FACILITY SERVICES

Energy Management Plan

Winter 2019

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1. ENERGY MANAGEMENT PLAN FRAMEWORK

1.1 McMaster University profile

Founded in 1887, McMaster University is home to more than 30,000 students, and almost 7,500 employees.

McMaster University offers a unique educational experience featuring state-of-the-art research facilities, a world-renowned medical program and innovative student services, and located only minutes from Cootes Paradise (a wetland that supports a large variety of plants and animals). Like most Canadian universities, the academic year runs from September until late April, and during this period, approximately 3,700 students occupy the university's 12 residence buildings. In the summer months (May-September) many of the residence buildings and classrooms remain unoccupied. Campus occupancy decreases significantly to around 10,000 including summer students, campus maintenance staff, and conference guests. However, this presents a unique challenge to energy management as the buildings that are partially occupied must have access to heating, lighting and ventilation, thus increasing energy costs, even with lower occupancy.

Figure 1 is a schematic map showing the location and relative size of the campus buildings.

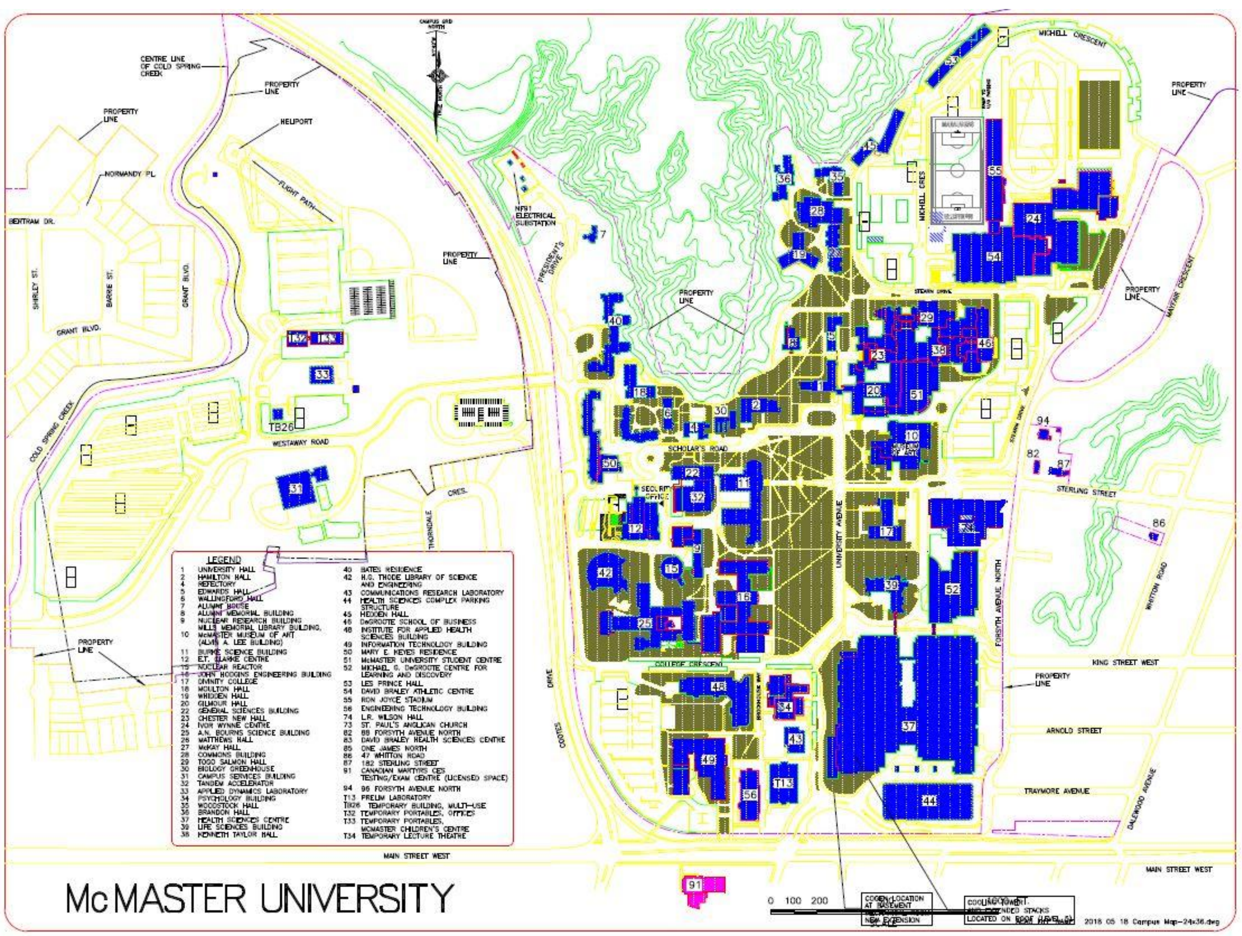

Figure 1: McMaster University Campus (2017-2018 academic year)

Building Name	Building No.	NSM[1]	Primary Usage	Year
Arthur N. Bourns Building	25	23,319	Classroom & Research	1968
Alumni House	7	487	Administration	1930
Alumni Memorial Hall	8	1,071	Hospitality	1949
Applied Dynamics Lab	33	1,773	Research	1967
Bates Residence	40	13,514	Residence	1971
Biology Greenhouse	30	702	Research	1967
Brandon Hall	36	9,206	Residence	1968
Campus Services Building	31	4,519	Administration	1968
Charles E. Burke Science Building	11	15,379	Classroom & Research	1953
Chester New Hall	23	6,913	Classroom	1964
Commons Building	28	4,659	Administration & Hospitality	1965
Communications Research Laboratory	43	2,480	Research	1983
David Braley Athletics Centre	54	12,918	Athletics	2007
DeGroote School of Business	46	6,855	Classroom	1990
Divinity College	17	3,002	Grad Studies	1959
E.T. Clarke Centre	12	4,618	Administration	1954
Edwards Hall	5	1,930	Residence	1929
Engineering Technology Building	56	12,280	Classroom & Research	2009
Gilmour Hall	20	7,467	Administration	1959
General Sciences Building	22	4,778	Classroom & Research	1962
H. G. Thode Library of Science & Engineering	42	7,752	Library	1976
Hamilton Hall	2	3,758	Classroom	1929
Health Sciences Centre	37	105 363	Health Services	1972
Hedden Hall	45	8,327	Residence	1989
Information Technology Building	49	10,311	Classroom & Research	1955
Institute for Applied Health Sciences	48	8,914	Classroom	2000
Ivor Wynne Centre	24	17,597	Athletics & Research	1964
John Hodgins Engineering Building	16	22,851	Classroom & Research	1958
Kenneth Taylor Hall	38	10,028	Classroom	1971
Les Prince Hall	53	8,239	Residence	2006
L.R. Wilson Hall	74	14,195	Classroom & Research	2016
Life Sciences Building	39	8,769	Classroom & Research	1970
M.G.D. Centre for Learning and Discovery	52	24,976	Classroom & Research	2004
Mary E. Keyes Residence	50	11,252	Residence	2002
Matthews Hall	26	4,867	Residence	1964
McKay Hall	27	6,003	Residence	1964
McMaster University Student Centre	51	12,388	Hospitality	2002
Mills Memorial Library	10	19,620	Art Gallery/Library	1950
Moulton Hall	18	4,807	Residence	1959
Nuclear Reactor	15	1,648	Research	1957
Nuclear Research Building	9	5,020	Research	1950
Preliminary Laboratory (T13)	T13	2,015	Classroom	1967
Psychology Building	34	8,098	Classroom & Research	1970
Refectory	4	1,516	Hospitality	1929
Ron Joyce Stadium	55	3,719	Athletics	2008
Scourge Building (TB26)	TB26	184	Administration	1989
Tandem Accelerator	32	2,827	Research	1966
Togo Salmon Hall	29	11,654	Classroom	1965
University Hall	1	3,669	Administration	1929
Wallingford Hall	6	1,835	Residence	1929
Whidden Hall	19	5,594	Residence	1959
Woodstock Hall	35	5,039	Residence	1968
Temporary Portables (T32)	T32	500	Classroom	2013
Temportary Portables (McMaster's Children's Centre T33)	T33	631	Daycare	2013

Note 1: NSM = Net Square Metres
Source: Database and Master Inventory

Table 1: Building Profile at McMaster University Campus (2017-18 Academic Year)

Note: the scope of this Energy Management Plan does not include Divinity College, Health Sciences Centre (HSC), and off-campus buildings (Halton Family Health Care Centre, McMaster Automotive Resource Centre, One James North, and Ron Joyce Centre in Burlington).

Table 1 above presents the size of each of the buildings of Figure 1. This supported the creation of an energy profile for the university.

Figure 2 shows the uses of assigned space on campus. It should be noted that building and residence occupancy during the summer months and building occupancy during the evening and night also poses challenges to energy management, as buildings that are partially occupied for evening classes still require full heating, lighting and ventilation. Libraries, labs and classrooms often remain occupied until midnight or later, and do not run on a predictable schedule, which stresses the University's energy management systems. Caretakers and custodial staff in buildings later in the night and early in the morning also increase energy usage.

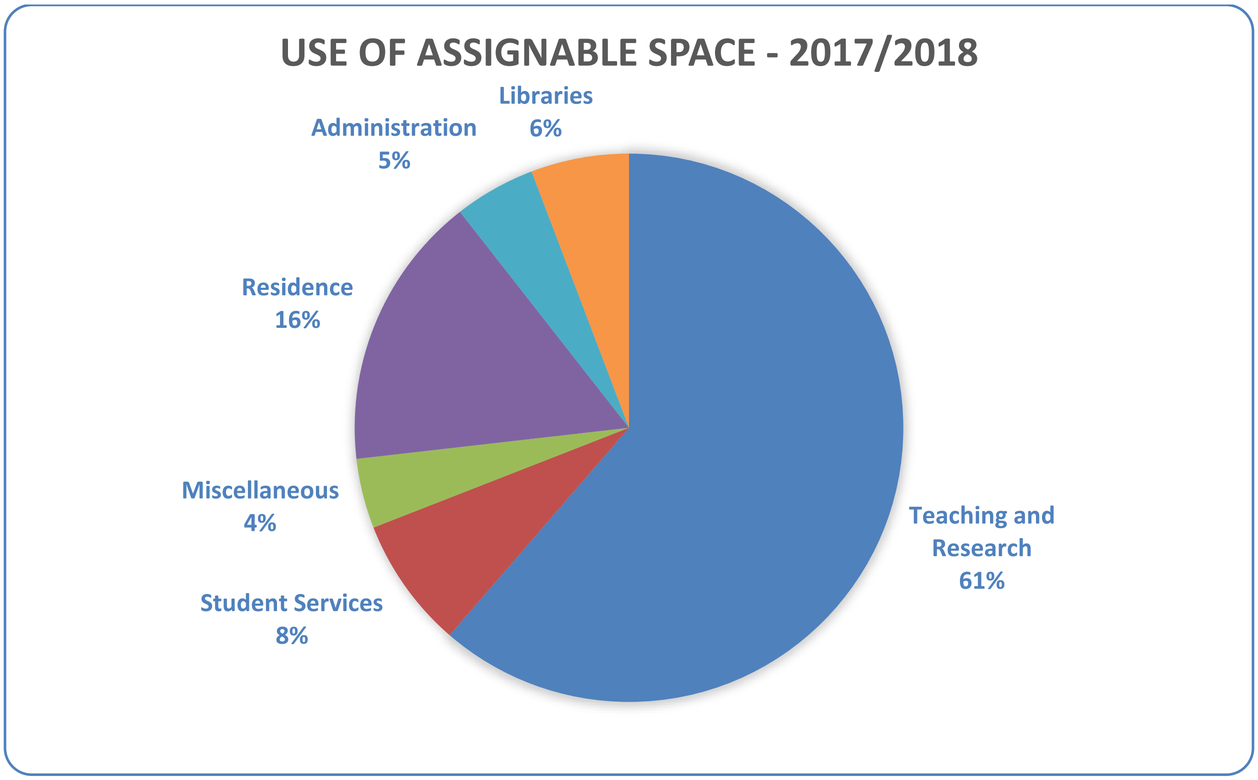

Figure 2: Uses of Assigned Space on Campus

2. BASIS FOR THE PLAN

Home to a diverse and innovative faculty and internationally renowned researchers, McMaster University has traditionally affirmed the need for triple-bottom-line decision making considering the environmental, social (i.e. user comfort and safety) and economic ramifications of the University's actions. The underlying motivation behind each of these three considerations is described below.

2.1 Environmental

Energy production and usage typically produces greenhouse gases, which contribute to global climate change. Concerns about global energy supply and global health effects due to the high consumption of fossil fuels have led many nations and organizations to advocate for a sustainable energy future. Facility Services is working with the University community and is moving towards greater energy conservation through occupant behaviour change, increased energy efficiency in buildings through technical retrofits, and renewable energy production. Organizations all across North America are feeling the challenge of maintaining standards of service, and quality of life, while reducing energy consumption in order to remain cost competitive.

In accordance with these principles, in October 2010 the university's president, Patrick Deane, signed the University and College Presidents' Climate Change Action Plan, committing McMaster to reducing its greenhouse gas emissions. Other agreements signed include the Hamilton Climate Change Action Charter and the Ontario Regional Climate Change Consortium.

The University and College President's Climate Change Action plan mandates that Canadian University signatories must commit themselves to reducing emissions in collaboration with their communities to develop reduction targets and measurement procedures and develop initiatives to achieve these targets.

The campus greenhouse gas emissions by source are shown in Figure 3 below.

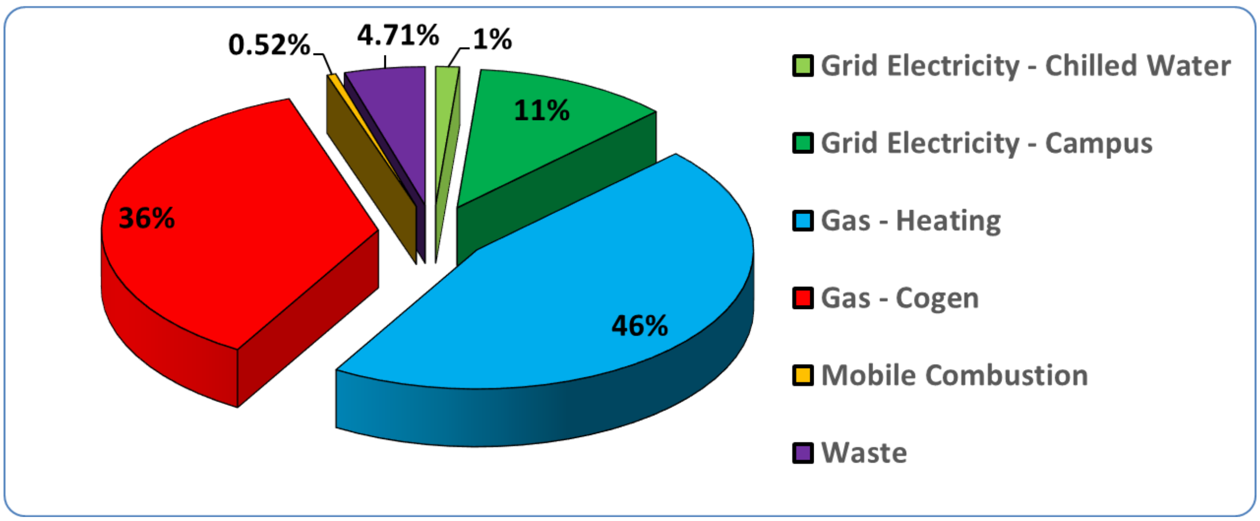

Figure 3: McMaster University Greenhouse Gas Emissions by Source

Clearly, the two largest sources are burning of gas by the Cogen and for building heating, which can be addressed by an effective Energy Management plan to significantly reduce emissions across campus and help achieve emission reduction targets.

There are several provincial energy reduction mandates that also support energy conservation across university campuses.

