe control system. The boxes are old and per operating staff problematic. Over the past several years, a number of lab spaces have been renovated. During these renovations, the VAV boxes have been replaced and the controls upgraded to the Environet System.

As the system was designed to be VAV, and the fans are already fitted with VFD's, we recommend a duct static pressure sensor be installed and the VFD's programmed to control around this set point. In this way, additional fan power savings can be realized.

Savings presented for this ECM are based on a modest reduction in fan speed of 5% (estimated).

5.6.4. Nighttime Setback

The majorities of the building HVAC systems are constant volume and run 24/7. As systems are renovated, we recommend the implementation of VAV/CV boxes and the might setback strategies. We recommend these be upgraded as part of a campus wide master plan. Please refer to the Site Wide Initiatives / Capital Project Discussion

5.7. [redacted] Educational Center [redacted]

The following energy conservation measures (ECMs) can be achieved by modifying the [redacted] *Educational Center* [redacted].

	ECM	Note	Savings	Cost	Payback	Annual kwh Savings	Annual klbs Saved
Educational Center	Repair / Install Missing Pipe Insulation	O&M	$ 1,194	$ 5,186	4.3	3,183	72
	Implement Night Setback on AHU-1, AHU-2 and AHU-3	O&M	$ 64,151	$ 9,000	0.1	171,070	3,849
	Night Setback For Fan Coil Units	O&M	$ 10,242	$ 1,000	0.1	27,313	615
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 583	$ 750	1.3	1,555	35
	Repair Leaking Control Valves	O&M	$ 899	$ 1,500	1.7	2,398	54
	1st Floor Lighting Retro-fit	Capital	$ 2,028	$ 10,967	5.4	5,407	122
	Install VFD on Penthouse HW Pump - Convert 3-way	Capital	$ 6,774	$ 16,300	2.4	18,064	406
	Pneumatic to DDC Control Upgrade	Capital -Beyond scope of this assessment				-	-
	Lighting Occupancy Sensors	Capital - Screened out	$ 2,416	$ 16,730	6.9		

5.7.1. Insulation

During system inspections, several sections of hot water and steam piping were found to be missing insulation. Properly insulated pipe reduces heat losses and gains by a factor of 10 (approximately). As such, we recommend pipe insulation be installed on the identified locations. [redacted]:

The savings potential is based on the heating loss savings with the associated campus $10.00 per thousand pound of steam generated from the [redacted] central steam plant. Costs were estimated utilizing 2" of pipe insulation on steam pipes and 1" of insulation on chilled water and steam condensate lines.

5.7.2. AHU-1, 2 and 3 - Nighttime Setback

The building's HVAC systems are constant volume and currently run 24/7. As this building is used for general office space and classroom activities, the opportunity exists to implement a nighttime setback program. Shutting the AHU's and exhaust systems down daily from 10 PM to 6 PM would result in $64,000 in annual savings.

Potential savings are based on the reduction in run hours, fan power and condition

savings. **5.7.3. Fan Coil Unit Time of Day / Unoccupied Setbacks**

Educational Center currently has over 300 fan coil units throughout the building. The fan coil unit system is currently tied into the Honeywell building automation system via electric relays. Originally, the building system was programmed to keep floors B-2 and 9-13 on from 5:50am to 7:50pm and floors 3-8 on from 5:50am to 11:50pm. Upon the [redacted] BMS review, it was noted that the program has been overridden and the system now operates on a 24/7 basis. We recommend consider activating the ToD programing.

Potential savings are based on the reduction in run hours, fan power and condition savings.

5.7.4. Sensor Calibration

Three sensors in AHU-3 were found out of calibration during the BMS review. Sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.
The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.7.5. Valve Leak-by Remediation

Several control valves were found to be leaking by while inspecting the AHUs. These leaking valves unnecessarily increase energy usage and should be corrected. The leak-by can be attributed to a multitude of factors: age, control pressure/signal, internal wear, etc.

The following AHUs were found to have potential leak-by issues:

Educational Building – Supply 1, Supply 2

While the exact cause of leak-by could not be determined within the scope of this study, based on our past retro-commissioning experience it is anticipated that the majority of the corrections will require controls/signal repair between the valves and BMS rather than removal or replacement of the existing valves. Though additional troubleshooting will be required by the in house staff we recommend these valves be addressed.

