HGA

ENERGY AUDIT REPORT

JANUARY 3, 2014

CONTENTS

AUDIT SUMMARY

INTRODUCTION

Hammel, Green and Abrahamson, Inc. (HGA) performed an energy audit on the complex including both the Clinical Science Center and the American Family Children's Hospital. The energy audit identified excellent opportunities to reduce energy consumption while maintaining or improving occupant comfort and indoor environmental quality. The energy audit addressed heating, ventilating, and air conditioning (HVAC) systems, lighting, domestic hot water and the building envelope.

As part of the study, HGA evaluated the energy savings and implementation costs of the most significant opportunities and created a facility improvement measure list. This list provides a starting point for the to begin a comprehensive energy management plan. It enables the facilities group to prioritize measures such that the most cost effective improvements are completed first.

Table 1: Project Timeline

Project Stage	Dates Completed
Kickoff	July 24, 2013
Audit Phase	August-October 2013
Audit Report Complete	October 17, 2013
Cold Weather Review and Follow-Up	October-December 2013

The energy audit focused on identifying opportunities and did not include any reporting requirements or implementation activities. HGA updated Focus on Energy as the audit progressed but did not initiate participation in a Focus on Energy program.

The Clinical Science Center (CSC) is a 3.3 million ft^2 building that includes a hospital with 566 inpatient beds and 117 medical clinics as well as the and research labs. The facility was built in the late 1970s and underwent significant remodel and expansion activity from the mid 1990s through 2009.

The Children's Hospital is a 400,000 ft^2 facility adjacent to the main hospital. The facility houses 61 pediatric beds and associated hospital services. The 2nd floor is primarily an outpatient clinic space. An extensive addition to the upper floors is scheduled for completion in 2014.

Electricity, district steam and chilled water are all supplied from the physical plant. The steam and chilled water rates are quite economical as indicated below in Table 2.

Table 2: Utility unit costs based on most recent 12 months of data

Energy Cost Data		
Electric	Steam	Chilled Water
$0.086/kW-hr	$5.91/MMBtu	$5.89/MMBtu

HISTORICAL UTILITY CONSUMPTION

Prior to the energy audit, HGA reviewed utility data for the building complex. The results are summarized in Table 3. uses more energy than a typical hospital facility. However, due to the low cost of steam and chilled water, the total cost of energy for the facility is *lower* than a comparable building. The Energy Star score is a tool to compare the energy performance of one building with a large database of similar buildings in the US. Energy Star scores range from 0 to 100 – a higher score indicates a more energy efficient building. The current Energy Star score for is 23 and is considered below average. However, HGA recommends the following changes to the Energy Star profile to describe the energy performance of the complex with more accuracy:

- Calculate two separate energy star scores for CSC and CH to provide more detailed feedback for each facility.
- Modify the space use data in the Energy Star system to better reflect actual usage. For example, CSC is listed as 100% hospital. However, a significant portion of the building includes labs which use over twice the energy of typical hospital spaces.
- Subtract the interstitial space square footage from the overall square footage of the building. Energy Star does not include interstitial space as part of overall building square footage. This change will lower the overall score for CSC.

Table 3: Energy Benchmarks for CSC and CH

Energy Benchmarks for CSC & CH, July 2012-June 2013						
Building	**Area [ft^2]**	**Energy Use Intensity - Site [kBTU/ft^2/yr]**	**Energy Use Intensity - Source [kBTU/ft^2/yr]**	**Energy Cost [$/yr]**	**Energy Cost Intensity [$/ft^2/yr]**	**Energy Star Score (1-100)**
CSC	3,300,000	289	431	$8,328,000	$2.52	23
CH	400,000	195	332	$839,000	$2.10	

AUDIT FINDINGS

HGA identified over 20 significant measures to reduce energy consumption at the hospital. HVAC improvements accounted for the majority of the measures in addition to some lighting improvements.

The most significant savings identified are related to equipment scheduling. Certain spaces are currently conditioned 24/7 but are only occupied for a fraction of that time, including the clinic spaces and research offices and labs. In many cases, existing control systems must be upgraded to allow more precise control options. At present, an air handler may operate at full capacity even if only one of a dozen spaces actually requires conditioning. That system should have the ability to adjust flow based on the actual needs of its spaces.

Significant savings were also identified in the lab spaces. Labs use an enormous amount of energy due to the large amounts of outside air and exhaust air required to provide proper ventilation. There are over 100 fume hoods in the facility, atypical for a hospital. HGA identified 2 measures that would reduce energy associated with the hoods by over 50%. Saving energy on these hoods would bring the energy consumption profile of the building more in line with a typical hospital.

The lighting products in the hospital are efficient fluorescent fixtures with the exception of some incandescent lighting in a limited number of dimming applications. The energy audit identified areas where better controls could turn off lights when spaces are vacant. These areas included the basement, interstitial spaces, mechanical rooms and intermittently occupied spaces such as conference rooms, exam rooms and break rooms.

In general, the HVAC systems in the building are well maintained. The audit identified few maintenance related energy saving measures as compared to a similar facility.

In the long term, many capital intensive upgrades could improve energy performance:

- Seal supply and exhaust ducts in areas identified with high leakage
- Replace constant volume terminal boxes with variable volume units in select areas
- Retrofit pneumatic terminal box controls to DDC controls in spaces not operated 24/7
- Retrofit constant volume fume hoods to variable volume fume hoods
- Improve lighting controls and light levels

HGA encourages the construction and facilities groups to collaborate on upcoming projects to incorporate these capital intensive upgrades with upcoming remodel and renovation projects. Additionally, the hospital should continue to use 3rd party commissioning firms for renovations that concern HVAC systems. Commissioning that starts in the planning stage and continues through system handover will improve reliability, energy performance and maintainability.

The sum of steam, water, chilled water and cost savings for all measures are shown in Table 4. If all measures were implemented, energy consumption would drop by almost 20%.[1] The cost of those measures would pay themselves back within 4 years, with a total implementation cost of $7.3 million dollars.

Table 4: Audit annual savings summary for identified measures

Steam Savings	Electric Savings	Chilled Water Savings	Cost Savings	Cost Avoidance	Simple Payback
15.5%	20.9%	28.1%	19.7%	$1,805,182/yr	4.0 yrs

[1] Interactions between the measures were not calculated at this time. These interactions would slightly reduce overall savings. A more accurate calculation of savings can be performed once an implementation plan with all final measures is approved.

The most significant energy saving measures are summarized in Table 5. Measures are grouped by type and listed in ascending order based on simple payback. Measures with less significant savings are summarized in the main body of this report in the "Additional Measures" section.

Table 5: List of Potential Energy Saving Measures

Type	ID#	EEM	Total Cost Savings ($/yr)	Estimated Installed Cost ($)	Payback (yrs)
HVAC- AHUs	M1	Change economizer switchover from 23 Btu/lb to 28 Btu/lb	$66,248	$1,000	0.0
HVAC- AHUs	M2	On AFCH AHU's, modify economizer switchover from 55°F to 28 Btu/lb (or 65°F)	$8,758	$2,500	0.3
HVAC- AHUs	M3	Eliminate humidification on units that have no humidity requirements or reduce setpoints	$137,759	$5,000	0.3
HVAC- AHUs	M4	Verify OA and exhaust requirements, then rebalance AHU's for specified outside air	$128,437	$40,000	0.3
HVAC- AHUs	M5	Re-implement DA temperature reset strategies for CV AHUs	$35,141	$40,000	1.1
HVAC- AHUs	M6	Resolve AHU damper and valve issues	$178,126	$250,000	1.4
HVAC- AHUs	M7	Improve scheduling of air handlers and tighten up schedules	$0	-	-
HVAC- AHUs	M8	Add drives to the CV AHU's that serve VAV system	$4,237	$30,000	7.1
HVAC- AHUs	M9	Seal supply ductwork on units with excessive leakage	$165,353	$930,000	5.6
HVAC- AHUs	M10	Seal exhaust ductwork on units with excessive leakage (calculation forthcoming)	$13,048	$160,912	12.3
HVAC- Boxes	M11	Schedule VAV boxes for non-24/7 spaces in AFCH	$15,586	$1,000	0.1
HVAC- Boxes	M12	Schedule existing DDC VAV's for non-24/7 spaces in CSC	$38,968	$15,000	0.4

Type	ID#	EEM	Total Cost Savings ($/yr)	Estimated Installed Cost ($)	Payback (yrs)
HVAC- Boxes	M13	Replace constant volume terminal boxes with VAV units	$352,166	$1,800,000	5.1
HVAC- Boxes	M14	Replace pneumatic VAV boxes with DDC boxes for non-24/7 space and implement scheduling	$139,168	$1,462,500	10.5
HVAC- Hoods	M15	Rebalance fume hood exhaust and supply to meet current standards of 100fpm at 18" sash height	$142,444	$51,000	0.4
HVAC- Hoods	M16	Decommission unused hoods	$26,029	$5,000	0.2
HVAC- Hoods	M17	Replace constant volume hoods with VAV hoods	$108,844	$1,216,800	11.2
Lighting	M18	Implement day lighting control in cafeteria atrium areas	$5,269	$10,000	1.9
Lighting	M19	Install lighting control in interstitial spaces	$62,974	$330,000	5.2
Lighting	M20	Install occupancy sensors or vacancy sensors for rooms that are intermittently used such as exam rooms, conference rooms and break rooms	$11,866	$100,000	8.4
Lighting	M21	Replace basement mercury vapor lighting with LED in conjunction with lighting control	$6,509	$75,000	11.5
		(additional measures)	$158,250	$756,000	5
Total Identified			**$1,805,182[2]**	**$7,281,712**	**4.0***

[2] As stated earlier, interactions between the measures were not calculated at this time. These interactions would slightly reduce overall savings. A more accurate calculation of savings can be performed once an implementation plan with all final measures is approved

IMPLEMENTATION PLAN

The following section outlines a strategy for implementing the energy conservation measures.

