Honeywell

Carleton University Energy Master Plan

Prepared for:
Carleton University
January 2, 2014

Prepared by:

Honeywell

Energy and Environmental Solutions

85 Enterprise Boulevard
Markham, ON L6G 0B5
Phone: (289) 333-1000
Fax: (289) 333-1333

Foreword

Carleton University retained Honeywell to develop Energy Master Plan for its campus along the following guidelines:

1. Take inventory of existing energy and water use to establish a baseline:
    a. Compile, review and analyse available energy and water bills to identify historic consumption patterns for the university campus
    b. Compile, review and analyse energy and water consumption data based on available sub-meters at the individual building levels
2. Review 2010 Campus Master Plan in view of:
    a. Campus growth
    b. Future energy and water service requirements
3. Energy conservation:
    a. Conduct ASHRAE Level 1 audits/assessments of selected facilities to identify energy and water conservation opportunities

Bldg. ID #	**Building Name**	**Building Function**	**Area ft^2**
1	Tory Building	Academic / Admin	127,581
2	MacOdrum Library	Academic	204,096
4	Southam Hall	Academic	99,487
7	University Centre	Ancillary / Academic/ Admin	127,581
10	Mackenzie Building	Academic	188,020
11	Maintenance Building	Ancillary	43,815
13	Herzberg Laboratories	Academic	152,501
15	Loeb Building	Academic	238,280
16	HHJ Nesbitt Biology	Academic	68,003
21	Dunton Tower	Academic	184,803
22	Architecture	Academic	92,687
23	St. Patrick's Building	Academic	75,460
27	Minto Centre	Academic	110,581
29	Carleton Technology	Ancillary	68,487
31	Azrieli Theatre	Academic	37,768
32	Azrieli Pavilion	Academic	49,496
37/38	Human Computer Int. & Visual	Academic	97,271
	Total		**1,965,917**

b. Identify buildings for future ASHRAE Level 2 and/or Level 3 audits/assessments.

Honeywell would like to thank Carleton University's senior management, facilities engineering team and other stakeholders for their cooperation, support and contributions to the development of this Energy Master Plan.

Analysis and Report Development

Discussions with Carleton University's Facilities Management & Planning staff, as well as other stakeholders were integral to the report development process. These discussions helped the Honeywell team fully appreciate Carleton University's goals and operations. The Energy Master Plan (EMP) was developed in three discrete phases:

Phase One: Campus Energy and Water Use Review

During the first phase of EMP development, the Honeywell collected and reviewed the campus historical utility billing records along with sub-metered utility data at the individual buildings level to better understand the campus energy and water use patterns (refer to Section 2).

Phase Two: Campus Master Plan and Future Energy Requirements

In the second phase, the Honeywell engineering team reviewed the university's plans for the future campus development as described in "Carleton University Campus Master Plan" by du Toit Allsopp Hiller dated January 2010. During this phase an analysis of future energy requirements to satisfy the campus growth was also completed (refer to Section 3).

Phase Three: Energy & Water Conservation

This phase included the site visits and facility walkthrough surveys by engineering team to assess and identify energy and water conservation opportunities in the existing buildings. Energy conservation efforts offer an opportunity to partially mitigate the future energy requirements and reduce future capital expenditures for building energy infrastructure and services (refer to Section 4).

Table of Contents

A. Utility Data Management

B. Campus Electrical Distribution Report

C. Facility Walkthrough Reports

D. Energy Master Plan Analysis – Utility Summaries and Other Supporting Information

1.0 Executive Summary

This Energy Master Plan document can be viewed as a supplement to the two already published documents:

- Defining Dreams – A Strategic Plan for Carleton University 2009
- Carleton University – Campus Master Plan 2010

The Strategic Plan provides a vision and sets goals for research and academic teaching excellence and enhancing student life.

The Campus Master Plan describes the future physical development of the campus to satisfy the goals set in the Strategic Plan.

The Energy Master Plan on the other hand looks at the campus historical energy and water use and the future requirements for these utilities to satisfy the campus physical development set in the Campus Master Plan. This document also identifies energy and water conservation opportunities that are available in the existing buildings that when implemented could reduce the future energy requirements.

Once the current Campus Master Plan is implemented the total campus building floor area will grow by 84% from 2012 level or from 4,737,324 ft^2 (440,097 m^2) to 8,720,050 ft2 (810,093 m^2).

The new campus annual electricity, fuel and water consumption are expected to increase by 57%, 55% and 66% from 2012 base year levels, respectively.

Energy conservation efforts offer an opportunity for the university to partially mitigate the future energy requirements and reduce future capital expenditures for building energy infrastructure and services.

Based on the preliminary assessment of the selected facilities about 17% and 3% reduction of energy and water use is possible, respectively. The data contained in this report (Section 4) may be used as a starting point for planning ongoing energy conservation efforts on campus.

Honeywell has identified the 5 facilities listed in Table 1.1 as good candidates for the future ASHRAE Level 2 and/or Level 3 assessments and potential energy conservation projects. These facilities offer the about $390,000 in annual utility savings. These future assessments will refine the potential savings and firm up project costs to allow the university's management a better decision making on how to proceed.

Table 1.1 – 5 Top Opportunities

Bldg. Code #	Building Name	PROJECTED ANNUAL UTILITY SAVINGS										
		Electricity		Steam		Natural Gas		Water		Total	BEPI	BEPI
		kWh	$	MMBtu	$	m3	$	m3	$	$	kWh/ft2	% change
1	Tory Building	453,654	$43,188	1,018	$18,663	5,976	$1,673	453	$1,298	$64,822	5.91	19.85%
7	University Centre	325,534	$30,991	2,029	$37,183	8,153	$2,283	171	$490	$70,947	5.68	14.63%
10	Mackenzie Building	567,242	$54,001	1,284	$23,538	0	$0	274	$784	$78,324	5.02	14.60%
15	Loeb Building	921,645	$87,741	1,138	$20,851	0	$0	564	$1,616	$110,208	5.26	18.83%
27	Minto Centre	585,727	$55,761	482	$8,842	0	$0	334	$956	$65,560	6.57	17.74%
	Total	**2,853,803**	**$271,682**	**5,951**	**$109,076**	**14,130**	**$3,956**	**1,797**	**$5,146**	**$389,860**		

2.0 Utility Analysis

Honeywell has compiled, reviewed and analyzed the campus available utility bills for the period of January 2009 to December 2012. In addition, the sub-metered utilities for individual buildings were also reviewed and analyzed for calendar years 2009 and 2012.

The results of this analysis are presented in this report. Utility billing summaries along with copies of the utility bills are included in on a CD attached to the back cover of this report.

2.1 Utility Map

Table 2.1 lists the utility accounts that have been analyzed for this report.

Table 2.1 - List of Utility Accounts

Service or Bldg. Name	Utility	Utility Type	Account No.
Main Electricity	Hydro Ottawa	Electricity	94028530003881956000
CHP Gas	Enbridge	Natural Gas	855101009990
Tory Building (#1)	Enbridge	Natural Gas	865287669992
Commons (#19)	Enbridge	Natural Gas	865587739991
Leeds (#30)	Enbridge	Natural Gas	865114569996
Ice House (#39)	Enbridge	Natural Gas	865621679994
Tennis Centre (#40)	Enbridge	Natural Gas	8658906779990
Canal Building (#42)	Enbridge	Natural Gas	910004965533
Lennox & Addington (#44)	Enbridge	Natural Gas	910008756332
Consolidated Gas	Enbridge	Natural Gas	000000655320
Water	Ottawa	Water	0055-2520-10
Water	Ottawa	Water	0055-2522-10
Water	Ottawa	Water	0055-2523-10
Water	Ottawa	Water	1007-2620-01

Consolidated Gas account summarizes the natural gas consumption in several buildings listed in Table 2.2

Table 2.2 - Consolidated Gas Account

Building Name	Supplementary Account #
University Centre (#7)	026501006516
Physical Recreation Centre (#9)	026509653514
Mackenzie Building (#10)	026509654303
Maintenance Building (#11)	026501037214
Maintenance Building Shed (#11)	026501533113
Steacie Building (#12)	026509653902
Loeb Building (#15)	026501801022
Architecture (#22)	026501117313
St. Patrick 's Building (#23)	026501014413
Social Sciences Research (#24)	026501016812
Day Care (#28)	026501015921
Prescott House (#34)	026501032110
Field House (#35)	026501031716
Frontenac House (#41)	026550256015

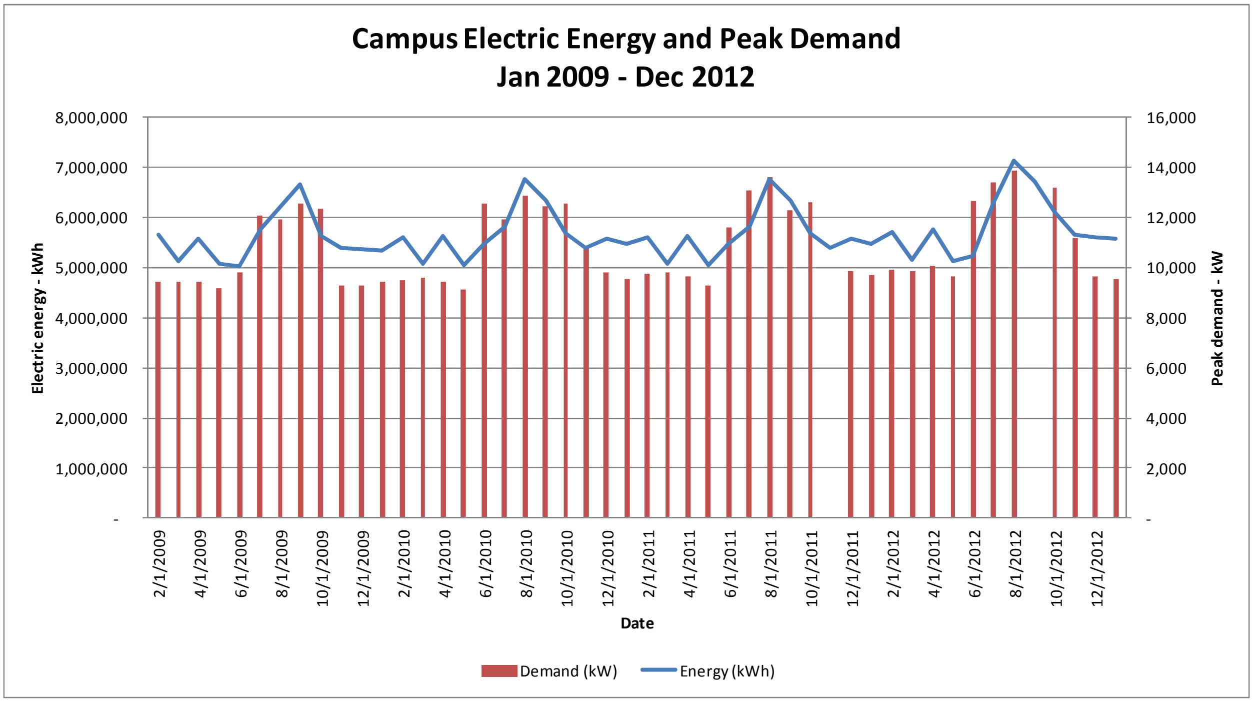
2.2 Utility Analysis

Electricity

A single electric meter measures the main feed electricity consumption for the entire university campus, which is further sub-metered at each building level.

The historic trend of campus energy and peak demand in Figure 2.1 shows a large base load: energy = 5,200,000 kWh/month and peak monthly demand = 9,500 kW and a characteristic summer cooling component.

Figure 2.1 - Electric Energy Consumption



Natural Gas

Several meters measure natural gas consumption on campus. For the purpose of this report the campus gas consumption has been grouped into 2 categories:

1. Central Heating Plant (CHP) gas – natural gas consumed in the CHP, which supplies steam to the vast majority of buildings on campus. This is the largest gas account in terms of volume. The historic trend of campus CHP gas use in Figure 2.2 shows a base load of about 260,000 m^3 and a characteristic winter heating component.

2. Other gas – natural gas consumed in the individual buildings (refer to Tables 2.1 and 2.2 in Section 2.1 Utility Map). The historic trend of campus other gas use in Figure 2.3 shows for years 2009-2011 a base load of about 25,000 m^3 and a characteristic winter heating component. Only a partial consumption data was available for 2012, hence the trend displays abnormal consumption profile. For more details refer to Utility Data Management in Appendix A.

Figure 2.2 - CHP Natural Gas Consumption

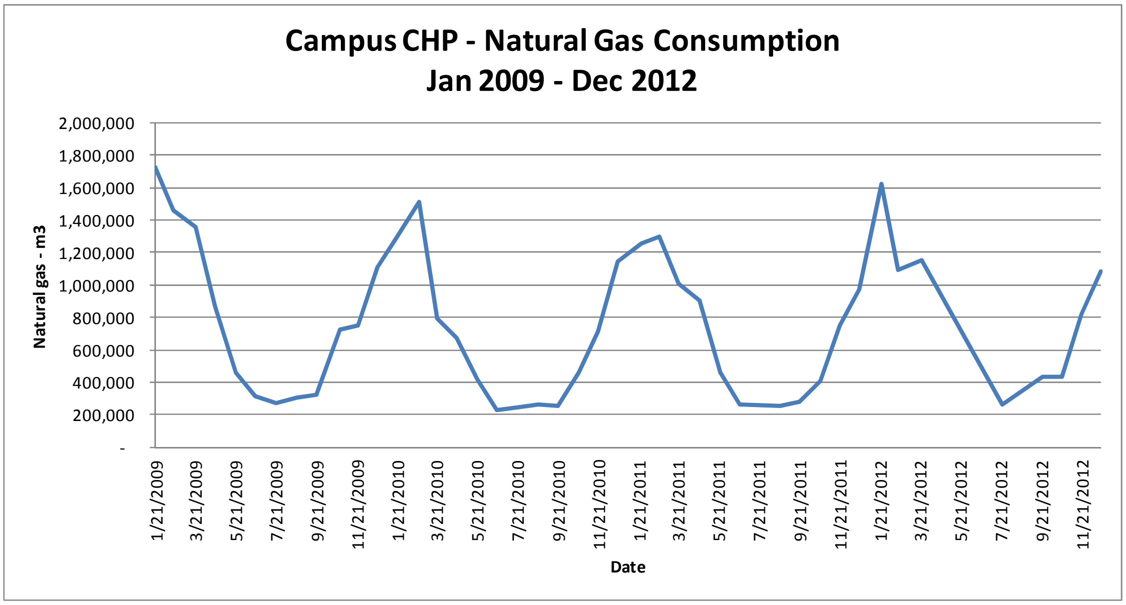
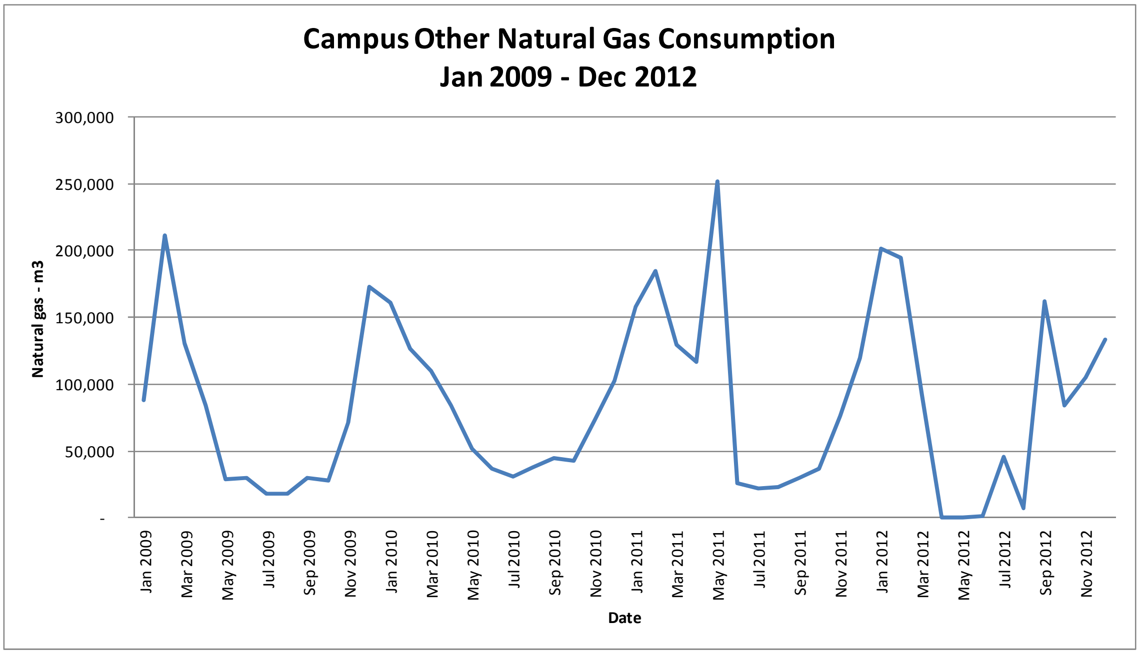


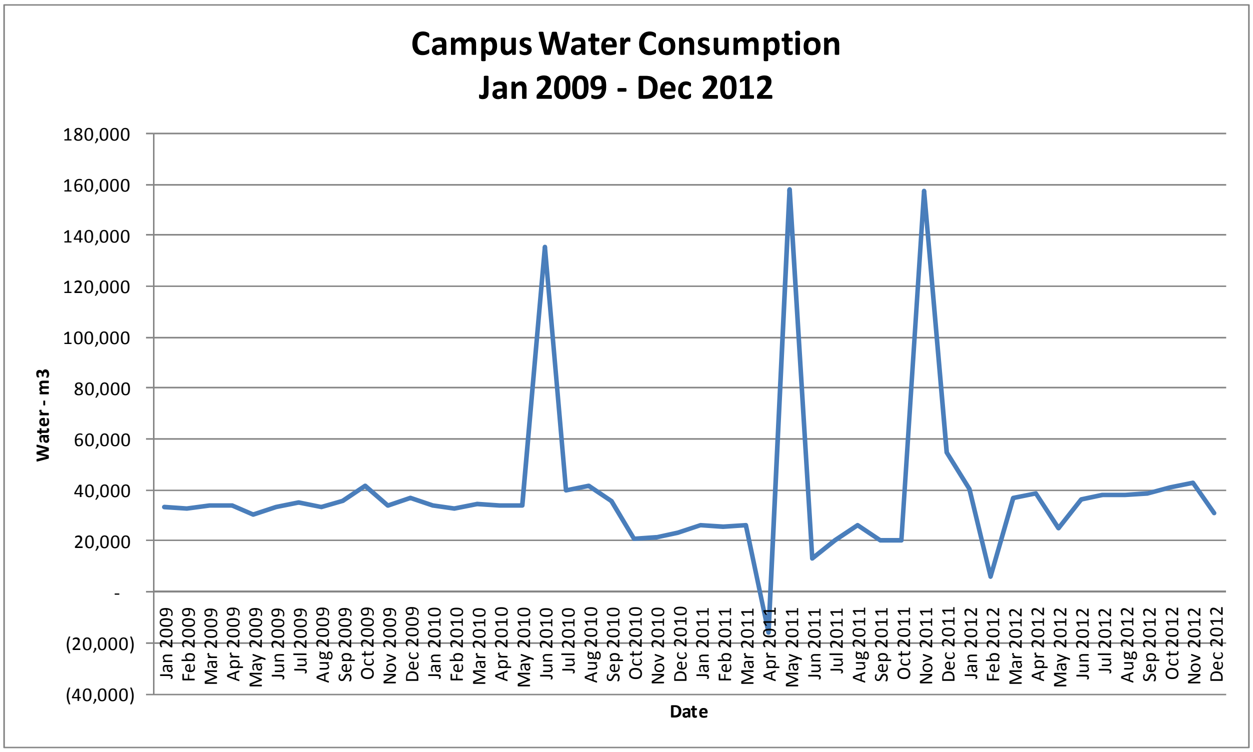
Figure 2.3 - Other Natural Gas Consumption



Water

Four water meters measure total consumption on campus. For the purpose of this report the data have been combined to reflect entire campus usage. The historic trend of campus water use in Figure 2.4 shows a relatively constant consumption of about 35,000 m^3/month up to May 2010 and again from March to December 2012. In the period between these dates the campus water consumption pattern was skewed by a series of meter reading errors. For more details refer to Utility Data Management in Appendix A.

Figure 2.4 - Water Consumption



2.3 Utilities vs. Campus Growth

Figure 2.5 overlays the annual total energy and water consumption over the total campus building floor area. This figure also includes the total student enrolment data. Units of measurements have been purposely modified to show all energy and water consumptions profiles over the campus growth in a single figure. Data source for this figure is summarized in Table 2.3.

Figure 2.5 - Utilities vs. Campus Growth

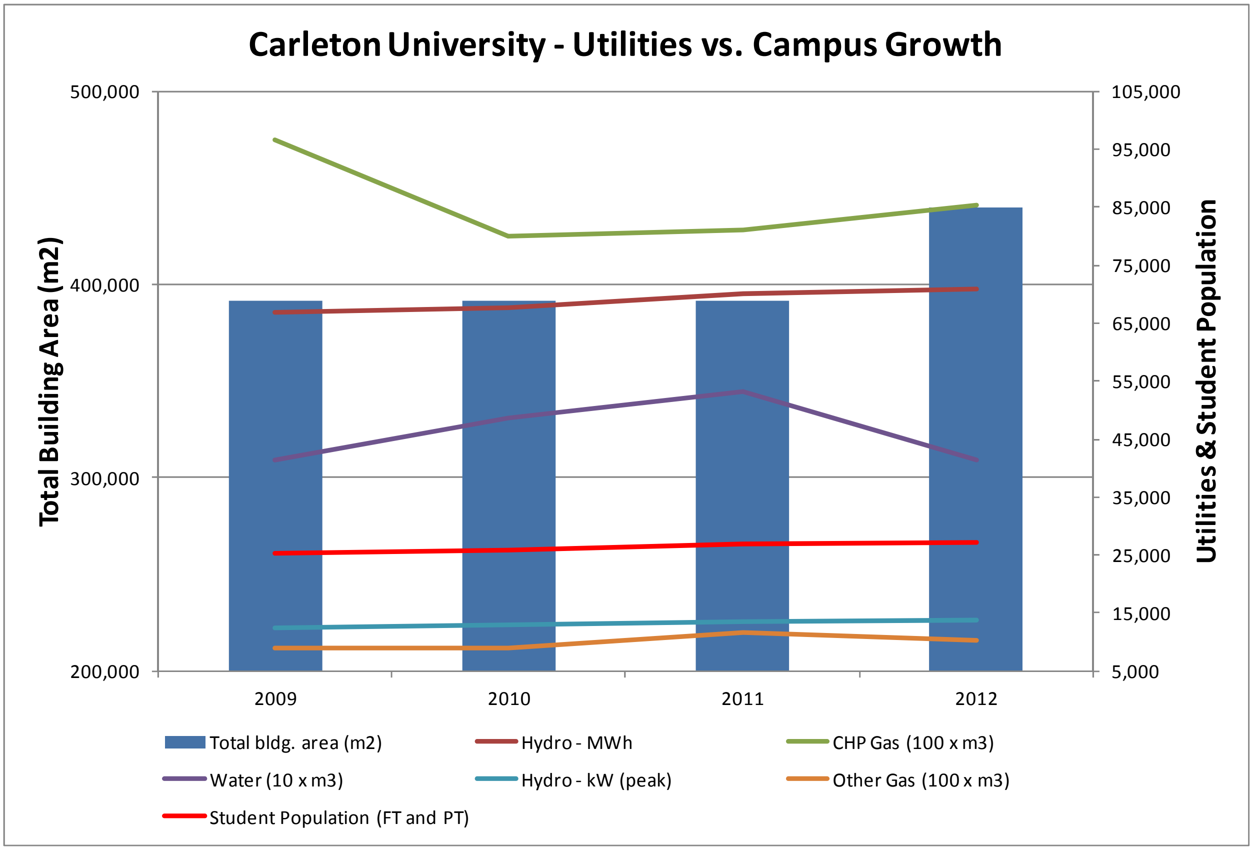


Table 2.3 – Utilities vs. Campus Growth

Year	**2009**	**2010**	**2011**	**2012**
Total bldg. area (m2)	391,492	391,492	391,492	440,097
HDD	4,605	4,063	4,753	4,292
CDD	146	308	294	331
Utilities				
Hydro - MWh	66,766	67,773	70,090	70,744
Hydro - kW (peak)	12,535	12,867	13,596	13,854
CHP Gas (100 x m3)	96,601	79,891	81,177	85,448
Other Gas (100 x m3)	9,091	8,997	11,716	10,251
Water (10 x m3)	41,433	48,627	53,133	41,334
Student Population				
Full and part time	25,295	25,917	26,791	27,241

Over the period of 2009 to 2012 total building floor area changed from 4,212,454 ft^2 (391,492 m2) to 4,735,449 ft^2 (440,097 m2) and the total full and part time student enrolment increased from 25,295 to 27,241. In this comparison, the weather sensitive factors affecting electricity and gas consumption patterns are somewhat muted except for the sharp drop of CHP gas from 2009 to 2010 due to warmer winter in 2010. Upward trend in energy and water consumption is easily visible due to the internal load growth, increase in student enrolment and the addition of new buildings on campus. Water and other gas consumption appear defy this trend in 2012, but this may be due to the fact that this analysis is based incomplete billing data for these utilities during this period.

2.4 Energy and Water Sub-metering

Majority of buildings on campus are equipped with the following types of sub-meters:

- Electricity – measure individual building energy consumption in kWh
- Steam – measure individual building steam or medium temperature hot water (MTHW) consumption in klbs (of steam)
- Natural gas – measure individual building gas consumption in m^3 (these are Enbridge gas meters, see Utility Map Tables 2.1 and 2.2)
- Water – measure individual building water consumption in m^3

Sub-metered energy and water use data for individual buildings for 2009 and 2012 calendar years are summarized in Tables 2.4 and 2.5, respectively.

The following deviations in energy and water use between the actual utility bills and the sub-meters have been noted:

Electric sub-meters:

Campus total billed electricity consumption was 10.2% and 11.6% higher in 2009 and 2012 than the total of the individual buildings electrical sub-meters for these years. The following non metered electrical loads may account for these deviations:

- Campus street and parking area lights
- Tunnel lights
- Sport fields lights
- Grounds Building (#45)
- Bronson Sub-station (#72)
- Accuracy of building electric sub-meters

Steam/MTHW sub-meters (CHP gas):

Individual building sub-meters measure thermal energy consumption expressed in klbs (1000 pounds) of steam. Conversion of natural gas input to CHP to the steam output was necessary to facilitate an easy comparison. For the purpose of this analysis the following assumptions and conversion factors have been utilized:

- CHP seasonal plant efficiency = 70%
- Steam consumed within CHP = 15% of total steam output
- 1 m^3 of natural gas = 0.03584 MMBtu

- 1 klbs of steam = 1 MMBtu

Total steam/MTHW use in the individual buildings correlated very well to the total billed natural gas consumption at CHP with - 0.1% and 2.5% deviations in 2009 and 2012, respectively.

Other Gas:
Campus total billed “Other gas” consumption was 18.4% and 6.8% lower in 2009 and 2012 than the total of individual buildings gas sub-meters for these years. These deviations may be accounted for by the billing estimates and subsequent corrections by Enbridge. For more details refer to Utility Data Management in Appendix A.

Water:
Campus total billed water consumption was 7.2% and 7.0% lower in 2009 and 2012 than the total of individual buildings water sub-meters for these years. This deviation may be accounted for by the accuracy of water sub-meters. For more details refer to Utility Data Management in Appendix A.