In 2005, the Ontario Power Authority released a report titled Supply-Mix Advice Report that forecasted a 24,000MW shortage in generation capacity by 2025 due to a growth in demand and a lack of new investments and projects in the electricity sector. This report announced that one of the methods that was being employed to reduce this shortage was stringent conservation measures across homes and industry.

The Green Energy Act of 2009, introduced the requirement for all publicly funded Ontario institutions to make their building energy consumption data available publicly and submit it to the Ministry of Energy along with an Energy Management Plan. The requirements to update this plan have recently been included in the Ontario Regulation 507/19 (January 1st, 2019).

Later, the Integrated Power System Plan released in 2011 made the following predictions about Ontario's electricity future:

- Aging grids, coal-phase out and nuclear maintenance will all contribute to stress on the electricity supply.
- The provincial government will continue to expand conservation plans and by 2030 will reduce peak demand by 7,100 MW, or 22% of total capacity for a total reduction of 28,000 TWh by 2030. The first "landmark" measured will be a savings of 4,550MW (14%) by 2015.
- Between 2011 and 2030, an anticipated investment of $12 billion will be used to meet these targets, with an estimated $27 billion in savings for ratepayers.

In 2013, declaring energy efficiency to be the cheapest, cleanest source of electricity, the updated Ontario Long Term Energy Plan 2013 titled "Conservation First" directed significant investments to expand provincial electricity conservation plans and achieve a 16% reduction of 30 TWh electrical energy in 2032 (the equivalent to more than all the power used by the City of Toronto in 2012).

These ambitious electricity consumption reduction goals are targeted to be achieved via a broad range of programs and initiatives. Many of these initiatives encourage domestic and business consumers to find innovative solutions to reduce their energy usage, through a series of financial incentives (through local distribution companies) and awareness campaigns.

The Province of Ontario through its regulatory agency, the Ontario Energy Board (OEB), has mandated natural gas utilities to deliver natural gas conservation plans and incentives for energy conservation projects.

These programs, campaigns and legislation suggest a real commitment to energy savings by the provincial and federal governments. As a responsible corporate citizen, McMaster University must also contribute to this conservation culture by monitoring and reducing its energy usage and encouraging responsible behaviour by its community.

2.2 Economic

Energy is one of the most expensive commodities on campus. Energy consumption is driven by research activities, campus population, facility utilization, new buildings and widely varying weather. Energy rates are driven by the provincial market, based on energy demand and government charges. With increases in energy consumption and electricity rates, higher energy costs are forecasted. The updated Energy Management plan focuses on avoiding these higher energy costs for the university.

An independent third party energy expert firm was engaged in 2014-2015 to review McMaster's performance over the past three years and develop an energy costs breakdown. Results are presented in Table 2 below.

Campus Utility Usage Building Breakdown
2014/2015

10/27/2

Building #	Building Name	Gross Floor Area (ft2)	Steam		Chilled Water		Municipal Water		Hydro		Comp Air/UCC	Total
			Usage (1000 lbs)	Cost	Usage (ton)	Cost	Usage (m3)	Cost	Usage (kWh)	Cost	Cost	
1	University Hall	33,816		$27,800.75		$8,528.81		$13,377.77	430,960	$69,412.16	$1,455.55	$120,575.03
2	Hamilton Hall	41,478		$38,218.78		$11,724.89		$18,390.94	590,109	$95,423.62	$2,001.00	$165,759.23
5	Edwards Hall	20,068	919,075	($16,683.94)	-	-	637	($1,810.41)	147,545	($19,251.52)	($2,330.26)	($40,076.13)
6	Wallingford Hall	19,766	1,631,110	($29,476.99)	-	-	3,398	($10,000.86)	103,341	($13,523.60)	($1,636.94)	($54,638.38)
8	Alumni Memorial Hall	13,389		$15,981.49		$4,902.85		$7,690.32	241,141	$39,902.14	$836.74	$69,313.54
9	Nuclear Research Building	33,970		$48,571.48		$14,900.92		$23,372.68	747,714	$121,271.95	$2,543.04	$210,660.07
10	Mills Memorial Library Building	199,826		$149,730.30		$45,934.77		$72,050.47	1,924,984	$373,842.58	$7,839.37	$649,397.49
11	Burke Science Building	147,861		$135,310.86		$41,511.12		$65,111.81	3,003,399	$337,840.50	$7,084.41	$586,858.70
12	E.T. Clarke Centre	57,825		$1,658,483.16		$727,332.33		$961,616.56	12,378,029	$3,668,996.79	$70,327.04	$7,086,755.88
15	Nuclear Reactor	18,107		$46,464.67		$14,254.59		$22,358.88	757,079	$116,011.73	$2,432.73	$201,522.60
16	John Hodgins Engineering Building	209,658		$293,831.61		$90,142.65		$141,392.26	4,419,023	$733,630.84	$15,384.02	$1,274,381.37
17	Divinity College	32,549	2,293,010	($42,224.00)	34,779	($7,200.53)	822	($2,346.52)	213,887	($27,729.38)	-	($79,500.43)
18	Moulton Hall		-	-	-	-	2,817	($8,469.44)	265,644	($34,695.58)	($4,199.66)	($47,364.68)
19	Whidden Hall	67,882	3,317,226	($59,958.07)	23,816	($3,957.94)	2,521	($7,459.91)	338,499	($44,122.30)	($5,340.69)	($120,838.92)
20	Gilmour Hall	109,225		$83,358.63		$25,573.04		$40,112.31	1,040,271	$208,127.57	$4,364.37	$361,535.92
22	General Sciences Building	62,689		$88,122.07		$27,034.39		$42,404.49	1,259,279	$220,020.82	$4,613.77	$382,195.54
23	Chester New Hall	85,419		$115,456.55		$35,420.15		$55,557.88	1,770,080	$288,268.79	$6,044.91	$500,748.28
24	Ivor Wynne Centre	134,121		$167,922.73		$51,515.90		$80,804.69	2,232,609	$419,264.94	$8,791.86	$728,300.13
25	A.N. Bourns Science Building	270,401		$820,763.42		$251,796.58		$394,952.71	12,904,965	$2,049,259.96	$42,972.37	$3,559,745.03
26	Matthews Hall	57,593	-	-	-	-	8,126	($24,612.93)	319,538	($41,843.31)	($5,064.84)	($71,521.08)
27	McKay Hall	66,382	2,405,644	($43,217.64)	-	-	8,854	($26,419.12)	359,209	($46,890.79)	($5,675.80)	($122,203.35)
28	Commons Building	55,845		$5,353.38		$1,642.33		$2,576.05	99,246	$13,366.16	$280.28	$23,218.21
31	Campus Services Building	49,209		$29,821.69		$9,148.80		$14,350.25	451,299	$74,458.00	$1,561.36	$129,340.10
32	Tandem Accelerator Building	26,510		$69,340.65		$21,272.56		$33,366.83	1,118,355	$173,127.86	$3,630.44	$300,738.34
33	Applied Dynamics Laboratory	18,328		$149,312.38		$45,806.56		$71,849.36	6,031,326	$372,799.11	$7,817.49	$647,584.90
34	Psychology Building	85,078		$140,732.45		$43,174.38		$67,720.69	2,224,128	$351,377.00	$7,368.27	$610,372.79
35	Woodstock Hall	54,896	2,315,868	($40,790.22)	42,000	($7,256.95)	9,578	($28,724.07)	455,121	($59,494.36)	($7,201.37)	($143,466.98)
36	Brandon Hall	54,896	6,232,952	($113,390.40)	42,000	($7,256.95)	1,351	($4,004.17)	817,934	($107,155.98)	($12,970.48)	($244,777.98)
37	Health Sciences Centre		12,412	($159,611.10)	-	($101,647.65)	249,864	($772,147.41)	249,864	($1,710,358.64)	($136,840.26)	($2,880,605.06)
38	Kenneth Taylor Hall	129,192		$73,144.44		$22,439.50		$35,197.23	1,070,020	$182,625.07	$3,829.59	$317,235.84
39	Life Sciences Building	95,249		$185,735.70		$56,980.63		$89,376.33	2,934,297	$463,739.88	$9,724.49	$805,557.02
40	Bates Residence	118,436	-	-	-	-	9,642	($29,013.70)	448,628	($58,673.93)	($7,102.07)	($94,789.69)
42	H.G. Thode Library of Science & Engineering	85,145		$61,575.93		$18,890.47		$29,630.44	968,669	$153,741.12	$3,223.91	$267,061.87
43	Communications Research Laboratory	26,683		$15,745.62		$4,830.50		$7,576.82	232,885	$39,313.24	$824.39	$68,290.57
45	Hedden Hall	94,749	3,420,360	($59,763.11)	189,870	($32,482.22)	12,214	($36,923.00)	865,083	($112,546.76)	($13,622.99)	($255,338.09)
46	DeGroote School of Business	78,812		$61,841.81		$18,972.04		$29,758.38	958,197	$154,404.97	$3,237.83	$268,215.04
48	Institute for Applied Health Sciences Building	160,940	6,385,920	$117,631.20	292,029	$59,924.35	4,936	$14,040.04	1,640,080	$211,922.94	-	$403,518.54
49	Information Technology Building	121,342		$88,496.25		$27,149.18		$42,584.54	1,258,620	$220,955.06	$4,633.36	$383,818.40
50	Mary E. Keyes Residence	121,430	30,987,871	($553,866.73)	381,785	($63,062.29)	18,313	($54,634.69)	1,421,833	($185,324.54)	($22,432.23)	($879,320.49)
51	McMaster University Student Centre	95,771	10,345,715	($191,450.60)	344,705	($70,782.86)	18,372	($56,715.95)	2,629,913	($355,932.81)	($8,876.00)	($683,758.22)
52	Michael G. DeGroote Centre	276,837		$477,943.77		$146,625.21		$229,987.33	7,162,586	$1,193,317.11	$25,023.50	$2,072,896.92
53	Les Prince Hall	100,793	13,002,900	($231,116.60)	56,376	($29,155.23)	6,020	($17,240.87)	811,130	($105,455.72)	($12,764.67)	($395,733.09)
54	David Braley Athletic Centre	164,058	5,224,164	($94,034.96)	344,705	($33,747.51)	8,145	($24,536.77)	1,631,273	($225,979.36)	-	($378,298.60)
55	Ron Joyce Stadium	21,120		$54,390.78		$16,686.19	5,859	$26,172.93	948,050	$135,801.43	$2,847.72	$235,899.04
56	Engineering Technology Building	115,505		$194,477.88		$59,662.58		$93,583.08	3,128,078	$485,567.13	$10,182.20	$843,472.86
	Sub Total		88,494,227	$3,779,976.06	1,752,066	$1,547,228.11	371,469	$1,621,904.23	85,003,912	$9,818,811.89	$14,817.74	$16,782,738.04
	Faculty of Health Science			$2,145,397.86		$537,813.11		$245,682.47		$2,558,728.43	$47,342.40	$6,707,486.27
	Total			$5,925,373.92		$2,085,041.22		$1,867,586.70		$12,377,540.32	$62,160.14	$23,490,224.31

Table 2: Building Energy Usage

The above campus utility usage breakdown forecasts a total energy budget of around $23.5 million per year.

The overall costs of energy usage across the university, between 2002-2018 are illustrated in Figure 4 below.

An important point to note is that Figure 4 only represents the total energy costs of operating facilities on campus, whereas Table 2 includes fixed costs for each building which are not represented in Figure 4.

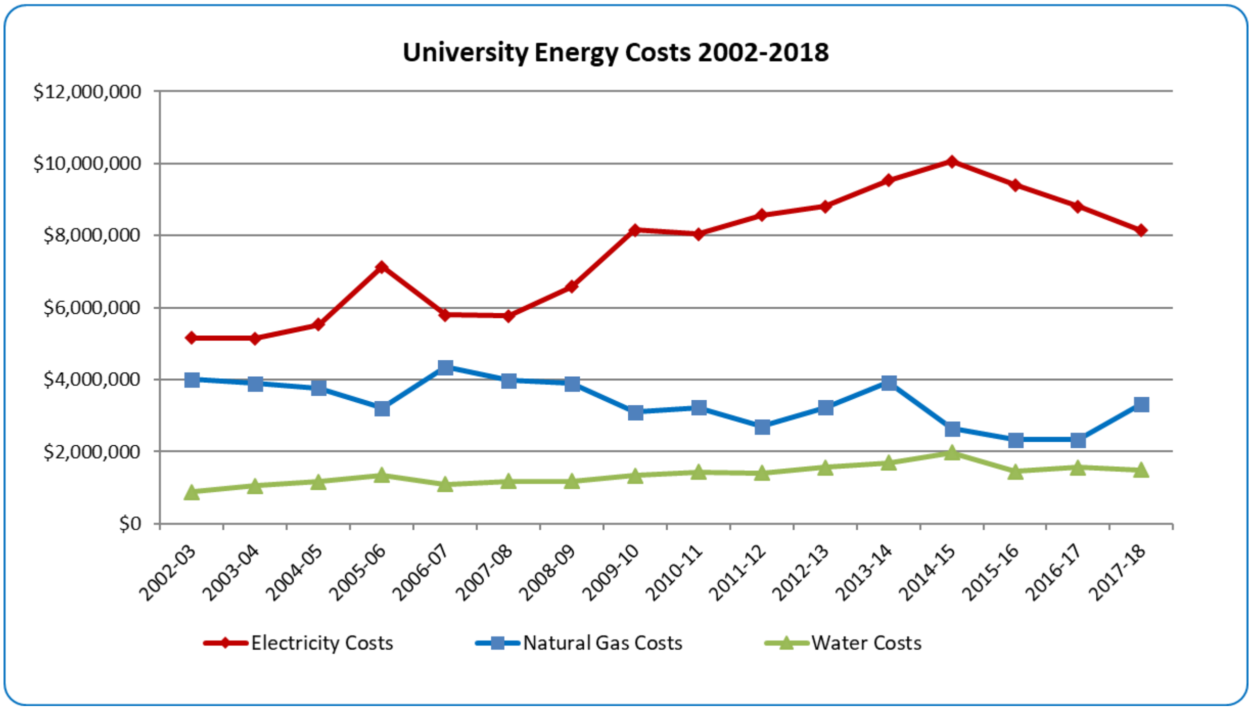

Figure 4: Energy Costs 2002-2018*

For comparison, Figure 5 shows energy consumption over the same time period.