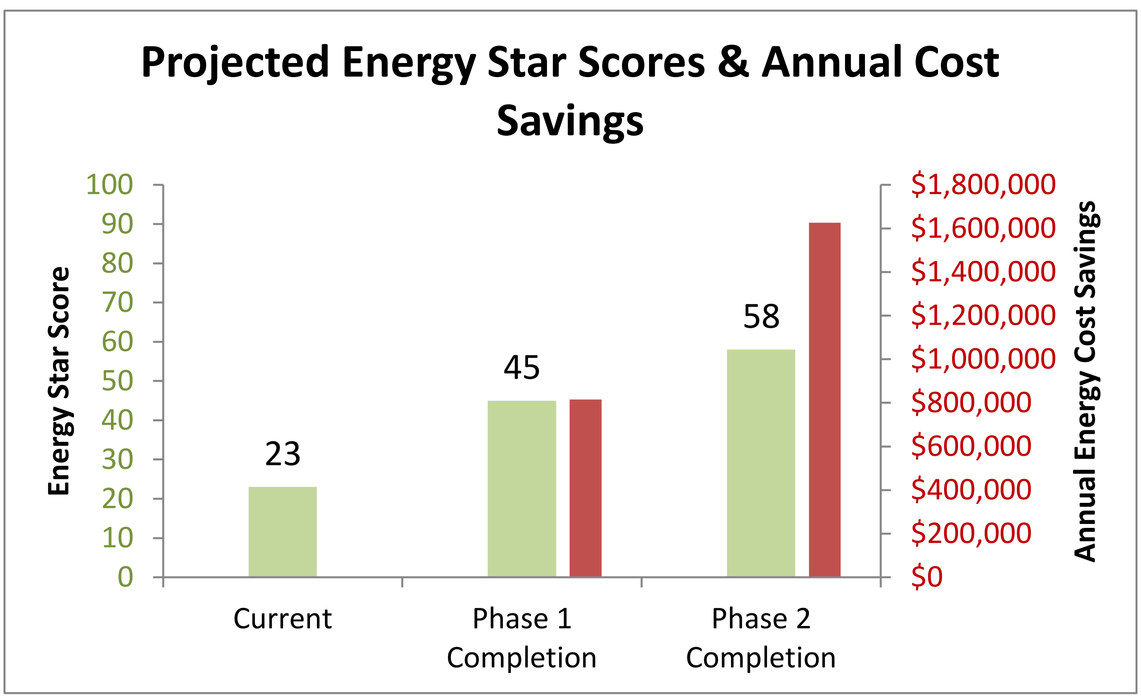
Phase 1 Measures

All measures with a simple payback less than 2 years should be completed as soon as possible. These measures are referred to as the "Phase 1" measures. would also be eligible to receive Focus on Energy incentives for these measures through the Retrocommissioning program, which would further reduce the simple payback of these measures.

Phase 2 Measures

All measures with a simple payback between 2 to 12 years should be incorporated into hospital remodel projects. These measures are referred to as "Phase 2" measures. The implementation costs of these measures may also be reduced when incorporated with remodel projects, further reducing the simple payback of the measures. It is recommended that the first set of Phase 2 energy efficiency measures implemented be monitored to further refine the costs and energy savings identified in this report. Using this feedback, the implementation strategy can be adjusted based on the actual measure cost and energy savings. In some cases, Phase 2 measures may make economic sense to implement independent of remodels, especially in areas that have no planned remodels.

Figure 1: Projected Energy Star Score and Cost Savings Based on Existing Space Classification



IDENTIFIED ENERGY EFFICIENCY MEASURES

OVERVIEW

The following section provides further detail for each energy efficiency measure. Each section includes a description of the measure, a breakdown of the utility savings and an implementation strategy.

In moving to the implementation phase, HGA recommends a 2 stage process. Stage 1 would be a trial for just one area of the hospital. After implementation, the results of stage 1 would be evaluated. Assuming a first stage success, stage 2 would take implementation of the measure throughout the facility and incorporate lessons learned during stage 1. This approach will improve the success of implementation by identifying issues such as occupant comfort or equipment operation problems early on and ease acceptance of the measures as they spread through the facility.

HVAC MEASURES

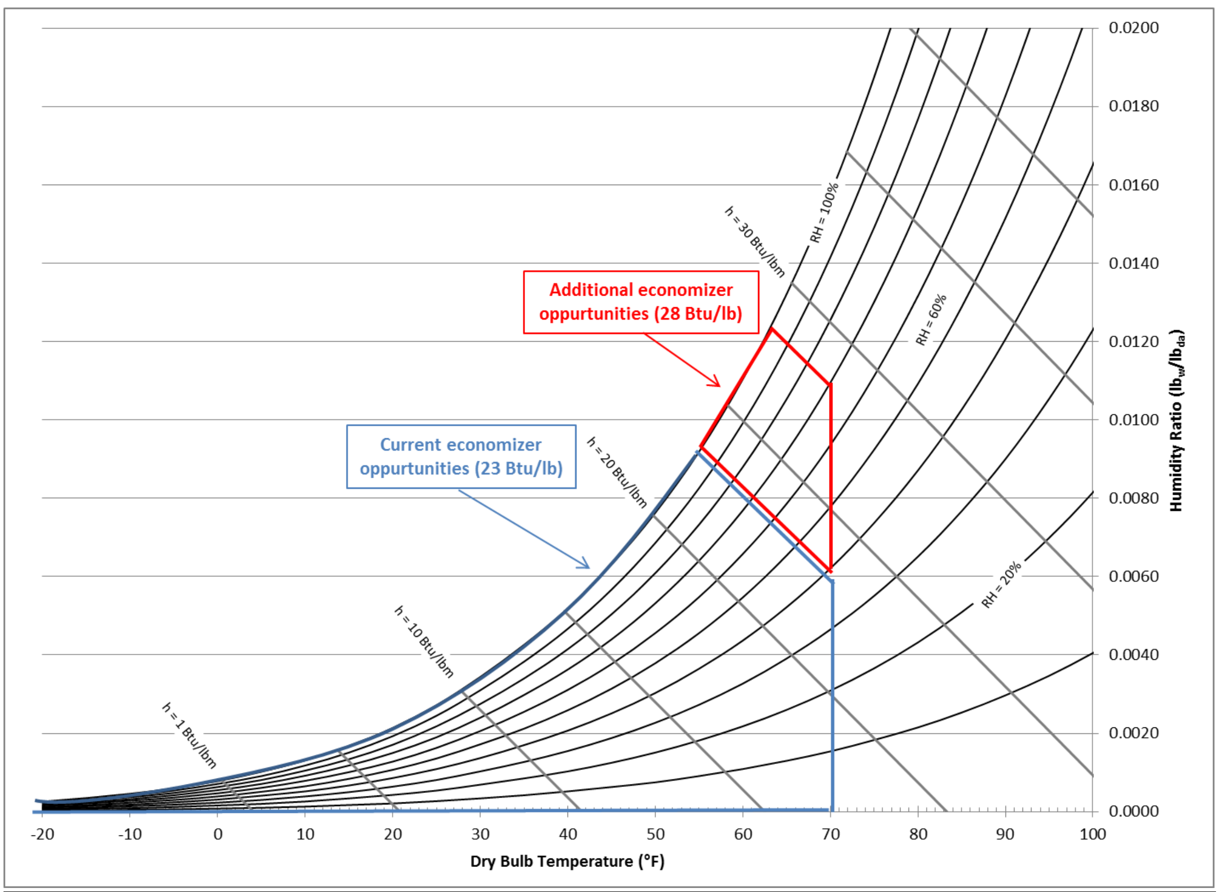
AIR HANDLING UNIT MEASURES

EEM #1 – CSC: Increase Economizer Changeover Outside Air Enthalpy Setpoint

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	-	11,248	$66,248	$1,000	0.0

Measure Description:

Currently at the CSC, the economizer of all air handlers is disabled when the outside air enthalpy is greater than 23 Btu/lb. Historically the switchover enthalpy was 28 Btu/lb but was changed to 23 Btu/lb to accommodate for issues associated with the newly installed AHU-100's. However, 28 Btu/lb is a more optimal setpoint, while still maintaining proper humidity levels in the space.