Table 2.4 – 2009 Building Energy and Water Use – Sub-meters

Bldg.	Building Name	EXISTING USAGE			
Code		Electricity	Steam - MTHW	Natural Gas	Water
#		kWh	MMBtu	m3	m^3
1	Tory Building	2,141,450	3,069	20,803	27,414
2	MacOdrum Library	4,085,033	6,785	0	15,085
3	Paterson Hall	1,047,456	10,257	0	4,478
4	Southam Hall	1,468,491	6,875	0	5,324
5	Renfrew House	247,716	2,774	0	3,596
6	Lanark House	213,032	3,042	0	5,235
7	University Centre	3,321,228	8,073	71,175	28,406
8	Gymnasium	578,196	0	210,392	2,776
9	Physical Rec Centre	1,803,356	11,103	13,655	21,107
10	Mackenzie Building	4,520,439	13,307	66	31,763
11	Maintenance Building	1,117,560	3,881	3,019	2,580
12	Steacie Building	3,317,104	24,546	384	16,443
13	Herzberg Laboratories	3,133,139	8,136	0	9,121
14	Russell/Grenville House	562,955	9,606	0	23,347
15	Loeb Building	3,229,891	8,722	10,383	9,205
16	HHJ Nesbitt Biology	1,079,573	11,578	0	18,100
17	Robertson Hall	1,887,744	4,216	0	7,831
18	Glengarry House	1,495,861	7,041	0	22,232
19	Residence Commons	1,856,258	12,262	75,757	21,856
21	Dunton Tower	1,643,380	4,276	0	16,707
22	Architecture	776,703	5,915	5,830	5,645
23	St. Patrick's Building	1,077,700	1,994	48,057	2,400
24	Social Sciences Research	145,563	0	18,250	1,500
25	Life Sciences Research	1,184,022	5,761	0	5,000
26	Stormont-Dundas	1,123,563	5,214	0	20,479
27	Minto Centre	3,601,736	8,913	0	15,538
28	Colonel By Child Care	75,147	0	11,240	657
29	Carleton Technology	1,481,882	3,777	0	6,814
30	Leeds House	1,272,607	0	135,063	22,742
31	Azrieli Theatre	520,943	1,108	0	9,670
32	Azrieli Pavilion	1,036,309	1,557	0	12,673
33	National Wildlife Research Centre	2,226,052	3,079	0	1,168
34	Prescott House	1,243,890	4,324	7,757	13,773
35	Fieldhouse	90,875	0	13,011	384
36	Alumni Hall	1,115,376	1,892	0	1,009
37/38	Human Computer Int. & Visual	1,588,677	2,090	0	13,542
39	Ice House	2,312,785	0	296,135	12,910
40	Tennis Centre	258,325	0	168,951	1,500
41	Frontenac House	718,098	1,122	4,345	6,464
	2009 Total	**60,600,115**	**206,295**	**1,114,273**	**446,474**
Actual consumption from 2009 bills		**66,765,583**	**206,000**	**909,062**	**414,331**
% deviation Actual vs. Submetered		**10.2%**	**-0.1%**	**-18.4%**	**-7.2%**

Table 2.5 – 2012 Building Energy and Water Use – Sub-meters

Bldg.	Building Name	EXISTING USAGE			
Code		Electricity	Steam - MTHW	Natural Gas	Water
#		kWh	MMBtu	m3	m^3
1	Tory Building	2,753,123	3,613	28,757	25,854
2	MacOdrum Library	2,750,652	5,846	0	22,943
7	University Centre	3,281,840	6,208	168,723	21,846
10	Mackenzie Building	3,762,182	9,221	39	16,437
11	Maintenance Building	1,925,540	526	5,031	2,126
12	Steacie Building	2,989,160	19,148	259	18,389
13	Herzberg Laboratories	2,910,217	6,708	0	4,259
15	Loeb Building	3,720,466	9,749	8,237	16,524
16	HHJ Nesbitt Biology	732,153	8,683	0	9,640
21	Dunton Tower	1,882,556	3,804	0	12,834
22	Architecture	565,793	1,617	6,695	2,453
23	St. Patrick's Building	1,607,684	2,517	66,099	3,963
27	Minto Centre	3,646,516	1,543	0	8,229
29	Carleton Technology	1,323,426	3,231	0	8,308
31	Azrieli Theatre	419,737	584	0	10
32	Azrieli Pavilion	900,469	559	0	587
37/38	Human Computer Int. & Visual	1,825,421	2,124	0	1,528
3	Paterson Hall	672,855	6,528	0	2,567
4	Southam Hall	1,275,616	5,162	0	5,817
5	Renfrew House	255,607	2,524	0	6,344
6	Lanark House	208,350	1,649	0	6,021
8	Gymnasium	251,157	0	64,993	3,712
9	Physical Rec Centre	1,572,976	8,380	14,797	29,258
14	Russell/Grenville House	537,152	4,390	0	7,744
17	Robertson Hall	2,927,808	4,153	0	13,056
18	Glengarry House	1,609,802	8,032	0	30,821
19	Residence Commons	1,372,519	16,383	99,337	22,751
24	Social Sciences Research	141,927	0	24,273	10,658
25	Life Sciences Research	1,169,991	4,602	0	14,438
26	Stormont-Dundas	960,943	3,941	0	35,091
28	Colonel By Child Care	72,710	0	14,964	855
30	Leeds House	1,283,503	0	162,773	27,167
33	National Wildlife Research Centre	2,492,752	3,497	0	1,120
34	Prescott House	1,208,162	3,024	8,339	12,865
35	Fieldhouse	268,833	0	30,635	540
36	Alumni Hall	811,009	1,229	0	961
39	Ice House	2,810,525	0	194,978	14,098
40	Tennis Centre	299,166	0	195,162	0
41	Frontenac House	667,700	2,633	1,765	6,407
42	Canal Building	1,779,784	9,367	0	1,020
43	River Building	776,977	1,668	0	851
44	New Residence	969,300	5,099	4,139	14,527
	2012 Total	**63,394,055**	**177,941**	**1,099,995**	**444,621**
Actual consumption from 2012 bills		**70,744,261**	**182,217**	**1,025,132**	**413,336**
% deviation Actual vs. Submetered		**11.6%**	**2.4%**	**-6.8%**	**-7.0%**

2.5 Utility Data Management

Over the years the University has made a great progress toward monitoring, collecting and managing energy and water operating data for the entire campus and the individual buildings. Virtually all buildings on campus are now equipped with energy (electricity, steam, natural gas) and water sub-meters.

The captured data from both the building sub-meters (electricity, steam, water) and individual building gas bills for a each budget year is entered and maintained in the spreadsheets (Excel format) for both “Ancillary” and “Non-Ancillary” facilities. This information has been used for the university energy budget forecasting and internal accounting and utilities cost recovery from various tenants and/or departments.

Honeywell used the data from these spreadsheets for the building energy and water use summaries shown in Tables 2.4 and 2.5 in Section 2.4 and building energy performance benchmarks shown in Table 3.2 in Section 3.3.

Capturing the building operating data is the first step toward improved management of the campus facilities. Analysis of this data and follow up actions constitute the second and third steps in driving operational excellence.

Observations of areas where corrective actions are recommended, are outlined in Appendix A.

3.0 Campus Master Plan & Future Energy Requirements

3.1 Overview

Energy Master Plan can be viewed as a supplement to the two already published documents:

- Defining Dreams – A Strategic Plan for Carleton University 2009
- Carleton University – Campus Master Plan 2010

Strategic Plan provides a vision and sets goals for research and academic teaching excellence and enhancing student life.

Campus Master Plan describes the future physical development of the campus to satisfy the goals set in the Strategic Plan.

Energy Master Plan on the other hand looks at the campus historical energy and water use and the potential future requirements for these utilities to satisfy the campus physical development set in the Campus Master Plan.

3.2 Campus Master Plan

Campus Master Plan by du Toit Allsopp Hillier in January 2010 describes the future physical development of the campus. It deals with the location and the size of buildings and their general use. This document does not provide any time frame for the campus development buildup as it is expected that this will vary over time due to availability of funding.

Figure 3.1 shows the existing building stock and future development under the Campus Master Plan. Table 3.1 provides the summary of new building massing statistics arranged by building type. Figure 3.2 shows the campus key map for the new buildings statistics.

The current plan calls for construction of new facilities with the total floor area of 4,472,898 ft^2 (or 415,532 m^2). Under this plan 490,172 ft^2 (45,537 m^2) of existing building stock will be removed. In the end, the campus will grow from the current 4,737,324 ft^2 (440,097 m^2) to 8,720,050 ft2 (810,093 m^2).

Figure 3.1 – Carleton University Campus Master Site Plan

Legend:

Existing Building	🟧
Vertical Expansion	▨
New Building	▭

Table 3.1 – Summary of Building Massing Statistics

New Buildings			
Tag	**Building Name**	**Area (ft2)**	**Type**
I1	Dunton Tower Infill	55,574	Academic
I2	Library Infill	31,571	Academic
I4	McKenzie Infill	21,775	Academic
C1	Paterson Replacement	292,466	Academic
C2	L.S.R. Replacement	139,791	Academic
C4	S.S.R. Replacement	122,289	Academic
C7	Library Road	91,084	Academic/Admin
V1	Library Expansion	45,316	Academic
V2	Herzberg Annex	11,539	Academic
	Academic Total	**811,405**	
C10	Old Gym + Daycare	141,492	Athletics
M1	Tennis Replacement	104,528	Athletics
M2	Bronson Frontage	325,436	Athletics
	Athletics Total	**571,456**	
N1	North Campus	59,158	Research
N2	North Campus	61,268	Research
N3	North Campus	60,407	Research
N4	North Campus	60,364	Research
N5	North Campus	71,903	Research
N6	North Campus	118,920	Research
N7	North Campus	114,700	Research
N8	North Campus	55,025	Research
N9	North Campus	55,886	Research
N10	North Campus	54,250	Research
N11	North Campus	104,022	Research
	Research Total	**815,903**	
R1	Residence	172,955	Residence
R2	Residence Commons Addition	37,867	Residence
R3	Residence	117,736	Residence
R4	Residence	117,736	Residence
R5	Residence	117,736	Residence
R6	Residence	117,736	Residence
R7	Residence	117,736	Residence
R8	Residence + Commons	264,921	Residence
	Residence Total	**1,064,423**	
C12	Maintenance Replacement	53,281	Ancillary
C13	Maintenance Replacement	71,881	Ancillary
C14	Garage Replacement	110,502	Ancillary
M3	New Maintenance	88,835	Ancillary
	Services Total	**324,499**	
I3	UniCentre Expansion	11,883	Student Centre
C8	Over Rail	231,618	Student Centre
C15	Alumni Park Back	49,557	Student Centre
	Student Centre Total	**293,058**	
C3	Parking Lot 1	94,959	Parking
C5	Parking Lot 2 N.	131,470	Parking
C6	Parking Lot 2 S.	104,259	Parking
C9	Parking Lot 4	133,139	Parking
C11	Parking Lot 11	128,327	Parking
	Parking Total	**592,154**	
	Grand Total	**4,472,898**	

Buildings to be removed			
Bldg. #	**Building Name**	**Area (ft2)**	**Type**
3	Paterson Hall	79,989	Academic
8	Gymnasium	28,159	Athletics
11	Maintenance	43,832	Ancillary
24	Social Sciences Research Bldg.	14,370	Academic
25	Life Sciences Research Bldg.	25,296	Academic
28	Colonel By Child Care Centre	5,662	Ancillary
40	Tennis Centre	36,006	Athletics
PG	Parking Garage	256,857	Ancillary
	Total to be removed	**490,172**	

Figure 3.2 – Key Map for New Buildings Statistics

Legend:

C – Core Area	M – Mid Campus
I – Infill	N – North Campus
V – Vertical Expansion	R – Residential Campus

3.3 Campus Energy Benchmarks

In simplistic terms, energy benchmarking can be defined as the process of comparing energy performance of a sample building to a similar facility or group of facilities. This process can be used for developing energy management plans where the performance of the existing facilities is compared to that of the best practice standard. In addition, the benchmarking can be used to as a forecasting tool to predict the future energy and water use of new facilities based on the past performance of existing facilities of similar type and operation.

For the purpose of this analysis we have used the principles of energy benchmarking to predict the future energy and water requirements for new facilities developed under the 2010 Campus Master Plan.

Table 3.2 provides the summary of energy and water consumption benchmarks for campus existing building stock arranged by building type based on 2012 data.

Average, maximum and minimum performance benchmarks were also calculated for the following building types:

- Academic
- Research
- Athletics
- Ancillary
- Residences

Table 3.2 - Energy Performance Benchmarks - Existing Building Stock

Bldg.	Building Name	Building	Area	EXISTING USAGE										
Code		Type	ft^2	Electricity				Steam - MTHW		Natural Gas		TOTAL BEPI	Water	
#				kWh	kW	kWh/ft^2	W/ft^2	MMBtu	ekWh/ft^2	m3	ekWh/ft^2	ekWh/ft^2	m^3	l/ft^2
2	MacOdrum Library	Academic	204,177	2,750,652	601	13.47	2.94	5,846	8.39	0	0.00	**21.86**	22,943	112
10	Mackenzie Building	Academic	188,095	3,762,182	822	20.00	4.37	9,221	14.37	39	0.00	**34.37**	16,437	87
15	Loeb Building	Academic	238,375	3,720,466	813	15.61	3.41	9,749	11.99	8,237	0.36	**27.96**	16,524	69
16	HHJ Nesbitt Biology	Academic	68,030	732,153	160	10.76	2.35	8,683	37.41	0	0.00	**48.17**	9,640	142
21	Dunton Tower	Academic	184,876	1,882,556	411	10.18	2.23	3,804	6.03	0	0.00	**16.21**	12,834	69
22	Architecture	Academic	92,723	565,793	124	6.10	1.33	1,617	5.11	6,695	0.76	**11.97**	2,453	26
23	St. Patrick's Building	Academic	75,490	1,607,684	351	21.30	4.65	2,517	9.77	66,099	9.19	**40.26**	3,963	52
27	Minto Centre	Academic	110,624	3,646,516	797	32.96	7.20	1,543	4.09	0	0.00	**37.05**	8,229	74
31	Azrieli Theatre	Academic	37,783	419,737	92	11.11	2.43	584	4.53	0	0.00	**15.64**	10	0
32	Azrieli Pavilion	Academic	49,516	900,469	197	18.19	3.97	559	3.31	0	0.00	**21.50**	587	12
37/38	Human Computer Int. & Visual	Academic	97,309	1,825,421	399	18.76	4.10	2,124	6.40	0	0.00	**25.16**	1,528	16
3	Paterson Hall	Academic	79,989	672,855	147	8.41	1.84	6,528	23.92	0	0.00	**32.33**	2,567	32
4	Southam Hall	Academic	99,526	1,275,616	279	12.82	2.80	5,162	15.20	0	0.00	**28.02**	5,817	58
42	Canal Building	Academic	96,609	1,779,784	389	18.42	4.03	9,367	28.42	0	0.00	**46.84**	1,020	11
43	River Building	Academic	181,593	776,977	170	4.28	0.94	1,668	2.69	0	0.00	**6.97**	851	5
1	Tory Building	Academic / Admin	138,110	2,753,123	602	19.93	4.36	3,613	7.67	28,757	2.19	**29.79**	25,854	187
		Academic Total			**Average**	**15.14**	**3.31**		**11.83**		**0.78**	**27.76**		**60**
					Maximum	**32.96**	**7.20**		**37.41**		**9.19**	**48.17**		**187**
					Minimum	**4.28**	**0.94**		**2.69**		**0.00**	**6.97**		**0**
12	Steacie Building	Research	107,104	2,989,160	653	27.91	6.10	19,148	52.40	259	0.03	**80.33**	18,389	172
13	Herzberg Laboratories	Research	152,562	2,910,217	636	19.08	4.17	6,708	12.89	0	0.00	**31.96**	4,259	28
24	Social Sciences Research	Research	14,370	141,927	31	9.88	2.16	0	0.00	24,273	17.74	**27.61**	10,658	742
25	Life Sciences Research	Research	25,296	1,169,991	256	46.25	10.11	4,602	53.32	0	0.00	**99.57**	14,438	571
		Research Total			**Average**	**25.78**	**5.63**		**29.65**		**4.44**	**59.87**		**378**
					Maximum	**46.25**	**10.11**		**53.32**		**17.74**	**99.57**		**742**
					Minimum	**9.88**	**2.16**		**0.00**		**0.00**	**27.61**		**28**
8	Gymnasium	Athletics	28,159	251,157	55	8.92	1.95	0	0.00	64,993	24.23	**33.15**	3,712	132
9	Physical Rec Centre	Athletics	125,199	1,572,976	344	12.56	2.75	8,380	19.62	14,797	1.24	**33.42**	29,258	234
35	Fieldhouse	Athletics	47,998	268,833	59	5.60	1.22	0	0.00	30,635	6.70	**12.30**	540	11
36	Alumni Hall	Athletics	37,503	811,009	177	21.63	4.73	1,229	9.61	0	0.00	**31.23**	961	26
39	Ice House	Athletics	99,914	2,810,525	614	28.13	6.15	0	0.00	194,978	20.49	**48.62**	14,098	141
40	Tennis Centre	Athletics	36,006	299,166	65	8.31	1.82	0	0.00	195,162	56.91	**65.22**	0	0
		Athletics Total			**Average**	**14.19**	**3.10**		**4.87**		**18.26**	**37.33**		**91**
					Maximum	**28.13**	**6.15**		**19.62**		**56.91**	**65.22**		**234**
					Minimum	**5.60**	**1.22**		**0.00**		**0.00**	**12.30**		**0**

Table 3.2 - Energy Performance Benchmarks - Existing Building Stock – cont'd

Bldg.	Building Name	Building	Area	EXISTING USAGE										
Code		Type	ft²	Electricity				Steam - MTHW		Natural Gas		TOTAL BEPI	Water	
#				kWh	kW	kWh/ft²	W/ft²	MMBtu	ekWh/ft²	m3	ekWh/ft²	ekWh/ft²	m³	l/ft²
7	University Centre	Ancillary / Academic/ Admin	177,183	3,281,840	717	18.52	4.05	6,208	10.27	168,723	10.00	**38.79**	21,846	123
17	Robertson Hall	Administrative	93,208	2,927,808	640	31.41	6.86	4,153	13.06	0	0.00	**44.47**	13,056	140
11	Maintenance Building	Ancillary	43,832	1,925,540	421	43.93	9.60	526	3.51	5,031	1.21	**48.65**	2,126	49
29	Carleton Technology	Ancillary	68,515	1,323,426	289	19.32	4.22	3,231	13.82	0	0.00	**33.14**	8,308	121
19	Residence Commons	Ancillary	185,323	1,372,519	300	7.41	1.62	16,383	25.91	99,337	5.63	**38.94**	22,751	123
28	Colonel By Child Care	Ancillary	5,662	72,710	16	12.84	2.81	0	0.00	14,964	27.75	**40.59**	855	151
33	National Wildlife Research Centre	Ancillary / Academic	60,000	2,492,752	545	41.55	9.08	3,497	17.08	0	0.00	**58.63**	1,120	19
		Ancillary Total			**Average**	**25.00**	**5.46**		**11.95**		**6.37**	**43.32**		**104**
					Maximum	**43.93**	**9.60**		**25.91**		**27.75**	**58.63**		**151**
					Minimum	**7.41**	**1.62**		**0.00**		**0.00**	**33.14**		**19**
5	Renfrew House	Residence	52,680	255,607	56	4.85	1.06	2,524	14.04	0	0.00	**18.89**	6,344	120
6	Lanark House	Residence	51,469	208,350	46	4.05	0.88	1,649	9.39	0	0.00	**13.44**	6,021	117
14	Russell/Grenville House	Residence	95,953	537,152	117	5.60	1.22	4,390	13.41	0	0.00	**19.01**	7,744	81
18	Glengarry House	Residence	154,715	1,609,802	352	10.40	2.27	8,032	15.22	0	0.00	**25.62**	30,821	199
26	Stormont-Dundas	Residence	118,192	960,943	210	8.13	1.78	3,941	9.77	0	0.00	**17.90**	35,091	297
30	Leeds House	Residence	169,139	1,283,503	280	7.59	1.66	0	0.00	162,773	10.10	**17.69**	27,167	161
34	Prescott House	Residence	135,005	1,208,162	264	8.95	1.96	3,024	6.57	8,339	0.65	**16.16**	12,865	95
41	Frontenac House	Residence	87,998	667,700	146	7.59	1.66	2,633	8.77	1,765	0.21	**16.57**	6,407	73
44	New Residence	Residence	170,000	969,300	212	5.70	1.25	5,099	8.79	4,139	0.26	**14.75**	14,527	85
		Residence Total			**Average**	**6.98**	**1.53**		**9.55**		**1.25**	**17.78**		**136**
					Maximum	**10.40**	**2.27**		**15.22**		**10.10**	**25.62**		**297**
					Minimum	**4.05**	**0.88**		**0.00**		**0.00**	**13.44**		**73**

3.4 Future Energy and Water Requirements

A number of existing buildings will be demolished to give way for the new construction. Table 3.3 provides the summary of buildings planned for demolition along with 2012 energy and water consumption data. Removed utilities will free up some capacity on the existing campus energy and water infrastructure systems.

Table 3.3 – Buildings Planned for Removal under 2010 Campus Master Plan

				Electricity		CHP Gas	Other Gas	Total Gas	Water
Bldg. #	**Building Name**	**Area (ft2)**	**Type**	**kW**	**MWh**	**MMBtu**	**MMBtu**	**MMBtu**	**m3**
3	Paterson Hall	79,989	Academic	147	673	9,326	0	9,326	2,567
8	Gymnasium	28,159	Athletics	55	251	0	2,329	2,329	3,712
11	Maintenance	43,832	Ancillary	421	1,926	751	180	931	2,126
24	Social Sciences Research Bldg.	14,370	Academic	31	142	0	870	870	10,658
25	Life Sciences Research Bldg.	25,296	Academic	256	1,170	6,574	0	6,574	14,438
28	Colonel By Child Care Centre	5,662	Ancillary	16	73	0	536	536	855
40	Tennis Centre	36,006	Athletics	65	299	0	6,995	6,995	0
PG	Parking Garage	256,857	Ancillary	358	266			0	0
	Total to be removed	**490,172**		**1,348**	**4,800**	**16,650**	**10,911**	**27,561**	**34,356**

Average energy and water consumption benchmarks for each building type have been used as the starting point for predicting the future energy and water requirements for the new buildings. Given the University management ongoing commitment to energy efficiency and environmental responsibility this analysis assumes that all new buildings will be constructed to the improved construction standards, utilizing high performance building materials, sustainable energy sources and high efficiency building technologies and equipment.

Table 3.4 shows the estimated energy and water reduction factors, which have been used for this analysis. It should be noted that these factors may further improve in the future due to ongoing advances in the development of high performance building materials and energy efficient equipment and building technologies. On another hand, the more conservative factors can be used, should the construction budget constraints dictate the use of the standard and/or less effective building materials, equipment and technologies.

Table 3.4 – Energy and Water Reduction Factors

Building type	**Electricity**	**Thermal**	**Water**
Academic	30%	40%	50%
Research	30%	40%	50%
Athletics	30%	40%	50%
Ancillary	30%	40%	50%
Residences	30%	40%	50%
Parking	50%		

Table 3.5 provides the summary of the estimated annual energy and water consumption for the new buildings based on improved construction standards and energy performance.

Table 3.5 – Projected Energy and Water Consumption in New Buildings

		Electricity		Fuel	Water
Building type	**Area (ft2)**	**Peak kW**	**MWh**	**MMBtu**	**m3**
Academic	811,405	1,880	8,602	29,928	24,199
Research	815,903	3,217	14,723	81,345	154,210
Athletics	571,456	1,241	5,677	38,663	25,882
Ancillary	617,557	2,361	10,806	33,086	32,006
Residences	1,064,423	1,137	5,204	33,610	72,641
Parking	592,154	412	307		
Total	**4,472,898**	**10,249**	**45,318**	**216,632**	**308,938**

Table 3.6 provides the summary of the estimated annual energy and water consumption for the new and enlarged Carleton University campus.

Table 3.6 – Projected Energy and Water Consumption for New Campus

		Electricity		Fuel	Water
	Area (ft2)	**Peak kW**	**MWh**	**MMBtu**	**m3**
Existing buildings	4,737,324	13,854	70,744	342,987	413,336
Removed buildings	-490,172	-1,348	-4,800	-27,561	-34,356
New buildings	4,472,898	10,249	45,318	216,632	308,938
Projected campus total	**8,720,050**	**22,754**	**111,262**	**532,059**	**687,918**

Table 3.7 provides the projected perspectives on the future Carleton University campus once the entire scope of 2010 Master Plan development and the impact of the campus growth on the overall energy and water consumption. Once the Master Plan is implemented the total campus building floor area will grow by 84% from 2012 level. The new campus annual electricity, fuel and water consumption are expected to increase by 57%, 55% and 66%, respectively.

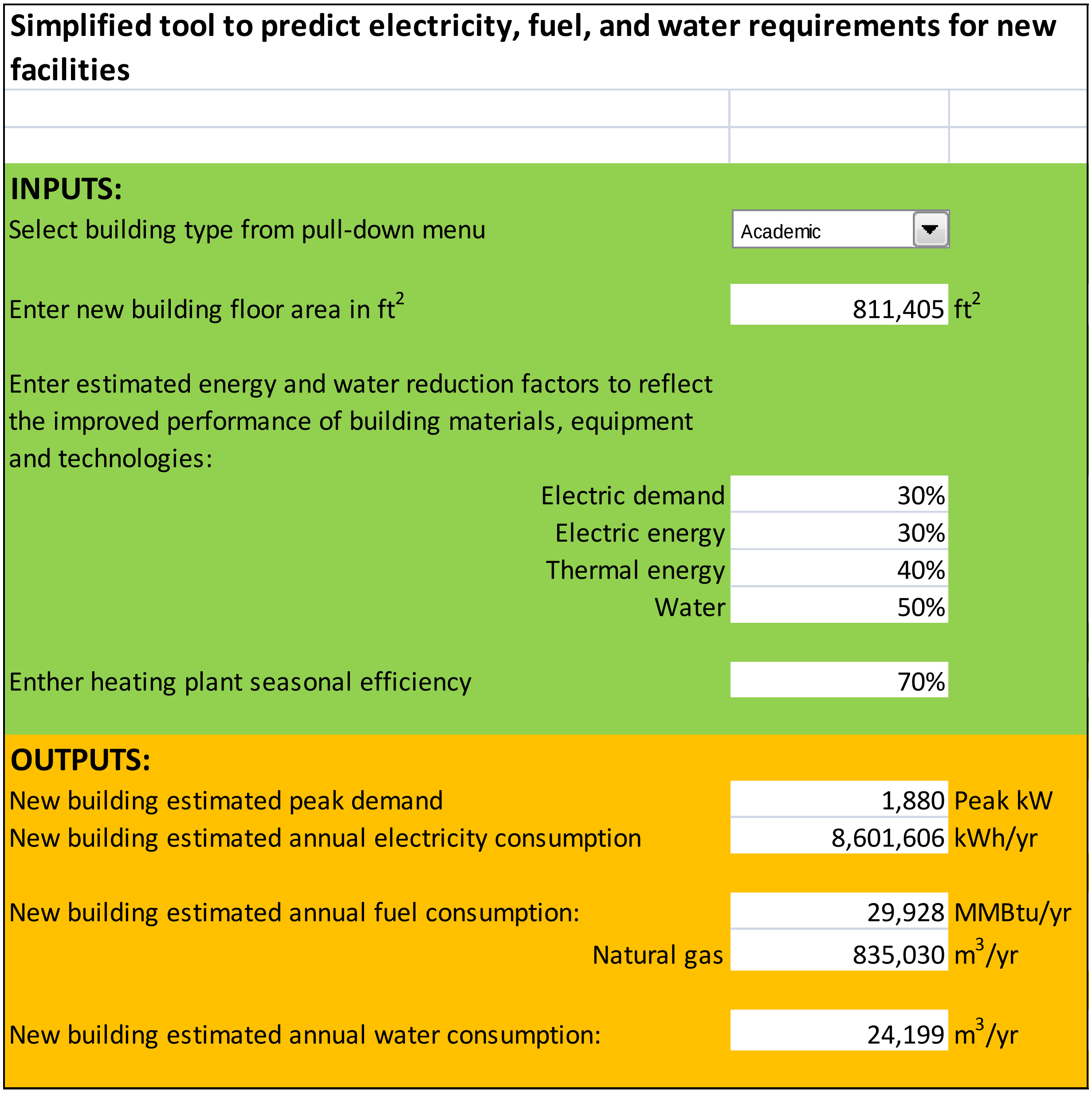
Table 3.7 – New Campus Statistics

	Building	Electricity		Fuel	Water
	Area	Demand	Energy		
Growth	84%	64%	57%	55%	66%

3.5 Calculator for Future Utility Requirements

Honeywell has developed a calculating tool to perform simple and quick calculations to predict the future energy and water use requirements for different building types (Figure 3.3). This tool is included on the attached CD in Appendix C. Sections 3.3 and 3.4 provide the details on how this calculator works.

Figure 3.3 – Calculator



Simplified tool to predict electricity, fuel, and water requirements for new facilities

INPUTS:

Select building type from pull-down menu	Academic ▼	
Enter new building floor area in ft^2	811,405	ft^2
Enter estimated energy and water reduction factors to reflect the improved performance of building materials, equipment and technologies:		
Electric demand	30%	
Electric energy	30%	
Thermal energy	40%	
Water	50%	
Enther heating plant seasonal efficiency	70%	

OUTPUTS:

New building estimated peak demand	1,880	Peak kW
New building estimated annual electricity consumption	8,601,606	kWh/yr
New building estimated annual fuel consumption:	29,928	MMBtu/yr
Natural gas	835,030	m^3/yr
New building estimated annual water consumption:	24,199	m^3/yr

Basic building information and assumptions are entered in the “INPUTS” section of the tool. The calculator performs calculations and spits out the results in the “OUTPUTS” section.