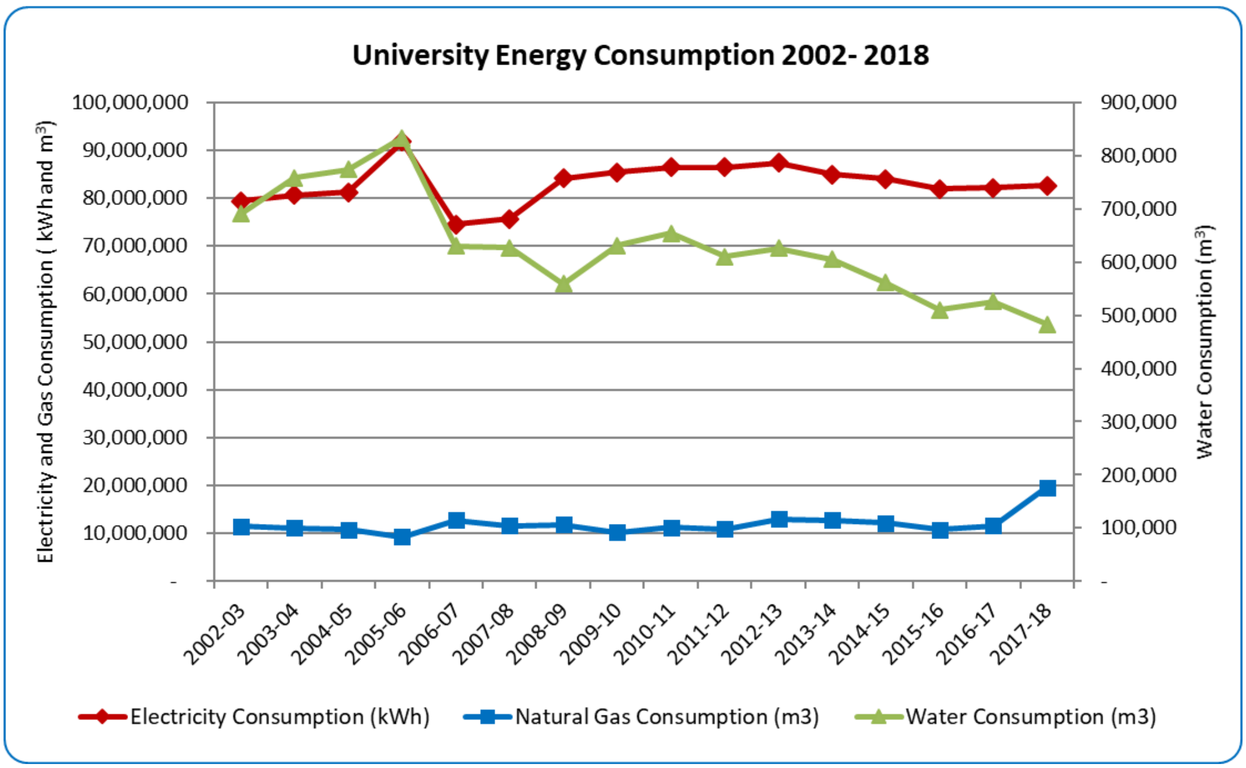

Figure 5: Campus Energy Consumption 2002-2018*

***Note: The above charts show the complete McMaster campus consumption (excluding the McMaster portion of the hospital). This chart has been updated from 2013 EMP. Historically, electricity and water consumed for producing other forms of energy (chilled water, steam, cooling) were deducted from the overall numbers. The above chart includes all purchased forms of energy.**

Figure 4 shows that an effective energy management plan has the potential to save the University hundreds of thousands of dollars each year. Figure 5 shows electricity consumption has been reduced since the implementation of EMP version 1, however electricity costs shown in Figure 4 have increased due to rate increases (shown in Figure 7).

The relative costs of each utility in the 2017-2018 academic year are shown in Figure 6 which demonstrates that electricity accounts for the bulk of energy costs.

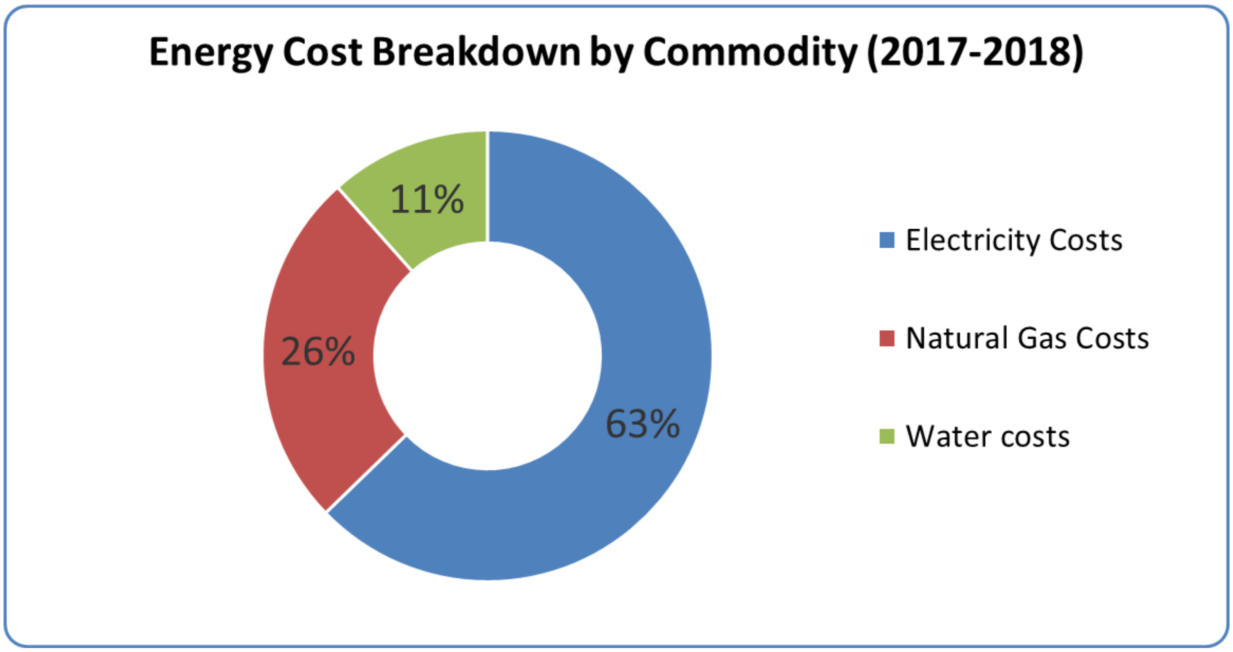

Figure 6: Relative Energy Costs Breakdown by Commodity (2017-2018)

Furthermore, the Ontario Energy Board (OEB) and the Independent Electricity Systems operator (IESO) predict an increase in energy costs with an increase in demand over the upcoming years.

Using a linear line fit for cost data from 2002-2018 alongside recent rate increase trends, it is possible that electricity prices may be as high as $180/MWh by 2020-21, leading to a drastic increase in hydro costs for the university, as shown in Figure 7.

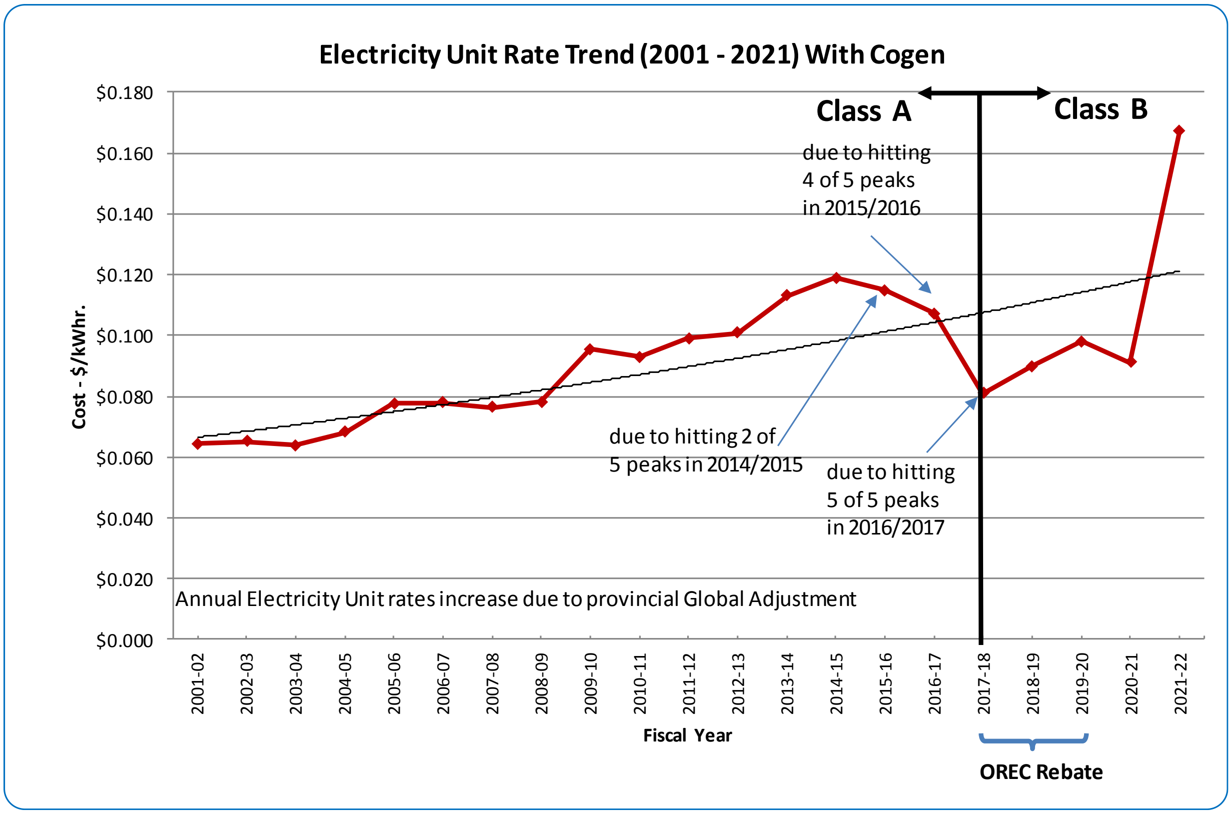

Figure 7: Actual Electricity Rates and Trend (2002-2021 – With Cogen)

Figure 7 shows the savings achieved due to chasing the peaks for 2014-2015, 2015-2016, and 2016-2017. The Ontario Rebate for Electricity Consumers (OREC) received in 2018 is also factored in the above electricity rates until 2020.

Gas prices however have declined and are forecasted to be stable over the long term due to shale gas technology efficiencies, as shown by Figure 8 below.

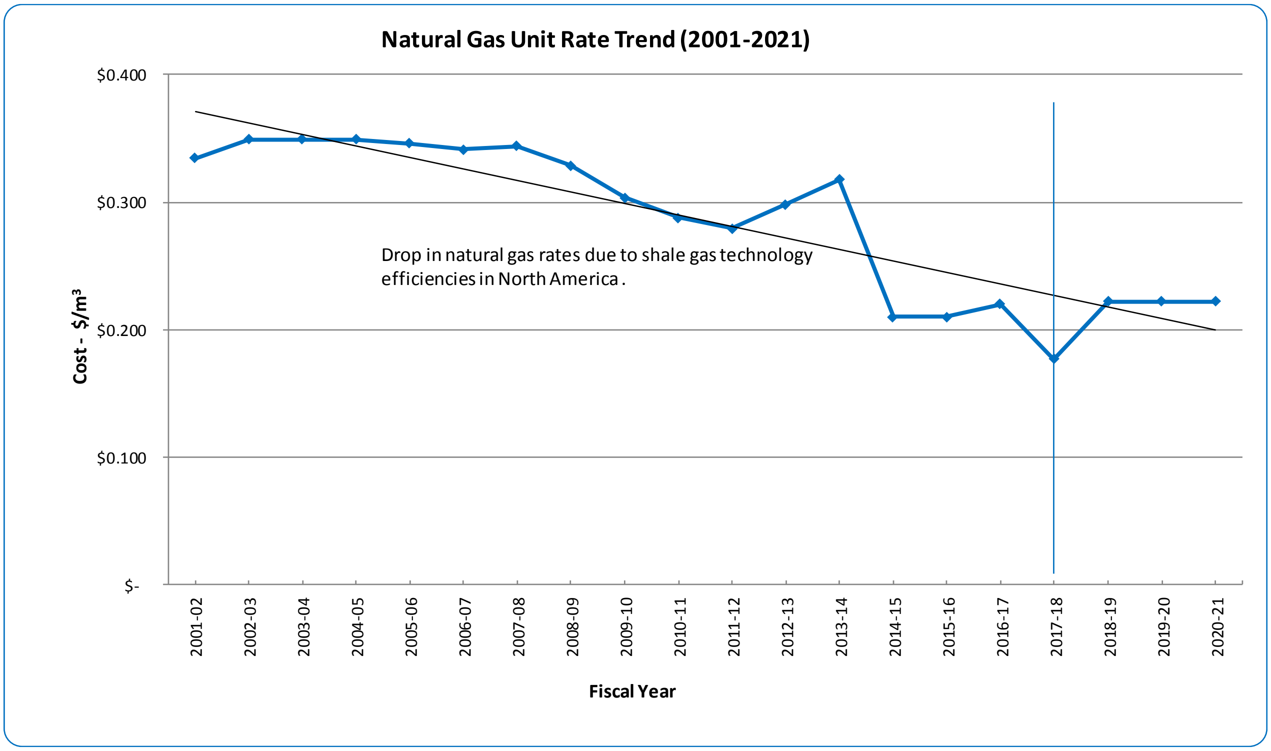

Figure 8: Actual Gas Rates and Trend (2002-2021)

However, water prices for the university display a steadily increasing price trend, as shown in Figure 9.

It should be noted that water prices increase proportionally to the electricity prices, City of Hamilton and infrastructure cost increases due to the electricity required to pump and filter domestic water for use on campus.

The updated energy management plan has been developed with the utility data to manage energy related costs and could potentially offset these rapidly increasing costs.

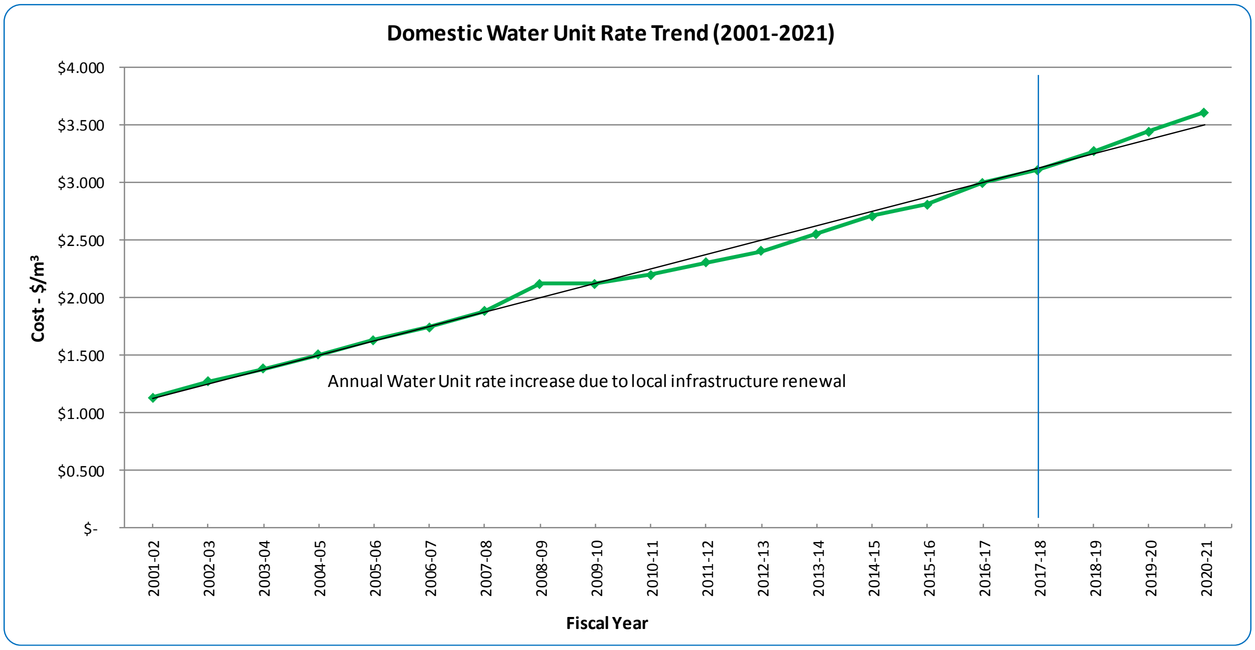

Figure 9: Actual and Forecasted Water Prices 2002-19

2.3 Social considerations

McMaster University states that our goal is to "provide and maintain healthy and safe working and learning environments for all employees, students, volunteers and visitors. To support this commitment both McMaster University and its employees are responsible jointly to implement and maintain an Internal Responsibility System directed at promoting health and safety, preventing incidents involving occupational injuries and illnesses or adverse effects upon the natural environment." (Source: McMaster University Workplace Health & Safety Policy, 2012)

This commitment suggests that one of the highest priorities of the university is to provide a safe and comfortable workplace and learning environment for all people using the campus. Therefore, any energy savings measure, despite its economic savings and environmental benefits must be made in the context of user health, safety and comfort. Furthermore, reducing energy costs reduces the overall operating costs of the university which creates a more cost-competitive business model.