The savings potential is based on eliminating an average of 3 degrees of preheat or chilled water leak-by during the shoulder season. The savings are derived from eliminating the excess heating and cooling loads associated with the leaks. The cost associated with this measure is based on an estimated cost of $2,500 per unit for controls programming and any equipment issue resolution that may be required.

5.7.6. First Floor Lighting Upgrade

The vast majority of the building is fitted with efficient T-8 lighting, however, T-12 lights were identified on the first floor. As lobby lighting is currently on 24/7, it is typically a cost effective retro-fit. Recently, LED tubes have been introduced that are direct replacements for T-8 and T12 bulbs, eliminating the need to replace ballasts, greatly reducing installation costs.

As the facility has experience with LED lighting retrofits, we recommend [redacted] consider upgrading the stairwell lighting.

5.7.7. Hot Water Pumps – Install VFDs

The hot water system operates seasonally, servicing the local heating requirements throughout the building. The system has two constant speed pumps, one of which is in normal operation, with the second acting as a standby pump. Energy could be saved via installing a VFD on the pumps and operating them to maintain system differential pressure. We recommend the facility consider this retro-fit.

Energy savings is estimated based on an average 10% speed reduction and an associated reduction in power consumption of 30%.

5.7.8. Pneumatic to DDC Control

The majority of the equipment in the building utilizes antiquated, local pneumatic controls. We recommend these be upgraded as part of a campus wide master plan. Please refer to the Site Wide Initiatives / Capital Project Discussion.

5.8. Office Building Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Office Building.

	ECM	Note	Savings	Cost	Payback	Annual kwh Savings	Annual klbs Saved
Office Building	Space Sensor Calibration Issues	O&M	$ 12,654	$ 1,250	0.1	33,744	759
	Stairwell Lighting Retro-fit	Capital	$ **669**	$ 3,145.80	4.7	1,784	**40**

5.8.1. Sensor Calibration

A number of critical HVAC sensors were found out of calibration during the BMS review. Sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following FCUs were found to have sensors out of

calibration: *Office Building – 3rd Floor, 5th Floor, 7th Floor*

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.8.2. Stairwell Lighting

The vast majority of the building is fitted with efficient T-8 lighting, however, T-12 lights were identified in the stairwells. As stairwell lighting is currently on 24/7, it is typically a cost effective retro-fit. Recently, LED tubes have been introduced that are direct replacements for T-8 and T12 bulbs, eliminating the need to replace ballasts, greatly reducing installation costs.

As the facility has experience with LED lighting retrofits, we recommend consider upgrading the stairwell lighting.

5.9. *Educational Building Improvements*

The following energy conservation measures (ECMs) can be achieved by modifying the Educational Building

	ECM	Note	Savings	Cost	Payback	Annual kwh	Annual klbs
Educational Building	Repair / Install Missing Pipe Insulation	O&M	$ 661	$ 691	1.0	1,762	40
	Repair Leaking Control Valves	O&M	$ 1,581	$ 3,000	1.9	4,216	95

5.9.1. Insulation

During system inspections, several sections of hot water, steam, and condensate piping were found to be missing insulation. Properly insulated pipe reduces heat losses and gains by a factor of 10 (approximately). As such, we recommend pipe insulation be installed on the identified locations. [redacted]:

The savings potential is based on the heating loss savings with the associated campus $10.00 per thousand pound of steam generated from the [redacted] central steam plant. Costs were estimated utilizing 2" of pipe insulation on steam pipes and 1" of insulation on chilled water and steam condensate lines.

5.9.2. Valve Leak-by Remediations

Several control valves were found to be leaking by while inspecting the AHUs. These leaking valves unnecessarily increase energy usage and should be corrected. The leak-by can be attributed to a multitude of factors: age, control pressure/signal, internal wear, etc.

The following AHUs were found to have potential leak-by

issues: *Educational Building – Supply 1, Supply 2*

While the exact cause of leak-by could not be determined within the scope of this study, based on our past retro-commissioning experience it is anticipated that the majority of the corrections will require controls/signal repair between the valves and BMS rather than removal or replacement of the existing valves. Though additional troubleshooting will be required by the in house staff we recommend these valves be addressed.

The savings potential is based on eliminating an average of 3 degrees of preheat or chilled water leak-by during the shoulder season. The savings are derived from eliminating the excess heating and cooling loads associated with the leaks. The cost associated with this measure is based on an estimated cost of $2,500 per unit for controls programming and any equipment issue resolution that may be required.