3.6 Existing Energy and Water Systems Infrastructure

The sheer magnitude of the planned campus development will impact the existing energy and water systems infrastructure.

The detailed analysis and condition assessment of the existing energy and water services is beyond the scope of this study. Hence the following comments provide a high level review only.

Central Electric Distribution (CED) System

Honeywell has worked with Chorley + Bisset Ltd., Consulting Engineers to conduct a review of the campus CED system and its capacity. Chorley's report is included in Appendix B. Existing electric service feed from Hydro Ottawa has a maximum supply capacity of 16 MVA. Current campus peak demand is 14.7 MVA. Campus peak demand is expected to increase by over 60% (Table 3.7) once the Master Plan development is completed. The upgrades to the electrical infrastructure will be required to serve the new facilities.

Preliminary CED upgrade options are listed below. They are not intended to be conclusive of all the available options.

- Option 1 – Expansion of Existing Substation:
  - This option increases the size of the existing substation along Bronson Avenue to accommodate the future campus demand (see 1 on Drawing ESK-1 in Appendix B).
- Option 2 – Addition of Second Substation at Opposite End of Campus
  - This option provides a second substation possibly near MacOdrum Library or existing residences (see 2a and 2b on Drawing ESK-1 in Appendix B)
- Option 3 – Remove Residences from Campus CED
  - This option takes advantage of the close proximity of residences to each other and to Colonel By Drive. From a site review, it appears Hydro Ottawa has existing underground utilities along Colonel By Drive which may be upgradable to support the residence buildings (see 3 on Drawing ESK-1 in Appendix B)
- Option 4 – Install Co-generation Heating Plant
  - Installation of a co-generation heating plant would allow replacement of aged CHP boiler(s) while also providing the additional power required (see 4 on Drawing ESK-1 in Appendix B)

Central Heating Plant (CHP) and Central Heat Distribution (CHD) System

Existing CHP infrastructure is nearly 50 years old and even with the good maintenance service likely near the end of its useful service life. The 2010 Master Plan calls for the replacement of the existing plant with new plant to serve the expanded campus. However, it appears that an interim solution will be required in near future to address the increasing reliability risks associated with the aged CHP infrastructure to provide uninterrupted heating service to the existing buildings.

Table 3.8 provides the summary of estimated peak heating and cooling loads for the new buildings. Peak heating load for the new buildings has been estimated at about 142,400 lbs/hr.

The peak cooling load for new buildings has been estimated at about 8,320 RTons. The cooling service can be provided by various means from centralized or dedicated cooling plants. This service can be provided by electric or steam absorption chillers (if a co-generation option is considered) and hence it is included in the CHP section.

Table 3.8 – 2010 Campus Master Plan - Heating and Cooling Load Estimates

2010 Master Plan Building Massing Statistics				Preliminary cooling & heating estimates	
Tag	Building Name	Area (ft2)	Type	Estimated Chilled Water Load (RTons)	Estimated Steam Load (lbs/hr)
I1	Dunton Tower Infill	55,574	Academic	123	1,945
I2	Library Infill	31,571	Library	70	1,105
I3	UniCentre Expansion	11,883	Student Centre	30	475
I4	McKenzie Infill	21,775	Research	54	871
V1	Library Expansion	45,316	Library	In Progress	
V2	Herzberg Annex	11,539	Laboratory	38	577
C1	Paterson Replacement	292,466	Academic	650	10,236
C2	L.S.R. Replacement	139,791	Academic	311	4,893
C3	Parking Lot 1	94,959	Parking	N/A	N/A
C4	S.S.R. Replacement	122,289	Academic	272	4,280
C5	Parking Lot 2 N.	131,470	Parking	N/A	N/A
C6	Parking Lot 2 S.	104,259	Parking	N/A	N/A
C7	Library Road	91,084	Office/Lecture	202	3,188
C8	Over Rail	231,618	Student Centre	579	9,265
C9	Parking Lot 4	133,139	Parking	N/A	N/A
C10	Old Gym + Daycare	141,492	Athletics	404	5,660
C11	Parking Lot 11	128,327	Parking	N/A	N/A
C12	Maintenance Replacement	53,281	Services	89	1,865
C13	Maintenance Replacement	71,881	Services	120	2,516
C14	Garage Replacement	110,502	Services	184	3,868
C15	Alumni Park Back	49,557	Student Centre	124	1,982
M1	Tennis Replacement	104,528	Services	174	3,658
M2	Bronson Frontage	325,436	Athletics	930	13,017
M3	New Maintenance	88,835	Services	148	3,109
N1	North Campus	59,158	Research	148	2,366
N2	North Campus	61,268	Research	153	2,451
N3	North Campus	60,407	Research	151	2,416
N4	North Campus	60,364	Research	151	2,415
N5	North Campus	71,903	Research	180	2,876
N6	North Campus	118,920	Research	297	4,757
N7	North Campus	114,700	Research	287	4,588
N8	North Campus	55,025	Research	138	2,201
N9	North Campus	55,886	Research	140	2,235
N10	North Campus	54,250	Research	136	2,170
N11	North Campus	104,022	Research	260	4,161
R1	Residence	172,955	Residence	288	6,053
R2	Residence Commons Addition	37,867	Residence	63	1,325
R3	Residence	117,736	Residence	196	4,121
R4	Residence	117,736	Residence	196	4,121
R5	Residence	117,736	Residence	196	4,121
R6	Residence	117,736	Residence	196	4,121
R7	Residence	117,736	Residence	196	4,121
R8	Residence + Commons	264,921	Residence	442	9,272
		4,472,898		8,316	142,401

Water Service System

Two 8-inch water lines from City of Ottawa in the meter chamber on Colonel By Drive are tied to the 16-inch water main serving the existing campus. Campus water consumption is expected to increase by over 60% (Table 3.7) once the Master Plan development is completed. The upgrades to the water distribution infrastructure will likely be required to serve the new facilities with the potential new feed line serving the new residential and research campuses at the North end of the university campus.

4.0 Energy Conservation

4.1 Overview

Honeywell, with assistance from Efficiency Engineering Inc. (EEI), conducted the site visits and facility walkthrough surveys to assess and identify energy and water conservation opportunities in the selected buildings (Table 4.1).

Table 4.1 – Buildings Selected for ASHRAE Level 1 Audits

Bldg. ID #	Building Name	Building Function	Area ft^2
1	Tory Building	Academic / Admin	127,581
2	MacOdrum Library	Academic	204,096
4	Southam Hall	Academic	99,487
7	University Centre	Ancillary / Academic/ Admin	127,581
10	Mackenzie Building	Academic	188,020
11	Maintenance Building	Ancillary	43,815
13	Herzberg Laboratories	Academic	152,501
15	Loeb Building	Academic	238,280
16	HHJ Nesbitt Biology	Academic	68,003
21	Dunton Tower	Academic	184,803
22	Architecture	Academic	92,687
23	St. Patrick's Building	Academic	75,460
27	Minto Centre	Academic	110,581
29	Carleton Technology	Ancillary	68,487
31	Azrieli Theatre	Academic	37,768
32	Azrieli Pavilion	Academic	49,496
37/38	Human Computer Int. & Visual	Academic	97,271
	Total		**1,965,917**

After the project commencement the scope of facility survey was modified and Southam Hall (#4) was substituted with Steacie Building (#12) due to major ongoing renovations in the former facility.

4.2 Energy Conservation Opportunities

Table 4.2 provides summary of existing energy and water use and potential savings identified in the selected buildings on campus. Energy conservation efforts offer an opportunity for the university to partially mitigate the future energy requirements and reduce future capital expenditures for building energy infrastructure and services.

Based on the preliminary assessment of the selected facilities about 17% and 3% reduction of energy and water use is possible, respectively.

The data contained in this table may be used as a starting point for planning ongoing energy conservation efforts on campus.

Two of the energy conservation project developed by Honeywell in fall of 2011 and spring 2013 are already under construction at Robertson Hall and Athletics facilities.

Based on our analysis the following five facilities have been identified as good candidates for future ASHRAE Level 2 and/ or Level 3 assessments and potential energy conservation projects as they offer the greatest opportunity for savings (in terms of magnitude). These future assessments will refine the savings and firm up project costs to allow the university a better decision making on how to proceed.

- Loeb Building (#15)
- Mackenzie Building (#10)
- University Centre (#7)
- Minto Centre (#27)
- Tory Building (#1)

Table 4.2 – Existing Energy Usage and Potential Savings

Bldg.	Building Name	Area	EXISTING USAGE															
Code		ft^2	Electricity					Steam - MTHW			Natural Gas			TOTAL		Water		TOTAL
#			kWh	kW	$	kWh/ft^2	W/ft^2	MMBtu	$	ekWh/ft^2	m3	$	ekWh/ft^2	BEPI	m^3	$	l/ft^2	$
1	Tory Building	138,110	2,753,123	602	$263,339	19.93	4.36	3,613	$62,856	7.67	28,757	$8,250	2.19	**29.79**	25,854	$74,388	187	$408,832
2	MacOdrum Library	204,177	2,750,652	601	$266,158	13.47	2.94	5,846	$104,680	8.39	0	$0	0.00	**21.86**	22,943	$65,806	112	$436,644
7	University Centre	177,183	3,281,840	717	$313,376	18.52	4.05	6,208	$108,194	10.27	168,723	$48,930	10.00	**38.79**	21,846	$62,141	123	$532,641
10	Mackenzie Building	188,095	3,762,182	822	$363,703	20.00	4.37	9,221	$162,056	14.37	39	$12	0.00	**34.37**	16,437	$46,780	87	$572,551
11	Maintenance Building	43,832	1,925,540	421	$186,294	43.93	9.60	526	$9,286	3.51	5,031	$833	1.21	**48.65**	2,126	$6,026	49	$202,439
12	Steacie Building	107,104	2,989,160	653	$287,777	27.91	6.10	19,148	$334,103	52.40	259	$44	0.03	**80.33**	18,389	$52,585	172	$674,509
13	Herzberg Laboratories	152,562	2,910,217	636	$280,483	19.08	4.17	6,708	$117,794	12.89	0	$0	0.00	**31.96**	4,259	$12,211	28	$410,487
15	Loeb Building	238,375	3,720,466	813	$356,023	15.61	3.41	9,749	$167,720	11.99	8,237	$2,389	0.36	**27.96**	16,524	$47,517	69	$573,649
16	HHJ Nesbitt Biology	68,030	732,153	160	$70,494	10.76	2.35	8,683	$153,991	37.41	0	$0	0.00	**48.17**	9,640	$27,510	142	$251,995
21	Dunton Tower	184,876	1,882,556	411	$180,853	10.18	2.23	3,804	$66,232	6.03	0	$0	0.00	**16.21**	12,834	$36,579	69	$283,665
22	Architecture	92,723	565,793	124	$54,643	6.10	1.33	1,617	$28,470	5.11	6,695	$1,898	0.76	**11.97**	2,453	$7,075	26	$92,086
23	St. Patrick's Building	75,490	1,607,684	351	$152,660	21.30	4.65	2,517	$44,117	9.77	66,099	$18,015	9.19	**40.26**	3,963	$11,251	52	$226,042
27	Minto Centre	110,624	3,646,516	797	$351,442	32.96	7.20	1,543	$27,067	4.09	0	$0	0.00	**37.05**	8,229	$23,565	74	$402,074
29	Carleton Technology	68,515	1,323,426	289	$126,237	19.32	4.22	3,231	$56,318	13.82	0	$0	0.00	**33.14**	8,308	$23,552	121	$206,107
31	Azrieli Theatre	37,783	419,737	92	$40,547	11.11	2.43	584	$9,804	4.53	0	$0	0.00	**15.64**	10	$29	0	$50,379
32	Azrieli Pavilion	49,516	900,469	197	$86,672	18.19	3.97	559	$9,808	3.31	0	$0	0.00	**21.50**	587	$1,693	12	$98,172
37/38	Human Computer Int. & Visual	97,309	1,825,421	399	$193,573	18.76	4.10	2,124	$37,996	6.40	0	$0	0.00	**25.16**	1,528	$11,729	16	$243,298
	Sub-Total	**2,034,302**	**36,996,934**	**8,085**	**$3,574,272**			**85,682**	**$1,500,490**		**283,840**	**$80,370**			**175,931**	**$510,437**		**$5,665,569**

Bldg.	Building Name	UTILITY SAVINGS															
Code		Electricity				Steam			Natural Gas			Water			Total	BEPI	BEPI
#		kW	kWh	kWh/ft2	$	MMBtu	kWh/ft2	$	m3	kWh/ft2	$	m3	l/ft2	$	$	kWh/ft2	% change
1	Tory Building	0	453,654	3.28	$43,188	1,018	2.16	$18,663	5,976	0.45	$1,673	453	3	$1,298	**$64,822**	**5.90**	**19.81%**
2	MacOdrum Library	121	504,979	2.47	$48,074	322	0.46	$5,901	0	0.00	$0	268	1	$769	**$54,744**	**2.94**	**13.43%**
7	University Centre	0	325,534	1.84	$30,991	2,029	3.36	$37,183	8,153	0.48	$2,283	171	1	$490	**$70,947**	**5.68**	**14.63%**
10	Mackenzie Building	5	567,242	3.02	$54,001	1,284	2.00	$23,538	0	0.00	$0	274	1	$784	**$78,324**	**5.02**	**14.60%**
11	Maintenance Building	214	164,270	3.75	$15,639	197	1.32	$3,610	968	0.23	$271	206	5	$589	**$20,108**	**5.30**	**10.89%**
12	Steacie Building	298	251,475	2.35	$23,940	920	2.52	$16,863	0	0.00	$0	374	3	$1,070	**$41,873**	**4.87**	**6.06%**
13	Herzberg Laboratories	0	386,614	2.53	$36,806	381	0.73	$6,991	0	0.00	$0	265	2	$758	**$44,555**	**3.27**	**10.22%**
15	Loeb Building	51	921,645	3.87	$87,741	1,138	1.40	$20,851	0	0.00	$0	564	2	$1,616	**$110,208**	**5.26**	**18.83%**
16	HHJ Nesbitt Biology	0	87,988	1.29	$8,376	867	3.74	$15,901	0	0.00	$0	1,140	17	$3,264	**$27,541**	**5.03**	**10.44%**
21	Dunton Tower	66	614,498	3.32	$58,500	36	0.06	$662	0	0.00	$0	574	3	$1,643	**$60,805**	**3.38**	**20.85%**
22	Architecture	1	123,191	1.33	$11,728	908	2.87	$16,648	5,086	0.58	$1,424	176	2	$504	**$30,304**	**4.78**	**39.89%**
23	St. Patrick's Building	36	403,605	5.35	$38,423	217	0.84	$3,979	20,990	2.92	$5,877	437	6	$1,252	**$49,531**	**9.11**	**22.62%**
27	Minto Centre	51	585,727	5.29	$55,761	482	1.28	$8,842	0	0.00	$0	334	3	$956	**$65,560**	**6.57**	**17.74%**
29	Carleton Technology	23	250,231	3.65	$23,822	347	1.48	$6,362	0	0.00	$0	283	4	$812	**$30,996**	**5.14**	**15.50%**
31	Azrieli Theatre	12	163,152	4.32	$15,532	246	1.91	$4,510	0	0.00	$0	248	7	$710	**$20,753**	**6.23**	**39.82%**
32	Azrieli Pavilion	0	154	0.00	$15	43	0.25	$779	0	0.00	$0	0	0	$0	**$794**	**0.25**	**1.19%**
37/38	Human Computer Int. & Visual	0	132,111	1.36	$12,577	388	1.17	$7,110	0	0.00	$0	183	2	$523	**$20,210**	**2.53**	**10.04%**
	Sub-Total	**877**	**5,936,071**		**$565,114**	**10,823**		**$198,391**	**41,174**		**$11,529**	**5,950**		**$17,040**	**$792,074**	**Energy**	**16.86%**
																Water	**3.38%**

EEI facility assessment reports are included in Appendix C. Table 4.3 provides a preliminary list of identified Energy Conservation Measures (ECMs) that could be implemented in the selected facilities.

Table 4.3 – Preliminary ECM List

	Carleton University Measure List	**Tory Building**	**MacOdrum Library**	**University Centre**	**Mackenzie Building**	**Maintenance Building**	**Steacie Building**	**Herzberg Laboratories**	**Loeb Building**	**HHJ Nesbitt Biology**	**Dunton Tower**	**Architecture**	**St. Patrick's Building**	**Minto Centre**	**Carleton Technology**	**Azrieli Theatre**	**Azrieli Pavilion**	**Human Computer Int. & Visual**
ECM	**Description**																	
ECM-1	Lighting retrofits/upgrades (T5, T8, LED)		x		x	x	x		x		x	x	x	x	x	x		x
ECM-2	Lighting controls	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
ECM-3	Tighten existing HVAC equipment operating schedules to match occupancy	x				x	x		x						x	x		
ECM-4	Expand BAS controls	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x
ECM-5	Implement demand ventilation controls on selected AHUs	x		x										x		x		
ECM-6	Reduce ventilation rates for the selected AHUs during low occupancy periods	x	x		x			x	x	x				x			x	x
ECM-7	Install high efficiency motors	x		x	x	x		x		x	x	x	x	x	x	x		x
ECM-8	Install VSDs on selected electrical motors (fans and pumps)	x		x	x	x		x	x	x	x	x	x	x	x	x		x
ECM-9	Upgrade constant air volume systems to variable air volume						x		x									
ECM-10	Upgrade constant air volume fume hoods to variable air volume	x					x											
ECM-11	Heat recovery									x								
ECM-12	Upgrade/replace steam traps	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
ECM-13	Electric to gas/steam fuel switch - DHW systems		x					x						x				
ECM-14	Insulate equipment and piping	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ECM-15	Install low flow plumbing fixtures	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
ECM-16	Eliminate city water use in AC/refrigeration applications									x								
ECM-17	Seal building envelope - weather strip windows and doors	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x
ECM-18	Replace windows				x													
ECM-19	Replace old boilers												x					
ECM-20	Replace AHUs												x					
ECM-21	Replace humidifiers												x					

Appendices

Appendix A	**Utility Data Management**
Appendix B	**University Campus Electrical Distribution Report**
Appendix C	**Facility Walkthrough Reports**
Appendix D	**Energy Master Plan Analysis – Utility Summaries and Other Supporting Information (attached on CD)**

Appendix A

Utility Data Management

Capturing the building operating data is the first step toward improved management of the campus facilities. Analysis of this data and follow up actions constitute the second and third steps in driving operational excellence.

Observations of areas where corrective actions are recommended, are outlined as follows:

General utility billing management

- No easy access to historical utility billing information
  - Longer than expected wait time to receive the required information slowed down Honeywell analysis
- Incomplete billing
  - Data received still incomplete with many missing bills especially for natural gas accounts (e.g. most bills missing from March to September 2012)
  - For the purpose of this analysis the consumption data for missing periods have been estimated based on the meter readings from available bills

Enbridge Consolidated Gas Account #000000655320

- Group account for 14 facilities listed in Table 2.2
- Shows the most inconsistent consumption data from all accounts analyzed:
  - Numerous meter reading errors
  - Meter readings frequently estimated not actual
    - some improvement in the frequency of actual meter readings observed in 2011 and 2012
  - Billing error corrections and reversal of charges in many cases encompass several billing periods with over 2 years as an extreme example
    - Bldg. #11 Shed June 6, 2011 includes corrected charges all the way back to January 8, 2009
    - Billing errors may affect gas consumption forecasting and utility cost recovery from tenants
    - Corrected bills show $ credits but not corrected gas consumption. The corrected gas consumption has to be manually calculated by the university staff
- University Centre (#7) – potential service address error
  - As of December 4, 2012 this building service address has been changed to Residence Commons (#19) resulting in 2 gas bills for the latter and none for the former
- Mackenzie Bldg. (#10) – very low gas use
  - Based on the available billing data the building total annual gas use range from as low as 2 m^3 in 2011 to as high as 66 m^3 in 2009
  - With almost no gas consumption, the University incurs an annual cost of over $1,000 (in 2012) in “Customer Charges” just for having a meter
  - There may be an opportunity to eliminate this cost by investigating the source of gas use and the real need for it in this building
- Bldg. #11 Shed
  - Shed meter service address is ambiguous as the University operating staff appear to be unfamiliar with the actual gas meter location

    - The meter's "Bldg. #11 Shed" label may also be misleading as to the true end use for the gas used

Water Accounts

- Historically two out of four water accounts (Table 2.1) recorded the majority of water consumption on campus, namely accounts #0055-2520-10 and #0055-2522-10
    - These 2 accounts appear to match the two feed lines from City of Ottawa and associated meters located in the meter chamber on Colonel By Drive and serving the campus water distribution system
    - All four accounts have the same service address but the location of the remaining 2 meters is currently not clear
- Historical trend of annual water consumption on campus shows a steady growth in consumption from 2009 to 2011
- This trend was sharply reversed in 2012 when the total annual water consumption dropped by about 22% compared to 2011
    - This drop in water consumption coincides with:
        - Account #0055-2523-10 and associated meter becoming dormant. No metered water consumption since May 2011
        - New water account #1107-2620-01 established sometime in 2012. Honeywell has received only 2 bills for this account for water consumption in November and December
    - No further evidence is available to account for potential reasons for the reduction in water consumption in 2012

Appendix B

University Campus Electrical Distribution Report

Chorley+Bisset
CONSULTING ENGINEERS

Carleton University
Campus Electrical Distribution Report

4 October 2013

INTRODUCTION

Chorley + Bisset Ltd was retained by Honeywell to conduct a high level review of the campus electrical distribution system and capacity at Carleton University, 1125 Colonel By Drive, Ottawa, Ontario.

This report is intended to provide guidance with respect to condition and capacity of normal power distribution at this campus with regards for planned future expansion.
The details presented are the results of our initial review only and does not include detailed observations or data on actual system performance from the facility Owner. It is not intended to present the results of a comprehensive audit and inspection of all equipment and systems in the facility.

As an example, concealed systems, conduit, wiring and equipment located within walls, below floors or above ceiling spaces, and secured areas, etc, were not accessible for review. This report is also not intended to provide a performance guarantee that existing systems or equipment is fully operational, or will remain fully operational for the anticipated lifetime of the buildings.

EXECUTIVE SUMMARY

The majority of the electrical distribution systems in original buildings on campus have main electrical infrastructure that is not in compliance with current codes and applicable standards. The existing electrical peak demand of the campus is near the maximum capacity of the current substation. Additional electrical load on campus will require modifications to increase available electrical distribution.
Four options for increasing electrical distribution system capacity are presented for discussion: Expansion of existing Bronson Avenue substation, addition of second substation at opposite end of campus, removal of residences from campus distribution, and installation of co-generation plant.

ELECTRICAL INFRASTRUCTURE

Campus Distribution

Electrical service to the campus is provided by two underground 13.8kV feeders supplied from Hydro Ottawa along Bronson Avenue. These feeders supply the Carleton substation adjacent to the Recreation Centre (See 1 on attached Drawing ESK-1).

Power is distributed throughout campus on 13.8kV loop feeders originating at the Bronson Avenue substation. In 2010, three loop feeders were split into five to increase capacity

available to each building. However, total campus capacity was not increased at this time. New cable installed in 2010 has increased ampacity over the existing cable; however the smaller original lead cable and loop switches limit the capacity of the feeders.
According to drawings from 2002, Hydro Ottawa has a maximum supply capacity of 16MVA. Current campus peak demand from Hydro Ottawa billing is 14.7MVA. The campus master plan nearly doubles the floor area on campus which will net a future peak demand larger than current supply capacity.

Building Distribution

In general, many of the older buildings on campus have original substations which are silicon filled, but were formerly PCB liquid cooled transformers. No PCB liquid filled transformers were observed on campus. In some cases, PCBs will leach out of the core/coil and overtime these transformers could be considered contaminated. These installations comply with current Ministry of Environment regulations. However, in some locations oil was observed on the floor of the electrical room. This is an indication of possible leaks from liquid filled transformers or PILC pot-heads. In both cases, this can lead to equipment failure.

Many of the original installations do not meet current Ontario Electrical Safety Code requirements with regards to spacing and exiting around equipment and limiting access to Medium Voltage equipment to authorized personnel only. The existing equipment is most likely not rated to interrupt or withstand the fault current available. Should a fault occur a nearby worker could be seriously injured due to space constraints and the resulting uncontained arc flash. Equipment damage can also result in building downtime. In addition, replacement parts may be difficult and/or expensive to source extending building downtime.

In some cases, transformers were observed significantly larger than the building demand, due to energy reduction measures. This is inefficient as no-load losses are proportional to the size of the transformer. Step-up transformers were observed with delta secondary configuration without ground detection lights. Should a ground-fault on the secondary side occur, it would go unnoticed until a second ground-fault occurs. For this reason, this installation is no longer permitted by the Ontario Electrical Safety Code.

Existing main services should be considered for replacement at the time of building renovation and/or addition. Replacement should be deferred, where possible, to avoid replacing equipment which may suit future plans for the building. For example, a 480V service could be replaced with a 600V service at the same time the mechanical systems are replaced. To address the delta secondary configurations, electrical systems should be reconfigured to eliminate delta secondary configurations. In the interim, ground detection lights need to be installed.

UPGRADING OPTIONS ELECTICAL INFRASTRUCTURE

The options listed below are not intended to be conclusive of all the available options to upgrade the electrical infrastructure required for the proposed buildings. Review and comment from Hydro Ottawa is required before accepting or eliminating any of the options.

Option 1 – Expansion of Existing Substation

Option 1 doubles the size of the existing substation along Bronson Avenue (See 1 on attached Drawing ESK-1) to accommodate the planned future campus demand. Two new feeders from Hydro Ottawa would be brought to the new substation. In addition, it would be suggested that an additional standby feeder from Hydro Ottawa be included for redundancy. New loop feeders would be installed to service new buildings at the North end of the campus. Existing feeders would be further split and/or replaced to meet the demands in the existing campus.

Option 2 – Addition of Second Substation at Opposite End of Campus

Option 2 provides a second substation at the opposite end of the campus near MacOdrum Library or the existing residences (See 2a and 2b on attached Drawing ESK-1). This substation could be fed from Hydro Ottawa feeders entering into the campus on Colonel By Drive. Provided Hydro Ottawa circuits are able to take a different route than the existing feeders, redundancy is provided in the event of a utility pole collision, storm or localized Hydro Ottawa disturbance.

A minimum of two new Hydro Ottawa feeders to the new substation would be required. As with option 1 above, an additional standby feeder from Ottawa Hydro should be provided at each substation for redundancy.

New loop feeders would be installed to service new buildings at the North end of the campus. Existing loop feeders could be reworked to originate at the exiting Bronson substation and the new substation. This would allow the campus to be fed from either substation. With this arrangement, special attention to the campus key-interlock is required to prevent inadvertently back feeding Hydro Ottawa circuits.

The main benefit of having two geographically isolated substations, with loop feeders originating at each, is redundancy. Currently a catastrophic failure at the Bronson Avenue substation would render the entire campus without power for a significant amount of time. Such catastrophic failures may be caused internally by fire or arc faults or externally by weather, floods or earthquakes. By changing open points in the loop feeders and shedding or rotating non-necessary loads (i.e. chillers); the entire campus can remain operational after a catastrophic event, at a reduced level of service.

Option 3 – Remove Residences from Campus Distribution

This option takes advantage of the close proximity of the residences to each other and to Colonel By Drive. From a site review, it appears Hydro Ottawa has existing underground utilities along Colonel By Drive which may be upgradable to support the residence buildings (See 3 on attached Drawing ESK-1).

The existing residences are currently fed from the campus 13.8kV system. In this option, all new and existing residences are removed from the campus 13.8kV system to free up capacity for new academic buildings. New services could be provided for each building directly from Hydro Ottawa. Pad mount transformers owned by Hydro Ottawa serving one or more residence buildings would be installed in close proximity to the residence buildings. The medium voltage feeders could be owned by Hydro Ottawa or Carleton University. With this option, main distribution boards may have to be altered to accommodate utility metering as each building would be a separate Hydro Ottawa meter.

The primary benefit of this option is that the service uptime would remain Hydro Ottawa’s responsibility. Should a transformer failure occur Hydro Ottawa would be required to replace the transformer. Given that Hydro Ottawa stocks transformers, service could be restored quicker than if the transformers were owned by Carleton University. Service uptime is very important, considering the nature of the residence buildings.