Cleaner, more energy efficient workplaces and student environments have been shown to increase productivity and improve employee health. Studies repeatedly show that employees take fewer sick days and contribute more, in greener workspaces. An effective energy management plan, and novel approaches to new building designs and refurbishments on campus can help to achieve this goal.

Furthermore, social responsibility dictates that McMaster University has an obligation to pursue initiatives that utilize resources sustainably.

2.4 Other Canadian Universities

Signatories of the University and College Presidents' Climate Change Action Plan include Queen's University, University of Calgary, Emily Carr University of Art and Design, University of Manitoba, St. Mary's University College, Dalhousie University, the University of Winnipeg and the University of Saskatchewan. These diverse educational institutions have all committed to reducing emissions by reducing energy usage and waste.

Other institutions, although not formally committed to the Climate Change Action Plan, have also taken significant measures to reduce energy usage across their campuses. Prominent examples include:

- The University of British Columbia's commitment to be a zero carbon emission campus by 2050, and a net positive energy producer by 2050. These goals were tackled by innovative optimization and refurbishment programs, awareness campus and real time energy and emissions monitoring systems, and earned the University one of the highest ranks on the College Sustainability Report Card rankings for several years in a row.
- University of Ottawa has been implementing Eco-Efficiencies energy retrofit program at a cost of $9.5 million and has plans for a Phase 2 at a cost $11.7 million.
- Western University has been implementing an electricity demand management and retrofit program.
- York University has been implementing a $40 million Energy Management Program, involving lighting retrofits, cogeneration, HVAC modifications and renewable energy installations.
- Wilfrid Laurier University released an extensive energy management plan that involved saving almost 16,000L of water per year, and outlined 9 other areas where the university will take measures to improve energy efficiency.

A full report of all Ontario Universities' sustainability and green initiatives can be found in the *Ontario Universities: Going Greener* report released by the Council of Ontario Universities in 2017.

As a leader in energy research and sustainability, McMaster University has a responsibility to ensure that it follows suit with energy management initiatives.

3. MONITORING AND METERING

A rigorous monitoring and metering program is required for McMaster to:

- ensure compliance with the initiatives outlined in the plans and to measure progress, and forecast future trends
- benchmark facilities for performance evaluation and identifying areas of improvement
- engage the campus community in energy conservation and sustainability
- generate energy incentives from outside funding sources

McMaster University Facility Services is primarily responsible for monitoring progress with regards to the Energy Management Plan. In this regard, McMaster Facility Services led nine other

Ontario Universities in the implementation of a University Utility Consumption and Benchmarking System with 100% funding from the Ministry of Training, Colleges and Universities.

Details on this initiative are listed in section 8.1 Completed Projects to date under the Energy Dashboard project.

Facility Services Energy Management & Sustainability Services monitors and reports progress every 3-6 months, along with a budget review to ensure achievement of the targets set forth in the Energy Management Plan. Reports would be made available to the Planning & Building Committee, the office of the Assistant Vice President and any other users who may require them for informational purposes. Awareness campaigns for users and operators are discussed later on in this report.

Campus Electronic Displays for Real Time information

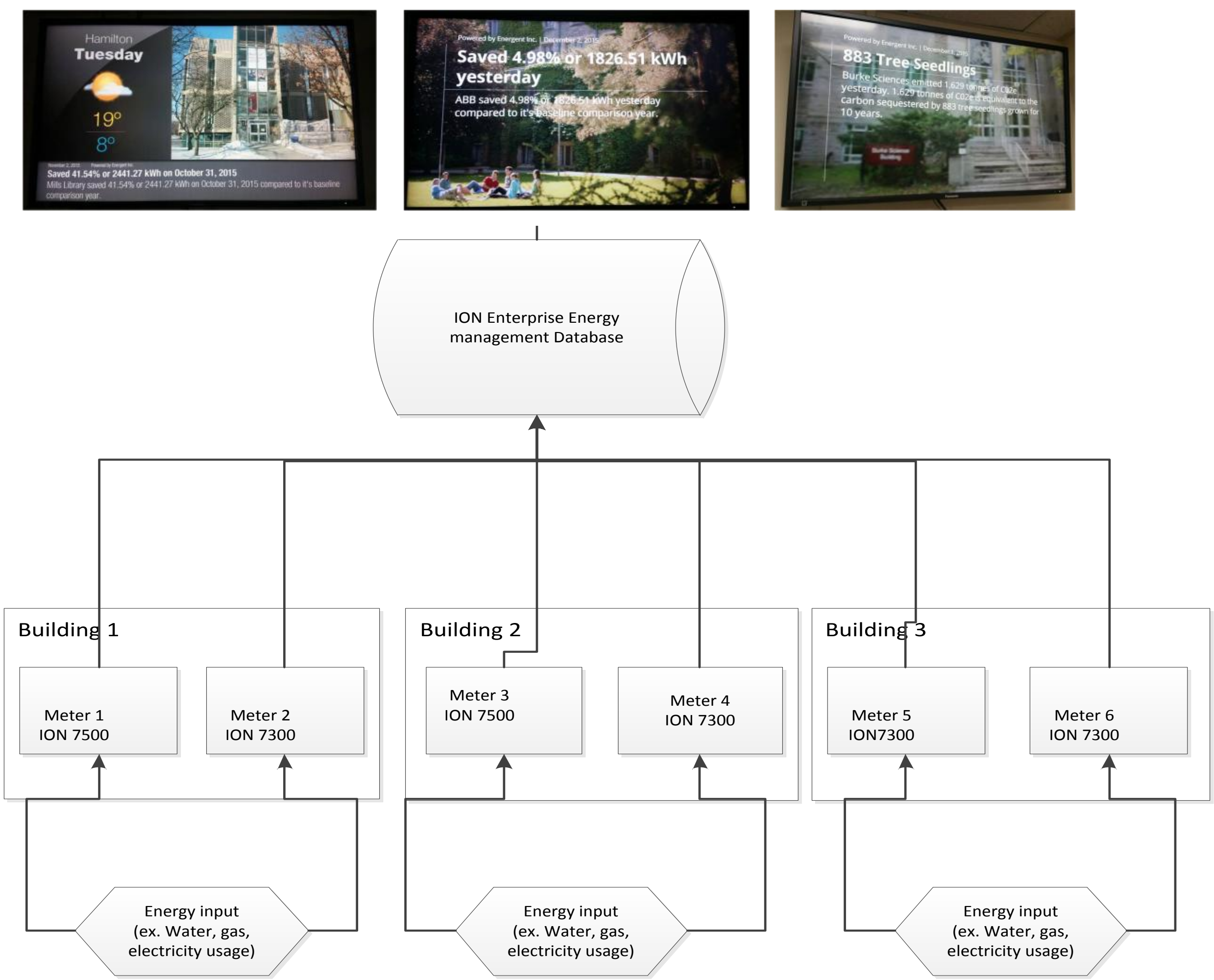

Figure 10: Schematic Diagram of McMaster University Metering and Display System

4. ENERGY PROCUREMENT POLICY

McMaster University's Energy Procurement policy aims to reduce the cost of purchasing utilities. This is accomplished by hedging energy prices; that is, buying a fixed amount of a utility at a fixed rate for several years into the future. This hedging process, based on forecasted consumption and price trends, protects McMaster from unforeseen price increases. The policy states that "commodity price hedging will only be undertaken to protect McMaster University against operating price risk." However, unit prices are low, therefore McMaster purchases at index instead of hedging.

The Energy Procurement policy also states that McMaster University will engage no fewer than three Master Supply Agreements with reputable, credit-worthy and financially stable supply organizations. This diversification of suppliers will reduce the risk of supplier default or failure. Furthermore, the university will continuously consult with external independent consultants to determine optimal utility prices, and these consultants will be independent and financially separate from any suppliers to avoid any conflicts of interest.

5. OCCUPANT COMFORT STANDARDS

The Occupant Comfort Standards state that:

The target range for indoor air temperatures in area serviced by a HVAC system will be:

Winter Minimum = 18°C (O. Reg.)

Summer Maximum = 24°C

This requirement will affect operation of the HVAC systems and therefore the energy consumption in each building.

Facility Services is committed to creating an Energy Management Plan that conserves energy but first and foremost continues to ensure the health and safety of all students, staff and faculty that use campus facilities. While the EMP is ambitious in its energy conservation targets, utmost care will be taken to ensure that occupant comfort standards and regulations are not compromised.

For a full report on Occupant Comfort Standards, please refer to McMaster's Risk Management Manual # 400.

6. ENERGY CONSUMPTION/COST PERFORMANCE DATA

6.1 Energy Profile

6.1.1 Annual Usage Data

Before we can set meaningful and realistic energy reduction targets, it is first necessary to evaluate the current energy consumption of the university and examine trends in consumption over the past few years.

For the purposes of this energy profile, "energy" will be considered from a water, electricity and gas consumption perspective. Figures 11-14 show the consumption trends from the 2002-03 academic year to the 2017-18 academic year. These figures have been updated from the 2013 EMP to show the complete McMaster campus energy consumption excluding the McMaster portion of the on campus hospital (Health Sciences Centre) and Divinity College, and off-campus buildings (Halton Family Health Centre in Burlington, McMaster Automotive Resource Centre, One James North in downtown Hamilton, and Ron Joyce Centre in Burlington). The same applies for all remaining energy figures in this plan. Historically, electricity and water consumed for producing other forms of energy (chilled water, steam, cooling) was deducted from the overall numbers.

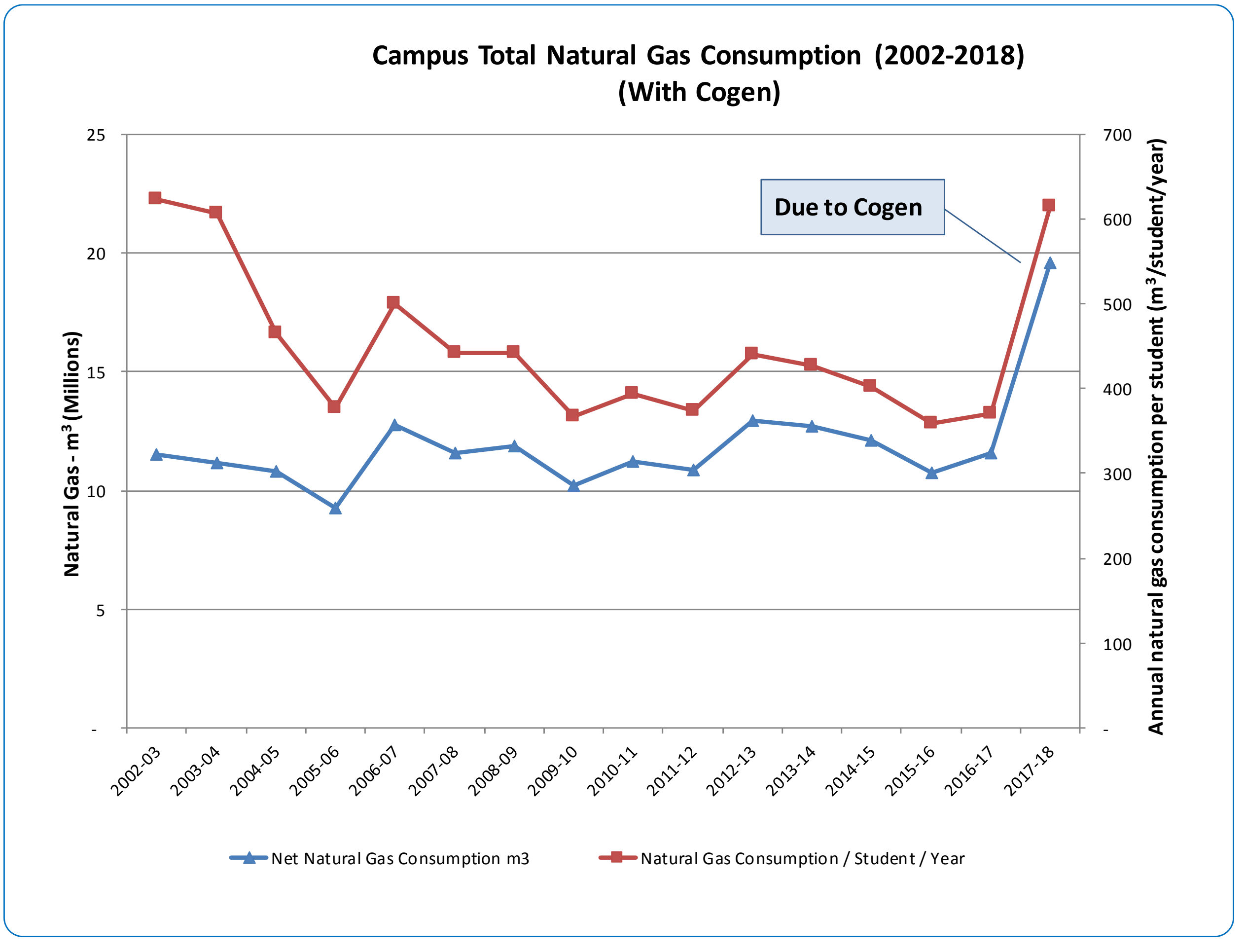

Figure 11: Campus Total Natural Gas Consumption Trends (With Cogen)

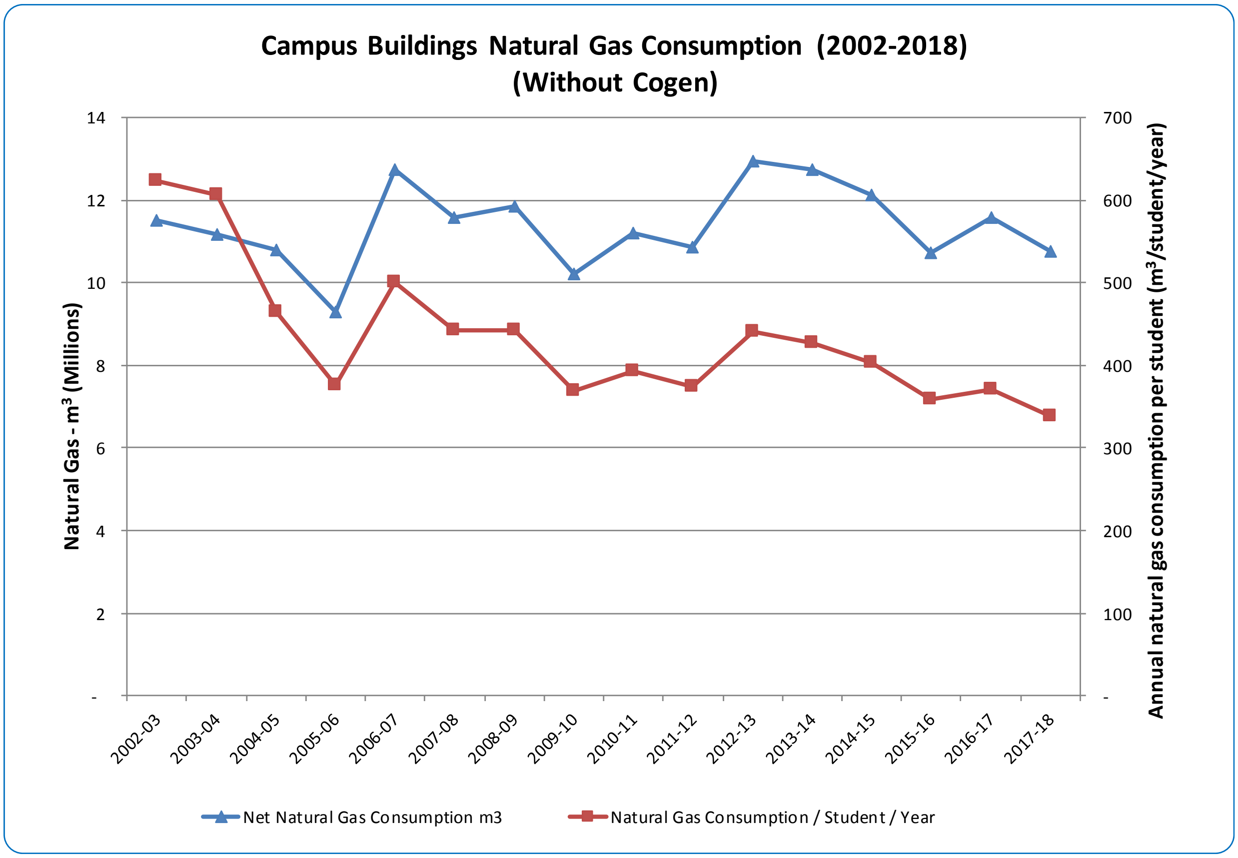

Figure 12: Campus Buildings Natural Gas Consumption Trends (Without Cogen)