Implementation Strategy:

This is a setpoint change that can be made the in Metasys software. AHU-100's would need to have an independent economizer switchover point if there is still an issue with economizing above 23 Btu/lb.

EEM #2 – AFCH: Increase Economizer Changeover from 55°F to 65°F Outside Air Temperature

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	-	1,487	$8,758	$2,500	0.3

Measure Description:

Currently at the AFCH, the economizer is disabled when the outside air temperature is over 55°F. However, there are a substantial number of hours above 55°F where free cooling (or economizer) is more efficient than utilizing chilled water, while still maintaining the required discharge temperature and humidity. HGA recommends that the economizer switchover is increased to 65°F.

Implementation Strategy:

This is a simple setpoint change that can be made the in Trane Tracer software.

EEM #3 – CSC: Eliminate Humidification in Areas with No Humidity Requirements

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	23,313	-	$137,759	$5,000	0.3

Measure Description:

All air handlers throughout the hospital are equipped with direct injection steam humidifiers supplied by the campus district steam system. Many currently humidified clinics, offices, and laboratory spaces do not require any humidification as per *ASHRAE Standard 170- Ventilation of Healthcare Facilities*. In addition, those areas with minimum humidification levels are typically operating with more humidity than required. Based on HGA observations, 85% of the air handlers do not need to be humidifying based on code requirements.

HGA recommends that these spaces are further evaluated to more carefully determine their humidity requirements. If there are no requirements, HGA recommends that the humidification setpoints are reduced to 0% and to valve off the humidifiers.

The table below summarizes the code required humidification levels. For a small number of spaces, such as the TLC and the burn unit, the current humidity setpoints are actually lower than those required by code.

Space Type	Minimum Humidity Requirement
Surgery and Operating Rooms	20%
Burn Unit	40%
TLC	30%
Recovery Room	20%
In-Patient Room	N/R
General Office	N/R
Research Lab	N/R

According to *ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality*, the water for humidifiers should be "… originated directly from a potable source or from a source with equal or better water quality. " The campus steam system should be investigated to ensure that proper indoor air quality is provided in the Complex.

Implementation Strategy:

Before changing humidity levels, the humidity requirements of each space should be assessed. Once a new humidity setpoint is chosen, the change is very easy and requires no additional cost.

In addition, humidifiers could be scheduled to run only when the spaces are occupied.

EEM #4 – CSC: Rebalance Outside Air to Specified Values

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	12,674	9,091	$128,437	$40,000	0.3

Measure Description:

On a design day, HGA collected all the mixed air, outside air and return air temperatures and calculated the outside air percentage. 29 air handlers were found to have outside air percentages greater than specified and 15 air handlers had significantly less outside air than specified. HGA recommends that the air handlers are further investigated and rebalanced as required to meet the specified outside air requirements.

The following air handlers had outside air quantities 10% greater than or less than the specified values as compared to the 2002 TAB reports from PSA.

AHU Tag	Module	Space Use	Actual OA% - Specified OA%
AHU's with Excess Outside Air			
AHU-15	H4/1	Cafeteria	49%
AHU-09	G5/1	Auditorium, offices	48%
AHU-01	K6/1	School of Nursing offices	40%
AHU-75	E3/2	Rehab clinic	39%
AHU-88		MRI spaces	33%
AHU-46	D4/6	in-patient	33%
AHU-07	H6/4	Peds clinic and offices	32%
AHU-78	H4/8	admin offices	31%
AHU-23	H4/5	allergy and cardio office with some lab	26%
AHU-04	H6/2	Nursing offices, some labs	25%
AHU-35	D6/1	Central supply	23%
AHU-66	B6/3	TLC, anesthiology	22%
AHU-29	E5/5	in patient support spaces and office	22%
AHU-20	F4/3	Ophthalmology offices and labs	21%
AHU-48	K4/B	Radiotherapy	21%
AHU-05	K6/3	Nursing offices and labs	20%
AHU-68	B4/3	Burn unit	19%
AHU-12	F6/4	In patient	19%
AHU-10	G5/2	Town Square	18%

AHU Tag	Module	Space Use	Actual OA% - Specified OA%
AHU-06	H6/3	Surgical offices	18%
AHU-44	D4/4	in-patient	17%
AHU-77	H4/7	surgery offices and labs	17%
AHU-61	C5/3	Dialysis and infusion	17%
AHU-03	K6/2	Nursing offices	16%
AHU-65	B6/6	in patient	16%
AHU-18	F4/2	Surgery clinic	15%
AHU-80	A7, C&/2&3, D6/2	TLC	14%
AHU-32	E5/3	1st day surgery	11%
AHU-17	H4/2	Ortho Clinic	11%
AHU's with Inadequate Outside Air			
AHU-38	D6/4	In patient	-11%
AHU-70	B4/5	in patient	-11%
AHU-02	H6/1	Simulation center	-12%
AHU-21	H4/4	peds office and research	-13%
AHU-76	E3/3	Radiology	-15%
AHU-71	B4/6	in patient	-16%
AHU-56	J5/2	Cancer clinic	-20%
AHU-63	B6/4	in patient	-23%
AHU-11	G5/3	Doc surgery office	-26%
AHU-31	E5/2	Admissions and pharmacy	-35%
AHU-42	D4/2	Cytology labs	-36%
AHU-28	F6/3	Cardiology surgery	-37%
AHU-39	D6/5	in patient	-42%
AHU-54	K4/6	cancer center offices	-70%

Implementation Strategy:

Air handler dampers and sensors should be evaluated to determine if they are functioning properly. If they are functional, a balancer should be brought in to rebalance the units to the specified cfm quantities. Most of this work can be completed without impacting hospital operations.

EEM #5 – CSC: Re-implement Temperature Reset for Constant Volume AHU's

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	5,947	-	$35,141	$40,000	1.1

Measure Description:

As part of the 2004WEI energy efficiency projects implementation, discharge temperature reset was implemented on most of the constant volume air handlers. This strategy was implemented by locating zone sensors in one room or return duct served by the AHU. The AHU discharge temperature setpoint was then modified based on whether any single thermostat needed cooling. Based on feedback from the facilities staff, many air handlers no longer use this reset strategy because of issues caused by resetting the AHU temperature based off of just one zone temperature.

In an ideal world, all the boxes would be DDC controlled and the temperature reset would incorporate temperature data from all boxes. Additionally, the VAV boxes serving core spaces (and high cooling loads) would be slightly oversized to allow the discharge air temperature reset to go upwards. As spaces are remodeled, HGA recommends that all boxes are retrofitted or replaced to allow DDC capability.

HGA proposes that duct reset strategies are revisited and improved.

Implementation Strategy:

The majority of time spent on this measure would be in identifying the reasons why this measure was not successful in the first place. Additional zone sensors may need to be installed. This measure would be part of a typical retrocommissioning project.

EEM #6 – CSC: Resolve AHU Damper and Valve Issues

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	20,214	9,963	$178,126	$250,000	1.4

Measure Description:

During the energy audit, HGA documented all air handlers operating in both full economizer mode and in full cooling mode on a design day. The performance of numerous air handlers suggested issues with chilled water valves, heating valves and control dampers. HGA suggests that these issues are further investigated and to repair issues where observed.

Implementation Strategy:

- Follow up on issues to determine if problem exists
- Repair issue
- Verify unit functions properly

EEM #7– CSC: Modify Air Handler Operation Schedules

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
-	-	-	$0	-	-

Measure Description:

Currently, there are schedules associated with some air handlers that serve spaces that do not operate 24/7. However, these schedules are applied to very few areas because there have historically been issues with shutting down air handlers including the following issues:

- 1-2 spaces overheat when the air handler goes off. Typically, these spaces contain a -80°C lab freezer or other device that rejects a significant amount of heat to the space.
- Occupants using the facility at odd hours complain their space is too warm/cold
- With stand-alone pneumatic control, there is no space temperature monitoring that can initiate the AHU to come on for a night heating/cooling setpoint. Facilities staff are concerned that critical spaces may over-heat/cool and result in dissatisfied occupants.
- Many non-24/7 spaces are labs with exhaust hood that must be supplied with make-up air by the AHUs to prevent the building pressure from going negative.
- Some clinic spaces may contain protective environment (PE) rooms that require positive pressure 24/7 and therefore require the AHU to be on

VAV box zone scheduling, recommended in a separate ECM, is one way to deal with troublesome spaces. However, the maximum energy will be saved if the units can be turned off when spaces are not occupied. A few solutions to eliminate the hot space issues would be the following:

- Capture heat generated at source and exhaust it into the interstitial space using a small exhaust fan
- Utilize water cooled freezers to eliminate the source of the heat rejection
- Install local cooling units, such as a fan coil unit, to provide space cooling to the one hot space

Due to the dynamic nature of the spaces and the continual repurposing, it is often difficult and expensive to engineer the solutions identified above. Therefore, VAV zone scheduling provides a good solution.