5.10. Staff Housing

No overt operational issues were identified with the Staff Housing systems. The high energy usage of the buildings is attributed to the age of the equipment, their constant volume design and 24/7 operation. Significant energy reductions would require substantial infrastructure changes to the fan coil units and central chiller. These capital projects exceed the scope of this assessment.

5.11. Advanced Research/Office Building Improvements

The following energy conservation measures (ECMs) can be achieved by modifying the Advanced Research/Office Building.

	ECM	Note	Savings	Cost	Payback	Annual kwh Savings	Annual klbs Saved
Adv. Research/ Office Building	Repair Heat Wheels	O&M	$ 72,466	$ 24,000	0.3	193,242	4,348
	Sensor Calibration Issues / Simultaneous heating and	O&M	$ 9,318	$ 3,750	0.4	24,847	559
	Repair Leaking Control Valves	O&M	$ 699	$ 1,500	2.1	1,865	42

5.11.1. Sensor Calibrations

A number of critical HVAC sensors were found out of calibration during the BMS review – sensor readings were either obviously erroneous or in conflict with upstream or downstream sensor readings. These issues contribute to system inefficiencies through over conditioning and simultaneous heating and cooling. We recommend the identified sensors be addressed.

The following units were found to have sensors out of calibration:

Advanced Research/Office Building – AHU-PH-2/RF-PH-2, AHU-PH-5/RF-PH-5, AHU-PH-6/RF-PH-6, AHU-PH-7/RF-PH-7, AHU-PH-8/RF-PH-8, AHU-PH-11, AHU-C-1/RF-C-1, AHU-C-2/RF-C-2, AHU-C-3, AHU-C-4, AHU-C-5, AHU-C-6, AHU-C-9

The savings potential described above is based on engineering rules of thumb for the typical savings associated to resolving calibration issues. The savings are estimated based on conditioning improvements of 2%. Conditioning costs are based on the calculated $/CFM for each unit type. The cost associated to this measure is based on an estimated cost of $250 per sensor.

5.11.2. Valve Leak-by Remediations

Several control valves were found to be leaking by while inspecting the AHUs and BMS. These leaking valves unnecessarily increase energy usage and should be corrected. The leak-by can be attributed to a multitude of factors: age, control pressure/signal, internal wear, etc.

The following AHUs were found to have potential leak-by issues: *Advanced Research/Office Building – SHU-C-4, AHU-C-7, AHU-C-8, AHU-C-9, SAB-B-C-16*

While the exact cause of leak-by could not be determined within the scope of this study, based on our past retro-commissioning experience it is anticipated that the majority of the corrections will require controls/signal repair between the valves and BMS rather than removal or replacement of the existing valves. Though additional troubleshooting will be required by the in house staff we recommend these valves be addressed.

The savings potential is based on eliminating an average of 3 degrees of preheat or chilled water leak-by during the shoulder season. The savings are derived from eliminating the excess heating and cooling loads associated with the leaks. The cost associated with this measure is based on an estimated cost of $2,500 per unit for controls programming and any equipment issue resolution that may be required.

5.11.3. Heat Wheel Remediation

Advanced Research/Office Building penthouse AHUs to the lab spaces are all 100% outside air units with enthalpy wheels. The purpose of the enthalpy wheels is to recover heating and cooling energy from the exhaust air stream. Under design conditions, the wheels should be recovering as much as 60% of the energy stream. Currently, 6 of the 8 energy recovery wheels are not working properly (they are not rotating). As the equipment is only 5 years old, we suspect bearing and belt issues as the most probable cause of the issues and recommended they be remediated as soon as possible.

5.12. Potential Site Wide Initiatives / Capital Projects

5.12.1. Control System Master Plan

As discussed, the most significant factors to the sites excessive energy consumption is the age of much of the infrastructure and the 24/7 operation of almost all of the facilities. This includes the antiquated pneumatic control systems and the current amalgam of different DDC systems. We recommend X consider developing a Control System Master Plan in which the future of the DDC system is defined. This should include the phasing out of all the stand alone pneumatic systems and may or may not include all of the existing DDC systems.

There are benefits to having more than one DDC system in a campus environment. Competition between vendors generally improves pricing and service. However, having as many systems as [redacted] currently does leads to confusion and inefficiencies (In addition to the 4 main DDC systems discussed, there are additional stand-alone control systems on site serving specific dedicated systems). If multiple DDC systems are desired, we recommend developing a Master Specification which details the following; what type of architecture is to be used, types of sensors and control elements, sequences of operation, how graphics are to be laid out and what information is to be presented on them. The Master Spec should then be utilized for all renovations and new construction, ensuring uniformity of installation and operation across all systems. This will improve the operators' abilities to utilize the control systems to their fullest and reduce site energy consumption.