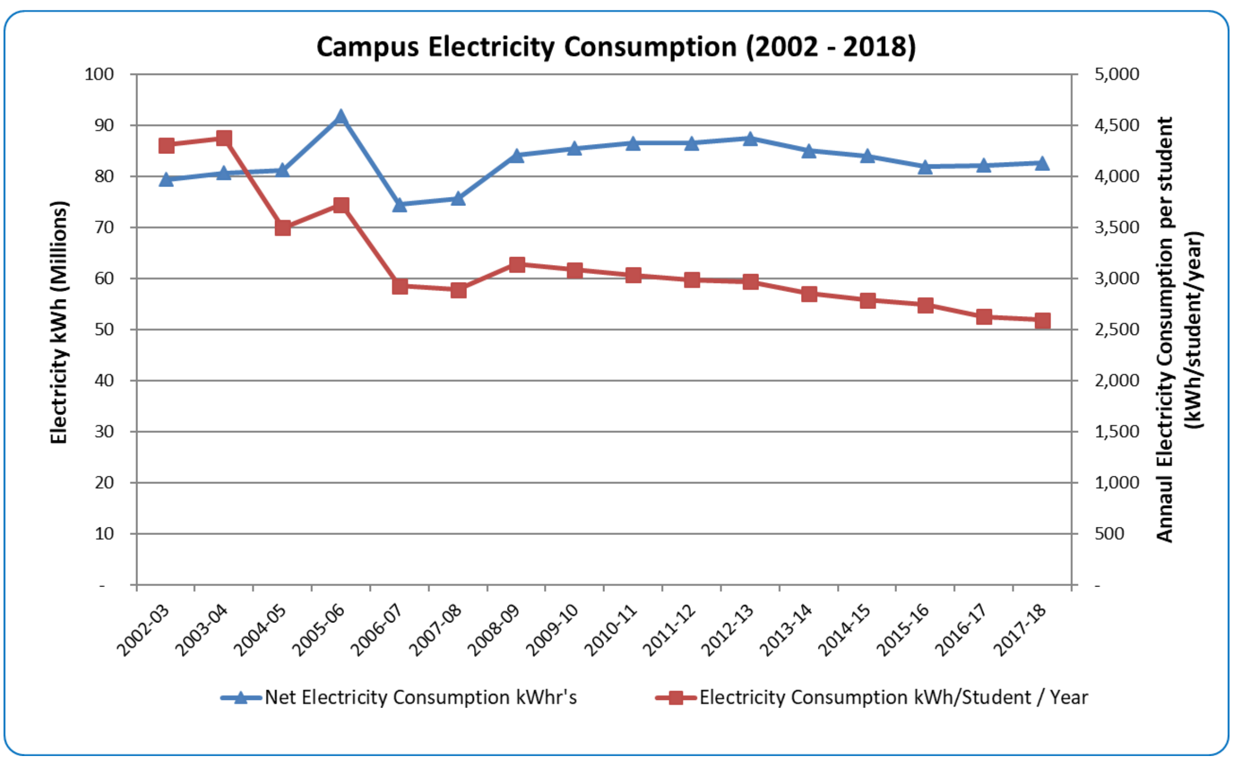

Figure 13: Electricity Consumption Trends

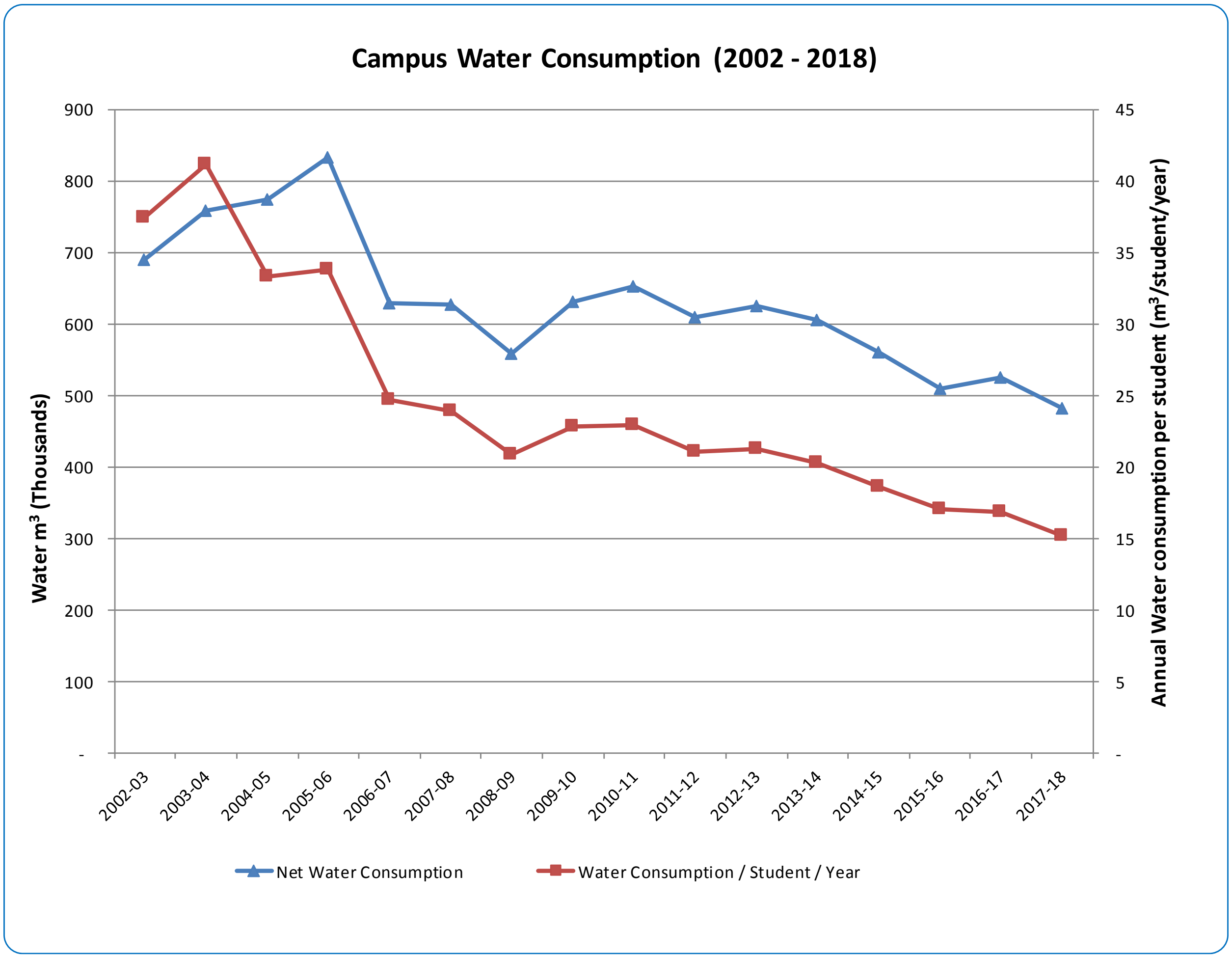

Figure 14: Water Consumption Trends

The above graphs show that the overall consumption of electricity has increased at a lower rate than the student population and that consumption on a per student basis has dropped significantly. Excluding the gas consumption by the co-generation plant, the overall consumption of gas has also increased at a lower rate than the student population. Electricity consumption per student has dropped by around 42% since 2002, natural gas consumption (excluding Cogen) dropped by 48%, and water consumption per student has dropped more than 61%. These graphs are based on student enrolment information from the Office for Institutional Research and analysis.

Figures 15-17 below present typical monthly energy consumption.

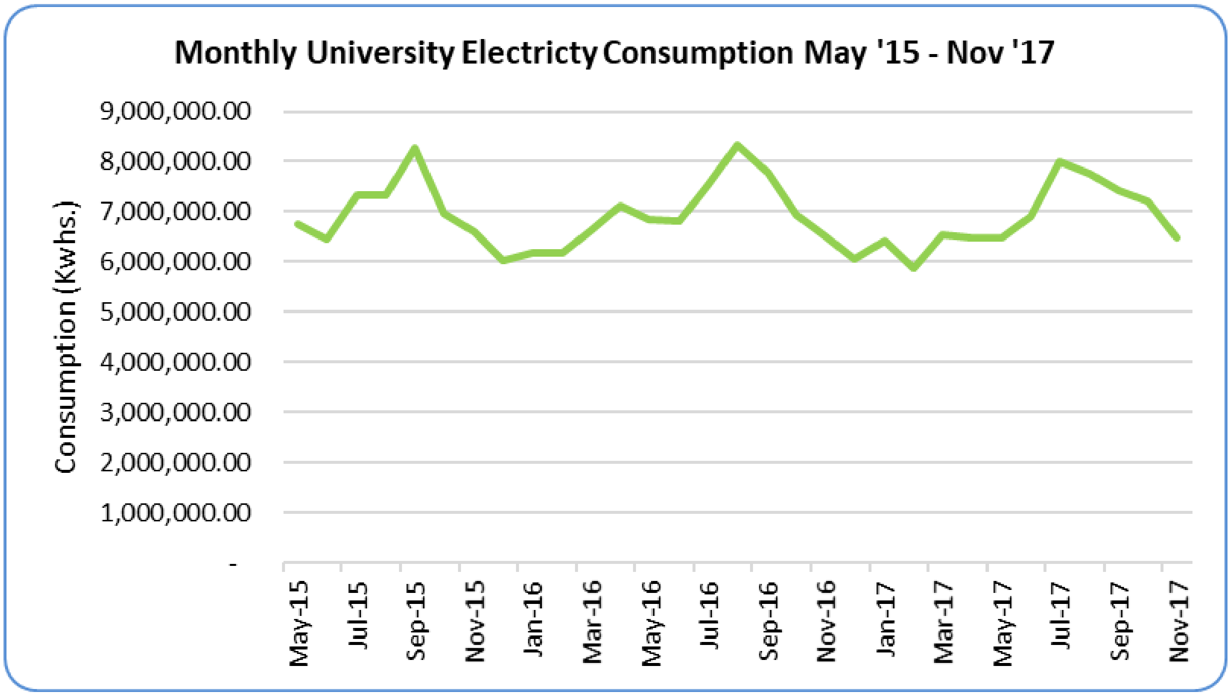

Figure 15: Monthly Electricity Consumption 2015-17

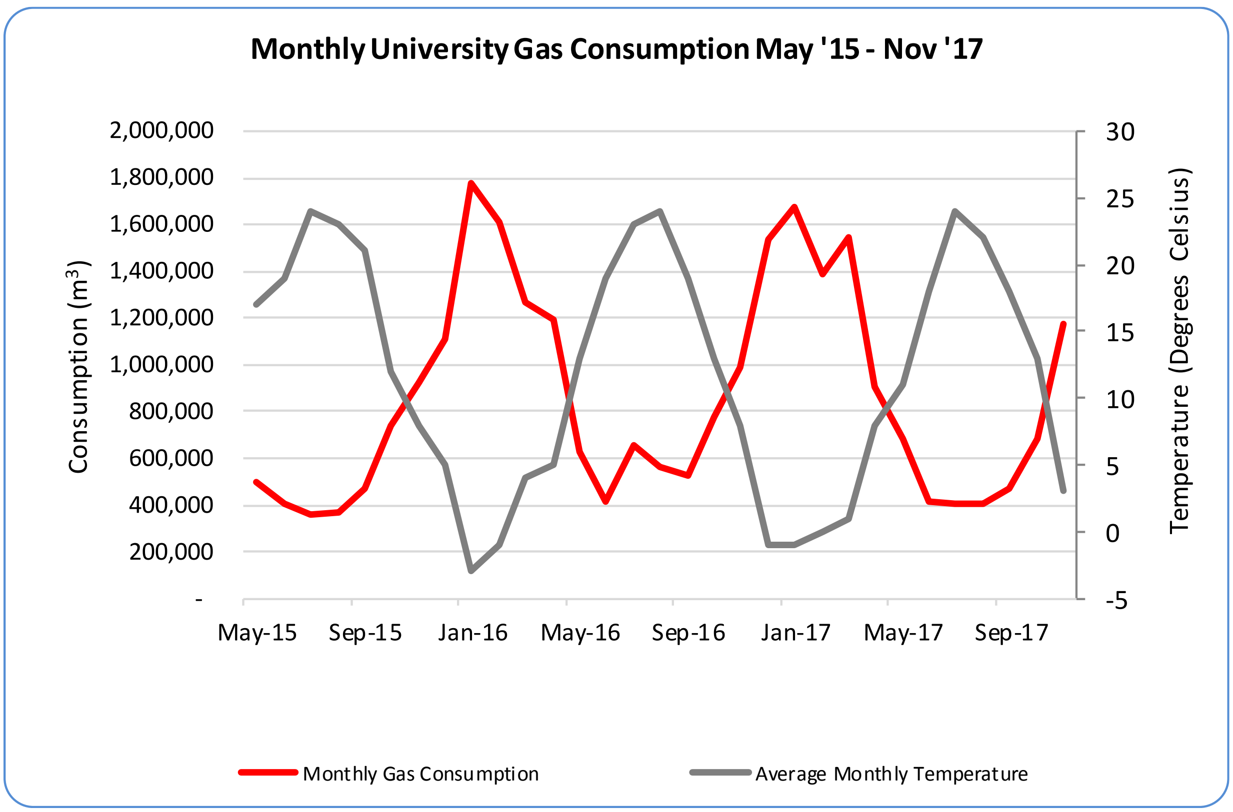

Figure 16: Monthly Gas Consumption 2015-17

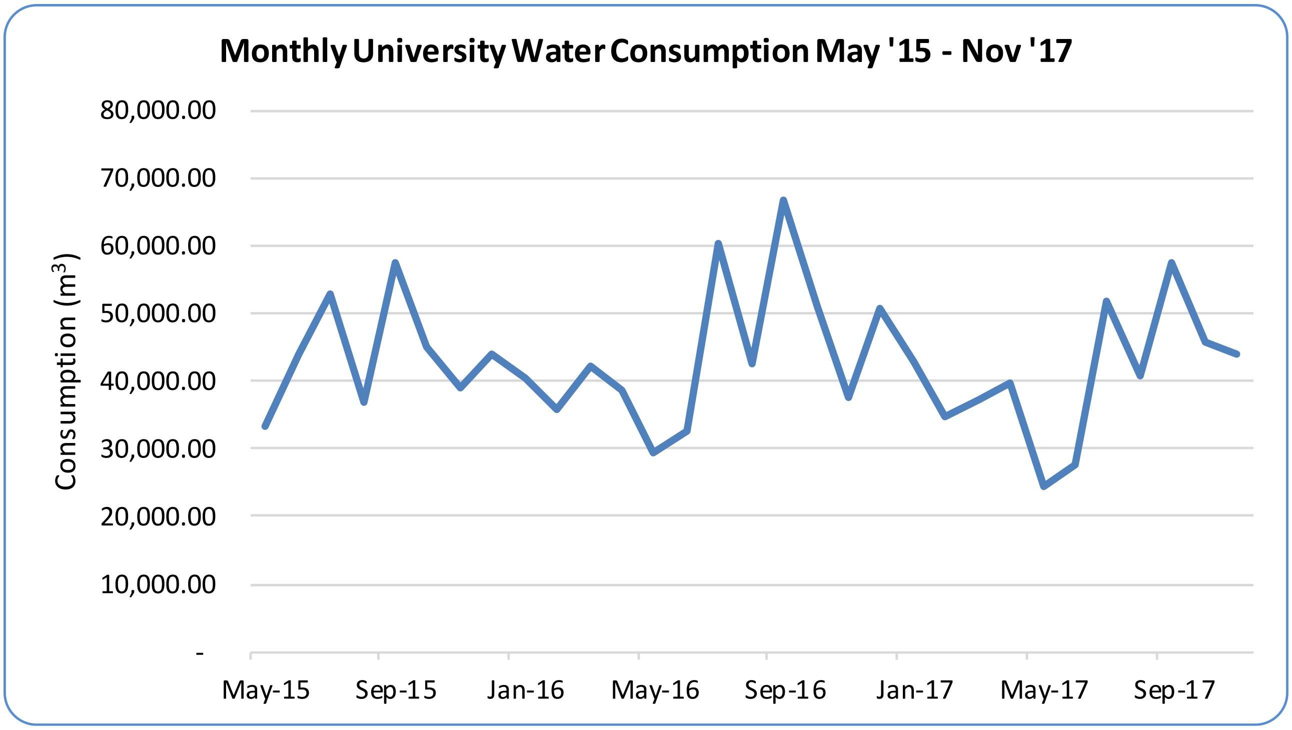

Figure 17: Monthly Water Consumption 2015-17

Figures 15-17 also show that gas and water consumption peaks occur between September and May each year, likely due to the fact that there are significantly more students on campus during the fall and winter terms, as compared to the summer term.