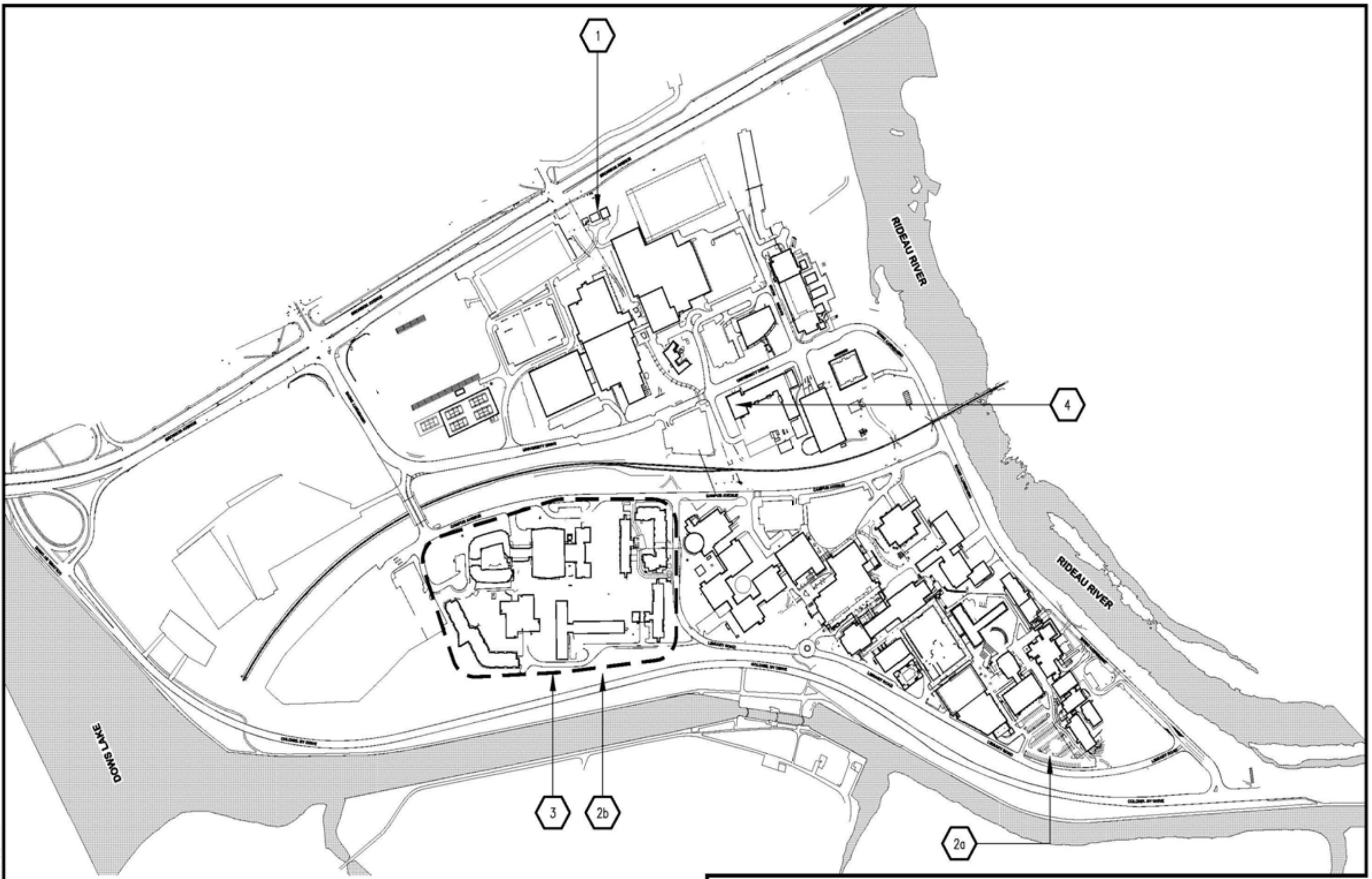
Option 4 – Install Co-Generation Heating Plant

Installation of a co-generation heating plant could allow for replacement of the existing campus boilers while also providing the additional power required (See 4 on attached Drawing ESK-1). The co-generation would run parallel with the incoming electrical grid from Hydro Ottawa. Any power produced in excess of current demand would be sold back to the grid. Interlocked controls would have to be provided to set the electrical production from the co-generation plant as a function of the loading on existing incoming Hydro Ottawa feeders, and for remote shutdown of the co-generation system by Hydro Ottawa for safety purposes.

There are many arrangements of co-generation plant, ranging in cost, payback and risk. Further study and risk assessment on the arrangements should be completed. For example, in the case of 100% reliance on the co-generation plant for electrical power without upgrading feeders from Hydro Ottawa, a failure in the heating plant could result in a cascading effect and loss of electrical service to the entire campus.

Option 4 used in conjunction with the previous options could provide a viable solution to meet the campus thermal and electrical power requirements, and provide opportunities to peak shave. The co-generation plant could also allow limited backup power to the entire campus during an extended Hydro Ottawa outage.

FILE NAME: 7206E001.DWG
DATE SAVED: 03-Oct-2013 5:31 PM
DATE PLOTTED: 03-Oct-2013 5:34 PM



Chorley+Bisset
CONSULTING ENGINEERS
369 YORK ST., SUITE 2B, LONDON ON, CANADA N6B 3R4
P: 519-679-8660 F: 519-679-2145 chorley.com

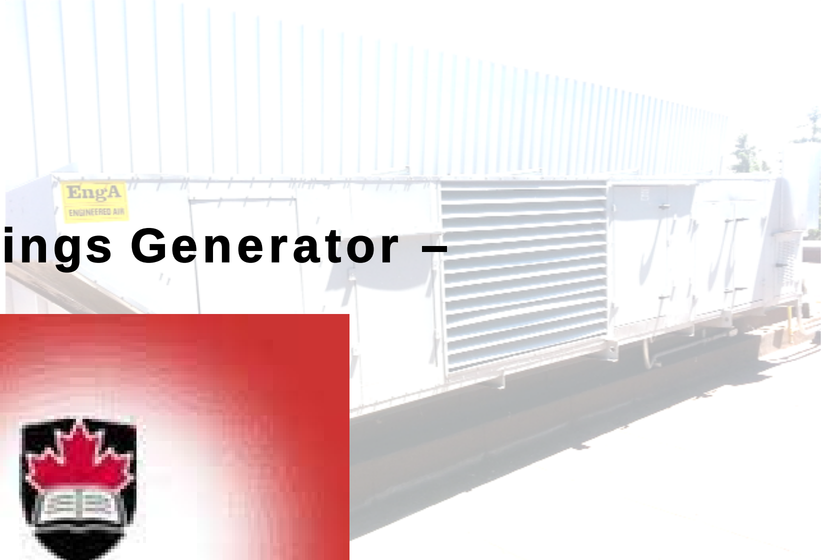
Title
CAMPUS MAP

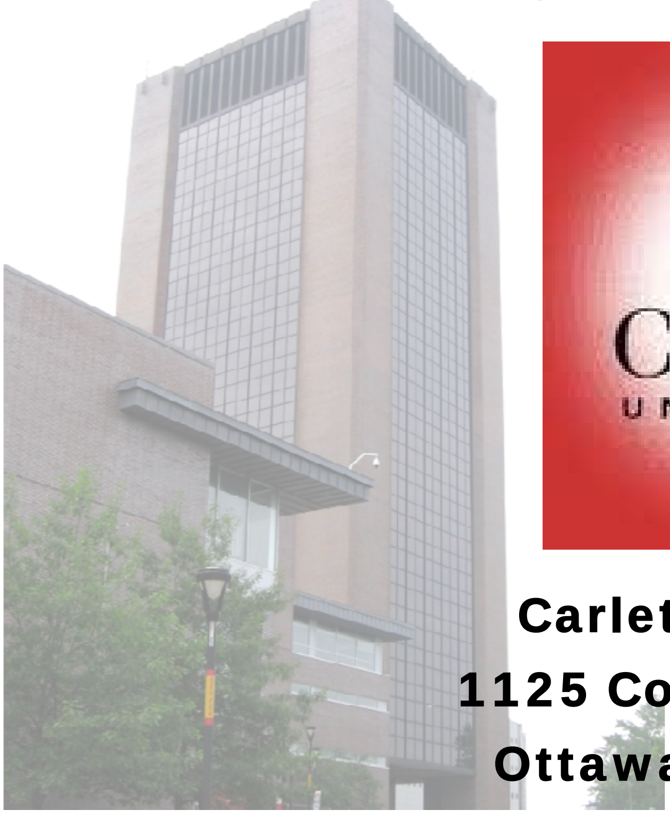
Project
CAMPUS ELECTRICAL DISTRIBUTION REPORT
CARLETON UNIVERSITY
OTTAWA, ONTARIO

Drawn	JPP	Date	3 OCT 2013
Checked	JPP	Project No.	7206
Approved	JPP	Drawing No.	ESK-1
Scale	NTS		

Appendix C

Facility Walkthrough Reports





Energy Savings Generator –

Carleton University
1125 Colonel Bay Drive,
Ottawa, ON K1S 5B6

Prepared By:

EFFICIENCY ENGINEERING INCORPORATED

519-624-9965
www.ee-solutions.com

Table 1. **ASHRAE Level 1 - Energy and Water Conservation Opportunity Assessment**

Facility #	Facility Name	Measure #	Measure	Electricity (kW)	Electricity (kWh)	Steam (Gas Fired) (klb	Natural Gas (m^3)	Water (m^3)	Annual Total Energy Savings (	Annual Tonnes C(	Total cost ($)	Simple Payback
1	Tory Building	1	Lighting Controls: Occupancy Sensors	0.00	243600.67	0.00	0.00	0.00	$ 23,190.78	182.94	$ 138,542.01	5.97
1	Tory Building	2	Install VFD's on Heating Hot Water Return Pumps	0.00	16695.62	0.00	0.00	0.00	$ 1,589.42	12.54	$ 18,837.90	11.85
1	Tory Building	3	Install VFD's on AHU-6 (Eng Air heating/cooling unit)	0.00	28459.16	0.00	0.00	0.00	$ 2,709.31	21.37	$ 15,061.05	5.56
1	Tory Building	4	Install VFD's on Domestic Water Booster Pumps (10HP)	0.00	31171.76	0.00	0.00	0.00	$ 2,967.55	23.41	$ 8,610.56	2.90
1	Tory Building	5	Install Variable Speed Fume Hood Exhaust Fans (where possible)	0.00	735.70	71.70	0.00	0.00	$ 1,384.28	4.45	$ 13,359.11	9.65
1	Tory Building	6	Install VFD on AHU-4, Lecture Hall	0.00	3678.29	0.00	0.00	0.00	$ 350.17	2.76	$ 5,936.92	16.95
1	Tory Building	7	Implement Demand Control Ventilation on AHU-4, -6	0.00	618.91	78.58	5976.17	0.00	$ 3,172.63	15.75	$ 6,723.09	2.12
1	Tory Building	8	Re-Schedule AHU-3 (Currently 24/7), Cycle On/Off based on Temperature	0.00	127175.69	0.00	0.00	0.00	$ 12,107.13	95.51	$ 335.60	0.03
1	Tory Building	11	Implement "Partial Occupancy" Schedule on AHU-1, -2, -3	0.00	1517.84	825.47	0.00	0.00	$ 15,275.44	46.04	$ 699.17	0.05
1	Tory Building	12	Water Conservation: Ultra Low Flow Aerators	0.00	0.00	42.39	0.00	453.28	$ 2,075.24	2.31	$ 1,077.66	0.52
	Tory Building Total			**0.00**	**453653.66**	**1018.15**	**5976.17**	**453.28**	**$ 64,821.97**	**407.07**	**$ 209,183.08**	**3.23**
2	Macodrum Library	1	Lighting Upgrade: Replace Magnetic Ballasts in West End	121.42	489564.23	0.00	0.00	0.00	$ 47,368.96	367.66	$ 601,338.89	12.69
2	Macodrum Library	3	Domestic Hot Water Conversion: Electric To Steam	0.00	3786.09	-13.64	0.00	0.00	$ 110.42	2.10	$ 22,627.31	204.92
2	Macodrum Library	4	Commission New Mechanical Room when Complete	0.00	791.97	106.55	0.00	0.00	$ 2,028.55	6.39	$ 47,566.10	23.45
2	Macodrum Library	5	Implement "Partial Occupancy" Schedule on AHU's	0.00	3480.70	229.02	0.00	0.00	$ 4,529.27	15.07	$ 3,495.86	0.77
2	Macodrum Library	6	Water Conservation: Ultra Low Flow Aerators	0.00	7355.82	0.00	0.00	268.44	$ 1,469.08	5.52	$ 1,390.53	0.95
	Macodrum Library Total			**121.42**	**504978.81**	**321.93**	**0.00**	**268.44**	**$ 55,506.29**	**396.74**	**$ 676,418.71**	**12.19**
7	University Centre	1	Lighting Controls: Occupancy Sensors	0.00	222346.89	0.00	0.00	0.00	$ 21,167.42	166.98	$ 129,864.88	6.14
7	University Centre	3	Water Conservation: Ultra Low Flow Aerators	0.00	0.00	16.01	0.00	171.24	$ 783.98	0.87	$ 1,981.51	2.53
7	University Centre	4	Install VFD's on AHU-1, AHU-2, AHU-3 Supply Fans, AHU-5, AHU-6	0.00	97179.92	0.00	0.00	0.00	$ 9,251.53	72.98	$ 76,713.72	8.29
7	University Centre	5	Implement Demand Control Ventilation on AHU-1, AHU-2, AHU-3, AHU-4, A	0.00	6007.69	2012.51	8153.48	0.00	$ 39,744.19	128.99	$ 36,977.02	0.93
	University Centre Total			**0.00**	**325534.50**	**2028.52**	**8153.48**	**171.24**	**$ 70,947.12**	**369.83**	**$ 245,537.13**	**3.46**
10	CJ Mackenzie	1	Lighting Upgrade: High Performance T8 Retrofit	4.50	39325.86	0.00	0.00	0.00	$ 3,772.09	29.53	$ 22,294.69	5.91
10	CJ Mackenzie	2	Lighting Controls: Occupancy Sensors	0.00	313119.11	0.00	0.00	0.00	$ 29,808.94	235.15	$ 168,025.21	5.64
10	CJ Mackenzie	3	Water Conservation: Ultra Low Flow Aerators	0.00	0.00	25.61	0.00	273.80	$ 1,253.54	1.39	$ 709.50	0.57
10	CJ Mackenzie	4	Replace current single pane windows	0.00	0.00	650.41	0.00	0.00	$ 11,922.08	35.38	$ 744,904.42	62.48
10	CJ Mackenzie	5	Install VFD's on Remaining AHU's, Reset to Outdoor Air Temperature	0.00	213161.15	0.00	0.00	0.00	$ 20,292.94	160.08	$ 173,851.08	8.57
10	CJ Mackenzie	6	Implement "Partial Occupancy" Schedule on AHU's	0.00	1636.30	608.12	0.00	0.00	$ 11,302.60	34.31	$ 3,495.86	0.31
	CJ Mackenzie Total			**4.50**	**567242.42**	**1284.14**	**0.00**	**273.80**	**$ 78,352.19**	**495.84**	**$ 1,113,280.77**	**14.21**
11	Maintenance Building	1	Install Steam Control Valve on DHW-1	0.00	0.00	47.18	0.00	0.00	$ 864.87	1.19	$ 2,829.14	3.27
11	Maintenance Building	2	Install VFD's on AHU-11A2 and 11A3	0.00	12762.04	0.00	0.00	0.00	$ 1,214.95	2.25	$ 19,351.46	15.93
11	Maintenance Building	3	Implement "Partial Occupancy" Schedule	0.00	5.80	116.54	968.12	0.00	$ 2,407.77	4.73	$ 3,495.86	1.45
11	Maintenance Building	4	Optimal start/stop of RTU-U1-Admin	0.00	1322.21	21.91	0.00	0.00	$ 527.52	0.79	$ 194.14	0.37
11	Maintenance Building	5	Lighting Upgrade: High Performance T8 Retrofit	196.68	96215.00	0.00	0.00	0.00	$ 10,394.73	17.00	$ 81,182.98	7.81
11	Maintenance Building	6	Lighting Upgrade: LED Exit Signs	1.62	1179.36	0.00	0.00	0.00	$ 122.45	0.21	$ 509.42	4.16
11	Maintenance Building	7	Lighting Upgrade: T5HO	16.08	11697.50	0.00	0.00	0.00	$ 1,214.58	2.07	$ 6,360.82	5.24
11	Maintenance Building	8	Lighitng Controls: Occupancy Sensors	0.00	41088.39	0.00	0.00	0.00	$ 3,911.61	7.25	$ 29,899.66	7.64
11	Maintenance Building	9	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	11.31	0.00	205.55	$ 795.96	0.29	$ 486.69	0.61
	Maintenance Building Total			214.38	164270.30	196.94	968.12	205.55	$ 21,454.44	35.77	$ 144,310.18	**6.73**

Table 1. ASHRAE Level 1 - Energy and Water Conservation Opportunity Assessment – cont'd

Facility #	Facility Name	Measure #	Measure	Electricity (kW)	Electricity (kWh)	Steam (Gas Fired) (kl	Natural Gas (m³)	Water (m³)	Annual Total Energy Savings (	Annual Tonnes C	Total cost ($)	Simple Payback
12	Steacie Building	1	Implement Night Setback for AHU-17 and 18	0.00	0.00	424.00	0.00	0.00	$ 7,771.86	10.70	$ 554.68	0.07
12	Steacie Building	2	Recommissioning	0.00	26568.98	437.51	0.00	0.00	$ 10,549.01	15.73	$ 74,811.46	7.09
12	Steacie Building	3	Install VAV Boxes	0.00	62907.72	0.00	0.00	0.00	$ 5,988.82	11.10	$ 109,330.42	18.26
12	Steacie Building	4	Insulate Steam and Hot Water Piping	0.00	0.00	39.26	0.00	0.00	$ 719.62	0.99	$ 976.80	1.36
12	Steacie Building	5	Lighting Upgrade: High Performance T8 Retrofit	292.68	124309.00	0.00	0.00	0.00	$ 13,672.11	21.98	$ 130,878.89	9.57
12	Steacie Building	6	Lighting Upgrade: Incandescent to CFL	5.04	3646.24	0.00	0.00	0.00	$ 378.77	0.64	$ 129.07	0.34
12	Steacie Building	7	Lighting Controls: Occupancy Sensors	0.00	34043.02	0.00	0.00	0.00	$ 3,240.90	6.00	$ 22,867.32	7.06
12	Steacie Building	8	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	19.18	0.00	373.58	$ 1,421.53	0.48	$ 556.21	0.39
	Steacie Building Total			**297.72**	**251474.97**	**919.95**	**0.00**	**373.58**	**$ 43,742.61**	**67.63**	**$ 340,104.86**	**7.78**
13	Herzberg Laboratories	1	Lighting Controls: Occupancy Sensors	0.00	238449.26	0.00	0.00	0.00	$ 22,700.37	179.07	$ 142,896.88	6.29
13	Herzberg Laboratories	2	Install VFD's on AHU-Level 2 B Block, AHU-Level 3 B Block, AHU-Level 4 B Bl	0.00	43520.81	0.00	0.00	0.00	$ 4,143.18	32.68	$ 42,905.64	10.36
13	Herzberg Laboratories	3	Remove Variable Inlet Vanes, Install VFD on AHU-Level 5 B Block	0.00	30486.37	0.00	0.00	0.00	$ 2,902.30	22.89	$ 19,569.75	6.74
13	Herzberg Laboratories	4	Install VFD's on Remaining AHU's, Reset to Outdoor Air Temperature	0.00	45972.69	0.00	0.00	0.00	$ 4,376.60	34.52	$ 94,007.58	21.48
13	Herzberg Laboratories	5	Implement "Partial Occupancy" Schedule on AHU's	0.00	834.06	393.94	0.00	0.00	$ 7,300.28	22.05	$ 4,894.21	0.67
13	Herzberg Laboratories	6	Water Conservation: Ultra Low Flow Aerators	0.00	7254.49	0.00	0.00	264.74	$ 1,448.85	5.45	$ 1,147.19	0.79
13	Herzberg Laboratories	8	DHW Conversion: Electric to Steam	0.00	3485.42	-12.56	0.00	0.00	$ 101.65	1.93	$ 22,627.31	222.60
13	Herzberg Laboratories	9	Install VFD on Domestic Water Booster Pumps	0.00	16610.54	0.00	0.00	0.00	$ 1,581.32	12.47	$ 7,855.40	4.97
	Herzberg Laboratories Total			**0.00**	**386613.64**	**381.38**	**0.00**	**264.74**	**$ 44,554.55**	**311.09**	**$ 335,903.97**	**7.54**
15	Loeb	1	Lighting Controls: Occupancy Sensors	0.00	451861.06	0.00	0.00	0.00	$ 43,017.17	339.34	$ 217,385.75	5.05
15	Loeb	2	Install VFD's on Induction Units A/B, C/D	0.00	122609.82	0.00	0.00	0.00	$ 11,672.45	92.08	$ 58,525.52	5.01
15	Loeb	3	Install VFD's on Dual Temperature Pumps BA, BB	0.00	20708.28	0.00	0.00	0.00	$ 1,971.43	15.55	$ 11,135.13	5.65
15	Loeb	4	Install VFD's on Chilled Water Pumps	0.00	94101.92	0.00	0.00	0.00	$ 8,958.50	70.67	$ 64,486.63	7.20
15	Loeb	5	Install VFD on Domestic Water Booster Pumps	0.00	16610.54	0.00	0.00	0.00	$ 1,581.32	12.47	$ 15,710.80	9.94
15	Loeb	6	Re-Schedule AHU-5 (Level 1 & 2, Currently 24/7), Cycle On/Off based on Te	0.00	64473.66	0.00	0.00	0.00	$ 6,137.89	48.42	$ 699.17	0.11
15	Loeb	7	Lighting Upgrade: High Performance T8 Retrofit	50.49	147019.94	0.00	0.00	0.00	$ 14,313.34	110.41	$ 250,046.47	17.47
15	Loeb	8	Implement "Partial Occupancy" Schedule on AHU's	0.00	2182.64	1084.74	0.00	0.00	$ 20,091.03	60.64	$ 1,747.93	0.09
15	Loeb	9	Lighting Upgrade: Incandescent to CFL	0.71	2077.10	0.00	0.00	0.00	$ 202.20	1.56	$ 218.01	1.08
15	Loeb	10	Water Conservation: Ultra Low Flow Aerators	0.00	0.00	52.78	0.00	564.38	$ 2,583.92	2.87	$ 1,807.69	0.70
	Loeb Total			**51.20**	**921644.95**	**1137.52**	**0.00**	**564.38**	**$ 110,529.26**	**754.01**	**$ 621,763.12**	**5.63**
16	HHJ Nesbitt	1	Lighting Controls: Occupancy Sensors	0.00	65540.32	0.00	0.00	0.00	$ 6,239.44	49.22	$ 38,848.66	6.23
16	HHJ Nesbitt	2	Recommission Hot Water Pumps P-8 and P-9 VFD, Reading 9 Hz	0.00	8390.35	0.00	0.00	0.00	$ 798.76	6.30	$ 1,398.35	1.75
16	HHJ Nesbitt	3	Install VFD on P-12 to AHU-2 & 3	0.00	5593.57	0.00	0.00	0.00	$ 532.51	4.20	$ 6,450.49	12.11
16	HHJ Nesbitt	4	Install VFD on AHU-4, Remove Bypass	0.00	7442.04	0.00	0.00	0.00	$ 708.48	5.59	$ 12,267.09	17.31
16	HHJ Nesbitt	5	Implement "Partial Occupancy" Schedule on AHU-1	0.00	110.24	40.97	0.00	0.00	$ 761.44	2.31	$ 349.59	0.46
16	HHJ Nesbitt	6	Water Conservation: Replace Single Pass Dry-O-Tron Unit	0.00	0.00	0.00	0.00	994.80	$ 2,849.12	0.00	$ 11,613.93	4.08
16	HHJ Nesbitt	7	Water Conservation: Ultra Low Flow Aerators	0.00	0.00	13.56	0.00	144.96	$ 663.66	0.74	$ 278.11	0.42
16	HHJ Nesbitt	9	Install Heat Reclaim on AHU-2	0.00	911.32	812.94	0.00	0.00	$ 14,987.96	44.90	$ 49,528.93	3.30
	HHJ Nesbitt Total			**0.00**	**87987.82**	**867.47**	**0.00**	**1139.76**	**$ 27,541.36**	**113.26**	**$ 120,735.14**	**4.38**

Table 1. ASHRAE Level 1 - Energy and Water Conservation Opportunity Assessment – cont'd

Facility #	Facility Name	Measure #	Measure	Electricity (kW)	Electricity (kWh)	Steam (Gas Fired) (klb	Natural Gas (m³)	Water (m³)	Annual Total Energy Savings (	Annual Tonnes C	Total cost ($)	Simple Payback
21	Dunton Tower	1	Recommission AHU-3	0.00	1179.90	4.54	0.00	0.00	$ 195.63	0.32	$ 1,678.01	8.58
21	Dunton Tower	3	Install VFD's on AHU-3 and 4	0.00	11694.63	0.00	0.00	0.00	$ 1,113.33	2.06	$ 30,826.32	27.69
21	Dunton Tower	4	Control P-28 to Turn Off	0.00	4053.79	0.00	0.00	0.00	$ 385.92	0.71	$ 734.33	1.90
21	Dunton Tower	5	Static Pressure Reset Control for AHU-1 and 2	0.00	30871.16	0.00	0.00	0.00	$ 2,938.93	5.44	$ 12,753.14	4.34
21	Dunton Tower	6	Lighting Upgrade: T8 High Perfromance System	61.80	314945.63	0.00	0.00	0.00	$ 30,370.90	55.68	$ 306,084.99	10.08
21	Dunton Tower	7	Lighting Upgrade: LED Retrofit	3.70	11095.85	0.00	0.00	0.00	$ 1,079.56	1.96	$ 6,734.26	6.24
21	Dunton Tower	8	Lighting Controls: Occupancy Sensors	0.00	240657.00	0.00	0.00	0.00	$ 22,910.55	42.44	$ 161,656.41	7.06
21	Dunton Tower	9	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	31.56	0.00	573.72	$ 2,221.69	0.80	$ 2,815.83	1.27
	Dunton Tower Total			**65.50**	**614497.95**	**36.11**	**0.00**	**573.72**	**$ 61,216.50**	**109.43**	**$ 523,283.29**	**8.55**
22	Architecture Building	1	Install Control Valves on Steam Supply	0.00	0.00	40.60	0.00	0.00	$ 744.18	1.02	$ 3,989.24	5.36
22	Architecture Building	2	Replace VIV's with VFD's on AHU-1 Supply and Return Fans	0.00	19954.78	0.00	0.00	0.00	$ 1,899.70	3.52	$ 25,773.39	13.57
22	Architecture Building	3	Replace VIV with VFD on AHU-2 Return Fan	0.00	4291.07	0.00	0.00	0.00	$ 408.51	0.76	$ 9,498.92	23.25
22	Architecture Building	5	Lighting Upgrade: Incandescent to CFL	0.88	7679.09	0.00	0.00	0.00	$ 736.58	1.36	$ 268.66	0.36
22	Architecture Building	6	Install Demand Control Ventilation on AHU's	0.00	36735.18	845.95	5086.38	0.00	$ 20,427.63	37.20	$ 22,788.65	1.12
22	Architecture Building	7	Replace Decommissioned Pump Housings with Insulated Straight Piping	0.00	10.97	0.00	0.00	2.13	$ 7.13	0.00	$ 121.27	17.00
22	Architecture Building	8	Lighting Controls: Occupancy Sensors	0.00	54520.27	0.00	0.00	0.00	$ 5,190.33	9.62	$ 36,623.56	7.06
22	Architecture Building	9	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	21.69	0.00	173.93	$ 895.68	0.55	$ 764.79	0.85
	Architecture Building Total			**0.88**	**123191.36**	**908.24**	**5086.38**	**176.05**	**$ 30,309.73**	**54.03**	**$ 99,828.48**	**3.29**
23	St Patrick's	1	Replace HP-2 Boilers B-1 to B-3	0.00	0.00	0.00	4084.39	0.00	$ 1,143.63	7.52	$ 53,734.60	46.99
23	St Patrick's	2	Install Proper Controls on AHU-2, HP-2, SP-3 and CH-2	0.00	3976.82	54.23	352.01	0.00	$ 1,471.17	2.72	$ 32,786.28	22.29
23	St Patrick's	3	Replace B-4 with Gas Fired Humidifier	0.00	0.00	0.00	7540.89	0.00	$ 2,111.45	13.89	$ 37,012.64	17.53
23	St Patrick's	4	Replace AHU-2 with a Proper HVAC Unit Designed for Art Galleries	0.00	68569.30	135.57	0.00	0.00	$ 9,012.84	15.52	$ 648,477.91	71.95
23	St Patrick's	5	Install Demand Control Ventilation and Optimize Schedule of AHU-1	0.00	59779.51	0.00	9012.97	0.00	$ 8,214.64	27.15	$ 9,080.15	1.11
23	St Patrick's	6	Replace AHU-1 Return Fan VIVs with VFD	0.00	9537.27	0.00	0.00	0.00	$ 907.95	1.68	$ 12,005.23	13.22
23	St Patrick's	7	Lighting Upgrade: T8 High Performance System	21.52	109690.00	0.00	0.00	0.00	$ 10,577.62	19.39	$ 106,604.76	10.08
23	St Patrick's	8	Lighting Upgrade: LED Retrofit	14.48	66519.08	0.00	0.00	0.00	$ 6,423.54	11.76	$ 29,291.19	4.56
23	St Patrick's	9	Lighting Controls: Occupancy Sensors	0.00	85533.52	0.00	0.00	0.00	$ 8,142.79	15.09	$ 57,455.40	7.06
23	St Patrick's	10	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	27.25	0.00	437.04	$ 1,751.16	0.69	$ 625.74	0.36
	St Patrick's Total			36.00	403605.49	217.05	20990.26	437.04	$ 49,756.79	115.41	$ 987,073.90	**19.84**
27	Minto Centre	1	Lighting Upgrade: High Performance T8 Retrofit	51.12	186063.08	0.00	0.00	0.00	$ 18,034.19	139.73	$ 253,159.77	14.04
27	Minto Centre	3	Lighting Controls: Occupancy Sensors	0.00	204012.71	0.00	0.00	0.00	$ 19,422.01	153.21	$ 105,111.78	5.41
27	Minto Centre	4	DHW Conversion: Electric to Steam	0.00	4710.03	-16.97	0.00	0.00	$ 137.36	2.61	$ 22,627.31	164.73
27	Minto Centre	5	Install VFD's on Heating Hot Water Pumps	0.00	5593.57	0.00	0.00	0.00	$ 532.51	4.20	$ 6,450.49	12.11
27	Minto Centre	6	Install VFD's on Chilled Water Pumps	0.00	20791.51	0.00	0.00	0.00	$ 1,979.35	15.61	$ 24,254.40	12.25
27	Minto Centre	7	Remove Variable Inlet Vanes, Replace with VFD: AHU-1, -7 & -8	0.00	98921.01	0.00	0.00	0.00	$ 9,417.28	74.29	$ 58,745.53	6.24
27	Minto Centre	8	Install VFD's on Remaining AHU's	0.00	53286.81	0.00	0.00	0.00	$ 5,072.90	40.02	$ 47,014.40	9.27
27	Minto Centre	9	Implement Demand Control Ventilation for AHU-3 (Strong Room), AHU-5 (	0.00	1574.57	184.59	0.00	0.00	$ 3,533.45	11.22	$ 5,932.10	1.68
27	Minto Centre	10	Implement "Partial Occupancy" Schedule on AHU's	0.00	1622.83	314.75	0.00	0.00	$ 5,923.90	18.34	$ 1,747.93	0.30
27	Minto Centre	11	Water Conservation: Ultra Low Flow Aerators	0.00	9150.91	0.00	0.00	333.95	$ 1,827.59	6.87	$ 1,042.90	0.57
	Minto Centre Total			**51.12**	**585727.05**	**482.37**	**0.00**	**333.95**	**$ 65,880.55**	**466.11**	**$ 526,086.61**	**7.99**