5.12.2. Campus-wide Laboratory Air Optimization

In recent years, the trend to capture energy savings in research facilities has been to reduce normal operating Air Change per Hour (ACH) criteria and to implement unoccupied and/or night ACH setbacks. [redacted] has helped several facilities implement this type of operation and understand a single ACH value cannot be applied across the board; each lab area has different supply and exhaust configurations, pressurization requirements, different research activities with varying air quality requirements as well as equipment densities that can impact lab heat load. Implementing these strategies is not simple and requires careful analysis and long term planning.

Specific to [redacted], the age and variety of systems, space usage and controls pose several challenges. Several opportunities for ACH reductions have been presented in this report. These systems are believed to be the most promising with respect to savings and implementation effort. Additional systems have also been commented on, but the analysis they will require due to their complexity exceeds the scope of this assessment.

In general, we recommend [redacted] consider air optimization as part of all future space renovations. The evaluations should be performed on a room by room basis, and implemented on a room by room basis via BAS controls, VAV fume hoods and VAV/CV boxes. Duct static pressures should be used to control fan speeds. In this way, night setback can be implemented in offices and low load lab spaces while high density areas (common equipment rooms) are unaffected.

6.0 Summary of Energy Savings Potential & Next Steps

After an overarching review of the air handling units, air distribution, heating and cooling systems, our findings indicate the systems were properly installed and are functioning adequately considering designed to conserve energy. As such, the recommendations identified during this assessment are designed to further improve and enhance the current energy strategies already in place.

This project uncovered a total of 210 issues and a total of thirty four (34) recommended energy conservation measures (ECMs) for implementation and further study. At this time, X estimates approximately $621,023 in annual cost savings can be realized as a result of implementing the measures explained in this report. The estimated payback for implementing these improvements is 1 year.

While the majority of strategies presented are relatively easy to implement and can most likely be completed through the expertise of in-house operations staff and qualified contractors, it is highly recommended that [redacted] complete a more detailed analysis, based on the following Action Plan, to determine the full economic benefits and feasibility of implementing the ECMs.

6.1. Action Plan - To be finalized after Draft Review with

To fully achieve the benefits of this project, we recommend the following course of action:

☐ Conduct additional studies to further develop ECMs, including:

- **Retro-commissioning (RCx) of**
- **Pneumatic to DDC Control Upgrade for Research Building 1, Science Building/Research Building 2, Educational Center**
- **Campus-wide Laboratory Air Optimization**

These phase II projects will also assist in identifying additional capital projects.

☐ Implement all Recommended ECMs,

☐ Aggressively close out the Energy Issues presented in the issues database. Due to the skill- of the operations staff, many of these items can be completed in-house.

Based on the findings of this report, we would recommend the buildings be addressed in the following order:

6.2. Additional NYSERDA Programs

Incentive programs from the New York State Energy Research and Development Authority (NYSERDA) and your local utility are available for eligible energy-efficiency projects. Facilities may take advantage of incentives from both NYSERDA and the local utility, but may not receive funding from both entities for the same measure.

Items recommended in this study are primarily operational in nature. Capital investment upgrades most likely require further investigation and analysis. NYSERDA offers cost-sharing on further technical assistance that may have been identified in this report.

[redacted]

- **FlexTech Program:** FlexTech offers up to 50% cost share of eligible energy studies, including energy audits, retro-commissioning and long term energy management.

- **Existing Facilities Program:** The Existing Facilities Program offers rebates and performance-based incentives for installing eligible energy efficiency equipment & systems. To receive performance-based incentives more detailed analysis than that provided in your Benchmarking and Operational Efficiency study is most likely required.

For FlexTech & Existing Facilities Program details, general information about NYSERDA and other funding opportunities, visit the homepage: http://nyserda.ny.gov

7.0 Appendix Data

- NYSERDA Benchmarking Program Appendix A (Application)
- NYSERDA Benchmarking Program Appendix B (Staff Interviews)
- NYSERDA Benchmarking Program Appendix C (CFR)
- NYSERDA Benchmarking Program Appendix D (Issues Database)
- NYSERDA Benchmarking Program Appendix E (Master List of Findings)