There were some spaces that may be able to be scheduled and were possibly overlooked in previous schedule implementation. Additional investigation should be completed to determine if the AHU's could be shut down at night on weekdays without impacting space operations. This includes the units listed below.

AHU Tag	Module	Space Use
AHU-20	F4/3	Ophthalmology office and labs
AHU-11	G5/3	Surgical Doctor's Offices
AHU-52	K4/4	Cancer labs
AHU-53	K4/5	Cancer labs and offices
AHU-54	K4/6	Cancer center offices
AHU-61	C5/3	Dialysis and infusion clinic
AHU-21	H4/4	Pediatric research and offices
AHU-62	B6/2	Specialty clinics
AHU-58	H4/6	Ob/gyn offices and labs
AHU-77	H4/7	Surgery offices and labs
AHU-3	K6/2	Nursing offices

Implementation Strategy:

would need to work with the space occupants to determine if additional scheduling can be implemented. Savings for this measure were not calculated because the success of implementation is unknown and the persistence of these measures tends to be short. Rather, savings were calculated for all these AHUs using the VAV zone scheduling and the CV to VAV conversion outlined a separate ECM.

EEM #8 – CSC: Add Drives to Supply and Return Fans on Air Handlers Serving VAV Boxes

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
49,091	-	-	$4,237	$30,000	7.1

Measure Description:

Currently there are two air handlers that serve mainly VAV boxes, but the AHU is a constant speed unit. AHU-90 and 91 serving K4/5 and K4/6 are the two units that have this condition. It is very atypical to have a constant speed fan installed in an AHU that serves VAV boxes – in this scenario, the energy benefits realized with the VAV boxes are not fully achieved. Additional investigation should be completed to verify that a drive would not negatively impact the performance of this unit.

Implementation Strategy:

This measure could be completed without affecting occupant activities. The motors need inverter duty – if not, they must be replaced. Variable Frequency Drives would be installed and connected to the building automation system. A duct static pressure sensor would also need to be installed in a suitable location, typically 2/3rds down the supply duct. The supply fan speed would be modulated to maintain the duct static pressure. The return fan would be controlled using data from a flow station, a return plenum pressure sensor, or using a different strategy.

Figure 2: Typical variable frequency drive

EEM #9 – CSC: Seal Supply Ductwork with Excessive Leakage

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
1,916,025	-	-	$165,353	$930,000	5.6

Measure Description:

Excessive supply ductwork leakage and AHU enclosure leakage was observed in this audit and documented in previous TAB work. Many of the supply air systems, especially in the original Phase 1 and Phase 2 areas have duct leakage in the 20-40% range. Current duct construction practices typically have duct leakage no greater than 5-10%.

HGA recommends that the worst offending areas are sealed. Duct leakage tests should be performed before and after sealing to verify the effectiveness of the work. The table below summarizes the worst performing AHU supply systems. Leakage was based on the 2002 TAB report, where leakage was assumed to be the difference between the air handler discharge cfm minus the sum of the diffusers. The calculation included savings from resealing all units with 20% or greater leakage.

After sealing, the areas served should be rebalanced and the supply and return fans should be resheaved, or slowed down to the appropriate speed with a variable speed drive.

AHU Tag	Module	Space Use	% Duct Leakage*
AHU-28	F6/3	Cardiology surgery	39%
AHU-22	F4/4	In patient beds	37%
AHU-39	D6/5	In patient	31%
AHU-31	E5/2	Admissions and pharmacy	30%
AHU-14	F6/6	In patient	29%
AHU-40	D6/6	In patient	28%
AHU-12	F6/4	In patient	28%
AHU-38	D6/4	In patient	27%
AHU-44	D4/4	In patient	27%
AHU-43	D4/3	Interventional radiology	26%
AHU-13	F6/5	In patient	26%
AHU-11	G5/3	Doc surgery office	26%
AHU-17	H4/2	Ortho Clinic	26%
AHU-30	E5/1	Central supply	25%
AHU-25	F4/6	In patient	25%
AHU-37	D6/3	OR	25%
AHU-46	D4/6	In patient	25%

AHU Tag	Module	Space Use	% Duct Leakage*
AHU-08	H6/5	med school offices and labs	25%
AHU-15	H4/1	Cafeteria	24%
AHU-91	K6/5	cancer research and offices	22%
AHU-18	F4/2	Surgery clinic	22%
AHU-54	K4/6	cancer center offices	21%
AHU-41	D4/1	facilities shops, staff office, control room	21%
AHU-23	H4/5	allergy and cardio office with some lab	21%
AHU-34	E5/6	in patient support and offices	20%
AHU-71	B4/6	In patient	20%
AHU-24	F4/5	In patient	20%
AHU-78	H4/8	admin offices	20%
AHU-42	D4/2	Cytology labs	20%
AHU-04	H6/2	Nursing offices, some labs	20%
AHU-20	F4/3	Ophthalmology offices and labs	20%

*- Leakage was based on the 2002 TAB report, where leakage was assumed to be the difference between the air handler discharge cfm minus the sum of the diffusers. The calculation included savings with resealing all units with 20% or greater leakage.

Implementation Strategy:

The hospital has completed duct sealing in previous areas and has the experience to continue the efforts. An excellent starting point would be duct sealing spaces that are short on flow. Whenever spaces are remodeled, ductwork should be sealed. Air handlers should also be resealed at this time, including a re-gasketing of doors and sealing of open penetrations in the units themselves.

EEM #10 – CSC: Seal Exhaust Ductwork with Excessive Leakage

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
163,101	-	-	$13,048	$160,912	12.3

Measure Description:

Many exhaust air systems were documented to have high leakage; some exhaust systems were measured by the TAB contractor with a leakage rate over 45%.

HGA recommends sealing for the worst offending areas. Duct leakage tests should be performed both before and after sealing to verify the effectiveness of the work. Aeroseal is a new duct sealing product with many claims of success in hospital settings with inaccessible exhaust duct shafts and other challenging locations.

After sealing is performed, the areas served by the exhaust fan should be rebalanced and the exhaust fan should be resheaved, or slowed down to the appropriate speed if on a variable speed drive.

EF Tag	Location	Areas Served	% Duct Leakage*
TE-10	PH/E6	4,5,6/E5, 3/D6, 3/F6	48%
E-2	PH/K7	Tunnel,1,2,3/K6	39%
GE-6G-4	PH/F7	E7/3	37%
TE-14	PH/D5	4,5,6/D4, 1,2,3/D5, 2,4,5,6/D6	37%
E-34	PH/D3	1,2,3,4,5,6/D4	36%
E-17	PH/G4	3/G5, Tunnel/G4	36%
TE-11A	PH/D7	1,4,5,6/D6	30%
E-23	PH/D7	1,3/D6	30%
TE-7	PH/F7	1,2,3,4,5,6/F6	29%
E-12	PH/G5	G5 tunnel	26%
E-3	PH/K5	1,2,3,PH/K5	25%
GE-2E-3	X3/B5	1,2,3,4,5,6/B5, 2/B6	25%
GE-4G	406/D7	3/E7	24%
E-4A	PH/J6	1,2/H6	24%
E-36	PH/E5	1,2,3,4,5,6/E5	23%
E-14	PH/F7	1,2,3,4/F6	22%
TE-12	PH/F3	1,2,3,4,5,6,/F4, 2/G5	22%
TE-2G-7	PH/B7	2,3,4,5,6/B6	20%

EF Tag	Location	Areas Served	% Duct Leakage*
TE-11D-6	X6/L4	2,3,4,5,6/L4, 2,3,4,6/K4	19%
TE-8	PH/G4	1,2,3,4,5,6/G4, 1/G5, 5/H4	19%
E-6	PH/H7	1,2,3,4,5,/H6	19%

*- Leakage was based on the 2002 TAB report, where leakage was assumed to be the difference between the exhaust fan cfm minus the sum of the exhaust inlet grilles. The calculation included savings with resealing exhaust ductwork with 20% or greater leakage.

Implementation Strategy:

The hospital has completed duct sealing in previous areas and has the experience to continue the efforts. Whenever spaces are remodeled, ductwork should be sealed during the construction process.