6.1.2 Energy Usage of Research Versus Non-Research Buildings

As an example, the electricity usage of two typical campus building is shown in Figure 18. The first, A.N. Bourns Science Building (ABB), is an example of a laboratory intensive space, while the second, the McMaster University Student Centre (MUSC) is mostly office and student space.

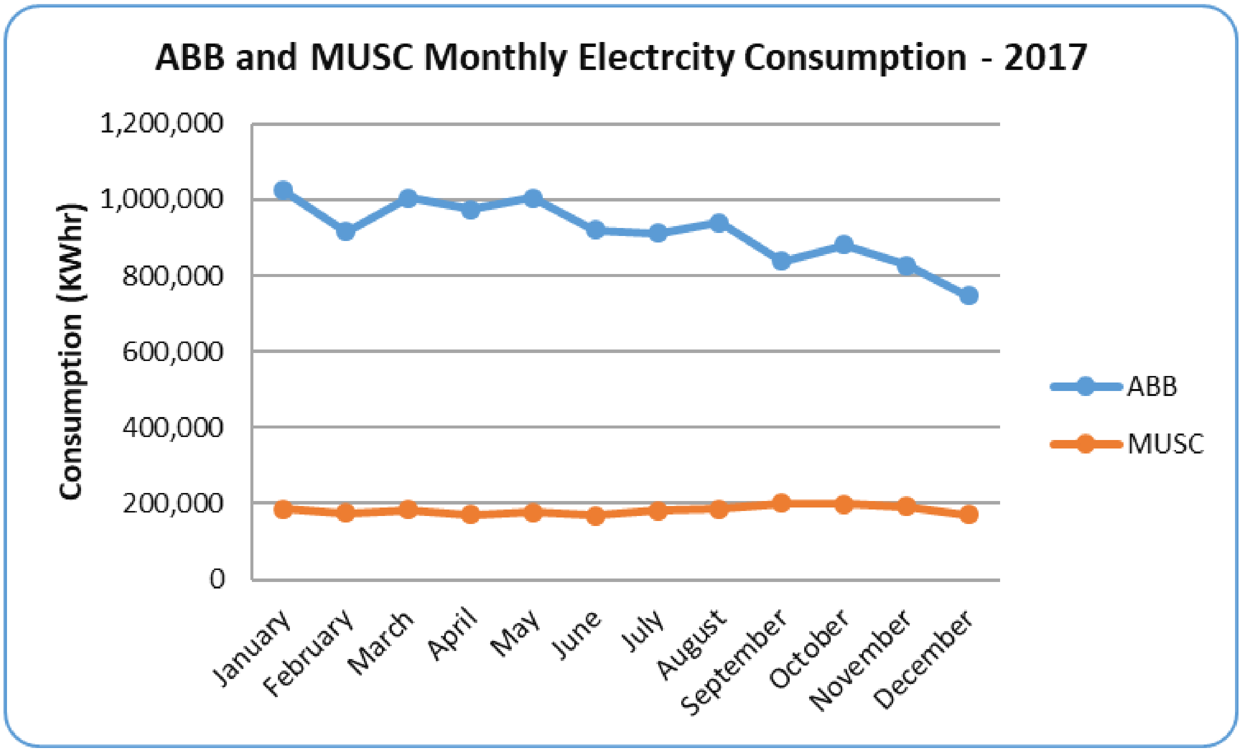

Figure 18: ABB and MUSC Electricity Consumption Trends - 2017

Similar trends are observed for all laboratory intensive buildings, identifying a considerable potential for energy savings by addressing electricity consumption in these research intensive buildings.

6.2 Energy Benchmarking

Natural Resources Canada (NRCAN) describes energy benchmarking as "a comparative analysis of energy uses per unit of physical production, otherwise known as energy intensity. Best practices benchmarking involves comparing operations and systems within your facility to best-in-class operations."

Energy benchmarking allows users to identify areas for improvement across their facilities, set reduction targets and identify factors to measure energy consumption.

The following section will outline possible benchmarking techniques to compare McMaster's performance with other educational institutions.

6.2.1 Campus Energy Benchmarking

A survey of 123 Canadian universities was conducted by NRCAN in 2003 to show energy (electrical and gas) consumption trends in universities, colleges and hospitals across Canada. The results for universities are presented in Table 3 below.

Province	Energy Intensity (GJ/m^2)
Prairies	2.26
Ontario	2.19
Quebec	1.94
Atlantic	1.69
British Columbia	1.64
Canada	2.04

Table 3: Canadian Universities Energy Use (NRCAN)– 2003

6.2.2 E2 Energy Benchmarking

Using funding from the Ontario Power Authority's (OPA) Conservation Fund, The Council of Ontario University via an energy consulting firm (E2 Energy) was able to conduct an extensive study of 22 Ontario university campuses between 2007 and 2009. Results are presented in Table 4 below.

OAPPA Energy Benchmarking	Energy Intensity (GJ/m^2)	Water Intensity (m^3/m^2)
OAPPA - 2008	1.54	
OAPPA - 2009	1.53	1.35

Table 4: The Council of Ontario Universities Energy Benchmarking Project – 2010

In order to compare McMaster to the above studies, energy consumption in 2003, 2008 and 2009 is presented in Table 5 below.

Year	McMaster Energy Intensity (GJ/m^2)	Water Intensity (m^3/m^2)
2003	2.14	2.07
2008	1.68	1.5
2009	1.7	1.28

Table 5: McMaster Energy and Water Intensities

The above show that McMaster energy consumption is below the Ontario average and slightly above the Canadian average in NRCan study. It is also slightly higher than the Ontario average in E2 Energy study. Water consumption at McMaster came below that of Ontario in E2 Energy study.

Although the E2 Energy study did not separate universities based on energy intensive research facilities on campus, it did account for these discrepancies by determining the percentage of space used for research facilities. Table 6 below shows the relative research intensities and the average energy intensities of each school surveyed.

It is also noteworthy that McMaster University falls below the average in high and low energy usage labs categories, and is below the average energy usage for Ontario Universities.

E2 Energy calculations address "energy" by surveying campus electricity, water and gas usage, whereas NRCAN only considers gas and electricity. Nevertheless, the two benchmarking studies provide a starting point for comparing McMaster's performance to the average.

	Academic s/Admin	Cafeteria	High Energy Usage Labs	Libraries	Low Energy Usage Labs	Other/Misc	Residenc es	Student Physical Education Centre	Average
Algoma	0.72		1.60	0.54	0.67	0.17	0.91	0.49	0.83
Brock	2.01	0.06	1.73	2.24	0.81	0.03	2.51	5.35	2.43
Carleton	1.33		2.56	1.28	2.67	0.51	0.88	1.60	1.43
Guelph	2.00	1.29	3.71	1.52	2.69		1.52	2.42	2.53
Lakehead	1.14		1.98	1.12	2.88		0.90	0.97	1.28
Laurention	1.28	0.77	0.96	0.95	2.16	1.01	1.04	1.51	1.21
Laurier	1.22	1.76	2.16	1.14	1.05		0.88	1.79	1.21
McMaster	1.42	1.06	1.74	0.76	0.99		0.87	1.07	1.31
Nippising	0.92						0.51	0.88	0.69
COCAD	1.51							3.15	1.51
Ottawa	1.51		0.81	0.82	1.17	2.74	1.02	1.37	1.30
Queens	1.48	2.11	2.45	1.84	1.94	0.67	1.20	1.31	1.57
Ryerson	1.63		1.39	1.60	1.31		1.02	1.69	1.36
Trent	2.51		2.29	1.09	1.86		1.09	1.72	1.72
UOIT	0.82		1.51	1.07			1.66	2.24	1.42
UTM	2.11		0.81	1.79	2.69	0.26	0.96	1.78	1.57
UTSC			3.39	1.68	2.43		1.42	2.78	2.66
UT St. G	1.14		2.10	1.07	2.09	0.72	0.18	1.40	1.66
Waterloo	1.38	1.87	1.85	1.14	1.17		1.08	1.43	1.41
Western	1.59	1.02	2.44	1.20	2.22	1.07	1.02	1.51	1.60
Windsor	1.10	1.25	2.40	1.29	2.52	-	1.27	1.67	1.45
York	1.26	0.16	1.63	0.94	2.31	0.09	0.96	0.19	1.04
Average	1.42	1.03	2.30	1.29	1.95	0.38	1.06	1.50	1.53

Table 6: E2 Energy Analysis

The study also unveils that McMaster university has one of the lowest energy intensities among the Group of Six Ontario Universities as presented in Table 7 below.

	Energy Consumption GJ's / year	Floor Area m^2	Energy Consumption $GJ's/m^2/year$
McMaster	544,503	414,461	1.31
Ottawa	693,722	531,772	1.30
Queens	794,382	507,016	1.57
UT St. G	2,078,243	1,248,784	1.66
Waterloo	716,805	507,994	1.41
Western	1,168,640	729,269	1.60

Table 7: E2 Energy and Research Intensity – 2009

The Association of Physical Plant Administrators (APPA), issues a yearly report for various universities in Canada. The energy spent per unit area for four major universities in Ontario is presented in Table 8 below from one of the APPA reports.

Year	2011-2012 ($/GSF)	2013-2014 ($/GSF)	2014-2015 ($/GSF)
McMaster	3.27	3.9	3.51
Queens	3.61	3.83	3.18
Western	2.64	3.87	4.41
Ottawa	3.29		2.69

Table 8: APPA – Utility Expenditure ($/Square Foot)

6.2.3 Campus Energy Intensities

Figures 19-22 present the energy (electricity, water, gas) usage per m^2 over different periods of time at McMaster University.