Table 1. ASHRAE Level 1 - Energy and Water Conservation Opportunity Assessment – cont'd

Facility #	Facility Name	Measure #	Measure	Electricity (kW)	Electricity (kWh)	Steam (Gas Fired) (klb	Natural Gas (m³)	Water (m³)	Annual Total Energy Savings (	Annual Tonnes C	Total cost ($)	Simple Payback
29	Carleton Tech & Training Centre	1	Install Steam Valves on HPS Side of PRV's When No Heating is Required	0.00	0.00	115.44	0.00	0.00	$ 2,116.03	0.01	$ 3,393.85	1.60
29	Carleton Tech & Training Centre	2	Repair Steam Leak on HPS Side	0.00	0.00	132.45	0.00	0.00	$ 2,427.83	0.01	$ 1,380.44	0.57
29	Carleton Tech & Training Centre	3	Install VFD's on P-1 and P-2	0.00	27165.02	0.00	0.00	0.00	$ 2,586.11	4.79	$ 23,977.99	9.27
29	Carleton Tech & Training Centre	4	Repair Fresh Air Damper on MAU-1	0.00	0.00	26.86	0.00	0.00	$ 492.40	0.00	$ 2,240.54	4.55
29	Carleton Tech & Training Centre	5	Install VFD on MAU-1	0.00	31430.76	0.00	0.00	0.00	$ 2,992.21	5.54	$ 22,969.07	7.68
29	Carleton Tech & Training Centre	6	Repair RTU-9 to Minimize Air Leakage From Building and Make Sure Dampe	0.00	0.00	5.34	0.00	0.00	$ 97.96	0.00	$ 309.12	3.16
29	Carleton Tech & Training Centre	7	Tighten All Control Schedules	0.00	5467.92	49.29	0.00	0.00	$ 1,424.06	0.97	$ 1,678.01	1.18
29	Carleton Tech & Training Centre	8	Lighting Upgrade: T8 High Performance System	20.23	103090.71	0.00	0.00	0.00	$ 9,941.27	18.22	$ 100,190.36	10.08
29	Carleton Tech & Training Centre	9	Lighting Upgrade: Interior LED's	2.57	8001.00	0.00	0.00	0.00	$ 777.83	1.42	$ 4,522.00	5.81
29	Carleton Tech & Training Centre	10	Lighting Controls: Occupancy Sensors	0.00	75075.34	0.00	0.00	0.00	$ 7,147.17	13.24	$ 51,103.44	7.15
29	Carleton Tech & Training Centre	11	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	17.68	0.00	283.49	$ 1,135.91	0.00	$ 973.37	0.86
	Carleton Tech & Training Centre Total			**22.80**	**250230.75**	**347.07**	**0.00**	**283.49**	**$ 31,138.79**	**44.21**	**$ 212,738.20**	**6.83**
31	Azrieli Theatre	1	Install Demand Control Ventilation for AHU-1, 2 and 3	0.00	13.61	211.67	0.00	0.00	$ 3,881.13	5.35	$ 15,417.42	3.97
31	Azrieli Theatre	2	Install VFD's on AHU-1 and 3	0.00	37157.03	0.00	0.00	0.00	$ 3,537.35	6.55	$ 37,404.22	10.57
31	Azrieli Theatre	3	Reschedule All Air Handling Units	0.00	19818.71	34.40	0.00	0.00	$ 2,517.21	4.36	$ 2,053.12	0.82
31	Azrieli Theatre	4	Lighting Controls: Occupancy Sensors	0.00	57654.00	0.00	0.00	0.00	$ 5,488.66	10.17	$ 31,178.96	5.68
31	Azrieli Theatre	5	Lighting Upgrade: T8 High Performance System	11.70	42511.00	0.00	0.00	0.00	$ 4,120.52	7.52	$ 57,841.05	14.04
31	Azrieli Theatre	6	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	5997.48	0.00	0.00	248.05	$ 1,281.38	1.06	$ 1,112.43	0.87
	Azrieli Theatre Total			**11.70**	**163151.83**	**246.06**	**0.00**	**248.05**	**$ 20,826.25**	**35.01**	**$ 145,007.20**	**6.96**
32	Azrieli Pavilion	2	Implement "Partial Occupancy" Schedule on AHU	0.00	154.27	42.52	0.00	0.00	$ 793.99	2.43	$ 699.17	0.88
	Azrieli Pavilion Total			**0.00**	**154.27**	**42.52**	**0.00**	**0.00**	**$ 793.99**	**2.43**	**$ 699.17**	**0.88**
37	Human Computer Interaction Building	1	Install VFD's on P-1 and 2, Open Balancing Valves on Pumps and Chiller	0.00	5926.79	0.00	0.00	0.00	$ 564.23	1.05	$ 6,886.32	12.20
37	Human Computer Interaction Building	2	Install VFD's on P-5 and 6, Open Balancing Valves on Pumps and Chiller	0.00	21073.02	0.00	0.00	0.00	$ 2,006.15	3.72	$ 22,683.14	11.31
37	Human Computer Interaction Building	3	Open Balancing Valves on P-3 and 4, Set Pump Speed on Valve Positions or	0.00	8768.08	0.00	0.00	0.00	$ 834.72	1.55	$ 2,358.54	2.83
37	Human Computer Interaction Building	4	Install VFD on Cooling Tower Fan	0.00	3887.28	0.00	0.00	0.00	$ 370.07	0.69	$ 14,900.82	40.26
37	Human Computer Interaction Building	5	Open Balancing Valves on P-7 and 8, Control Flow with Existing VFD's	0.00	2716.22	0.00	0.00	0.00	$ 258.58	0.48	$ 2,358.54	9.12
37	Human Computer Interaction Building	6	Implement "Partial Occupancy" Schedule on AHU's 1 and 2	0.00	25.91	367.81	0.00	0.00	$ 6,744.35	9.29	$ 1,398.35	0.21
37	Human Computer Interaction Building	7	Lighting Upgrade: T8 High Performance System	0.02	142.97	0.00	0.00	0.00	$ 13.71	0.03	$ 81.04	5.91
37	Human Computer Interaction Building	8	Lighitng Controls: Install Occupancy Sensors	0.00	89571.19	0.00	0.00	0.00	$ 8,527.18	15.80	$ 72,132.78	8.46
37	Human Computer Interaction Building	9	Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators	0.00	0.00	20.08	0.00	182.53	$ 890.89	0.51	$ 417.16	0.47
	Human Computer Interaction Building Total			**0.02**	**132111.45**	**387.89**	**0.00**	**182.53**	**$ 20,209.88**	**33.09**	**$ 123,216.69**	**6.10**
	Grand Total			**877.23**	**5936071.22**	**10823.30**	**41174.41**	**5949.61**	**$ 797,582.25**	**3810.95**	**$ 6,425,170.47**	**8.06**

1.0 Tory Building (#1) - Existing Building Profile

The facility is a 127,581 ft^2, 5 story building which serves primarily as offices along with some classroom and auditorium spaces.

Heating

Steam to Hydronic Heat Exchanger

Heat to the building is provided by the campus' centralized steam plant via shell and tube heat exchangers. Hot water from the heat exchanger then supplies a perimeter heating loop as well as hot water coils in the building's four main air handling units.

Steam to Hydronic Heat Exchanger

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by an instantaneous heat exchanger which draws from the University's centralized steam plant.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with two large McQuay chillers and a cooling tower. The chilled water plant serves several other buildings as well as the Tory Building.

Ventilation

The Tory Building is supplied with ventilation from the building's three main air handling units located in penthouse mechanical rooms across the roof. Each AHU is equipped with a hot water and a chilled water heating coil to provide conditioned air as well as ventilation throughout the building.

CO2 levels are monitored by the BAS which adjusts the outdoor air ventilation levels to maintain indoor air quality. This allows ventilation levels to be minimized, especially during unoccupied overnight and weekend hours.

The supply and return fans of AHU-1, AHU-2 and AHU-3 are equipped with variable speed drives.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted mainly of efficient 32W T8 lamps with electronic ballasts as well as some upgraded areas containing efficient T5 lamps. Pot light fixtures were equipped with compact florescent lamps. Exit signs have been converted to

LED's. The majority of lighting is controlled by local wall switches.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Controls: Occupancy Sensors

M01.1 - Existing Conditions

Many of the building's offices and classrooms are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M01.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M02 – Install VFD on heating hot water return pumps

M02.1 - Existing Conditions

Two 3 hp pumps, OP1-1P1 and OP2-1P2, and three 5 hp pumps, P-3, P-5A and P-5B are heating zone return pumps. They circulate heating hot water throughout the building perimeter heating and heating coils in the AHU's.

Pumps OP1-1P1, OP2-1P2 and P-5A, P-5B operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7, while the secondary pump cycles on if the primary pump were to fail.

M02.2 - Retrofit Conditions

We recommend installing a variable frequency drive (VFD) and inverter duty motor on the primary heating hot water pumps. The VFD will allow the pump speed to modulate to match the heating loads on the system at all times. Drive speeds will modulate based on supply/return temperature differential. If the primary pump or the VFD were to fail the secondary pump would run during the repair of the primary pump or VFD.

The costing and payback for this measure include installing a VFD on the "primary" pump only. A VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M03 – Install VFD on AHU-6 (Eng Air heating/cooling unit)

M03.1 - Existing Conditions

All of the buildings AHU's are recirculatory mixing air handling units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU's are currently equipped with VFD's to reduce air flows during off peak times. AHU-6, however, lacks any type of air flow control.

M03.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-6. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M04 – Install VFD on Domestic Water Booster Pumps

M04.1 - Existing Conditions

Two 10 hp domestic water booster pumps supply the necessary water pressure for the building. One pump runs continuously while the other pump cycles on only during times of peak loads (high domestic water consumption). As this building consists mainly of office and classroom spaces, the domestic water load is likely fairly constant throughout the occupied hours. This results very short intervals of high demand when the second booster pump would be required.

M04.2 - Retrofit Conditions

We recommend installing a variable speed drive and inverter duty motor on the primary domestic booster pump. Any PRV's on the main line leading to the mechanical room should be opened completely or entirely removed to reduce the system losses. A pressure sensor would be installed in the penthouse with the VFD modulating to maintain water pressure (say 20 psig) at that point.

As the second domestic water booster pump runs for only very short periods of time throughout the day, installing a VFD on this pump would significantly increase the implementation cost of this measure, but would not increase the savings proportionally.

The costing and payback for this measure include installing a VFD on the "primary" pump only. A VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M05 – Install VFD on Fume Hood Exhaust Fans

M05.1 - Existing Conditions

The building's exhaust fume hoods are currently scheduled to exhaust air 24 hours a day 7 days a week. The fans run at full speed even when they could be running slower.

By installing a VFD, less conditioned air will be exhausted resulting in less air needing to be conditioned.

M05.2 - Retrofit Conditions

We recommend installing a variable frequency drives (VFD's) and inverter duty motors on the fume hood exhaust fans. Fan speeds will modulate to maintain duct pressure set points in each zone of the exhaust fan. As a fume hood is opened the pressure will drop indicating a need to increase exhaust air, the fan speed will ramp up to exhaust more from the space.

M06 – Install VFD on AHU-4

M06.1 - Existing Conditions

AHU-4 is a mixed air unit which brings in controlled amounts of ventilation air and blend it with return air before delivering it to the theatre. The AHU is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for this AHU are sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M06.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-4. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M07 – Implement Demand Control Ventilation on AHU-4, -6

M07.1 - Existing Conditions

The air-handling units AHU-4 and AHU-6 provide heating, cooling and ventilation to the building, blending fresh air and return air to a fixed mixed air temperature setpoint. This provides temperature and humidity control in the space, but tends to bring in more ventilation air than needed, especially during partial occupancy periods. Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

M07.2 - Retrofit Conditions

CO_2 control on the air handlers would ensure that ventilation air volumes are matched to occupancy under all conditions. CO_2 sensors would be installed in occupied areas or return air ducts, as appropriate for each air handler. ASHRAE Standard 62 recognizes that ambient (outdoor) CO_2 levels can fluctuate, and that a better measure of ventilation requirements in the space is to use the difference between indoor and ambient levels. An outside sensor would also be installed to determine the ambient CO_2 levels. The new sensors would be connected to the building automation system, which would be reprogrammed to maintain the indoor air CO2 levels at 700 ppm above ambient.

The outside air and relief dampers would be replaced with low leakage dampers.

M08 – Reschedule AHU-3, Cycle on/off based on Temperature

M08.1 - Existing Conditions

AHU-3 is currently scheduled to run 24 hours a day 7 days a week. This AHU is a mixed air unit equipped with a hot water coil and a chilled water coil which provides heating and cooling to level 1 and 2 of the building. The fans run for long hours including evenings, nights and weekends.

The fans for the AHU are sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M08.2 - Retrofit Conditions

We recommend implementing a schedule based on actual occupancy of the building and shutting AHU-3 off during over night hours except when needed to maintain a minimum space temperature setting. This will greatly reduce the fan's hours of operation and, therefore, energy consumption. Implementation costs for this measure are relatively low. As all of the controls exist, only updating of the building automation system would be required.

M10 – Campus Wide Integrated Lighting Controls

M10.1 - Existing Conditions

Many of the building's offices, classrooms and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M10.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

M11 – Implement "Partial Occupancy" Schedule – AHU's -1, -2, -3

M11.1 - Existing Conditions

Ventilation to the building is provided by several recirculatory mixing air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 6 in the morning through until 10 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as office space with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M11.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M12 – Water Conservation: Ultra Low Flow Aerators

M12.1 - Existing Conditions

The majority of washroom sinks located throughout the building are equipped with standard low flow (2.2 gpm) aerators.

M12.2 - Retrofit Conditions

We recommend installing ultra low flow (0.5 gpm) aerators on all washroom faucets.

1.0 MacOdrum Library (#2) - Existing Building Profile

The facility is a 204,096 ft^2 building.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water coils in the building's main air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by single eletric heater tank located in the basement mechanical (chiller) room. A domestic hot water recirculation pumps delivers hot water on demand throughout the building.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with two newer Carrier Evergreen chillers and a newer cooling tower. The chilled water plant supplies chilled water coils in the building's main air handling units.

Ventilation

MacOdrum Library is supplied with ventilation from the building's main air handling units located in the mechanical penthouse. At the time of the audit, the Library was undergoing an extensive HVAC retrofit including the installation of numerous new air handling systems. Construction was in process but not completed. Each AHU is equipped with a hot water or glycol coil as well as a chilled water coil to provide conditioned air as well as ventilation throughout the building.

All of the newer air handling units at the facility are being installed with variable speed drives.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with standard 2.2 gpm faucet aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures on occupancy sensors. Linear florescent lighting throughout offices, stairwells, book aisles and common spaces consisted of efficient T5 and T8 lamps with electronic ballasts. However, the linear florescent lighting throughout the west end consisted of T8 lamps with magnetic ballasts. The garage levels are equipped with high pressure sodium lighting. Pot light fixtures are equipped with compact florescent lamps. Exit signs have been converted to LEDs.

The lighting systems at this facility were in the process of being upgraded during the time of this audit.

32W T8 Lighting on O/S

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Upgrade: Replace Magnetic Ballasts in West End

M01.1 - Existing Conditions

The west end of this facility is illuminated by 32 watt T8 lamps with magnetic ballasts in linear fluorescent fixtures. However, the lighting systems at this facility were in the process of being upgraded during the time of this audit.

M01.2 - Retrofit Conditions

We recommend retrofitting existing fixtures housing magnetic ballasts with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing T8 system and 49% savings over the existing T12 system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M02 – Combination photocell/occupancy sensor for new area currently under construction

M02.1 - Existing Conditions

The windows on the west end of this facility provide high levels of natural daylight. Lighting controls seemed to be in the process of being updated during the audit to occupancy sensors throughout the west end.

M02.2 - Retrofit Conditions

We recommend installing photocells to control the perimeter lighting in the west end of the facility.

Photocells turn lights “off” when natural daylight levels are sufficient to meet light level requirements for the space and “on” when daylighting levels fall below set threshold. Photocells used in combination with dimmable ballasts have the ability to slowly dim lighting level in accordance with natural daylighting levels entering the space. Many sensors allow “sensitivity” or “lighting thresholds’ to be adjusted to accommodate certain tasks and areas.

In general, we recommend installing occupancy sensors in any offices, common areas and corridors that has not yet been upgraded. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M05 – Implement “Partial Occupancy” Schedule – AHU’s

M05.1 - Existing Conditions

Ventilation to the building is provided by numerous recirculatory mixing air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 7 in the morning through until 10 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15-25%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as a library with office space with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M05.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current "occupied hours" minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M06 – Water Conservation: Ultra Low Flow Aerators

M06.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M06.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

M07 – Campus Wide Integrated Lighting Controls

M07.1 - Existing Conditions

Many of the building's offices, classrooms and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M07.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M03 – Domestic Hot Water Conversion: Electric To Steam

M03.1 - Existing Conditions

MacOdrum Library is supplied with domestic hot water from an electric heater tank located in the basement mechanical (chiller) room. Electricity, though efficient, is an expensive heat source. Steam is currently available within the basement mechanical room where the heater tank is located. The nearby steam piping should be taken advantage of as it has the capacity to heat the DHW at a lower cost than electricity.

M03.2 - Retrofit Conditions

We recommend replacing the existing electric heater tank with a DHW system supplied by the central steam plant. The existing heater tank should be replaced with a heat exchanger and domestic hot water storage tank.

M04 – Commission New Mechanical Room when Complete

M04.1 - Existing Conditions

MacOdrum Library was in the process of an extensive HVAC retrofit at the time of the audit. This retrofit included replacement of numerous air handling units, hot and chilled water pumps, exhaust fans etc. As equipment was in the process of being replaced, it's operation and control strategies could not be verified or confirmed.

The original design of most buildings involves many assumptions about occupancy, internal heat gains, lighting loads, building envelope performance, etc. As a result, design engineers make conservative assumptions and design for extreme conditions. Little thought is put into part-load efficiency.

Building commissioning focuses on occupancy comfort with little regard for energy consumption. Also, commissioning takes place at the end of a project, and often is neglected due to project delays, cost overruns, reduced budgets, etc.

M04.2 - Retrofit Conditions

We recommend a complete, independent commissioning of MacOdrum Library once renovations have been completed. Commissioning, especially of the HVAC systems should focus on energy conservation while improving occupancy comfort.

Commissioning generally consists of:

Step 1 – Develop plan and form project team.

Step 2 – Develop performance baseline.

Step 3 – Conduct system measurements and develop processed measures

Step 4 – Implement measures.

Step 5 – Document comfort improvements and energy savings.

Step 6 – Keep the commissioning continuous.

1.0 University Centre (#7) – Existing Building Profile

The facility is a 127,581 ft2 building containing office spaces, classrooms, a student cafeteria, a full service restaurant and a bookstore.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water coils in the building's main air handling units. Packaged rooftop units also supply heating with natural gas burners.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by the campus' central steam heating plant via an immersion steam to hot water heat exchanger located within the DHW storage tank. A domestic hot water recirculation pump delivers hot water on demand throughout the building.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with its own chiller as well as a cooling tower which is in good operating condition. The chilled water plant supplies chilled water coils in the building's main air handling units.

Ventilation

University Centre is supplied with ventilation from the building's main air handling units located in the mechanical penthouse as well as packaged rooftop units. Each AHU is equipped with a hot water or glycol coil and a chilled water coil to provide conditioned air as well as ventilation throughout the building.

Most of the larger air handling units are equipped with variable speed drives. Some smaller units are not.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets, urinals and showers as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted of efficient 32W T8 lamps with electronic ballasts. A large portion of this facility consists of pot light fixtures equipped with compact florescent lamps. Exit signs have been converted to LED's. The majority of lighting is controlled by local wall switch.

• 2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Controls: Occupancy Sensors

M01.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7. This is a high traffic facility that would greatly benefit from the use of occupancy sensors.

M01.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M02 – Install Photocells in Areas of High Natural Light

M02.1 - Existing Conditions

The main entrance and stairwell up to the cafeteria provide high levels of natural daylight.

M02.2 - Retrofit Conditions

We recommend installing photocells to control the lighting in the main entrance area as well as the stairwell up to the cafeteria.

Photocells turn lights “off” when natural daylight levels are sufficient to meet light level requirements for the space and “on” when day lighting levels fall below set threshold. Photocells used in combination with dimmable ballasts have the ability to slowly dim lighting level in accordance with natural day lighting levels entering the space. Many sensors allow “sensitivity” or “lighting thresholds’ to be adjusted to accommodate certain tasks and areas.

M03 – Water Conservation: Ultra Low Flow Aerators

M03.1 - Existing Conditions

The majority of washroom sinks located throughout the building are equipped with standard low flow (2.2 gpm) aerators.

M03.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all washroom faucets to further reduce water consumption.

M04 – Install VFD’s on AHU-1 (Main Lobby Eng Air Unit), AHU-2 (Bookstore), AHU-3 Supply Fans (Cafeteria), AHU-5 (Galleria), AHU-6 (Galleria)

M04.1 - Existing Conditions

All of the buildings AHU’s are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU’s is equipped with a hot water coil or a natural gas burner for heating as well as a chilled water coil for cooling.

The fans for each of these AHU’s is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU's are currently equipped with VFD's or variable inlet vanes to reduce air flows during off peak times. Several of the AHU's, however, lack any type of air flow control.

M04.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-1, -2, -3, -5 and -6. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M05 – Implement Demand Control Ventilation on AHU-1 (Main Lobby Eng Air Unit), AHU-2 (Bookstore), AHU-3 (Cafeteria), AHU-4 (Classrooms), AHU-5 (Galleria), AHU-6 (Galleria), AHU-7 (Unicentre Pub), UniCentre Mez 3rd Floor (Fans 607/608), AHU-Porter Hall (Fans 605/606), AHU-Penthouse VV (Fans 609, 610), AHU-UniMez South (Fans 301/302)

M05.1 - Existing Conditions

The air-handling units provide heating, cooling and ventilation to the entire facility, blending fresh air and return air to a fixed mixed air temperature setpoint. This provides temperature and humidity control in the space, but tends to bring in more ventilation air than needed, especially during partial occupancy periods. Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

M05.2 - Retrofit Conditions

CO_2 control on the air handlers would ensure that ventilation air volumes are matched to occupancy under all conditions. CO_2 sensors would be installed in occupied areas and return air ducts, as appropriate for each air handler. ASHRAE Standard 62 recognizes that ambient (outdoor) CO_2 levels can fluctuate, and that a better measure of ventilation requirements in the space is to use the difference between indoor and ambient levels. An outside sensor would also be installed to determine the ambient CO_2 levels. The new sensors would be connected to the building automation system, which would be reprogrammed to maintain the indoor air CO_2 levels at 700 ppm above ambient.

The outside air and relief dampers would be replaced with low leakage dampers.

M06 – Campus Wide Integrated Lighting Controls

M06.1 - Existing Conditions

Many of the building's offices, classrooms and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M06.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)

- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

1.0 Mackenzie Building (#10) - Existing Building Profile

The facility is a 188,020 ft^2 building containing offices and classrooms.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water reheat coils in the building's supply air duct work. Each space is typically equipped with its own thermostat for temperature control.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by the campus' central steam heating plant via a steam to hot water heat exchanger. A domestic hot water recirculation pump delivers hot water on demand throughout the building.

Cooling

The entire facility is supplied with air conditioning through chilled water coils in the main air handling units.

Chilled water is supplied by a chilled water plant located in another building. The remote chilled water plant is served by a cooling tower located on the rooftop of the MacKenzie building. The cooling tower is equipped with a variable speed drive.

Ventilation

The MacKenzie Building is supplied with ventilation from the building's main air handling units located in various mechanical rooms throughout the building. Each AHU is equipped with a chilled water coil for cooling.

None of the air handling units are currently equipped with variable speed drives.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Washroom sink with low flow

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear fluorescent lighting throughout offices, classrooms, corridors and common spaces consisted of efficient T8 lamps with electronic ballasts. Linear florescent lighting throughout stairwell spaces consisted of T8 lamps with magnetic ballasts. All mechanical rooms were equipped with occupancy sensor timer switches. Pot light fixtures were equipped with compact florescent lamps. Exit signs have been converted to LEDs. The majority of lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Upgrade: High Performance T8 Retrofit

M01.1 - Existing Conditions

The linear fluorescent fixtures in the stairwells at this building house 32 watt T8 lamps and inefficient magnetic ballasts. Some ballasts have been updated to electronic ballasts as they fail.

M01.2 - Retrofit Conditions

We recommend retrofitting existing 4ft T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M02 – Lighting Controls: Install Occupancy Sensors

M02.1 - Existing Conditions

Many of the building’s offices, classrooms and washrooms are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M02.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M03 – Water Conservation: Ultra Low Flow Aerators

M03.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M03.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

M05 – Install VFD’s on AHU’s and Reset to Outdoor Air Temperature

M05.1 - Existing Conditions

All of the buildings AHU’s are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a chilled water coil which provides cooling. All of the AHU's are also equipped with terminal re-heat coils (hot water) located in the duct work which allows each individual room supplied by the air handling unit to have independent temperature control.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M05.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of the AHU's. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M06 – Implement "Partial Occupancy" Schedule – AHU's-2, -3, 10D-112, -3, -4, -5, -6, -9, -10, -11

M06.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 7 in the morning through until 10 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as classroom and office space with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M06.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M07 – Campus Wide Integrated Lighting Controls

M07.1 - Existing Conditions

Many of the building's offices, classrooms and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M07.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M04 – Replace Current Single Pane Windows

M04.1 - Existing Conditions

There are single pane windows in several areas of the facility. Glass has very little thermal resistance, so the windows represent a major area of heat loss in winter and heat gain in summer. In addition, the existing frames and operable sections are leaky, so there is significant air infiltration around them.