TERMINAL BOX MEASURES

EEM #11 – AFCH: Schedule VAV Boxes Serving non-24/7 Spaces

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
98,183	817	388	$15,586	$1,000	0.1

Measure Description:

There is significant space in the Children's Hospital that is not used 24/7 (such as the 2nd floor clinic space). Ideally, air handlers can shut down during unoccupied times. However, in many cases, the air handler may need to serve other 24/7 spaces or maintain positive pressure in spaces. An alternative to turning the air handler off is to schedule VAV boxes that serve areas that do not need to maintain positive pressure or ventilation.

HGA proposes that all the VAV boxes that serve non-24/7 spaces (without pressure requirements) are scheduled to the unoccupied mode when the spaces are vacant. During unoccupied mode, the temperature set points would be relaxed slightly. If the temperature was satisfied in the space, the minimum air flow would be set to 0 cfm. The proposed VAV box parameters in the unoccupied mode would be as follows:

Occupied schedule: Based on specific space requirements

Unoccupied Setpoints:

Heating setpoint: 68°F
Cooling setpoint: 76°F
Maximum cooling cfm: same as occupied mode
Minimum cooling cfm: 0 cfm
Maximum heating cfm: same as occupied mode
Minimum heating cfm: same as heating cfm

During the unoccupied mode, the space temperature would continue to be maintained at comfortable temperatures, but the deadband would be increased to reduce the amount of simultaneous heating and cooling taking place in adjacent spaces with different setpoints. Where return boxes are installed, unoccupied control would also need to be coordinated with the return box.

Because the minimum cfm is reduced to zero, the total airflow that the associated AHU is delivering will be reduced, thereby reducing the supply and return fan energy consumption. The AHU airflow reduction will also reduce the amount of cooling required in the cooling season.

Implementation Strategy:

AFCH VAV and return boxes are already controlled by the building automation system. Scheduling of the boxes would require no capital investment and would only require a few hours of time from the zone mechanic to identify areas that should be scheduled, a few hours from the Trane tech to make the programming changes and a few hours to verify that the changes work as intended.

HGA has had great success with this strategy and often the occupants never realize that any changes have been made. In situations where people come in during typically unoccupied hours, the manual override on the thermostats (where installed) can be used to bring the box into an occupied mode.

EEM #12 – CSC: Schedule DDC Controlled VAV Boxes Serving Non-24/7 Spaces

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
245,457	2,043	970	$38,968	$15,000	0.4

Measure Description:

This is an identical measure to that described in EEM #11. While the majority of the boxes in the Clinical Science Center (Main Hospital) are controlled with stand-alone pneumatic controls, there are some addition and remodel spaces that have DDC controlled VAV boxes. Where these boxes serve non-24/7 space, HGA recommends that boxes are scheduled using the same strategy identified earlier at AFCH. The following areas could be further evaluated for VAV box scheduling:

- 1st Day Surgery (E5/3)
- OB/Gyn Office and Labs (H4/6)
- Cancer Clinic (J3/1)
- Radiotherapy (K4/B)
- Therapeutic Radiology (L5/B)
- Therapeutic Radiology (L7/B)

Implementation Strategy:

Scheduling of the boxes would require no capital investment and would only require a few hours of time from the zone mechanic to identify areas that should be scheduled, a few hours from the JCI tech to make the programming changes and a few hours to verify that the changes work as intended.

EEM #13 – CSC: Replace Select Constant Volume Terminal Boxes with DDC Controlled VAV Boxes

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
2,794,100	12,252	6,560	$352,166	$1,800,000	5.1

Measure Description:

There are numerous areas served by constant volume terminal boxes that are better suited to VAV boxes. Constant volume boxes are generally suited for spaces with non-varying loads or spaces that have high air change requirements. However, using constant volume boxes in space with varying loads results in excessive reheat energy because most of the time more air is being delivered to the space than required. To avoid overcooling the space, the air needs to be reheated by the reheat coil.

Additionally, upgrading to a DDC controlled VAV box enables the box to be scheduled when it serves spaces that are not occupied 24/7.

The following table outlines areas that are good candidates for converting from constant volume to VAV (and DDC) boxes. This table includes all the areas served by constant volume boxes except modules that have patient rooms, central supply, lab intensive areas and other spaces requiring high air changes.

AHU Tag	Module	Space Use
AHU-08	H6/5	Med school offices and labs
AHU-11	G5/3	Doc surgery office
AHU-17	H4/2	Ortho Clinic
AHU-19	H4/3	Surgical offices and research labs
AHU-20	F4/3	Ophthalmology offices and labs
AHU-21	H4/4	Pediatric office and research
AHU-23	H4/5	Allergy and cardio office with some lab
AHU-31	E5/2	Admissions and outpatient pharmacy
AHU-41	D4/1	Facilities shops, staff office, control room
AHU-50	K4/2	Chemotherapy
AHU-51	K4/3	Oncology offices and labs
AHU-52	K4/4	Cancer labs
AHU-53	K4/5	Oncology offices and labs
AHU-54	K4/6	Cancer center offices
AHU-55	J5/1	Office, Mendota market, mezzanine
AHU-61	C5/3	Dialysis and infusion

Implementation Strategy:

Implementation of this measure would be best coordinated with the construction team to coincide with area remodels and renovations. It may be possible to complete this work in coordination with the occupants without affecting occupancy for flexible and non-critical spaces.

EEM #14 – CSC: Replace non-24/7 Pneumatic VAV Boxes with DDC VAV Boxes

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
876,631	7,296	3,464	$139,168	$1,462,500	10.5

Measure Description:

Approximately 50% of all the terminals in the hospital are constant volume boxes while the other half are variable volume (VAV) boxes. Of the VAV boxes, 90% of them are stand-alone pneumatically controlled. Approximately half of these VAV spaces are not occupied 24/7 and would be well suited to VAV box scheduling as outlined in the previous measure. However, stand-alone pneumatically controlled boxes cannot be scheduled. Replacement of the pneumatic boxes with DDC boxes would make this scheduling possible. In some instances, tying an occupancy sensor into the VAV box control would be advantageous, when use is intermittent and not consistent from day to day.

Units listed below that are successfully scheduled off at night should be the last areas to be retrofitted. The following areas are good candidates for converting from pneumatic to DDC boxes based on the space usage:

Scheduled	AHU Tag	Module	Space Use
N	AHU-002	H6/1	Simulation center
N	AHU-003	K6/2	Nursing offices
N	AHU-010	G5/2	Town Square
N	AHU-018	F4/2	Surgery clinic
N	AHU-027	F6/2	ASC
N	AHU-062	B6/2	Specialty clinics
N	AHU-077	H4/7	Surgery offices and labs
N	AHU-081	K4/7	Surgery office with some coolers
N	AHU-082	K4/8	Neurology office and labs
N	AHU-083	K4/9	School of medicine office and labs
N	AHU-102	G7/1	Transplant clinic
N	AHU-103	G3/1	Breast clinic
Y	AHU-001	K6/1	School of Nursing offices
Y	AHU-004	H6/2	Nursing offices, some labs
Y	AHU-005	K6/3	Nursing offices and labs
Y	AHU-007	H6/4	Pediatric clinic and offices
Y	AHU-009	G5/1	Auditorium, offices
Y	AHU-075	E3/2	Rehab clinic
Y	AHU-078	H4/8	Admin offices

Scheduled	AHU Tag	Module	Space Use
Y	AHU-091	K6/5	Cancer research and offices
Y	AHU-104	G3/2	ENT clinic
Y	AHU-108	J3/1	Cancer clinic
Y	AHU-109	J3/2	Oncology
Y	AHU-110	G3/4	Cancer clinic

Implementation Strategy:

Implementation of this measure would be best coordinated with the construction team to coincide with area remodels and renovations. It may be possible to complete this work in coordination with the occupants without affecting occupancy for flexible and non-critical spaces.

FUME HOOD AND EXHAUST MEASURES

EEM #15 – CSC: Rebalance Fume Hoods to 100fpm at 18” Sash Height

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
877,000	5,658	5,658	$142,444	$51,000	0.4

Measure Description:

Currently, fume hoods are balanced to 100 fpm at the full open position. Industry practice is to balance the hoods to 100fpm at the operating position, which is typically 18” sash height. HGA recommends that the hoods are rebalanced to this industry standard and the sash height is limited to 18” maximum height. In this scenario, further height adjustment would require the physical removal of a stop device. This stop device could only be removed with special tools in order to prevent users from operating the sash in an unsafe position.

To reduce exhaust hood flow, the following conditions must be verified:

- Room cooling loads can still be met after supply is reduced to offset reduced exhaust quantities
- Room air change requirements are maintained after reducing supply and exhaust flows
- Space pressure requirements are maintained with reduced flows

Based on the changes, the supply system would also require rebalancing and air handlers will need to be re-sheaved and outside air quantities revised as well.