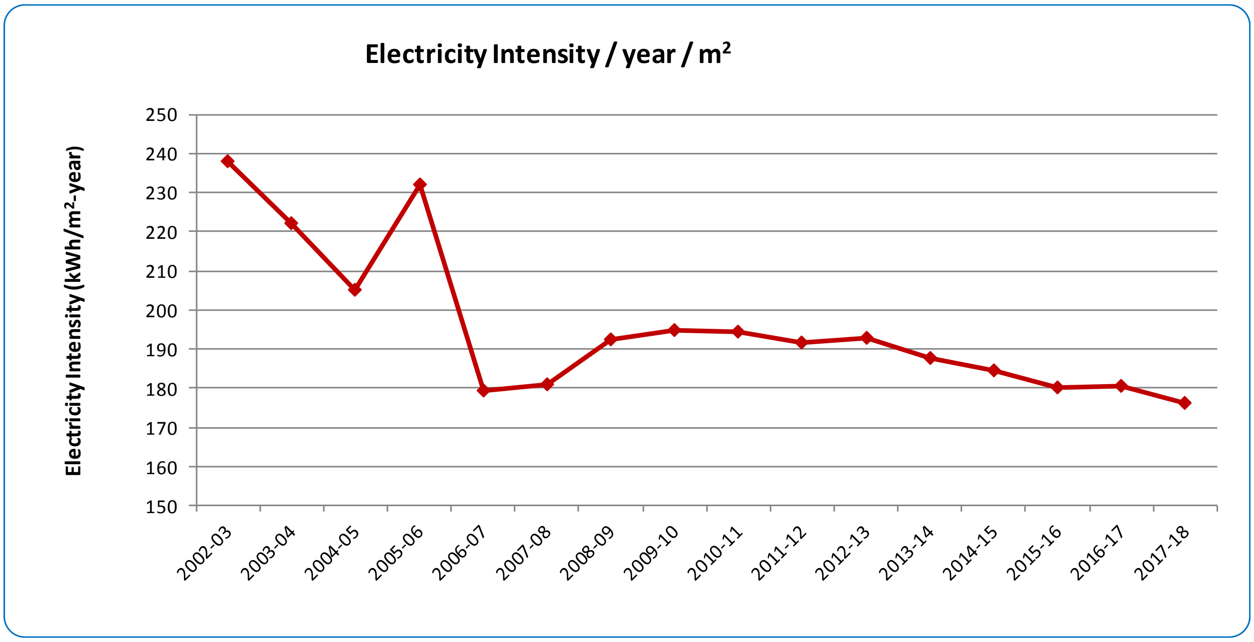

Figure 19: Electricity Intensity Trends 2002-2018

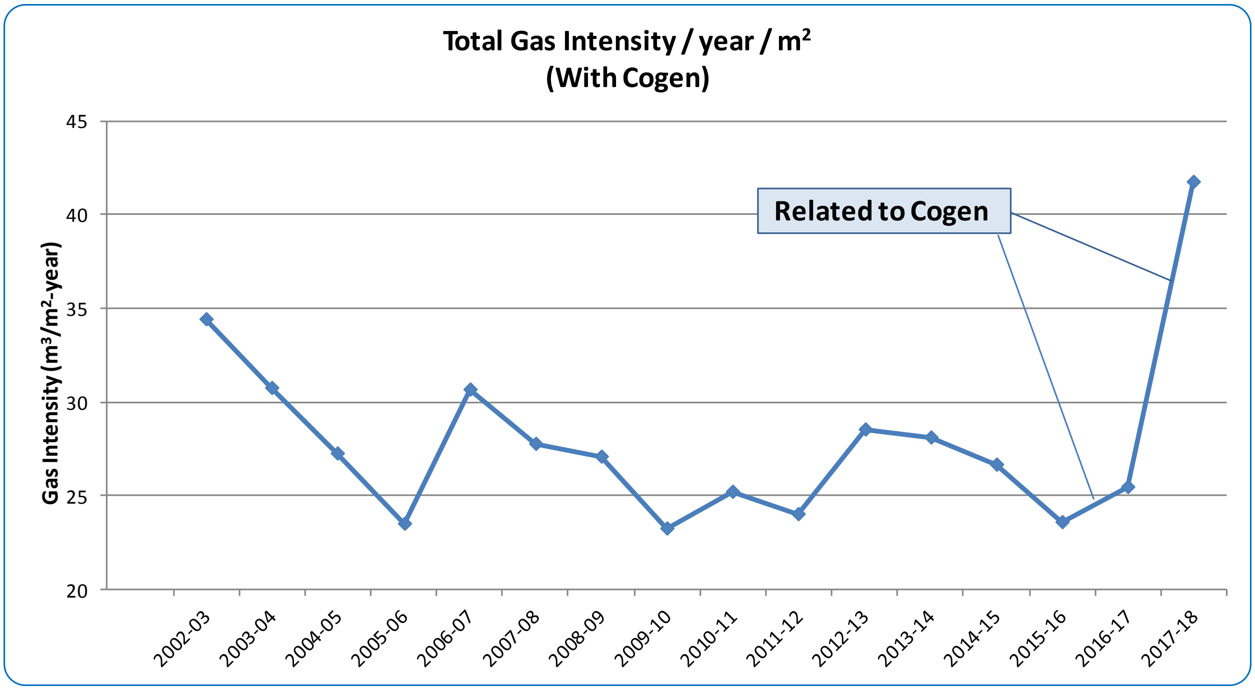

Figure 20: Total Gas Intensity Trends (With Cogen) 2002-2018

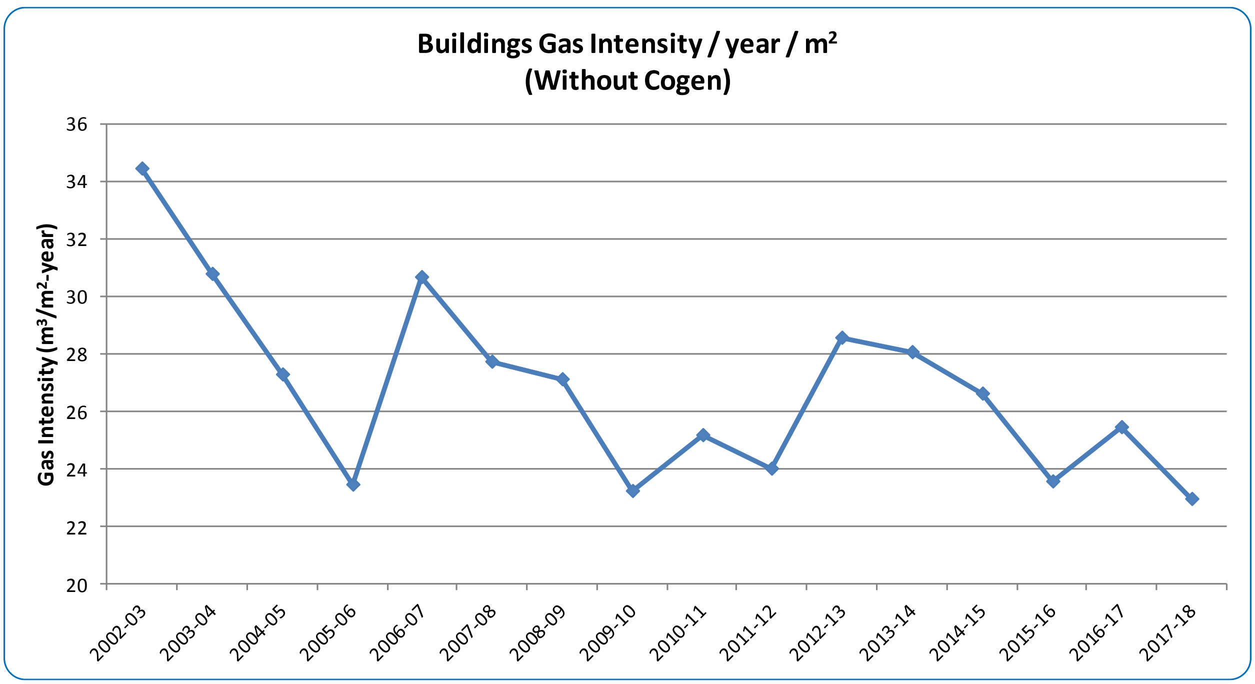

Figure 21: Buildings Gas Intensity Trends (Without Cogen) 2002-2018

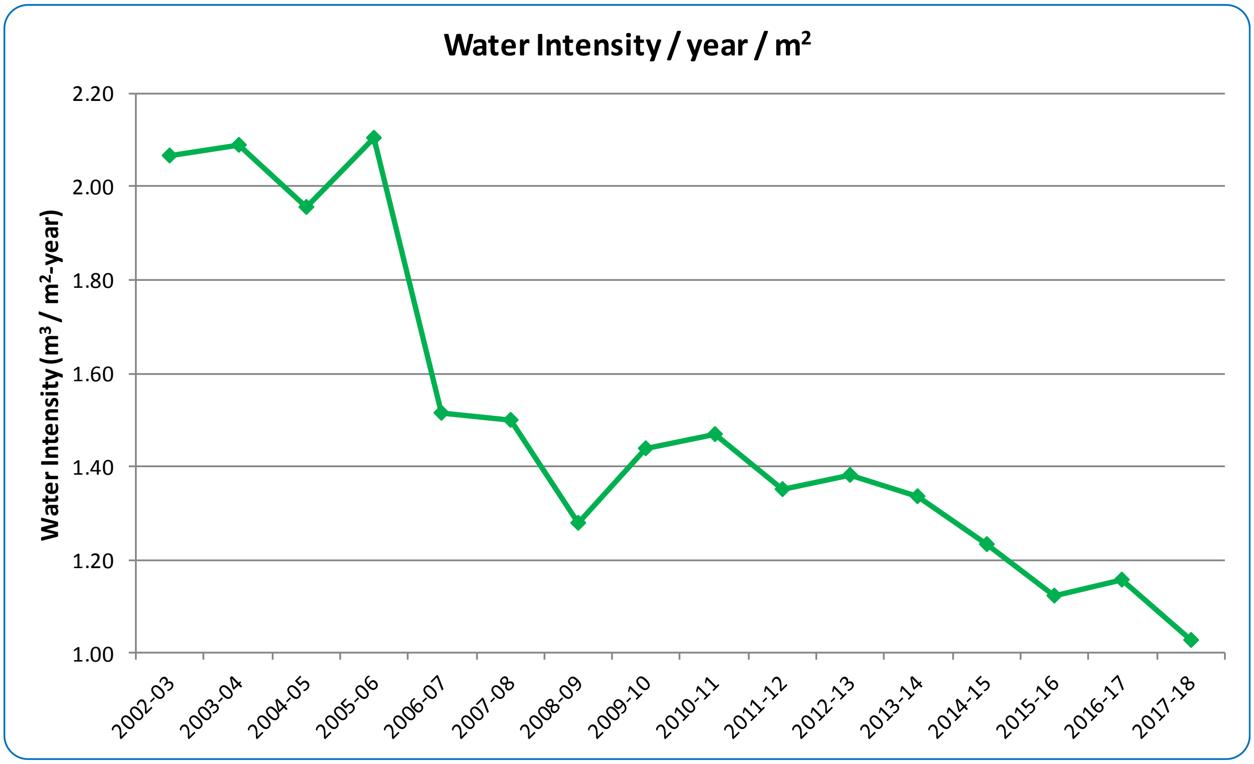

Figure 22: Water Intensity Trends 2002-2018

This data shows that significant energy commodity intensity decrease across all commodities over the 2002-2017 period. Table 9 shows a comparison of consumption in 2002 and 2017 and summarizes the data in Figures 19-22.

	Net Consumption		Consumption/student/year		Consumption/m^2/year	
	2002-03	**2017-18**	**2002-03**	**2017-18**	**2002-03**	**2017-18**
Electricity	79,411,402 kWh	82,623,183 kWh	4,307 kWh/student/yr	2,595 kWh/student/yr	238 kWh/m^2/yr	176 kWh/m^2/yr
Gas (with Cogen)	11,491,093 m^3	19,579,806 m^3	623 m^3/student/yr	615 m^3/student/yr	34.4 m^3/m^2/yr	41.8 m^3/m^2/yr
Gas (Without Cogen)	11,491,093 m^3	10,759,055 m^3	623 m^3/student/yr	338 m^3/student/yr	34.4 m^3/m^2/yr	22.9 m^3/m2/yr
Water	690,230 m^3	482,634 m^3	37 m^3/student/yr	15 m^3/student/yr	2.1 m^3/m2/yr	1.03 m^3/m^2/yr

Table 9: McMaster Energy Use 2002-2017 Comparisons

7. ENERGY CONSUMPTION/COST REDUCTION TARGETS

In order to develop meaningful energy conservation targets Facility Services researched relevant literature.

Some relevant targets are discussed below:

1. The provincial government has set electricity conservation targets in the Ontario Long Term Energy Plan (LTEP) issued end of 2013. These targets involve a 16% reduction in gross demand by 2032.
2. The Council of Ontario Universities (COU) released a report titled Going Greener in 2011, which outlines general expectations for universities to invest in green energy and cut carbon emissions over the next decade. Furthermore, the COU encourages all participating organizations to develop strategic plans to reduce energy consumption on campus.
3. The Energy Conservation Responsibility Act of 2006 encouraged energy conservation from all public sector institutions, and required them to submit upon request detailed plans to outline the fulfilment of conservation targets.
4. In February 2016, the Government of Ontario introduced the Climate Change Mitigation Act and Low-Carbon Economy Act introduced by the Government of Ontario in 2016 that sets GHG reduction targets of 15% and 37% below 1990 levels by 2020 and 2030 respectively.

Energy efficiency projects and initiatives have led to savings in consumption on campus by 5% in electricity, 4% in gas, and 11% in water.

Building on the achieved savings in McMaster's 2013 EMP and the above directives, Facility Services recommends reducing absolute electricity consumption on campus by 4%, gas consumption by 4 % and water consumption by 7% over the next five years to contribute to the overall culture of sustainability and energy conservation in Ontario and the Ontario LTEP set reduction targets.

This target will also work to reduce the electricity intensity shown in Figures 19-22 and Table 9. Currently campus electricity, gas and water intensities are significantly lower than in 2002; reducing consumption will help to further reduce this value.

Electricity, gas and water consumption trends and forecasts are shown in Figures 23-25 below.