M04.2 - Retrofit Conditions

It is recommended that the single pane windows be replaced with double pane thermally broken aluminum frame windows. Existing operable windows should be replaced with operable windows. Newer windows will have a higher R-value (better insulating characteristics), and will also have tighter frames resulting in less infiltration. Specify argon-filled windows with a low-emissivity interior coating to block some of the summer radiant heat gain and to reduce color fading of furniture or carpets.

1.0 Maintenance Building (#11) - Existing Building Profile

The facility is a 43,815 ft^2, 2 storey building which serves primarily as offices as well as some maintenance shop areas.

Heating

Heat to the building is provided to the building from various heat sources including multiple air handling units (using heat from the campus' centralized steam plant), electric resistance coils, and several rooftop units equipped with gas fired furnaces.

DHW Heat Exchanger

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by an instantaneous heat exchanger which draws from the University's centralized steam plant. A DHW recirculation pump distributes hot water throughout the building.

Cooling

The entire facility is supplied with air conditioning.

The building is equipped with multiple rooftop air handling units which have their own direct expansion cooling as well as air handling units which are supplied by a chilled water loop.

Ventilation

The Maintenance building is supplied with ventilation from the building's multiple air handling units located in mechanical rooms and across the roof. Each AHU is equipped with a heating coil. Some units are equipped with cooling coils. The majority of the air handling units are constant volume with recirculatory mixing ventilation.

All systems are monitored by the BAS and are programmed to a schedule according to occupancy.

Typical Washroom Sink

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Lighting is a mixture of T12 and T8 linear fluorescent lamps with magnetic ballasts. The new addition is primarily illuminated by 32 watt T8 lamps with electronic ballasts. The large majority of exit signs are LED with a few incandescent exit signs still remaining in the front entrance corridor. The boiler plant houses high pressure sodium highbay fixtures. Lighting is controlled by local wall switch.

Exterior lighting is high pressure sodium wall packs and recessed pot lights.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Install Steam Control Valve on DHW-1

M01.1 - Existing Conditions

This facility has a domestic hot water loop which is fed from the University's centralized steam loop. The DHW heat exchanger currently has steam passing through it constantly, regardless of the heating demand of the hot water.

M01.2 - Retrofit Conditions

We recommend that a two way steam control valve be installed to control the flow of the steam based on the temperature of the DHW loop. This allows the heat output of the heat exchanger to more closely match the actual DHW heating demand.

M03 – Implement "Partial Occupancy" Schedule – All AHU's

M03.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 5-7 in the morning through until 5-7 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (10-25%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as office space with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M03.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M04 – Optimal start/stop of RTU-U1-Admin

M04.1 - Existing Conditions

The building has a rooftop unit which heats and cools the administration area. The current BAS schedule for this unit is longer than the occupied hours of the area.

M04.2 - Retrofit Conditions

Operating HVAC units for longer hours than necessary consumes excess electrical energy to run the fans. Additionally, these units bring in ventilation air which must be heated or cooled to the supply air temperature before being delivered to the space. We recommended that the schedule be updated to serve the current occupied hours within the space.

M05 – Lighting Upgrade: High Performance T8 Retrofit

M05.1 - Existing Conditions

Linear fluorescent fixtures throughout the building house a mixture of T12 and T8 lamps in combination with inefficient magnetic ballasts. As the magnetic ballasts sporadically fail they are being replaced with electronic ballasts.

M05.2 - Retrofit Conditions

We recommend retrofitting existing fixtures housing magnetic ballasts with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing T8 system and 49% savings over the existing T12 system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M06- Lighting Upgrades: LED Exit Signs

M06.1 - Existing Conditions

A number of exit signs still house incandescent lamps which roughly consume 30-50 watts per fixtures.

M06.2 - Retrofit Conditions

We recommend replacing all incandescent exit signs with LED exit signs that consume less than 5 watts per unit.

M07– Lighting Upgrade: T5 High Output Lighting

M07.1 - Existing Conditions

The boiler room is illuminated by high pressure sodium (HPS) high bay fixtures and T12 & T8 strip lighting. The high bay fixtures remain on 24/7.

M07.2 - Retrofit Conditions

We recommend replacing the HPS high bay fixtures with T5 high output lighting. T5HO lighting creates up front energy savings by reducing consumption. Average lamp life of T5HO lamp is slightly greater than that of HPS; 30,000 -36,000 hrs vs 24,000 hrs and T5HO lamps also have exceptional lumen maintenance of 95%. Additional benefits lay in T5HO lighting's ability to instantly turn off and on with no re-strike time. T5HO lighting works exceptionally well with occupancy sensors, creating further savings.

M08 – Lighting Controls: Install Occupancy Sensors

M08.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors and Boiler Room are typically left on 24/7.

M08.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, corridors, washrooms and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M09 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M09.1 - Existing Conditions

Water faucets throughout the building are currently equipped with standard 2.2 gallon per minute (gpm) aerators in the washrooms.

M09.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M10 – Campus Wide Integrated Lighting Controls

M10.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M10.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)

- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M02 – Install VFD's on AHU-11A2 and 11A3

M02.1 - Existing Conditions

AHU-11A2 and 11A3 both supply multiple zones throughout the maintenance building and are currently scheduled by the BAS.

The fans for each of these AHU's are sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. AHU's 11A2 and 11A3, lack any type of air flow control during off peak periods.

M02.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-11A2 and 11A3. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

1.0 Steacie Building (#12) - Existing Building Profile

The facility is a 107,104 ft^2, 5 storey building which serves primarily as laboratories and classrooms with some offices.

Heating

Heat to the building is provided to the building from the campus' centralized steam plant. The steam is fed directly and through heat exchangers to multiple air handling unit heating coils to provide space heating and also feeds the perimeter heating throughout the building.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by an instantaneous heat exchanger which draws from the University's centralized steam plant and is equipped with a recirculation loop and pump.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with two large McQuay chillers and two Marley cooling towers. The chilled water plant serves the Steacie Building along with a few other buildings.

Ventilation

The Steacie Building is supplied with ventilation from the building's multiple air handling units. Each AHU is equipped with heating and cooling coils. The majority of the air handling units are recirculatory mixing ventilation with the acception of AHU-2 which is 100% fresh air.

All systems are monitored by the BAS has a programmed schedule according to occupancy.

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Several areas of this facility have recently been renovated and new T5 fixtures have been installed. In areas where renovations have not taken place, the lighting primarily remains linear fluorescent 32 watt T8 lamps with inefficient magnetic ballasts. There are compact fluorescent pot lights and incandescent fixtures throughout the building. Exit signs are LED. Lighting is primarily controlled by local wall switch.

Exterior lighting is primarily pot light fixtures housing parabolic lamps. Exterior lighting is controlled by photocell.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 –Implement Night Setback for AHU-17 and 18

M01.1 - Existing Conditions

AHU-17 and 18 currently supply to the east and west zones. They are re-circulatory mixing air handlers with a hot and cold deck (dual duct) for the capability of simultaneous heating and cooling to multiple zones. The supply and return fans are equipped with variable speed drives which are controlled by matching the speed of the building's exhausts to maintain positive pressure. They are currently scheduled to run 24/7 on the BAS control.

M01.2 - Retrofit Conditions

We recommend optimizing the BAS controls by scheduling the AHU's to maintain a lower temperature during unoccupied hours of the building. Implementing a night time reset temperature would allow the air handlers to consume less energy during unoccupied hours when there is no in the building to be comforted. The air handlers will maintain the lower temperatures during unoccupied periods, and then return to maintain the desired occupied temperature based on the schedule. Implementation costs for this measure are relatively low. As all of the controls exist, only updating of the building automation system would be required.

M02 – Re-commissioning

M02.1 - Existing Conditions

The Steacie building is currently operating with multiple labs and classrooms. All major HVAC equipment is currently monitored by the BAS, but most schedules are running the equipment for all hours of the day. There were some schedules which reduce the operating time of some equipment, but the schedules have the potential to be optimized further.

There is also the potential that some equipment be replaced with newer and more efficient equipment.

M02.2 - Retrofit Conditions

When older buildings which have only been commissioned since they were constructed, equipment tends to be neglected and starts operating inefficiently or incorrectly. Re-commissioning can save anywhere from 1% to 5% in energy savings through equipment optimization and operational corrections.

We recommend re-commissioning the Steacie building and its mechanical systems in order to optimize the equipment schedules and to find out if all equipment is operating the way it was originally designed to.

M04 – Insulate Steam and Hot Water Piping

M04.1 - Existing Conditions

The mechanical room was observed to have a high ratio of bare hot water piping. The piping for the radiator supply was exposed to the room's environment. Bare hot water piping is always a potential for energy savings because it shows a great amount of heat loss potential.

Un-insulated Steam Piping

M04.2 - Retrofit Conditions

During the winter months, the steam heat exchanger will supply a hot water loop which supplies the perimeter radiators with heat. The less heat that is lost before the hot water reaches the radiators, the more efficiently the system will operate.

We recommend insulating the radiator hot water piping in order to lower the amount of heat lost. The steam heat exchanger will therefore require less input to the radiator loop because of the lower piping heat loss.

M05 – Lighting Upgrade: High Performance T8 Retrofit

M05.1 - Existing Conditions

In areas where renovations have not taken place, the lighting primarily remains linear fluorescent 32 watt T8 lamps with inefficient magnetic ballasts.

M05.2 - Retrofit Conditions

For areas that are not scheduled for renovation in the near future, retrofitting the existing fixture is the most cost effective way to achieve significant savings.

We recommend retrofitting existing T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M06 – Lighting Upgrade: Incandescent to CFL

M06.1 - Existing Conditions

The fourth floor of the Steacie building still houses some incandescent lamps in recessed ceiling fixtures.

M06.2 - Retrofit Conditions

We recommend replacing all incandescent with compact fluorescent equivalents.

M07 – Lighting Controls: Install Occupancy Sensors

M07.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M07.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M08 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M08.1 - Existing Conditions

Water faucets throughout the building are currently equipped with 2.2 gallons per minute (gpm) aerators in the washrooms.

M08.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M09 – Campus Wide Integrated Lighting Controls

M09.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M09.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M03 – Install VAV Boxes

M03.1 - Existing Conditions

The supply air for the Steacie building is currently guided through a hot and cold deck system. This allows different zones to have different supply temperatures (different set points, heat gains, occupants, etc.). There is currently no control over the volume of air supplied to each zone.

M03.2 - Retrofit Conditions

If variable air volume (VAV) boxes are installed, the air handler supply and return fans can be controlled based on static pressure inside the ducts. The VAV box begins to close because the zone is at the desired temperature, and less air is required.

Reducing the amount of air supplied to each zone reduces energy consumption in a couple ways. It reduces the amount of energy needed to condition the smaller volume of air. The supply and return fans would be controlled to maintain a static pressure level, and when the VAV boxes close, it makes it easier to maintain this pressure level. This allows the fans to lower their speed and electrical consumption due to the lower level of air required to maintain the duct pressure.

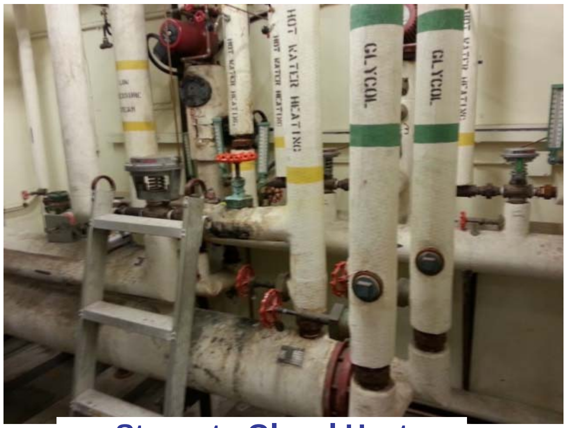
By installing the VAV boxes and controlling the fans based on static duct pressure, less heating, cooling, and electrical energy can offer a reduction in total energy consumption of this building.

1.0 Herzberg Laboratories (#13)- Existing Building Profile

The facility is a 152,501 ft2 building containing offices, labs and classrooms.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water or glycol heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water heating coils in the building's air handling units.



Steam to Glycol Heat

Domestic Hot Water (DHW)

Electric Heater Tank

Domestic hot water to the facility is supplied by an electric hot water heater tank located in a first floor mechanical room. A domestic hot water recirculation pump delivers hot water on demand throughout the building.

Cooling

The entire facility is supplied with air conditioning through chilled water and chilled glycol coils in the building's air handling units.

Chilled water is supplied by a chilled water plant located in another building. Chilled glycol is supplied by a Kool Air rooftop chiller.

Ventilation

Herzberg Laboratories is supplied with ventilation from the building's main air handling units located in various mechanical rooms throughout the building. Each AHU is equipped with a hot water coil for heating and either a chilled water or chilled glycol coil for cooling.

Most of the air handling units are not currently equipped with variable speed drives.

Ventilation to labs and storage rooms is supplemented by multiple exhaust fans and fume hoods.

Typical Air Handling Unit

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. Some washrooms already consist of ultra low flow aerators. No running/leaking fixtures or damaged aerators were observed.

Washroom sink with ultra low flow aerator

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted of efficient 32W T8 lamps with electronic ballasts. Portions of the mechanical rooms were equipped with occupancy sensor timer switches. Pot light fixtures were equipped with compact florescent lamps. Exit signs have been converted to LEDs. The majority of lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Control: Occupancy Sensors

M01.1 - Existing Conditions

Many of the building's offices, classrooms and common areas are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M01.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M02 –Install VFD's on AHU-Level 2 B Block, AHU-Level 3 B Block, AHU-Level 4 B Block

M02.1 - Existing Conditions

All of the buildings AHU's are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU's are currently equipped with VFD's or variable inlet vanes to reduce air flows during off peak times. Several of the AHU's, however, lack any type of air flow control.

M02.2 - Retrofit Conditions

We recommend removing the fan bypass ducts and installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-Level 2 B Block, AHU-Level 3 B Block and AHU-Level 4 B Block. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M03 – Remove Variable Inlet Vanes, Install VFD on AHU-Level 5 B Block

M03.1 - Existing Conditions

All of the buildings AHU's are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

Air conditioning. heating and ventilation to part of the building is supplied by variable air volume (VAV) fan systems in AHU-Level 5 B Block. Variable inlet vanes (VIVs) on the supply and return fans modulate to maintain the required duct pressure and air flow. The VIVs throttle air flow by creating flow resistance. Under these conditions, which occur during partial system load, the fans operate inefficiently. The return fan already has an installed VFD.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M03.2 - Retrofit Conditions

We recommend replacing the variable inlet vanes and fan motor with variable frequency drives (VFDs) and inverter-duty motors on the supply fan of the AHU. The duct pressure and air flow will then be maintained by automatic adjustment of the fan motor speeds. The fan motors will draw less power because the fans will have less flow resistance to overcome.

M05 – Implement "Partial Occupancy" Schedule on all of the AHU's

M05.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 7 in the morning through until 11 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (10 - 15%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as offices, labs and classrooms with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M05.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M06 – Water Conservation: Ultra Low Flow Aerators

M06.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M06.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

M07 – Campus Wide Integrated Lighting Controls

M07.1 - Existing Conditions

Many of the building's offices, classrooms, laboratories and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M07.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.

- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

M09 – Install VFD on Domestic Water Booster Pumps

M09.1 - Existing Conditions

Two 7.5 hp domestic water booster pumps supply the necessary water pressure for the building. One pump runs continuously while the other pump cycles on only during times of peak loads (high domestic water consumption). As this building consists mainly of office and classroom spaces, the domestic water load is likely fairly constant throughout the occupied hours. This results very short intervals of high demand when the second booster pump would be required.

M09.2 - Retrofit Conditions

We recommend installing a variable speed drive and inverter duty motor on the primary domestic booster pump. Any PRV's on the main line leading to the mechanical room should be opened completely or entirely removed to reduce the system losses. A pressure sensor would be installed in the penthouse with the VFD modulating to maintain water pressure (say 20 psig) at that point.

As the second domestic water booster pump runs for only very short periods of time throughout the day, installing a VFD on this pump would significantly increase the implementation cost of this measure, but would not increase the savings proportionally.

The costing and payback for this measure include installing a VFD on the "primary" pump only. A VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M04 – Install VFD's on Remaining AHU's, Reset to Outdoor Air Temperature

M04.1 - Existing Conditions

All of the buildings AHU’s are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU’s is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU’s is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU’s are currently equipped with VFD’s or variable inlet vanes to reduce air flows during off peak times. Several of the AHU’s, however, lack any type of air flow control.

M04.2 - Retrofit Conditions

We recommend installing a variable frequency drives (VFD’s) and inverter duty motors on the supply and return fans of the remaining 11 AHU’s. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M08 – Domestic Hot Water Conversion: Electric To Steam

M08.1 - Existing Conditions

This facility was once equipped with DHW storage tank complete with an immersion steam/hot water heat exchanger. The original equipment has been decommissioned and left in place. The DHW tank/heat exchanger system has since been replaced with an electric DHW tank. Electricity, though efficient, is an expensive heat source. The nearby steam piping should be taken advantage of as it has the capacity to heat the DHW at a lower cost than electricity.

M08.2 - Retrofit Conditions

The existing heater tank should be replaced with a heat exchanger and domestic hot water storage tank using the steam piping that is already available from the previous system.

1.0 Loeb Building (#15) - Existing Building Profile

The facility is a 238,280 ft^2 building containing offices, classrooms and lecture halls.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water heating coils in the building's air handling units.

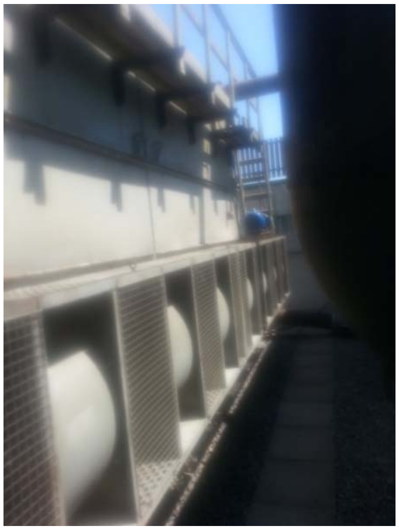
Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by the campus' steam heating plant via an instantaneous steam to hot water heat exchanger. A domestic hot water recirculation pumps delivers hot water on demand throughout the building.

Cooling

The building contains a centralized chilled water plant which supplies chilled water to cooling coils in the building's five main air handling units. This plant also supplies chilled water to other buildings on campus (Southam Hall and Patterson Hall). The plant is equipped with newer Carrier Evergreen chillers and a newer cooling tower controlled to eight stages of operation.

Most of the larger, newer pumps within the chilled water plant have been equipped with VFD's, however several older pumps were not upgraded during the retrofit. These older pumps lack VFD's.



Newer 8 Stage Cooling tower

Ventilation

The Loeb building is supplied with ventilation from the building's five main air handling units. Two of the AHU's are induction units while the remaining three are dual duct (hot deck/cold deck) units. Each AHU is equipped with either a hot water or steam coil for heating and a chilled water coil for cooling.

The dual duct systems are currently equipped with VFD's while the induction units are not.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Washroom sink with low flow

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted mainly of efficient 32W T8 lamps with electronic ballasts as well as some linear florescent lighting of efficient T5 lamps. Approximately 40% of the building consisted of T8 lamps with magnetic ballasts. The mechanical rooms in this facility were equipped with occupancy sensor timer switches. Pot light fixtures were equipped with compact florescent lamps. The majority of lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Upgrade: Occupancy Sensors

M01.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M01.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M02 – Install VFD’s on Induction Units A/B, C/D

M02.1 - Existing Conditions

The two induction air handling units bring in controlled amounts of ventilation air and blend it with return air before delivering it to terminal units located around the facility. Each of the AHU’s is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU’s is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU’s are currently equipped with VFD’s or variable inlet vanes to reduce air flows during off peak times. Several of the AHU’s, however, lack any type of air flow control.

M02.2 - Retrofit Conditions

We recommend installing a variable frequency drives (VFD’s) and inverter duty motors on the supply and return fans of Induction Units A/B and C/D. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M03 – Install VFD’s on Dual Temperature Distribution Pumps

M03.1 - Existing Conditions

Two 15 hp dual temperature distribution pumps, BA and BB, circulate water through the dual temperature loop throughout the building supplying perimeter heating and heating and cooling coils in the AHU’s.

The pumps operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7, while the secondary pump cycles on if the primary pump were to fail.

M05.2 - Retrofit Conditions

We recommend installing a variable frequency drive (VFD) and inverter duty motor on the primary dual temperature distribution pump. The VFD will allow the pump speed to modulate to match the heating and cooling loads on the system at all times. Drive speeds will modulate based on supply/return temperature differential. If the primary pump or the VFD were to fail the secondary pump would run during the repair of the primary pump or VFD.

The costing and payback for this measure include installing a VFD on the “primary” pump only. A VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M04 – Install VFD’s on Chilled Water Pumps

M04.1 - Existing Conditions

Five distribution pumps, P15-15, -16, -17, -18, and -19 circulate chilled water throughout the building supplying cooling coils in the AHU’s as well as supplying two additional buildings with chilled water.

Pumps P15-15 and P15-16 operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7, while the secondary pump cycles on if the primary pump were to fail.

Pumps P15-17, -18 and -19 turn on automatically with the chilled water plant.

M06.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD’s) and inverter duty motors on the five chilled water pumps. The VFD’s will allow pump speeds to modulate to match the cooling loads on the system at all times. Drive speeds will modulate based on supply/return temperature differential. If the primary pump or the VFD were to fail the secondary pump would run during the repair of the primary pump or VFD.

The costing and payback for this measure include installing a VFD on the “primary” pump (P15-15) and secondary pump (P15-16) as it still provides an attractive payback for the measure.

M05 – Install VFD’s on Domestic Water Booster Pumps

M05.1 - Existing Conditions

Two 7.5 hp domestic water booster pumps supply the necessary water pressure for the building. One pump runs continuously while the other pump cycles on only during times of peak loads (high domestic water consumption). As this building consists mainly of office and classroom spaces, the domestic water load is likely fairly constant throughout the occupied hours. This results very short intervals of high demand when the second booster pump would be required.

M05.2 - Retrofit Conditions

We recommend installing a variable speed drive and inverter duty motor on the primary domestic booster pump. Any PRV’s on the main line leading to the mechanical room should be opened completely or entirely removed to reduce the system losses. A pressure sensor would be installed in the penthouse with the VFD modulating to maintain water pressure (say 20 psig) at that point.

As the second domestic water booster pump runs for only very short periods of time throughout the day, installing a VFD on this pump would significantly increase the implementation cost of this measure, but would not increase the savings proportionally.

The costing and payback for this measure include installing a VFD on the “primary” pump only. A VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M06 – Reschedule AHU-5 (Level 1&2), Cycle on/off based on Temperature

M06.1 - Existing Conditions

AHU-5 is currently scheduled to run 24 hours a day 7 days a week. This AHU is a mixed air unit equipped with a hot water coil and a chilled water coil which provides heating and cooling to level 1 and 2 of the building. The fans run for long hours including evenings, nights and weekends.

The fans for the AHU are sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M06.2 - Retrofit Conditions

We recommend implementing a schedule based on actual occupancy of the building and controlling it to outdoor temperatures. The unit will cycle the supply and return fans on/off based on outdoor air temperature to reduce the run time of the fans during unoccupied times (evenings, weekends, during extended breaks) while ensuring the temperature of the supplied area never falls below a minimum temperature. This will reduce the unnecessary amount of fan runtime. Implementation costs for this measure are relatively low. As all of the controls exist, only updating of the building automation system would be required.

M07 – Lighting Upgrade: High Performance T8 Retrofit

M07.1 - Existing Conditions

Approximately 40% of this facility contained linear fluorescent fixtures that house 32 watt T8 lamps and inefficient magnetic ballasts. Some ballasts have been updated to electronic ballasts as they fail.

M07.2 - Retrofit Conditions

We recommend retrofitting existing 4ft T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M08 – Implement "Partial Occupancy" Schedule – AHU's-1, -2, -3, -4, -5

M08.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 6 in the morning through until 10 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as offices, classrooms and lecture halls with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M08.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M09 – Lighting Upgrade: Incandescent to CFL

M09.1 - Existing Conditions

There is still a small amount of incandescent lighting throughout this facility.

M09.2 - Retrofit Conditions

We recommend replacing incandescent lamps with equivalent compact fluorescent lamps (CFLs). There are compact fluorescent lamps (CFLs) on the market today to be utilized in almost any application. In preparation for the 2014 ban on "General Use" incandescent lamps, companies are producing quality CFLs which produce light of similar colour and lumen output as incandescent, all while consuming less than ¼ of the energy and lasting 10 times longer than standard incandescent bulbs.

M10 – Water Conservation: Ultra Low Flow Aerators

M10.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M10.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

M11 – Campus Wide Integrated Lighting Controls

M11.1 - Existing Conditions

Many of the building's offices, classrooms and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M11.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

1.0 HHJ Nesbitt Building (#16) - Existing Building Profile

The facility consists of a 68,000 ft2 building containing offices, classrooms, labs and greenhouses.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as hot water heating coils in the building's four main air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by the campus' steam heating plant via an instantaneous steam to hot water heat exchanger. A domestic hot water recirculation pumps delivers hot water on demand throughout the building.

Cooling

Cooling for the building is provided by chilled water from a remote source. Chilled water is supplied to cooling coils in the building's four main air handling units.

Ventilation

The Nesbitt Building is supplied with ventilation from the building's four main air handling units. Each AHU is equipped with a hot water coil for heating and a chilled water coil for cooling.

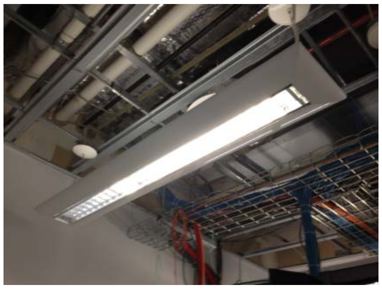
All units except for AHU-4 (5 hp) are currently equipped with VFD's.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted of efficient 32W T8 lamps with electronic ballasts. Some corridors and pot light fixtures were equipped with compact florescent lamps. Exit signs have been converted to LEDs. The majority of lighting is controlled by local wall switch.



32W T8 Lighting

Exceptional Equipment

A single pass water cooled heat pump located in the basement mechanical room supplies temperature control to laboratory aquariums. Condenser water from this heat pump passes through the unit and goes directly to drain.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Controls: Occupancy Sensors

M01.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many office and classroom lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M01.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M02 – Re-commission Hot Water Pumps P-8 and P-9 VFD, Reading 9Hz

M02.1 - Existing Conditions

The VFD controlling P-8 and P-9 was malfunctioning at the time of the audit. The pumps circulate heating hot water throughout the building supplying perimeter heating and heating coils in the AHU's.

The pumps operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7, while the secondary pump cycles on if the primary pump were to fail.

At the time of the audit, the VFD controlling the primary pump was displaying a reading of 9Hz which is below the operational capacity of most pumps.

M02.2 - Retrofit Conditions

We recommend re-commissioning the variable frequency drives (VFD) on pumps P-8 and P-9. The VFD allows the pump speed to modulate to match the heating loads on the system at all times. It is suspected that the existing drive requires maintenance or, possibly, replacement.

M03 – Install VFD on P-12 to AHU-2, AHU-3

M03.1 - Existing Conditions

One 5 hp pump, P-12, circulates heating hot water through heating coils in AHU-2 and AHU-3.

The pump operates continuously, 24/7, during the heating season.

M03.2 - Retrofit Conditions

We recommend installing a variable frequency drive (VFD) and inverter duty motor on the heating hot water pump. The VFD will allow the pump speed to modulate to match the heating loads on the system at all times. Drive speeds will modulate based on supply/return temperature differential.

M04 – Install VFD on AHU-4, Remove Bypass

M04.1 - Existing Conditions

All of the buildings AHU's are mixed air units, with the exception of the make-up air unit (AHU-2), which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU's are currently equipped with VFD's to reduce air flows during off peak times. AHU-4, however, lacks flow control.

M02.2 - Retrofit Conditions

We recommend removing the fan bypass duct on AHU-4 and installing variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-4. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M05 – Implement "Partial Occupancy" Schedule on AHU-1

M05.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units and one make-up air unit. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 7 in the morning through until 9 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as offices, classrooms, labs and greenhouses with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M05.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M06 – Water Conservation: Replace Single Pass Dry-O-Tron Unit

M06.1 - Existing Conditions

A single pass water cooled heat pump located in the basement mechanical room supplies the laboratory aquarium room. Condenser water from this heat pump passes through the unit and goes directly to drain. This system may no longer meet code requirements.