Implementation Strategy:

This measure would be beneficial to complete in conjunction with the revaluation of the spaces outside and exhaust air requirements. This measure would require the coordination of an engineer and balancing firm.

EEM #16 – CSC: Decommission Unused Hoods

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
110,286	2,263	533	$26,029	$5,000	0.2

<u>Measure Description:</u>

A significant number of hoods are no longer used by lab personnel but remain in normal operation. HGA recommends that unused hoods are taken out of service. Rebalancing will likely be required on hoods using the same exhaust ductwork.

<u>Implementation Strategy:</u>

A complete survey of all the hoods should be completed to determine the number of unused hoods. could then work with to determine which hoods could be decommissioned.

Figure 3: Typical Unused Fume Hood in Operation

EEM #17 – CSC: Rebalance Constant Volume Hoods with VAV Hoods

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
461,167	9,464	2,228	$108,844	$1,216,800	11.2

Measure Description:

There are over 100 exhaust hoods in the main hospital. Approximately 75% of these hoods are located in research spaces. All of these hoods are constant volume hoods; with a constant volume hood, the exhaust volume is constant regardless of sash position. Variable volume hoods maintain a constant face velocity and reduce airflow (and therefore energy use) as the sash is closed. This measure would greatly reduce exhaust and make up-air requirements when hoods are either not in use or closed.

The existing exhaust systems can be retrofitted for variable flow by installing a VAV exhaust box and VAV supply box in the existing system. VAV hoods would be best suited for the more intensive lab spaces because the savings is not as significant for spaces with only one hood.

Implementation Strategy:

This measure would be best implemented during space renovations. However, it could also be completed with some minor disruption to operations. In addition to local hood modifications, the supply boxes would also require retrofit. The air handler and exhaust fan also require evaluation to determine changes to the flows, controls, and other factors that are impacted by going to a VAV system. The hood systems that are not modified should also be evaluated and rebalanced as needed to maintain the required face velocity.

LIGHTING MEASURES

LIGHTING

EEM #18 – CSC: Modify Cafeteria Atrium Lighting for Daylighting Control

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
61,059	-	-	$5,269	$10,000	1.9

<u>Measure Description:</u>

The cafeteria atrium is lit extensively during the day despite adequate natural light in the space. HGA recommends that the lighting control system is modified to take advantage of the natural daylight.

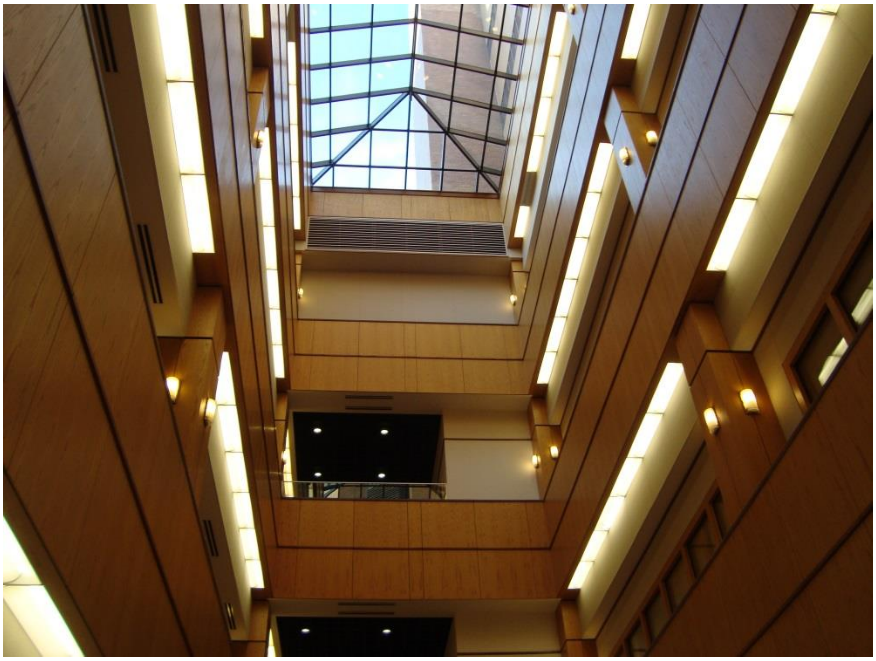
Unfortunately, most of the lighting in the atrium area is not dimmable, so effective day lighting control is not feasible without completing a costly lighting retrofit. An alternate daylighting control scheme would include an astronomical timer that would turn the lights off 2 hours after sunrise and back on 2 hours before sunset.

This measure would involve some adjustment to achieve appropriate lighting levels in the space over a wide variety of ambient light conditions. Additionally, a photocell in the space could provide a timed override for the lights during periods of low daylight (such as a thunderstorm).

Implementation Strategy:

There are many ways to implement this measure. The first step would be to determine light levels in the space under various ambient conditions while also varying the artificial light level in the space. This process will lead to a lighting control scheme.

Figure 4: Cafeteria Atrium Lighting



EEM #19 – CSC: Implement Lighting Control in Interstitial Spaces

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
729,708	-	-	$62,974	$330,000	5.2

Measure Description:

Currently, lighting in the interstitial spaces is controlled by manual wall switches. The lighting is generally left on after people leave the space for various reasons. Based on HGA's observations, 90% of the interstitial lighting is on at any given time, but only 5% of that space may be occupied. This measure is a superb opportunity for savings because the interstitial space accounts for 40% of the total hospital square footage.

HGA proposes that interstitial lighting is swept off at all shift changes with the following sequence:

- At a shift change, main lights flash off 5 minutes before scheduled off time, then flash again 1 minute before off time before going off.
- Emergency lighting would flash off at shift change, then flash again 1 minute before off time before going off.
- A manual press of the wall switches would bring the lighting back on. Manual press of the wall switch would also turn the light off, if it was previously on.

Occupancy sensors were considered, but poor sight lines within the interstitial space make such devices a poor choice.

Implementation Strategy:

HGA recommends attempting this measure in a single test area before a full hospital-wide implementation. This work could be completed at any time, as work in the interstitial space does not affect the operation in the main floors.

Figure 5: Typical Interstitial Space Lit 24/7

EEM #20 – CSC: Install Occupancy and Vacancy Sensors in Applicable Spaces

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
137,500	-	-	$11,866	$100,000	8.4

<u>Measure Description:</u>

HGA observed numerous spaces throughout the Clinical Science Center with traditional light switches. However, many of these spaces, such as conference rooms, exam rooms, offices and other intermittently used spaces are suitable for occupancy or vacancy sensors. Occupancy sensors are great for rooms with no windows and intermittent occupancy. Vacancy sensors are a variation on occupancy sensors where an absence of motion will result in the lights going off, but detection of motion does nothing. A vacancy sensor is well suited for a day lit space where the user may want to use the space without the lights on.

<u>Implementation Strategy:</u>

This measure is relatively straightforward and could be completed in house by electricians. The first step would be to identify the specific rooms that are suitable for sensors. The larger rooms with more energy saving opportunity, are a good first step. In most cases, replacing the wall switch with an occupancy (or vacancy) sensor would work. In some cases, a ceiling sensor may be more appropriate.

Figure 6: Conference Room with lights on and no occupants

EEM #21 – CSC: Retrofit Basement Lighting and Lighting Control

Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Chilled Water Savings (MMBtu/yr)	Energy Cost Savings ($/yr)	Estimated Implementation Cost ($)	Payback (yrs)
75,424	-	-	$6,509	$75,000	11.5

Measure Description:

Currently, the basement is lit primarily with high pressure sodium lamps that run 24/7. HGA proposes that these lights are replaced with LED fixtures. Where applicable, occupancy sensors should also be tied into these lamps. For areas used during regular business hours, these lamps can be tied into the BAS for time clock control.

Implementation Strategy:

This work can be completed at any time as it will not impact hospital operations. This retrofit would be a good time to greatly improve the basement lighting levels in work areas. With some adjustment to the layout of light fixtures (via a photometric survey), better lighting quality could be achieved with fewer fixtures.

ADDITIONAL MEASURES

ADDITIONAL MEASURE SUMMARY

Beyond the major energy efficiency measures documented above, HGA identified additional measures that save less money but are still worth consideration. Additional investigation is needed to calculate energy savings and implementation cost associated with these measures.