M06.2 - Retrofit Conditions

We recommend installing an air source heat pump instead of the single pass water cooled heat pump. The savings will come from water and sewage charges on the water going directly to the drain.

M07 – Water Conservation: Ultra Low Flow Aerators

M07.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M07.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

M08 – Campus Wide Integrated Lighting Controls

M08.1 - Existing Conditions

Many of the building's offices, classrooms, laboratories and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M08.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be

configured such that only the fixtures in that entrance and exit pathway or area shall be left on.

- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized. Typically the installation of an integrated lighting control system has a simple payback of 2-5 years.

M09 – Install Heat Reclaim on AHU-2

M09.1 - Existing Conditions

AHU-2 is a 100% outdoor air make up air unit that brings in ventilation air that is exhausted by a large dedicated exhaust fan. This unit brings in a lot of outdoor air. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

M09.2 - Retrofit Conditions

We recommend installing a heat reclaim unit with a glycol loop to precondition the outdoor air being brought in to the building. By reclaiming the heat from the exhaust air and preconditioning the incoming outdoor air, will reduce the heating and cooling loads required to condition the incoming air.

1.0 Dunton Tower (#21) - Existing Building Profile

The facility is a 184,803 ft^2, 24 story building which serves primarily as offices.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam convertors. Hot water from the heat exchanger then supplies induction unit reheat coils throughout the building as well as hot water and preheat coils in the building's four air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by an instantaneous heat exchanger which draws from the Universities centralized steam plant and includes a recirculation loop and pump.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with a Carrier chiller and BAC cooling tower. The chilled water from CH-1 supplies AHU-1,2 and 3 as well as the perimeter induction unit coils.

Ventilation

Dunton Tower is supplied with ventilation from the building's four air handling units located in penthouse and basement mechanical rooms. AHU-1 and 3 are equipped with a preheat coil, cooling coil, and a heating coil. AHU-2 is equipped with a heating coil and cooling coil. AHU-4 is equipped with a single heating coil. All the AHU's provide mixed air ventilation for the various zones within the building.

The BAS controls the ventilation from a programmed schedule based on occupancy.

The supply and return fans of AHU-1 are equipped with VFD's.

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchenette and washroom sinks with standard aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Lighting in this facility is primarily T8 with magnetic ballast. There are several T12 linear fluorescent fixtures with magnetic ballasts located in the basement and elevators. The 2nd floor elevator lobby houses metal halide pendant fixtures. Pot lights house compact fluorescent lamps. There are several halogen lamps located on the 17th floor. Some pot light fixtures which typically house halogen lamps have been undated to LED. Exit signs are LED. Exterior fixtures are a mixture of high pressure sodium and metal halide wall packs and poles.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

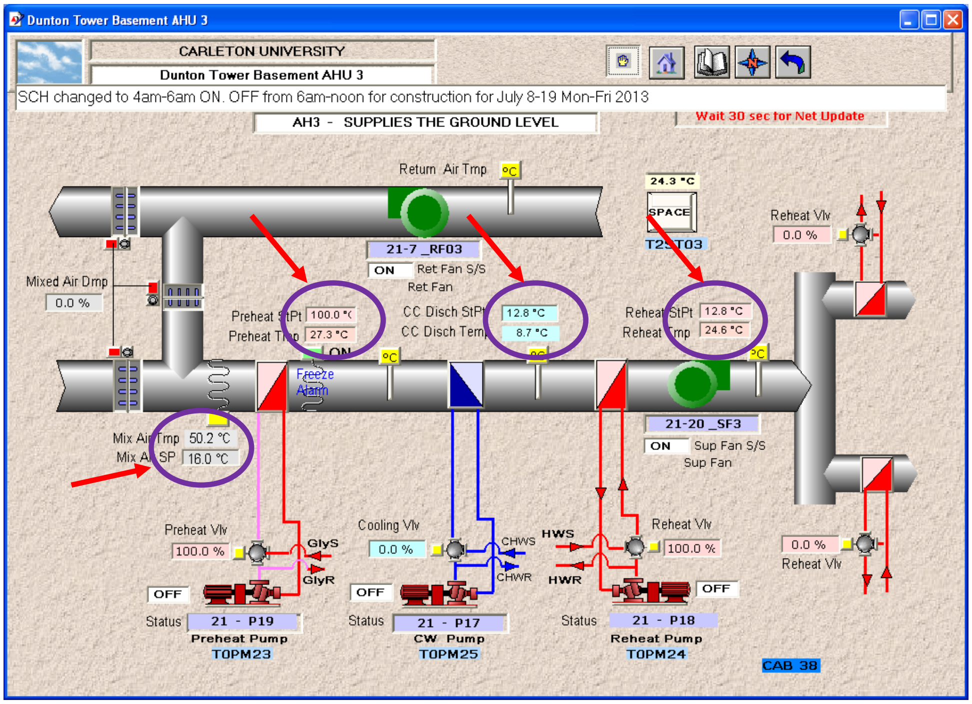
M01 – Re-commission AHU-3

M01.1 - Existing Conditions

This air handling unit was observed to have either malfunctioning equipment or BAS issues. The readings from the BAS screenshots show that the sequence of operation is not optimized or that equipment (sensors) are not functioning properly. Although the system is in operation and no alarms are present, the temperature measurements were observed to fluctuate without reason, possibly due to malfunctioning sensors or improper sequencing of the BAS.

M01.2 - Retrofit Conditions

We recommend re-commissioning this unit along with the BAS controls equipment to insure proper operation and monitoring of the system.


Dunton Tower Basement AHU 3

CARLETON UNIVERSITY
Dunton Tower Basement AHU 3
SCH changed to 4am-6am ON. OFF from 6am-noon for construction for July 8-19 Mon-Fri 2013
AH3 - SUPPLIES THE GROUND LEVEL
Wait 30 sec for Net Update

Return Air Tmp °C
Space 24.3 °C
Reheat Vlv 0.0 %
Mixed Air Dmp 0.0 %
21-7 _RF03: ON Ret Fan S/S
Preheat StPt 100.0 °C
Preheat Tmp 27.3 °C
CC Disch StPt 12.8 °C
CC Disch Temp 8.7 °C
Reheat StPt 12.8 °C
Reheat Tmp 24.6 °C
Mix Air Tmp 50.2 °C
Mix Air SP 16.0 °C
21-20 _SF3: ON Sup Fan S/S
Preheat Vlv 100.0 %
Cooling Vlv 0.0 %
Reheat Vlv 100.0 %
Reheat Vlv 0.0 %
Status OFF — 21 - P19 Preheat Pump TOPM23
Status OFF — 21 - P17 CW Pump TOPM25
Status OFF — 21 - P18 Reheat Pump TOPM24

M04 – Control P-28 to Turn Off

M04.1 - Existing Conditions

The building has a small pump which circulates a glycol loop for preheating coils. These coils serve as preheat for colder outdoor temperatures, but it was observed in June that the pump was still circulating the glycol.

M04.2 - Retrofit Conditions

It is recommended that the pump is equipped with a controller which turns the pump off when the outdoor air temperature rises above a set point (~38 ^{o}F), and turns on when it drops below that set point. This will reduce the pumping hours of the unit when preheating is not necessary and will reduce the electrical consumption.

M05 – Static Pressure Reset Control for AHU-1 and 2

M05.1 - Existing Conditions

The Dunton Tower has a two air handling units equipped with VFDs. They modulate their speed to maintain a constant static pressure and are scheduled to operate during occupied hours of the building. Typically when VAV boxes close, they dump their excess air flow into the ceiling spaces, which wastes heating, cooling and ventilation energy.

M05.2 - Retrofit Conditions

It is recommended that VAV boxes are equipped with damper position indicators. The indicators will allow the fans to slow down based on the position of the VAV dampers. When the dampers close because heating/cooling is no longer required to the zones, the VFDs will slow the fan motors down to a minimum. When the dampers begin to open, the VFDs will ramp up the speed of the fan motors accordingly.

M06 – Lighting Upgrade: T8 High Performance System

M06.1 - Existing Conditions

A large majority of the linear fluorescent fixtures in this building house 32 watt T8 lamps and inefficient magnetic ballasts. Some ballasts have been updated to electronic ballasts as they fail. A few areas in the basement and elevators still house T12 lamps and magnetic ballasts.

M06.2 - Retrofit Conditions

We recommend retrofitting existing 4ft T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

We recommend retrofitting all T12 fixtures with high efficiency electronic ballasts and corresponding lamps specific to fixture length.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M07- Lighting Upgrade: LED Retrofit

M07.1 - Existing Conditions

The 17th Floor lecture room still houses many halogen lamps on dimmer control.

M07.2 - Retrofit Conditions

We recommend replacing all interior halogen lamps with quality LED equivalents.

Currently the top choice in dimmable efficient lighting technology is LED. Quality LEDs have the ability to maintain warm colour temperatures while dimming to 10% and achieving efficacy of 60-90 lumens per watt while lasting 25,000 – 50,000 hours.

Care should be taken in selecting a quality LED which meets the needs of the application while being supported by a reputable company guaranteeing a lengthy warranty. Energy Star certification requires that energy and other identified performance parameters of the LEDs can be consistently measured and verified through testing. Energy Star certification should be the minimum requirement in choosing any energy efficient lighting product.

M08 – Lighting Controls: Occupancy Sensors

M08.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M08.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M09 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M09.1 - Existing Conditions

Water faucets throughout the building are currently equipped with standard 2.2 gallon per minute (gpm) aerators in the washrooms.

M09.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M10 – Campus Wide Integrated Lighting Controls

M10.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M10.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.

- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.
As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M03 – Install VFD's on AHU-3 and 4

M03.1 - Existing Conditions

AHU-3 and 4 currently are mixed air units which provide a constant volume of air. The units supply the 2nd floor lobby (AHU-3) and basement (AHU-4). These units are sized to provide adequate air flow during times of peak heating and cooling loads.

M03.2 - Retrofit Conditions

It is recommended that the supply and return fans are equipped with variable frequency drives (VFDs) to modulate the flow of supply air based on outdoor air temperature. During the "shoulder seasons" when heating and cooling loads are lower than peak, fan speeds will be reduced to supply a lower air flow. As heating/cooling requirements increase, fan speeds will increase accordingly based on outdoor air temperatures (outdoor air temperature reset curve).

1.0 Architecture Building (#22) - Existing Building Profile

The facility is a 92,687 ft^2, 5 story building which serves primarily as offices along with some classroom and auditorium space.

Heating

Heat to the building is provided by the campus' centralized steam plant via shell and tube heat exchangers. Hot water from the heat exchanger (MTHW) then supplies a perimeter heating loop as well as hot water coils in the building's two main air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is stored in a tank which is fed off MTHW through a heat exchanger which draws from the Universities centralized steam plant and has an electric heater assist.

Cooling

The entire facility is supplied with air conditioning.

It is supplied chilled water from the Tory building's chilled water plant which feeds the cooling coils in AHU-1 and AHU-2.

Ventilation

The Architecture building is supplied with ventilation from the building's 2 main air handling units located on the 5th floor in the mechanical rooms. Each AHU is equipped with a preheat, hot water and a chilled water coil to provide conditioned air as well as ventilation throughout the building.

CO_2 levels are monitored by the BAS which adjusts the outdoor air ventilation levels to maintain indoor air quality. This allows ventilation levels to be minimized, especially during unoccupied overnight and weekend hours.

The supply and return fans of AHU-1 and AHU-2 are equipped with variable inlet vanes (VIV's).

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Lighting is primarily 32 watt T8 linear fluorescent lamps with electronic ballasts. Pot lighting is primarily compact fluorescent. Incandescent lamps remain in the 2nd floor library/lounge. Interior lighting is controlled primarily by local wall switch with several occupancy sensors in washrooms throughout the building. The building was designed to allow abundant natural light into the interior space. All exit signs are LED. Exterior lighting is high pressure sodium.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Install Control Valves on Steam Supply

M01.1 - Existing Conditions

All the heat exchangers throughout the building were observed to be turned on during the site visit.

M01.2 - Retrofit Conditions

This measure involves installing control valves on the heat exchangers to control the flow of heating based on the demand of the building. This will lower the baseline demand from the MTHW heating plant.

M02 – Replace VIV's with VFD's on AHU-1 Supply and Return Fans

M02.1 - Existing Conditions

AHU-1 currently has supply and return fans which are equipped with variable inlet vanes (VIV's). These types of fans are able to modulate the pitch of their blades to control the volume of supplied air.

M02.2 - Retrofit Conditions

This retrofit recommends the removal of the VIV's and the installation of VFD's with inverter duty fan motors. The VFD's will control the volume of supply air by modulating the speed of the fans based on the mixed air temperature and set point. This is a more efficient way of controlling the air flow and lowering the consumption of the fans.

M05 – Lighting Upgrade: Incandescent to CFL

M05.1 - Existing Conditions

The 2nd floor library/lounge currently houses incandescent lamps in recessed fixtures.

M05.2 - Retrofit Conditions

We recommend replacing incandescent lamps with equivalent compact fluorescent lamps (CFLs). There are compact fluorescent lamps (CFLs) on the market today to be utilized in almost any application. In preparation for the 2014 ban on "General Use" incandescent lamps, companies are producing quality CFLs which produce light of similar colour and lumen output as incandescent, all while consuming less than ¼ of the energy and lasting 10 times longer than standard incandescent bulbs.

M06 – Install Demand Control Ventilation on AHU's

M06.1 - Existing Conditions

The building's air handling units currently supply air based on the temperature of the return air, and the outdoor air dampers are set in a fixed position.

M06.2 - Retrofit Conditions

It is recommended that the AHU's operate their fans to control the amount of supplied air based on the CO_2 levels in the return air. When the return air CO_2 levels rise above a set point, the outdoor air damper will open and supply more fresh air to the occupant spaces. When the CO_2 levels are low, the outdoor air dampers will begin to close. By controlling the amount of fresh air introduced to the building, a minimal amount of fresh air will be conditioned to the desired space temperatures.

M08 – Lighting Controls: Occupancy Sensors

M08.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M08.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, corridors, classrooms, washrooms and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M09 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M09.1 - Existing Conditions

Water faucets throughout the building are currently equipped with 2.2 gallons per minute (gpm) aerators in the washrooms.

M09.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M10 – Campus Wide Integrated Lighting Controls

M10.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M10.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to

immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.
As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M03 – Replace VIV with VFD on AHU-2 Return Fan

M03.1 - Existing Conditions

AHU-2 currently has a supply fan with a VFD, but the return fan is still equipped with variable inlet vane (VIV). These types of fans are able to modulate the pitch of their blades to control the volume of supplied air, but not in the most efficient way.

M03.2 - Retrofit Conditions

This retrofit recommends the removal of the VIV and the installation of a VFD with an inverter duty fan motor. The VFD will control the volume of return air by modulating the speed of the fan, in synchronization with the way the supply fan speeds. This is a more efficient way of controlling the air flow and lowering the consumption of the return fan.

M07 –Replace Decommissioned Pump Housings with Insulated Straight Piping

M07.1 - Existing Conditions

One of the pumps that served the chilled water loop had its motor removed and the opening was covered with a steel plate. The area was observed to be leaking significantly.

M07.2 - Retrofit Conditions

It is recommended that the entire pump section be replaced with a straight pipe and insulated to save the chilled water leakage and cooling losses.

1.0 St. Patrick's Building (#23) - Existing Building Profile

The facility is a 75,460 ft^2 building which serves primarily as an art gallery along with some classroom and auditorium spaces.

Heating

A portion of the building's heat is provided by the campus' MTHW hot water plant, which in turn is heated by the University's centralized steam plant. Hot water from MTHW then supplies perimeter heating radiators throughout the building. A second heating plant (HP-2) supplies hot water to coils in the building's air handling units. HP-2 consists of older, low efficiency atmospheric boilers which have exceeded their life expectancy.

Domestic Hot Water (DHW)

Domestic hot water to the facility is stored in two electric heater tanks and is preheated using the hot water loop MTHW. The domestic hot water system is equipped with a recirculating pump which distributes DHW throughout the building.

Cooling

The entire facility is supplied with air conditioning.

Chilled water from the two chilled water plants (CH-1 and CH-2) feeds the cooling coils in AHU-1 and AHU-2 as well as other buildings in the proximity.

Ventilation

The St. Patrick's building is supplied with ventilation from the building's 2 main air handling units located on the 1st floor in the mechanical rooms. AHU-1 is equipped with chilled water coils to provide conditioned air as well as ventilation throughout the building. AHU-2 has a dual temperature coil which provides heating or cooling to the conditoned zones based on the demand.

CO_2 and static duct pressure levels are monitored by the BAS. The return fan of AHU-1 is equipped with variable inlet vanes (VIVs) and a VFD on the supply fan. AHU-1 is controlled by a programmed schedule on the BAS. AHU-2 is equipped with a supply fan which runs continuously, 24/7 to provide conditioning and humidity control to the art gallery.

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Lighting at this facility is primarily T8 linear fluorescent with magnetic ballasts. The 3rd floor has been partially upgraded to newer, higher efficiency T5 lighting. Many areas of the building are house halogen lamps. Exit signs are LED. Lights are controlled by local wall switch and dimmer.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M05 – Install Demand Control Ventilation and Optimize Schedule of AHU-1

M05.1 - Existing Conditions

The building has a single air handling unit which supplies conditioned air to most of the building, excluding the art gallery areas. This unit is currently monitored and scheduled by the BAS system.

M05.2 - Retrofit Conditions

It is recommended that demand control ventilation be installed on the air handling unit to regulate the ventilation rates (outdoor air damper position) based on actual demand rather than on a schedule. Additionally, the unit runs for long hours every day despite the occupancy varying widely at this building. It is recommended that the operating hours be tightened to actual occupancy schedules. These hours of operation may need to be re-visited on monthly or on “academic semester” basis as scheduled activities may change.

CO_2 control on the air handlers would ensure that ventilation air volumes are matched to occupancy under all conditions. CO_2 sensors would be installed in occupied areas and return air ducts, as appropriate for the air handler. ASHRAE Standard 62 recognizes that ambient (outdoor) CO_2 levels can fluctuate, and that a better measure of ventilation requirements in the space is to use the difference between indoor and ambient levels. An outside sensor would also be installed to determine the ambient CO_2 levels. The new sensors would be connected to the building automation system, which would be reprogrammed to maintain the indoor air CO_2 levels at 700 ppm above ambient.

The outside air and relief dampers would be replaced with low leakage dampers.

M06 – Replace AHU-1 Return Fan VIVs with VFD

M06.1 - Existing Conditions

AHU-1 is a mixed air unit which brings in controlled amounts of ventilation air and blend it with return air before delivering it throughout the facility. It is equipped with a dual temperature loop for heating and cooling.

AHU-1 is currently equipped with a VFD on its supply fan and variable inlet vanes (VIV’s) on its return fan. Both these devices allow the air flow through the system to modulate based on loads. The fans are sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M06.2 - Retrofit Conditions

We recommend removing the VIV’s and installing a variable frequency drive (VFD) and inverter duty motor on the return fan of AHU-1. Fan speed will modulate to match the supply fan.

M07 – Lighting Upgrade: T8 High Performance System

M07.1 - Existing Conditions

In areas where renovations have not taken place, the lighting primarily remains linear fluorescent 32 watt T8 lamps with inefficient magnetic ballasts. Some of the ballasts have been replaced with electronic ballasts as they fail.

M07.2 - Retrofit Conditions

For areas that are not scheduled for renovation in the near future, retrofitting the existing fixture is the most cost effective way to achieve significant savings.

We recommend retrofitting existing T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M08 - Lighting Upgrade: LED Retrofit

M08.1 - Existing Conditions

There are many halogen lamps in corridors, theatre and gallery rooms. These lamps typically consume 40-90 watts per lamp and have relatively short lamp lives of 3,000-6,000 hours.

M08.2 - Retrofit Conditions

We recommend replacing all interior parabolic and halogen lamps with quality LED equivalents.

Currently the top choice in dimmable efficient lighting technology is LED. Quality LEDs have the ability to maintain warm colour temperatures while dimming to 10% and achieving efficacy of 60-90 lumens per watt while lasting 25,000 – 50,000 hours.

Care should be taken in selecting a quality LED which meets the needs of the application while being supported by a reputable company guaranteeing a lengthy warranty. Energy Star certification requires that energy and other identified performance parameters of the LEDs can be consistently measured and verified through testing. Energy Star certification should be the minimum requirement in choosing any energy efficient lighting product.

M09 – Lighting Controls: Occupancy Sensors

M09.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M09.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M10 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M10.1 - Existing Conditions

Water faucets throughout the building are currently equipped with standard 2.2 gallon per minute (gpm) aerators in the washrooms.

M10.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M11 – Campus Wide Integrated Lighting Controls

M11.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M11.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.
As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M01 – Replace HP-2 boilers B-1 to B-3

M01.1 - Existing Conditions

HP-2 supplies heating coils in the building's air handlers as well as some perimeter heating throughout the building. This heating plant is equipped with 3, older, Weil McClain boilers which each have an input capacity of 148 MBH. The boilers have reached or exceeded their life expectancy.

These boilers are a low first cost item, but expensive in long term energy use.

M01.2 - Retrofit Conditions

We recommend replacing the existing boilers with new high efficiency boilers and proper digital (or BAS based) controls.

M02 – Install Proper Controls on AHU-2, HP-2, SP-3 and CH-2

M02.1 - Existing Conditions

The controls on AHU-2, HP-2, SP-3 (the building's steam humidification plant) and CH-2 are stand alone controls on do not allow the equipment to operate at maximum efficiency. The controllers are outdated and have limited capabilities.

M02.2 - Retrofit Conditions

This retrofit involves the replacement of the current controller systems with new controllers and sensors. The new controllers could either be included to the BAS or continue to be stand alone. Either option will provide offer greater accuracy of the inputs and outputs of the system.

M03 – Replace B-4 with Gas Fired Humidifier

M03.1 - Existing Conditions

B-4 is an older gas fired humidifier which provides steam humidification for the gallery areas within the St. Patrick's building. The existing boiler is older and has reached or exceeded its life expectancy.

M03.2 - Retrofit Conditions

We recommend replacing this older unit with a newer gas fired humidifier. Newer humidification units operate at a higher efficiency and will lower the building's natural gas base load which is currently very high.

M04 – Replace AHU-2 with a Proper HVAC Unit Designed for Art Galleries

M08.1 - Existing Conditions

The building's AHU-2 is a mixed air unit which currently provides conditioned air and humidity control to the art gallery spaces. It also provides a chemical filtration process for the outdoor air brought into the building.

The existing unit is older and shows signs of significant degradation. As these systems age, their efficiency decreases and maintenance costs increase making the units steadily more expensive to operate.

M08.2 - Retrofit Conditions

It is recommended that the air handling unit be replaced by a newer air handler which is specifically designed for art galleries to increase the efficiency of the system.

1.0 Minto Centre (#27) - Existing Building Profile

The facility is a 110,581 ft^2 building containing offices, classrooms and lecture halls.

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchangers then supplies perimeter heating as well as hot water heating coils in the building's air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by the an electric heater tank located in the first floor pump room. A domestic hot water recirculation pumps delivers hot water on demand throughout the building.

Cooling

The entire facility is supplied with air conditioning through chilled water coils in the building's air handling units.

Chilled water is supplied by a chilled water plant located in another building.

Ventilation

Minto Center is supplied with ventilation from the building's air handling units. Each AHU is equipped with either a hot water or steam coil for heating and a chilled water coil for cooling.

One of the air handling units is already equiped with a variable frequency drive while the other units are controlled to an occupancy schedule through the campus' BAS.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, stairwells and common spaces consisted mainly of efficient T8 lamps with electronic ballasts as well as some upgrades to efficient T5 lamps. However, linear florescent lighting throughout the labs on level 4 of the facility is a mixture of T8 and of T12 lamps as they are specialty lighting for lab purposes. The elevators in this facility contain T12 lamps as well. Pot light fixtures were equipped with compact florescent lamps. The large majority of exit signs are LED with a few incandescent exit signs still remaining. Lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Lighting Upgrade: High Performance T8 Retrofit

M01.1 - Existing Conditions

Approximately 75% of level 4 of this facility contained linear fluorescent fixtures that house T12 lamps and inefficient magnetic ballasts. Also, the elevators in this facility contained linear fluorescent fixtures that house 32 watt T8 lamps and inefficient magnetic ballasts.

M01.2 - Retrofit Conditions

We recommend replacing all existing T12 lamps and 32 watt T8 lamps with reduced wattage 25 watt T8 lamps. Savings of 22% is achieved when retrofitting a standard 2 lamp fixtures while minimally reducing light output. Please note that reduced wattage lamps do not function well in temperatures below 70 F.

M02 – Campus Wide Integrated Lighting Controls

M02.1 - Existing Conditions

Many of the building's offices, classrooms, laboratories and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M02.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

M03 – Lighting Controls: Occupancy Sensors

M03.1 - Existing Conditions

Many of the building's offices, classrooms, laboratories and lecture halls are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M03.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M05 – Install VFD's on Heating Hot Water Pumps

M05.1 - Existing Conditions

Two 5 hp distribution pumps, P-1 and P-2, circulate heating hot water throughout the building, supplying perimeter heating and heating coils in the AHU's.

The pumps operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7 during the heating season, while the secondary pump cycles on if the primary pump were to fail.

M05.2 - Retrofit Conditions

We recommend installing a variable frequency drive (VFD) and inverter duty motor on the primary heating hot water pump. The VFD will allow the pump speed to modulate to match the heating loads on the system at all times. Drive speed will modulate based on supply/return temperature differential. If the primary pump or the VFD were to fail the secondary pump would run during the repair of the primary pump or drive.

The costing and payback for this measure include installing a VFD on the "primary" pump only. A second VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M06 – Install VFD's on Chilled Water Pumps

M06.1 - Existing Conditions

Two 20 hp distribution pumps, P-13 and P-14, and two 15 hp unlabelled distribution pumps circulate chilled water throughout the building supplying cooling coils in the AHU's.

The pumps operate in a Primary/Stand-by configuration. One pump operates continuously, 24/7 (during the cooling season), while the secondary pump cycles on if the primary pump were to fail.

M06.2 - Retrofit Conditions

We recommend installing variable frequency drives (VFD's) and inverter duty motors on the two primary chilled water pumps. The VFD's will allow pump speeds to modulate to match the cooling loads on the system at all times. Drive speeds will modulate based on supply/return temperature differential. If the primary pump or the VFD were to fail the secondary pump would run during the repair of the primary pump or drive.

The costing and payback for this measure include installing a VFD on the "primary" pump only. A second VFD can also be installed on the secondary pump in this system. Installation of the VFD on the standby pump would approximately double the implementation cost of the measure. As the standby pump in this system operates only occasionally, however, the energy and dollars saved would not increase significantly. We recommend installing a VFD on the primary pump only to minimize installation costs and to provide the most attractive payback for the measure.

M07 – Remove Variable Inlet Vanes, Replace with VFD: AHU-1, AHU-7 and AHU-8

M07.1 - Existing Conditions

All of the buildings AHU's are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

Air conditioning. heating and ventilation to the building is supplied by variable air volume (VAV) fan systems in AHU-1, AHU-7 and AHU-8. Variable inlet vanes (VIVs) on the supply and return fans modulate to maintain the required duct pressure and air flow. The VIVs throttle air flow by creating flow resistance. Under these conditions, which occur during partial system load, the fans operate inefficiently.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements.

M07.2 - Retrofit Conditions

We recommend replacing the variable inlet vanes and fan motor with variable frequency drives (VFDs) and inverter-duty motors on the supply and return fans of each AHU. The duct pressure and air flow will then be maintained by automatic adjustment of the fan motor speeds. The fan motors will draw less power because the fans will have less flow resistance to overcome.

M08 – Install VFD's on AHU-3, -5, -11

M08.1 - Existing Conditions

All of the buildings AHU's are mixed air units which bring in controlled amounts of ventilation air and blend it with return air before delivering it to specific areas of the facility. Each of the AHU's is equipped with a hot water coil and a chilled water coil which provides heating and cooling.

The fans for each of these AHU's is sized to supply adequate air flows during times of peak heating, cooling or ventilation load requirements. Some of the AHU's are currently equipped with VFD's or variable inlet vanes to reduce air flows during off peak times. Several of the AHU's, however, lack any type of air flow control.

M08.2 - Retrofit Conditions

We recommend installing a variable frequency drives (VFD's) and inverter duty motors on the supply and return fans of AHU-3, -5 and -11. Fan speeds will modulate to maintain space temperature set points in each zone of the air handling unit. As a space calls for heating, the heating control valve for the reheat coil will open. If space temperature cannot be maintained once the reheat coil has reached 100%, the fan speed will ramp up to provide more heat to the space.

M09 – Implement Demand Control Ventilation on AHU-3 (Strong Room), AHU-5 (Theatre)

M09.1 - Existing Conditions

The air-handling units AHU-3 and AHU-5 provide heating, cooling and ventilation to the Strong Room and Theatre, respectively, blending fresh air and return air to a fixed mixed air temperature setpoint. This provides temperature and humidity control in the space, but tends to bring in more ventilation air than needed, especially during partial occupancy periods. Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

M09.2 - Retrofit Conditions

CO_2 control on the air handlers would ensure that ventilation air volumes are matched to occupancy under all conditions. CO_2 sensors would be installed in occupied areas or return air ducts, as appropriate for each air handler. ASHRAE Standard 62 recognizes that ambient (outdoor) CO_2 levels can fluctuate, and that a better measure of ventilation requirements in the space is to use the difference between indoor and ambient levels. An outside sensor would also be installed to determine the ambient CO_2 levels. The new sensors would be connected to the building automation system, which would be reprogrammed to maintain the indoor air CO2 levels at 700 ppm above ambient.

The outside air and relief dampers would be replaced with low leakage dampers.

M10 – Implement "Partial Occupancy" Schedule – AHU's-1, -7, -8, -10, -11

M10.1 - Existing Conditions

Ventilation to the building is provided by several mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 6 in the morning through until 9 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15-25%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as offices, classrooms and lecture halls with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 6pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M10.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M11 – Water Conservation: Ultra Low Flow Aerators

M11.1 - Existing Conditions

All of the toilets and urinals throughout the building are low flow fixtures. The sinks located throughout the building have standard (2.2 gpm) aerators installed.

M11.2 - Retrofit Conditions

We recommend installing ultra low flow, 0.5 GPM, aerators on all faucets to further reduce water consumption.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M04 – Domestic Hot Water Conversion: Electric to Steam

M04.1 - Existing Conditions

This facility was once equipped with DHW storage tank complete with an immersion steam/hot water heat exchanger. The original equipment has been decommissioned and left in place. The DHW tank/heat exchanger system has since been replaced with an electric DHW tank. Electricity, though efficient, is an expensive heat source. The nearby steam piping should be taken advantage of as it has the capacity to heat the DHW at a lower cost than electricity.

M04.2 - Retrofit Conditions

The existing heater tank should be replaced with a heat exchanger and domestic hot water storage tank using the steam piping that is already available from the previous system.

1.0 Carleton Technology & Training Centre (#29) - Existing Building Profile

The facility is a 68,487 ft^2, 4 storey building which has several laboratories along with some classroom and auditorium spaces.

Heating

Heat to the building is provided by the campus' centralized steam plant via shell and tube heat exchangers. Hot water from the heat exchangers then supplies perimeter heating radiators, air handler coils, and reheat coils.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied through an instantaneous heat exchanger. The domestic hot water is recirulated through this heat exchanger.

Cooling

The entire facility is supplied with air conditioning.

Cooling is supplied from heat pumps paired with the two rooftop cooling towers (CT-1 and CT-2) which supply conditioned air to the spaces.

Ventilation

The Carleton Technology building is supplied with ventilation from the building's air handling units located on the roof in the mechanical rooms.

All air handling units are monitored by the BAS.

Four roof mounted exhaust fans ventilate different areas of the building.

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

A large majority of the lighting at this facility is T8 linear fluorescent with magnetic ballasts. Corridors are illuminated by wall sconce and potlight fixtures housing compact fluorescent lamps. There are some incandescent lamps found in the retail areas of the building. Metal halide fixtures illuminate the two story open areas of the entrances. There are several areas that utilize halogen lighting to provide dimming or accent lighting. Exit signs are compact fluorescent.

Exterior lighting is primarily metal halide and controlled by photo sensors.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Install Steam Valves on HPS side of PRV's, Close Valves when No Heating is Required

M01.1 - Existing Conditions

This facility draws heat off of the main campus' steam plant for multiple heating processes. Currently, there are 5 high pressure steam lines with PRV's, only 1 is needed for the DHW for the building. The mechanical room where the steam lines enter the building was extremely hot due to the excess steam lines. The audit was performed during the cooling season when steam consumption at the building should have been minimal. This indicates that heat is being unnecessarily consumed in this mechanical room.

M01.2 - Retrofit Conditions

It is recommended that the unnecessary high pressure steam lines be valved off, either manually or with a controller to make sure no heat is being wasted and help the campus conserve steam energy.

M02 – Repair Steam Leak on HPS Side

M02.1 - Existing Conditions

It was noted during the site visit that there was a leak in the high pressure steam line within the building. Leaks in steam piping waste significant amounts of energy due to the energy required to produce and maintain steam pressure and temperature.

M02.2 - Retrofit Conditions

It is recommended that the steam leak be repaired to avoid unnecessary energy consumption.

M03 – Install VFD's on P-1 and P-2

M03.1 - Existing Conditions

The heat pump loop is supplied by a heat exchanger which draws off of the LPS loop. Pumps P-1 and P-2 operate as a primary/backup pair and circulate water from the heat exchanger to the perimeter radiators and reheat coils in supply air duct work supplied by some of the air handling units. Currently, the pumps operate at 100% regardless of the actual heating load of the reheat coils.

M03.2 - Retrofit Conditions

It is recommended that the balancing valves be opened and the supply pumps are equipped with Variable Frequency Drives (VFD's). The pumps will control the flow based on the demand from the hot water loop as determined by the difference in temperature measured between the supply and return water. As heating loads increase, the temperature difference between supply and return water will also increase, signaling the requirement for pump speed to increase.

M04 – Repair Fresh Air Damper on MAU-1

M04.1 - Existing Conditions

The building has a make-up air unit which supplies 100% fresh air to the building. During the site visit, it was observed to have a broken fresh air damper which was stuck in the 100% open position. This results in a large amount of outdoor air infiltration into the building during overnight hours when the make-up air unit is scheduled off. Any outdoor air introduced into the building must then be conditioned by heating/cooling equipment, so its best to minimize it.

M04.2 - Retrofit Conditions

It is recommended that the fresh air damper be repaired so it can function properly. Once the damper is fixed, the outdoor air damper will close when the unit is scheduled off.

M05 – Install VFD on MAU-1

M05.1 - Existing Conditions

MAU-1 supplies 100% fresh air to meet a portion of the building's ventilation demand. Currently, this unit operates at full speed during all occupied hours regardless of the actual demand based on occupancy levels. As the building occupancy fluctuates significantly, especially during late evening and on weekends, more ventilation air is being supplied than is necessary.

M05.2 - Retrofit Conditions

We recommend installing a VFD on the supply air fan and to be controlled by a demand control ventilator. This control will monitor CO_2 levels within the supplied areas and will lower the demand from the unit when CO_2 levels are minimal, and speed up the unit when CO_2 levels rise above the programmed set point.

M06 – Repair RTU-9 to Minimize Air Leakage from Building and Make Sure Dampers are Shut

M06.1 - Existing Conditions

One of the rooftop units has its outdoor air dampers fully open. A panel is also missing resulting in a large amount of outdoor air infiltration into the ductwork.

M06.2 - Retrofit Conditions

It is recommended that the panel be replaced and the dampers repaired to allow for proper control of the fresh air supply.

M07 – Tighten All Control Schedules

M07.1 - Existing Conditions

The building has an installed building automation system which monitors and controls various pieces of HVAC equipment. There are some schedules implemented, but they are weak correlations to the existing building's occupancy levels throughout the day. Some equipment is monitored only by the BAS, without any type of operating/occupancy schedule.

M07.2 - Retrofit Conditions

It is recommended that all equipment is scheduled based on the demand and occupancy of the building, and that all existing schedules are optimized for maximum savings.

M08 – Lighting Upgrade: T8 High Performance System

M08.1 - Existing Conditions

A large majority of the linear fluorescent fixtures at this facility house 32 watt T8 lamps with magnetic ballasts. When the magnetic ballasts have failed they have been replaced with electronic ballasts. An estimated 60-75% of the fixtures still house old inefficient magnetic ballasts.

M08.2 - Retrofit Conditions

We recommend retrofitting existing T8 fixtures with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M09 – Lighting Upgrade: Interior LED’s

M09.1 - Existing Conditions

Many of the retail spaces and health and dental offices house halogen and parabolic lamps. These lamps typically consume 50-90 watts per lamp.

M09.2 - Retrofit Conditions

We recommend replacing all interior parabolic and halogen lamps with quality LED equivalents.

Currently the top choice in dimmable efficient lighting technology is LED. Quality LEDs have the ability to maintain warm colour temperatures while dimming to 10% and achieving efficacy of 60-90 lumens per watt while lasting 25,000 – 50,000 hours.

Care should be taken in selecting a quality LED which meets the needs of the application while being supported by a reputable company guaranteeing a lengthy warranty. Energy Star certification requires that energy and other identified performance parameters of the LEDs can be consistently measured and verified through testing. Energy Star certification should be the minimum requirement in choosing any energy efficient lighting product.

M10 – Lighting Controls: Occupancy Sensors

M10.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M10.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M11 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M11.1 - Existing Conditions

Water faucets throughout the building are currently equipped with 2.2 gallons per minute (gpm) aerators in the washrooms.

M11.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M12 – Campus Wide Integrated Lighting Controls

M12.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M12.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

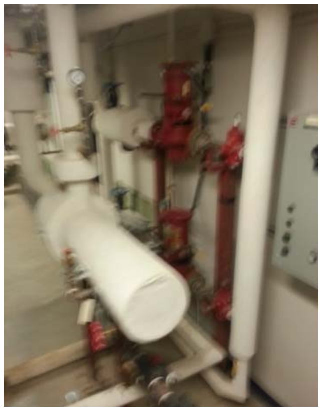
To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.
As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

1.0 Azrieli Theatre (#31) - Existing Building Profile

The facility is a 37,768 ft^2 building containing four large auditoriums and some office spaces.


Steam to Glycol Heat

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water or glycol heat exchangers. Hot water/glycol from the heat exchanger then supplies perimeter heating as well as heating coils in the building's air handling units.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by small individual electric hot water heater tanks located in various areas near their respective points of consumption.

Cooling

The entire facility is supplied with air conditioning through chilled water coils in the building's air handling units.

Chilled water is supplied by a chilled water plant located in another building.

Ventilation


AHU-1 equipped with glycol heat reaclaim loop

Azrieli Theatre is supplied with ventilation from the building's three main air handling units located in various mechanical rooms throughout the building. Each AHU is equipped with a hot water coil for heating and either a chilled water or chilled glycol coil for cooling.

Two of the air handling units are equipped with glycol heat reclaim loops but do not have VFD's installed.

The third AHU is equipped with a VFD but no heat reclaim loop. At the time of the audit, the outdoor/exhaust air dampers were set to 0%.

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted of efficient T8 lamps with electronic ballasts. Pot light fixtures were equipped with compact florescent lamps.

The majority of lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Install Demand Control Ventilation for AHU-1, 2 and 3

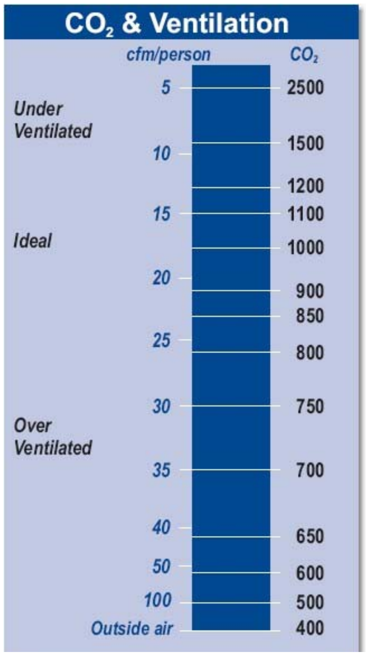
M01.1 - Existing Conditions

The Azrieli Theatre building currently has 3 mixed air handling units which provide space heating, cooling, and ventilation. The air handling units all have an outdoor air damper which is set at a minimum of 10 to 15%. This brings in a set amount of ventilation air to the building regardless of actual ventilation demands which are driven by occupancy. Any outdoor air brought into the building must be conditioned by heating or cooling equipment, so its best to minimize it.

M01.2 - Retrofit Conditions

CO_2 control on the air handlers would ensure that ventilation air volumes are matched to occupancy under all conditions. CO2 sensors would be installed in occupied areas and return air ducts, as appropriate for each air handler. ASHRAE Standard 62 recognizes that ambient (outdoor) CO2 levels can fluctuate, and that a better measure of ventilation requirements in the space is to use the difference between indoor and ambient levels. An outside sensor would also be installed to determine the ambient CO2 levels. The new sensors would be connected to the building automation system, which would be reprogrammed to maintain the indoor air CO2 levels at 700 ppm above ambient.

The outside air and relief dampers would be replaced with low leakage dampers.



CO2 to ventilation rate conversion assuming 400ppm outside ambient level. reference: U.S. Federal Energy Management Program

M02 – Install VFD's on AHU-1 and 3

M02.1 - Existing Conditions

AHU-1 and 3 currently have supply fans which are constant volume fans. They operate at a single speed during operation to supply a constant volume of air to the building.

M02.2 - Retrofit Conditions

It is recommended that AHU-1 and 3 VIV's be removed and the supply and return fans be equipped with variable frequency drives (VFD's). VFD's are an efficient way of controlling fans because they allow the fan motors to use less electricity. A duct pressure sensor monitors the pressure levels inside the supply duct and controls the fan based on the pressure set point. The duct pressure increases when the variable air volume (VAV) boxes require less air and begin to shut. When this is sensed, the VFD will be programmed to slow its speed and provide a lower volume of air to save unnecessary electrical consumption.

M03 – Reschedule All Air Handling Units

M03.1 - Existing Conditions

The building's main air handling units supply heating cooling and ventilation to the spaces. They currently operate for long hours, regardless of whether or not the spaces are scheduled to be occupied. The units currently operate for 16-18 hours per day, seven days a week. The operating schedules, once set, do not get re-set on a regular basis to reflect actual building occupancy.

M03.2 - Retrofit Conditions

We recommend that the air handlers be scheduled on a weekly or monthly schedule to operate in a closer relation to the building's actual occupancy schedule. Shutting the air handling units off when their respective spaces are unoccupied reduces electrical consumption due to fan operation as well as steam consumption due to air infiltration.

M04 – Lighting Controls: Occupancy Sensors

M04.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors and Boiler Room are typically left on 24/7.

M04.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, corridors, washrooms and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M05 – Lighting Upgrade: T8 High Performance System

M05.1 - Existing Conditions

Linear fluorescent fixtures throughout the building house a mixture of T12 and T8 lamps in combination with inefficient magnetic ballasts. As the magnetic ballasts sporadically fail they are being replaced with electronic ballasts.

M05.2 - Retrofit Conditions

We recommend retrofitting existing fixtures housing magnetic ballasts with reduced wattage (25w) lamps and high efficiency electronic ballasts. A high performance retrofit achieves 37% savings over the existing T8 system and 49% savings over the existing T12 system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The "flicker" and "hum" that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M06 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M06.1 - Existing Conditions

Water faucets throughout the building are currently equipped with standard 2.2 gallons per minute (gpm) aerators in the washrooms.

M06.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M07 – Fully Integrated Lighting Controls (BAS or Stand Alone)

M07.1 - Existing Conditions

Many of the building's offices, classrooms and storage rooms are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M07.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed.

1.0 Azrieli Pavilion (#32) - Existing Building Profile

The facility is a 49,496 ft2 building containing four large auditoriums and some office spaces

Heating

Heat to the building is provided by the campus' centralized steam plant via steam to hot water heat exchangers. Hot water from the heat exchanger then supplies perimeter heating as well as the heating coil in the building's main handling unit.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by small individual electric hot water heater tanks located in various areas near their respective points of consumption.

Electric Heater Tank, Newer, In Good Operating Condition

Cooling

Rooftop Chiller

The entire facility is supplied with air conditioning through chilled water coils in the building's air handling units.

Chilled water is supplied by a chilled water plant located in another building.

Specific areas of the building are equipped with cooling only heat pumps. Cooling for the heat pump loop is provided by a rooftop mounted chiller.

Ventilation

Azrieli Pavilion is supplied with ventilation from the building's main air handling unit, AHU-1 located on the building's rooftop. It is equipped with a heating coil and chilled water coil for conditioning supply air. The unit is equipped with a VFD.

AHU-1. Serves Entire

Water Fixtures

Water fixtures at the facility consist primarily of low flow flushometer toilets and urinals as well as washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Most lighting throughout the facility has been upgraded to higher efficiency lamps and fixtures. Linear florescent lighting throughout offices, classrooms, corridors, stairwells and common spaces consisted of efficient T8 lamps with electronic ballasts. Some office and storage areas of this facility have been upgraded with occupancy sensors. Pot light fixtures were equipped with compact florescent lamps. The majority of lighting is controlled by local wall switch.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M02 – Implement "Partial Occupancy" Schedule on AHU-1

M02.1 - Existing Conditions

Ventilation to the building is provided by one mixed air handling unit. This unit brings in fixed amounts of outdoor air and blends it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU brings in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling unit operates seven days per week, 365 days per year. It typically operates from 7 in the morning through until 11 at night with slightly reduced hours on weekends. During these hours of operation, the unit is bringing in ventilation air at a rate based on the minimum outdoor air damper position (10%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as large auditoriums and some office spaces with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU continues to bring in large amounts of ventilation air during these times of "partial occupancy".

M02.2 - Retrofit Conditions

We recommend implementing a "Partial Occupancy" schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU's will be updated to include a "Partial Occupancy" schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled "Partial Occupancy" hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M03 – Campus Wide Integrated Lighting Controls

M03.1 - Existing Conditions

Many of the building's offices and auditoriums are being controlled by local wall switches. In many cases lights remain on longer than the space is occupied.

M03.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide.

As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

1.0 Human Computer Interaction (#37) and Visualization & Simulation Building (#38) - Existing Building Profile

Both buildings with total floor area of 97,271 ft^2 serve primarily as offices along with some classroom and auditorium space.

Heating

Heat to the building is provided by the campus' centralized steam plant via shell and tube heat exchangers. Hot water from these heat exchanger supplies hot water coils in the building's two main air handling units as well as some perimeter heating.

Domestic Hot Water (DHW)

Domestic hot water to the facility is supplied by a heat exchanger which draws from the University's centralized steam plant for pre-heat, and is then "topped up" by an electric heater tank.

Cooling

The entire facility is supplied with air conditioning.

It is equipped with a single chiller and a cooling tower which supply chilled water to the building's two main air handling units. There are also two air cooled condensors which serve the heat pumps for the server room.

Ventilation

The Human Computer Interaction building is supplied with ventilation from the building's two main air handling units. Each AHU is equipped with a hot water and a chilled water heating coil to provide conditioned air as well as ventilation throughout the building.

CO_2 levels are monitored by the BAS however the ventilation rates are controlled by to minimum levels according to an occupancy schedule. The supply fans on both AHU's are equipped with VFD's.

Water Fixtures

Water fixtures at the facility consist of low flow flushometer toilets and kitchen and washroom sinks with aerators. No running/leaking fixtures or damaged aerators were observed.

Lighting

Linear florescent lighting throughout the two buildings consists of efficient T8 lamps with electronic ballasts. Pot light fixtures were equipped with compact fluorescent lamps. The elevator in the Human Computer Interaction building still houses T12 lamps and magnetic ballasts. Exit signs are LED.

2.0 Energy Savings Scenario

The *Energy Savings Scenario* consists of all Opportunities that are recommended based primarily on the energy and utility cost saving benefits.

M01 – Install VFD’s on P-1 and 2, Open Balancing Valves on Pumps and Chiller

M01.1 - Existing Conditions

The pumps P-1 and 2 currently serve the chilled water plant as the main distribution return pumps. They maintain a single pump speed when there is a demand for chilled water to be circulated on warmer days when the building must be cooled. The pumps are currently throttled down using valves which are approximately 60% open.

M01.2 - Retrofit Conditions

It is recommended that the valves be opened to 100% and these two pumps be equipped with VFD’s to give them the ability to modulate their flow based on the demand from the buildings HVAC equipment. By modulating the speed of the pumps with a VFD and allowing them to control the flow, a lower electrical consumption can be achieved.

M02 – Install VFD’s on P-5 and 6, Open Balancing Valves on Pumps and Chiller

M02.1 - Existing Conditions

The pumps P-5 and 6 currently serve the chilled water plant as the condenser (cooling tower) circulators. They maintain a single pump speed when there is a demand for condenser water to be circulated on warmer days when the building must be cooled. The pumps are currently throttled down using ball valves which are approximately 60% open. Throttling the flow using valves results in increased pressure drops through the system and causes the pumps to consume more electrical energy than is required.

M02.2 - Retrofit Conditions

It is recommended that the valves be opened to 100% and these two pumps be equipped with VFD’s to give them the ability to modulate their speed based on the demand from the building’s HVAC equipment. By modulating the speed of the pumps with a VFD and allowing them to control the flow, a lower electrical consumption can be achieved.

M03 – Open Balancing Valves on P-3 and 4 to AHU-1 and 2 Cooling Coils

M03.1 - Existing Conditions

The pumps P-3 and 4 currently serve the chilled water plant as the main distribution supply pumps. They are equipped with VFD’s but throttled with valves set approximately 60% open. Throttling the flow using valves results in increased pressure drops through the system and causes the pumps to consume more electrical energy than is required.

M03.2 - Retrofit Conditions

It is recommended that the valves be opened to 100% and the flow controlled by the existing pump VFD's. By modulating the speed of the pumps with the existing VFD's and allowing the drives to fully control the flow, a lower electrical consumption can be achieved.

M05 – Open Balancing Valves on P-7 and 8, Control Flow with Existing VFD's

M05.1 - Existing Conditions

The pumps P-7 and 8 currently serve the two air cooled condensers as the main distribution supply pumps for the data centre cooling. They are equipped with VFD's but throttled with ball valves set approximately 60% open. Throttling the flow using valves results in increased pressure drops through the system and causes the pumps to consume more electrical energy than is required.

M05.2 - Retrofit Conditions

It is recommended that the valves be opened to 100% and the flow controlled by the existing pump VFD's based on the demand for cooling. By modulating the speed of the pumps with a VFD and allowing the drives to fully control the flow, a lower electrical consumption can be achieved.

M06 – Implement "Partial Occupancy" Schedule on AHU's-1 and 2

M06.1 - Existing Conditions

Ventilation to the building is provided by two mixed air handling units. These units bring in fixed amounts of outdoor air and blend it with return air before returning it to the space. Any outdoor air brought into the building must be heated or cooled by the building's HVAC systems, so it's best to minimize it.

The AHU's bring in a variable amount of outdoor air based on outdoor and supply air temperatures. The minimum amount of outdoor air being brought in by a particular AHU is controlled by the minimum outdoor air damper position set at the BAS. Typically, the minimum ventilation level (minimum outdoor air damper position), would be set to provide adequate ventilation during times of peak occupancy (fully occupied hours). Any outside air brought into the building has to be conditioned by heating or cooling equipment, so it is best to minimize it.

Currently, the air handling units operate seven days per week, 365 days per year. They typically operate from 6-7 in the morning through until 8-9 at night with slightly reduced hours on weekends. During these hours of operation, the units are bringing in ventilation air at a rate based on the minimum outdoor air damper position (15-25%). This minimum ventilation rate is typically based on the expected normal peak occupancy of the building.

The building is primarily used as office space with peak occupancy occurring during normal business hours, Monday-Friday from 8am to 5pm. Occupancy during early morning, late evening and weekend periods is drastically lower. Currently, however, the AHU's continue to bring in large amounts of ventilation air during these times of "partial occupancy".

M06.2 - Retrofit Conditions

We recommend implementing a “Partial Occupancy” schedule to reduce the amount of fresh air supplied during times of lower occupancy (evenings, weekends, during extended breaks). The existing Occupied/Unoccupied schedule for the AHU’s will be updated to include a “Partial Occupancy” schedule at the beginning and end of each day as well as over weekends and during summer and winter breaks as appropriate. During the scheduled “Partial Occupancy” hours, the minimum outdoor air damper position will be reset to a lower value than the current occupied hours minimum position to reflect the greatly reduced occupancy loads. This will reduce unnecessary amounts of outdoor air needing to be conditioned. Implementation costs for this measure are relatively low for the scheduling. As all of the controls exist, only updating of the building automation system would be required.

M07 – Lighting Upgrade: T8 High Performance System

M07.1 - Existing Conditions

The elevator in the Human Computer Interaction building still houses T12 linear fluorescent lamps with magnetic ballasts.

M07.2 - Retrofit Conditions

We recommend retrofitting existing T12 fixtures with reduced wattage (25w) T8 lamps and high efficiency electronic ballasts. A high performance retrofit achieves 40% savings over the existing system.

July 1, 2010 saw the ban of magnetic ballast production in Canada. This includes the large majority of T12 and T8 magnetic ballasts. This means that when a magnetic ballast fails it must be replaced with an electronic ballast. There are many benefits to changing to electronic ballasts, well beyond the improved efficiency. Total Harmonic Distortion (THD) is greatly reduced. The “flicker” and “hum” that magnetic systems are notoriously known for are greatly reduced. Electronic ballasts have longer average life spans, improve lamp life and because they can drive up to 4 lamps versus just 1 or 2 lamps, and they create less waste.

M08 – Lighting Controls: Install Occupancy Sensors

M08.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when rooms remain unoccupied. Corridors are typically left on 24/7.

M08.2 - Retrofit Conditions

We recommend installing occupancy sensors in many of the offices, classrooms, corridors, and storage rooms. Typical energy savings range from 30%-60%, depending on the pattern and frequency of room use. It is important that qualified contractors are familiar with all building code and by law requirements regarding the installation of occupancy sensors, lighting level requirements and fire code. Safety of occupants should always be addressed when determining suitable applications for occupancy sensors.

M09 – Water Conservation: Install Ultra Low Flow 0.5 gpm Faucet Aerators

M09.1 - Existing Conditions

Water faucets throughout the building are currently equipped with standard 2.2 gallon per minute (gpm) aerators in the washrooms.

M09.2 - Retrofit Conditions

We recommend installing ultra low flow faucet aerators on all existing faucets with 2.2 gpm aerators. These ultra low flow aerators supply hand sanitation at a much lower flow rate at 0.5 gpm.

M10 – Campus Wide Integrated Lighting Controls

M10.1 - Existing Conditions

Lighting is primarily controlled by local wall switch. Many lights are left on when areas remain unoccupied or in areas where adequate natural light is illuminating the area. Corridors are typically left on 24/7.

M10.2 - Retrofit Conditions

An efficient integrated lighting control system should take advantage of savings through time scheduling, daylight harvesting, task tuning, occupancy control, personal control and variable load shedding. Combined effectively, these methods can result in 50-75% energy savings.

To achieve maximal energy savings an effective integrated lighting control system should provide:

- a user friendly interface that would allow on site staff to control lighting throughout the entire facility or campus using a point and click set up (interface can be on a network PC system or web-based for ultimate control for future portfolio monitoring and control)
- the ability to adjust settings, limits, and time schedules on event specific, daily, weekly, or monthly basis
- allow for interface with HVAC and Security control systems and equipment to share data such as occupancy status and adjust for status. This type of system would allow individuals to immediately identify which areas of a building or campus are occupied at what hours, providing additional information to security personnel.
- allow monitoring of occupancy sensors, dimmers and wall switches to enable zones to be configured such that only the fixtures in that entrance and exit pathway or area shall be left on.
- allow for personal settings to be adjusted and set for specific fixtures or group of fixtures. This can increase productivity as it ensures that individuals can select the amount of light that best enables them to perform a task.
- the ability to illustrate and report consumption, light levels, light status, power density, and occupancy status help ensure that the system is being effectively utilized while also having the added benefit of simple assurance that all individuals have vacated the facility.

We recommend that a high performance integrated lighting control system meeting the above criteria be installed campus wide. As electrical rates and time of use charges increase, it is becoming more critical that energy savings are achieved not only by installing efficient lighting but by controlling the way and time of use lighting is utilized.

3.0 Longer Payback Scenario

The Longer Payback *Scenario* consists of Opportunities that are not as financially attractive as the Energy Savings Scenario. These measures should be considered when equipment failure occurs or as Capital Renewal projects as equipment reaches its end of life.

M04 – Install VFD on Cooling Tower Fan

M04.1 - Existing Conditions

The building has two cross flow cooling towers which help the condenser water to cool off. The fan which draws this air though the tower is a 15 hp axial fan which runs on a 2 speed motor with a high and low speed. The speed of the fan is controlled by the condenser supply temperature based on the set point on the BAS.

M04.2 - Retrofit Conditions

It is recommended that the 15 hp fan from CT-01 be equipped with a VFD to control the speed of the tower fan based on the condenser supply temperature. The VFD will modulate the speed of the fan and allow it to run at a wider range of speeds, resulting in a lower consumption of electricity.