Table 6: Additional Improvement Summary Table

Category	Measure	Estimated Savings	Estimated Payback
HVAC	Implement OR standby mode to reduce air changes and relax temperature dead bands when space is not in use	$30,000	2 years
HVAC	Reduce thermostat adjustability range to reduce simultaneous heating and cooling (AFCH)	$5,000	1 year
HVAC	Closed chilled water bypass valve (AFCH)	-	-
HVAC	Improve chilled water plant pumping pressure control to avoid leaky chilled water valves with high pumping pressure	$25,000	1 year
HVAC	Implement reset schedule on HW (AFCH)	$2,000	1 year
HVAC	Improve hot water pump sequencing control (AFCH)	$750	2 years
HVAC	Right size computer room a/c units	$5,000	15 years
IT	Implement computer power management control	$10,000	5 years
Lighting	Reduce lighting levels in over lit spaces	$35,000	7 years
Lighting	Replace mechanical room lighting from incandescent to fluorescent and add lighting control	$15,000	7 years
Lighting	Retrofit Generator 12 lighting to h.o. fluorescent	$500	7 years
Lighting	Replace dimmable incandescent in procedure, OR and reading rooms with LED	$10,000	4 years
Lighting	Replace auditorium incandescent lighting with led. G5/119, G5/113	$1,000	5 years
Lighting	Replace audiology incandescent with LED's	$500	5 years
Lighting	Relamp poorly designed corridors	$15,000	8 years
Lighting	Remove pole lighting at cafeteria atrium	$500	3 years
Lighting	Add controls to corridor lighting in K4/7,8,9 (currently on switches)	$3,000	5 years

ADDITIONAL INVESTIGATION SUMMARY

The measures below were identified during the energy audit as having good potential for energy savings but additional investigation is needed to determine the scope of the issue and the potential energy savings.

Category	Measure
HVAC	Consider a recommissioning effort for heat reclaim coils and other heat recovery opportunities
HVAC	Determine if electrical room air handler outside air dampers need to be open when not economizing
HVAC	Evaluate modification of AFCH face and bypass dampers to avoid the unnecessary addition of heat to the airstream
HVAC	Audit required exhaust flow quantities to determine if requirements are consistent with current space use and code
HVAC	Evaluate shutting off AFCH perimeter heat when outside air is above 40°F
HVAC	Compile, review and address issues identified in 2002 CSC TAB report
HVAC	Evaluate the installation of control valves on devices which use chilled water but are not AHU coils
Plumbing	Evaluate potential for low flow hot water fixtures for sinks and showers

APPENDICES

APPENDIX A: BUILDING ENVELOPE THERMOGRAPHY

The energy audit scope included evaluation of the building envelope for potential energy efficiency upgrades or modifications. HGA completed the thermal imaging on Friday December 27th, 2013. The conditions were partly cloudy, with an outdoor air temperature of 30°F.

The building envelope consists of an insulated panel system with foam core and painted steel skin. The windows are double pane glazing throughout the facility. The roof is generally a ballasted membrane flat roof with an undetermined amount of rigid insulation under the membrane.

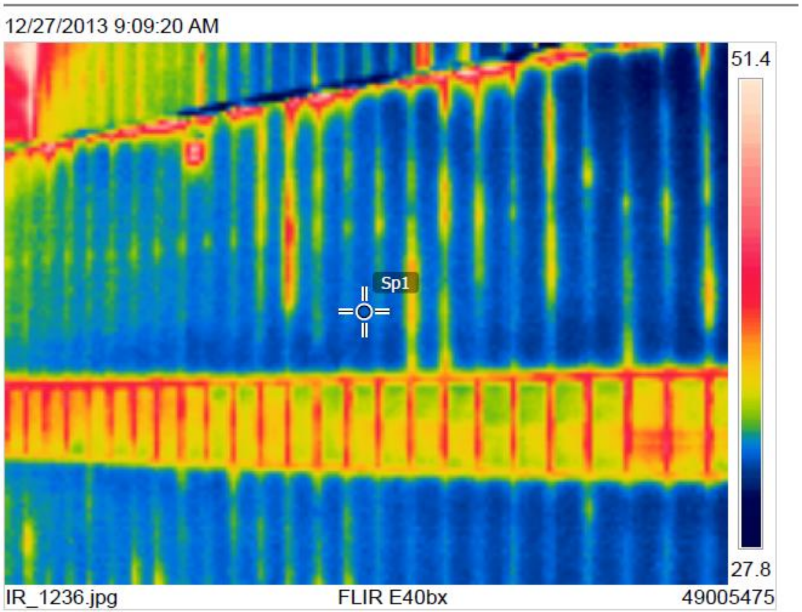
Overall, the building envelope is performing well as a thermal barrier. facilities staff did report some moisture and water infiltration issues at some locations throughout the building.

Upgrades to the building envelope were not included in the recommendations for energy efficiency improvements because there would be a very long payback associated with these upgrades. The building has very little exterior exposure relative to the core spaces. This creates a building that is largely internal-load dominated, when compared to smaller buildings with a greater exterior to core ratio.

While the payback associated with envelope upgrades is poor, should address any current issues with moisture infiltration to maintain a healthy indoor environment. Maintaining an effective moisture barrier will reduce the risk of mold related issues that are typical of water and moisture infiltration into buildings.

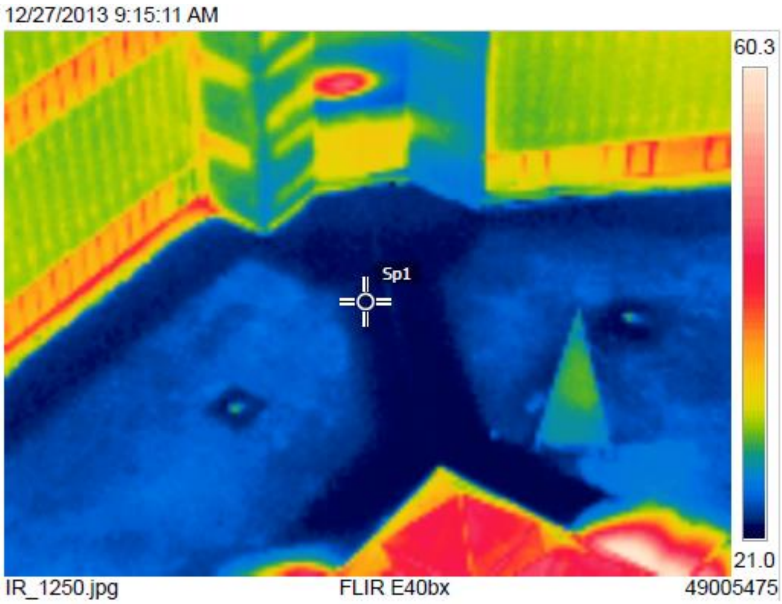
A sample of the thermal images is included in the following pages as an example of the observations made on-site. All the thermal images taken of the buildings can also be seen on the attached CD in the thermal image folder in the "Site Visit" folder on the 12-27-2013 site visit.

Figure 7: F4 Façade as seen from H4 Roof



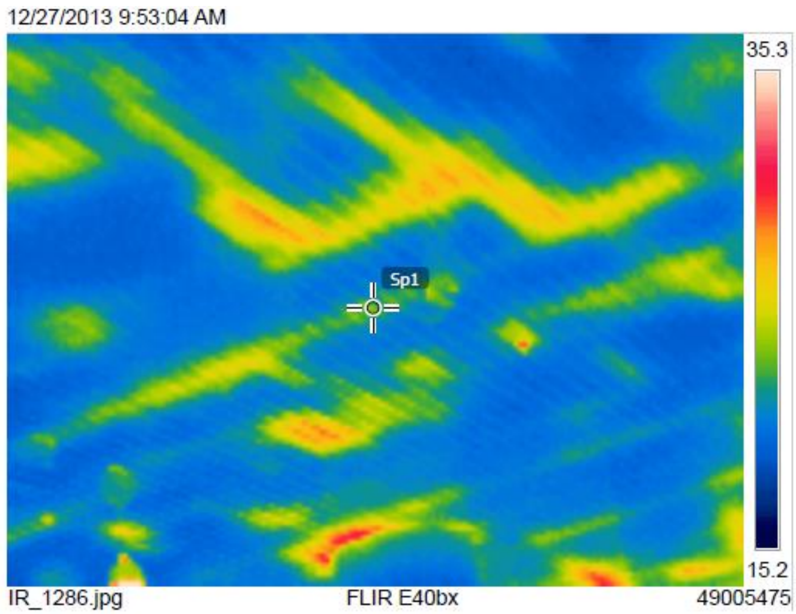
As seen in Figure 7 above, the paneled siding is providing effective thermal insulation. Panel surface temperature was observed at 33°F, with an outdoor air temperature of 30°F. Seams of the panels and the parapet have more heat loss than other areas. This module had higher heat loss at seams than others, but overall the thermal performance of the walls is adequate.

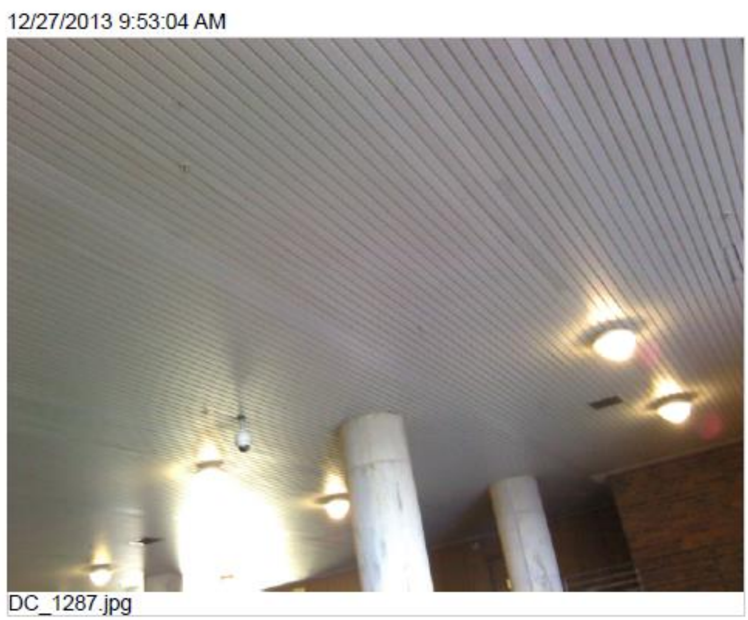
Figure 8: G5 Atrium Roof as Viewed from H4 Roof



As seen in Figure 8 above, the G5 roof shows an interesting heat loss pattern as indicated by both the snow melt pattern and thermal image. One potential reason for this pattern is the increased insulation on the perimeter to facilitate drainage to the roof drains. Melted areas of snow are at the smoke purge vents that were being tested in the atrium area.

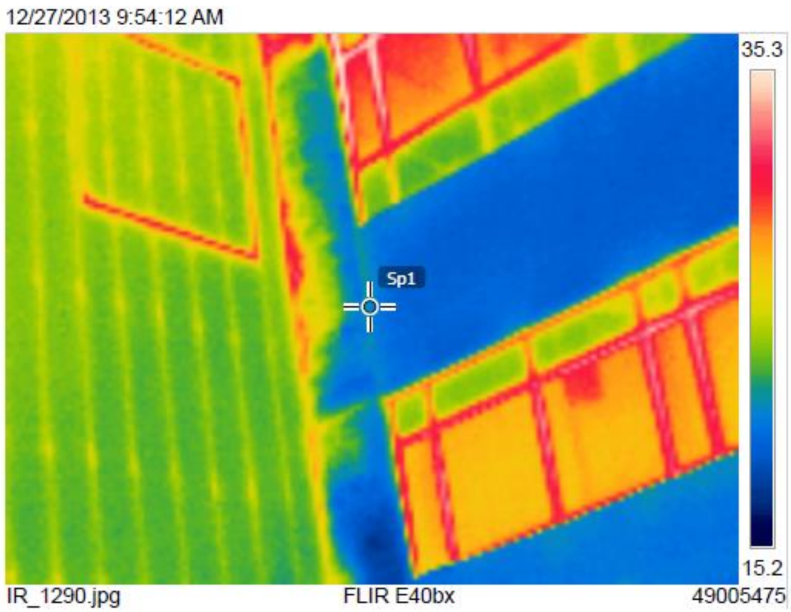
Figure 9: Underside of the CSC Loading Dock Canopy





As seen in Figure 9 above, the canopy insulation is providing adequate insulation for the spaces above the loading dock. There is some additional heat loss, potentially at the seams of the insulation, as seen in the yellow and red areas of the thermal image.

Figure 10: CSC and AFCH at Loading Dock Entrance



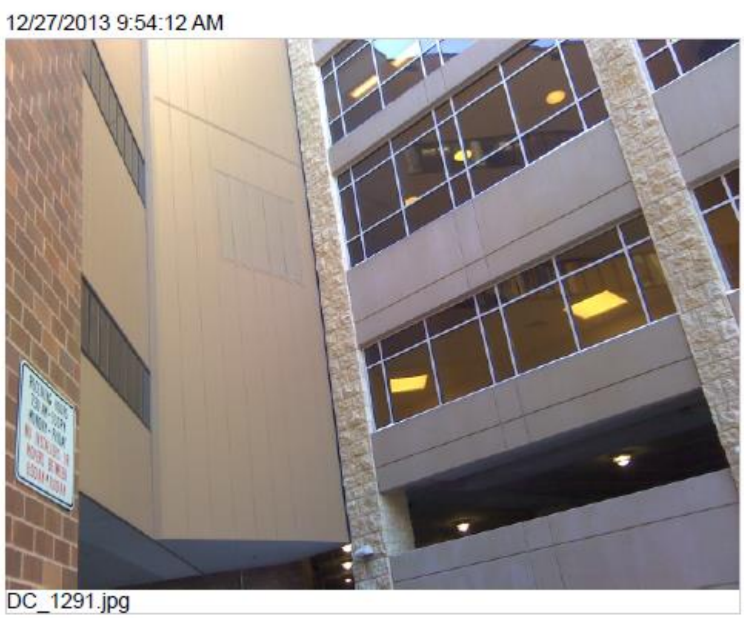
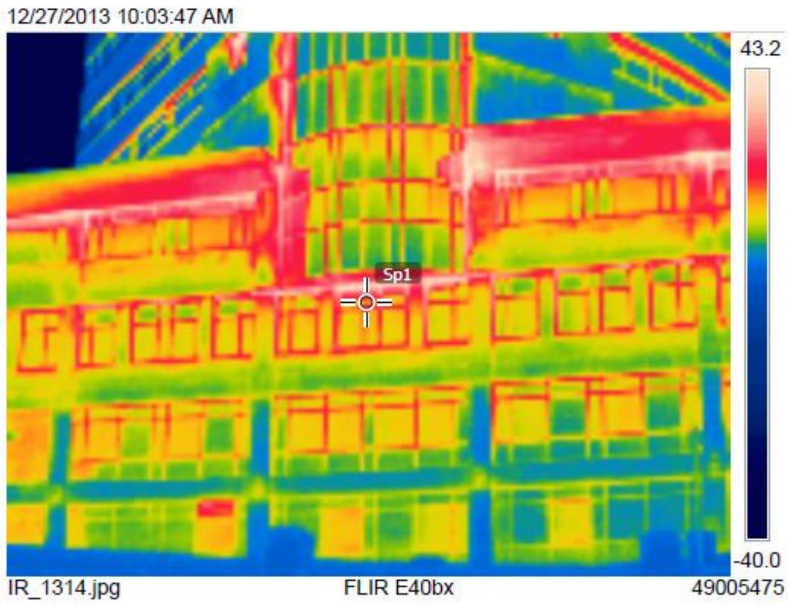


Figure 10 above is a thermal image of both CSC and CH. When compared concurrently, the AFCH exterior paneling was slightly cooler than CSC. There is some heat loss at the connection of the 2 buildings, which is typical.

Figure 11: AFCH Looking South Along University Bay Drive



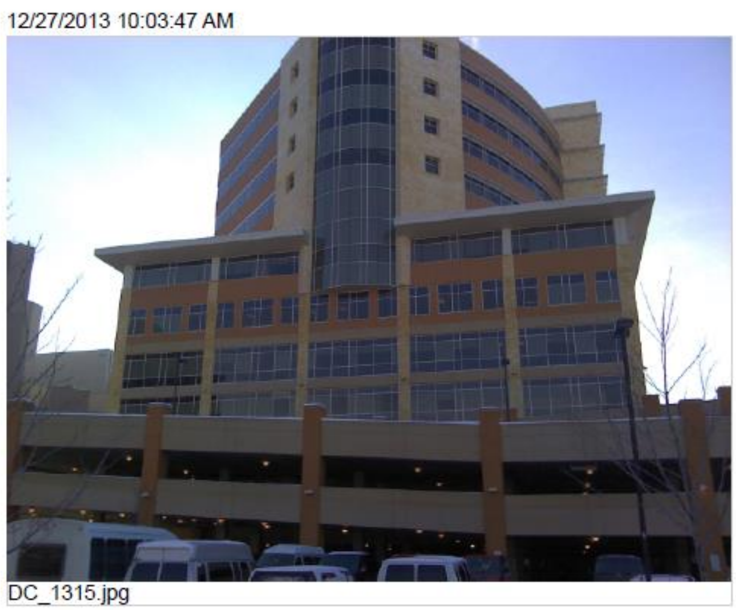


Figure 11 is a thermal image of the north face of AFCH. There is high heat loss from the overhangs of the building that indicate poor air sealing between the conditioned space and the overhang cavity. At this point, fixing this issue would no longer be cost effective.

APPENDIX B: SUMMARY OF ENCLOSED CD FILES

A CD has been included with the hard copy report. This CD contains all the information that was used to compile this report. Some of the information may be useful to the owner for further use, such as the summary of the air handlers.

The word .doc file and .pdf are also included on this CD in the "Report" folder.

HGA