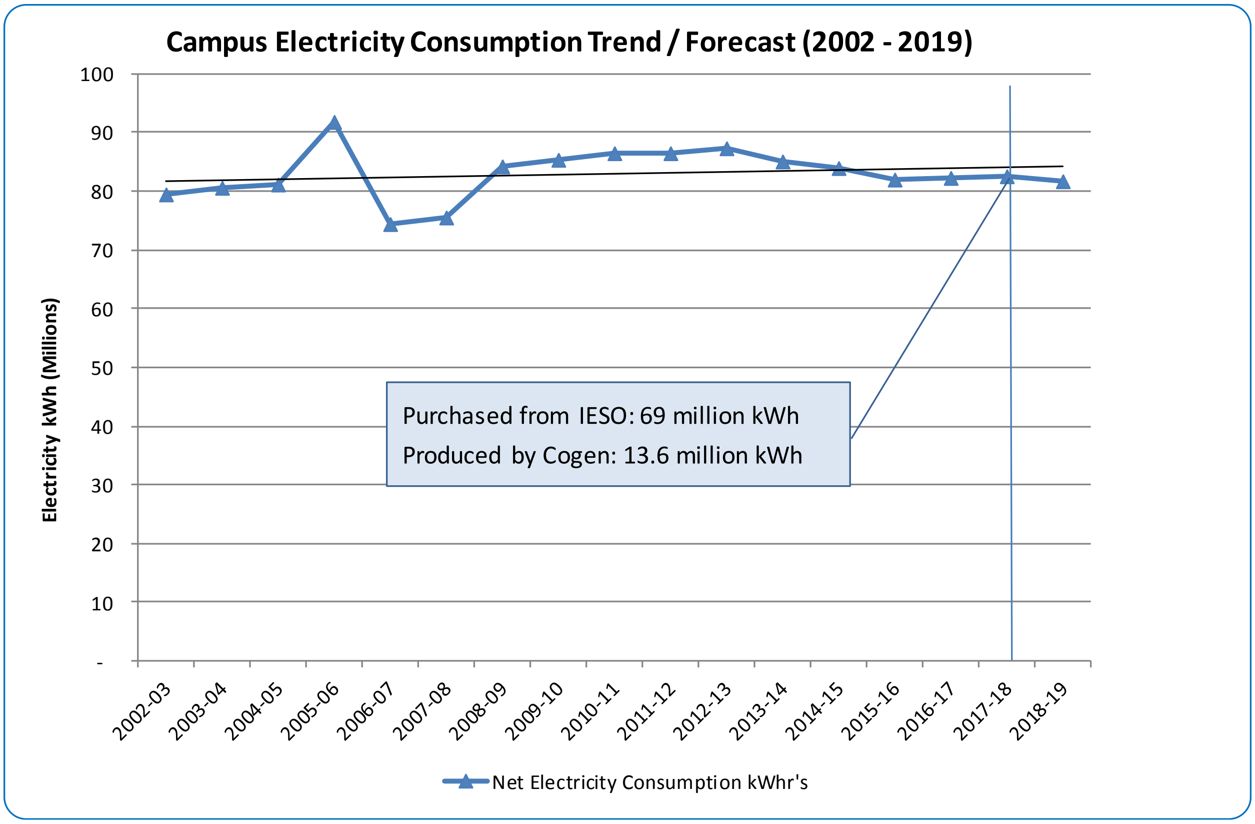

Figure 23: Electricity Consumption Trends and Forecast 2002-19

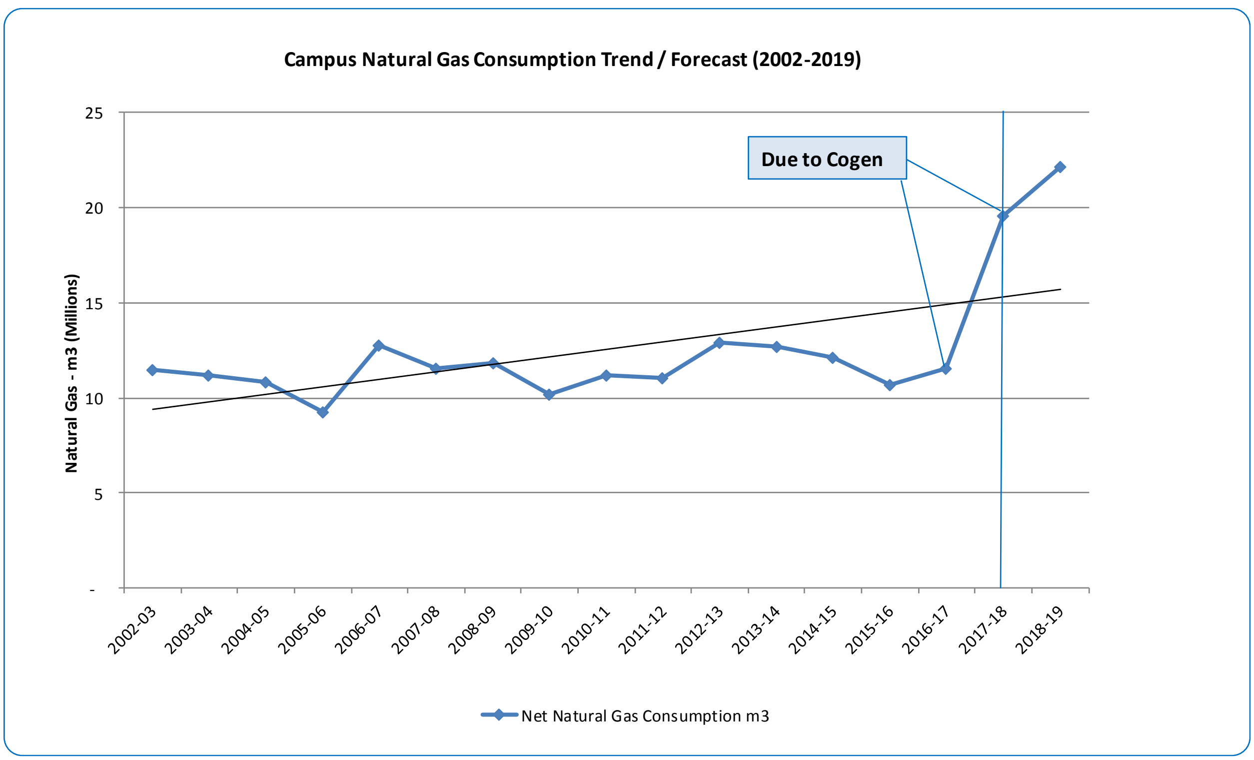

Figure 24: Gas Consumption Trends and Forecast 2002-19

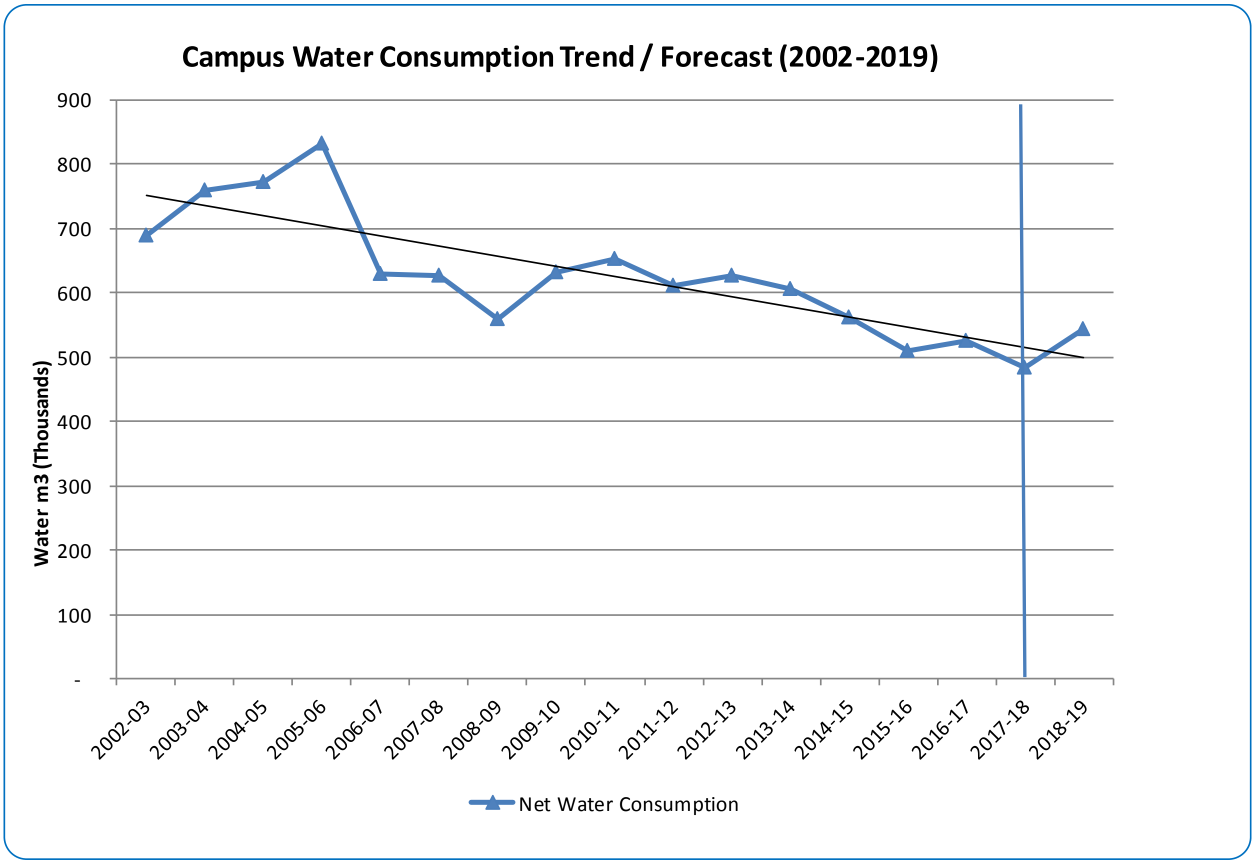

Figure 25: Water Consumption Trends and Forecast 2002-19

8. ENERGY ACTION PLAN

The goal of the energy action plan is to reduce McMaster University's energy costs by reducing overall consumption, as well as by reducing the cost of purchase of utilities.

This section has been updated based on 2013 EMP performance to date, current utility rate forecasts, and market conditions.

This section shows projects in the following categories:

8.1 Completed Projects to Date

8.2 Projects not Proceeding

8.3 Partially Completed and Ongoing Projects

8.4 New Projects – Energy Efficiency

8.5 New Projects – Renewable Energy

8.6 Energy Action Plan Conclusion

8.1 Completed Projects to Date

8.1.a Grid Balancing Pilot project

Background and Proposed Solution:

Traditionally, meeting electricity demand variations has been achieved by regulating the supply end with the local electrical utility, such as Horizon Utilities, (i.e. turning on and off gas-powered generators when demand increases or decreases). However, this solution is expensive and stresses the electricity grid, leading to economic instabilities and technical failures. Instead, novel solutions are turning to regulating demand on the customers' end.

In 2013, McMaster University implemented a pilot project to exploit the flexibility of McMaster University's existing electrical equipment. The project was completed in collaboration with ENBALA Power Networks Inc., a Canadian technology company. ENBALA operates a smart-grid platform that creates a network of large electricity users, and uses the inherent variations in their usage to balance the electricity system, thus providing system balance to the Independent Electricity Systems Operator (IESO). Other major institutions involved in the network include Sunnybrook Health Sciences Centre, TELUS Whistler Centre, and Confederation Freezers.

The pilot project focused solely on the university's use of electricity to produce chilled water, and involved changing the set points of the temperature of the water entering and leaving the system (within a defined temperature range) to compensate during higher and lower electricity demand periods. The idea is to maintain a constant electricity load on the provincial electricity grid.

There were no capital costs to McMaster for this three-year pilot project. Revenues to McMaster for delivering electricity flexibility to the provincial grid were around $12,000.

The successful project has been mentioned in the Ontario Long Term Energy Plan 2013 as an example of energy innovation in Ontario.

Funded by: IESO (for ENBALA) plus Utility Budget (for labour)

8.1.b Building Exhaust Fans and Domestic Hot Water Pumps

Project Description:

This project involved implementing automated digital controls on the facility exhaust fans which were running 24/7. The new controls now schedule their operation based on time of day and switches off the equipment overnight and during weekends and holidays.

The scope also included shutting down domestic hot water pumps after hours and during weekends to reduce energy.

Equipment was installed in the following buildings:

- ABB (Building #25)
- JHE (Building #16)
- Gilmour Hall (Building #20)
- Chester New Hall (Building #23)
- Mills Library (Building #10)

- DeGroote School of Business (Building #46)
- Togo Salmon Hall (Building #29)
- University Hall (Building #1)

The project was completed in 2014. Cost and energy savings of this project are shown in Table 10 below.

Project	Capital cost	Annual Cost Avoidance	Energy Incentives
Building Exhaust Fan Control	$118,916 *	$15,511	$ 17,406
	Gas Savings	**Electricity savings**	**Simple Payback Period**
	29,500 m^3	90,052 kWh	6.5 years
	GHG Avoidance		
	67.3 metric tonnes of CO_2 equivalent		

Table 10: Building Exhaust Fan

** Funding: EMP loan*

8.1.c Energy Dashboard

The 2013 EMP proposed implementing an energy dashboard from McMaster Energy Management Funds.

In 2013, McMaster University Facility Services was successful in generating Ministry of Training, Colleges and Universities (MTCU), Productivity and Innovation Funding (PIF) for implementing a web based energy consumption dashboard and benchmarking system towards 100% of the cost of the project.

McMaster Facility Services, Energy Management and Sustainability staff led the implementation of this system at 10 Ontario Universities including:

- Carleton University
- Brock University
- Lakehead University
- Laurentian University
- McMaster University
- Queens University
- Trent University
- University of Ottawa
- University of Waterloo
- University of Windsor

The total project grant funding awarded was $575,000 towards covering the complete project costs. The implemented system is the largest of its type in Ontario. The first two years of support and service costs for the system were covered under the project grant funding.

The system automatically gathers energy data from utility meters and reports it in an easy to use format, allowing for energy tracking and identification of top / worst performing facilities. Further, the system allows for benchmarking facilities against similar facilities at other universities.

McMaster's real time energy information is now being communicated to the campus via building display systems that encourage the community to conserve energy and support the development of a culture of conservation. McMaster is the leader in this emerging area of behavioural energy conservation.

The costs and energy savings are shown in Table 11 below.

	Capital cost	**Annual Savings**	**Energy Incentive**
Energy Dashboard and Benchmarking System	$575,000 *	$99,300	$ 124,000
	Electricity Savings	**Gas Savings**	**Water savings**
	304,500 kWh	104,500 m^3	15,500 m^3
	Annual GHG Avoidance	**Simple Payback**	
	236 metric tonnes	<1years	

Table 11: Energy Dashboard

***** *Project funded by Ministry of Training, Colleges and Universities (MTCU) and Productivity and Innovation Fund (PIF) grant.*

Taking advantage of this new system McMaster University has run facility energy competitions Chasing the Peak.

8.1.d Chasing the Peak

To allow large electricity consumers to manage rising electricity rates, the Province of Ontario in 2010 introduced the Industrial Conservation Initiative. The provincial peak electricity demand drives overall system electricity costs. Electricity, unlike other commodities, cannot be stored in large amounts, requiring real time demand and supply matching. Higher peak electricity demand requires additional standby electricity generation plants to be constructed and serviced for the few annual peak hours that they may be required. The Industrial Conservation Initiative provides large electricity consumers with an opportunity to manage electricity rates by reducing consumer electricity demand during 5 peak annual electricity hours and paying a lower electricity rate based on performance the subsequent year.

Utilizing the capabilities for real time energy monitoring and communication of the campus energy display system, Facility Services ran the summer Chasing the Peak initiative in 2014. The yearly campus electricity demand is typically the highest in summer due to operation of the cooling plant. Facility Services actively monitored the provincial electricity demand and reduced campus central plant load during peak electricity hours. In order to engage the community in helping conserve electricity, a campus electricity conservation competition was run amongst the top electricity consuming facilities. Ongoing communication notified the campus of peak electricity hours, daily metrics on individual facility performance and comparison with other facilities on campus. Overall, electricity consumption was reduced amongst all major electricity consuming facilities as presented in Tables 12, 13, 14 and 15 below for 2014 and 2015.

Ongoing electricity cost savings require annual monitoring and running of these competitions to ensure that McMaster's peak demand is minimized during provincial peak electricity demand.

The initiative resulted in lowering McMaster's contribution to the Provincial Peak Electricity Demand in 2014 and 2015 to its lowest levels since 2010 at 0.05% and 0.045% respectively of the total provincial electricity demand.

A minimum of 2% of overall electricity consumption savings was achieved amongst all major electricity consuming facilities. The top performing facility, Mills Memorial Library (Building #10), achieved 22% peak reduction and received the Top Performing Facility Award in a ceremony held on the Annual Campus Sustainability day (October 16th, 2014) at MUSC Atrium. In 2015, Ivor Wynne Centre achieved the top performance (20% peak reduction).

Tables 16 and 17 below present the electricity performance of the top energy consuming buildings on campus for 2014 and 2015 respectively.

Global adjustment was established by the Ontario government in 2005 to cover cost for providing adequate generating capacity and conservation programs in Ontario. It may be a positive or negative number that depends on whether the Hourly Ontario Energy Price (HOEP) is higher or lower than the fixed rates.

The IESO (hydro) invoice is broken down into four portions:

1. Commodity Price
2. Global Adjustment (GA)
3. Network Charge – Monthly peak charge
4. Administrative costs

The savings associated to chasing the peak targets point # 2 above, the Global Adjustment (GA). McMaster is charged a portion of the GA based on the campus contribution to the 5 peak days of the previous year. The IESO looks at the hour in which the peak occurred for each of the 5 peak days, the campus load during the peak hour, and adds up our consumption during the peak hours. The result is divided by the total provincial usage during the 5 hours. This assigns the university a multiplier.

Since the implementation of Chasing the Peak, McMaster has saved about $2M annually.

CHASING THE PEAK - Summer 2014

Table 12: Summary Results - Summer 2014			
Date	Campus Electricity Demand Reduction Achieved		
	% Reduced	MW Reduced	Electricity Demand Reduction in terms of an Ontario Household Electricity Consumption *
21-Jul-14	-24%	-3.40	106.4
22-Jul-14	-24%	-3.53	110.3
11-Aug-14	-36%	-5.67	177.3
25-Aug-14	-27%	-4.47	139.8
26-Aug-14	-37%	-6.00	187.4
5-Sep-14	-10%	-1.75	54.7
Overall to date	-26%	-24.82	775.8

* Based on Average Canadian's Annual Electricity Consumption of 11,670 KWh/year which correlates to 32 KWh/day

Table 13: Top 5 Peak Days' Savings - Summer 2014				
Rank	Date:	Campus Electricity Demand Reduction Achieved (MWh)	Campus Electricity Demand (MWh)	Ontario Demand (MW)
1	7-Jan-15	-	10.02	21,038
2	19-Feb-15	-	8.96	20,976
3	26-Aug-14	6.00	10.20	20,967
4	22-Jul-14	3.53	10.962	20,744
5	23-Feb-15	-	10.37	20,774
Overall to date		9.53	50.50	104,499

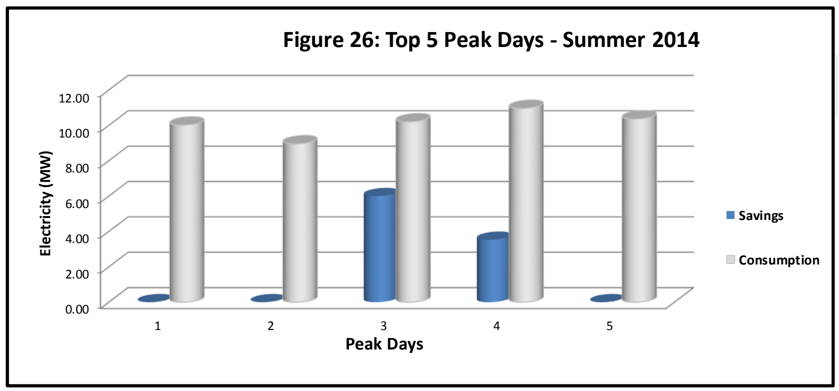

Table 12: Summary Results - Summer 2014

Table 13:Top 5 Peak Days' Savings - Summer 2014

Figure 26: Top 5 Peak Days - Summer 2014

CHASING THE PEAK - Summer 2015

Table 14: Summary Results - Summer 2015			
Date	Campus Electricity demand reduction achieved (% and MWh)		Number of households in Ontario whose combined consumption is equivalent to Campus Electricity reduction achieved
	% Reduced	MW Reduced	Based on Average Canadian's Annual Electricity Consumption of 8,500 KWh/year which correlates to 708 KWh
7-Jul-15	-31%	-4.00	5.6
13-Jul-15	-25%	-3.50	4.9
19-Jul-15	-31%	-4.20	5.9
20-Jul-15	-29%	-3.70	5.2
27-Jul-15	-17%	-2.40	3.4
28-Jul-15	-30%	-4.60	6.5
29-Jul-15	-35%	-4.90	6.9
30-Jul-15	-29%	-3.60	5.1
17-Aug-15	-26%	-3.50	4.9
19-Aug-15	-36%	-4.60	6.5
1-Sep-15	-35%	-4.50	6.4
2-Sep-15	-34%	-4.40	6.2
8-Sep-15	-35%	-4.80	6.8
Overall	-30%	-52.70	74.4

Table 15: Top 5 Peak Days' Savings - Summer 2015				
Rank	Date:	Campus Electricity demand reduction achieved (MWh)	Campus Electricity demand (MWh)	Ontario Demand (MW)
1	28-Jul-15	4.60	9.59	23,024
2	29-Jul-15	4.90	9.36	22,835
3	17-Aug-15	3.50	7.93	22,892
4	27-Jul-15	2.40	11.793	22,323
5	3-Sep-15	-	14.96	22,860
Overall		15.40	53.62	113,935

Figure 27: Top 5 Peak Days - Summer 2015

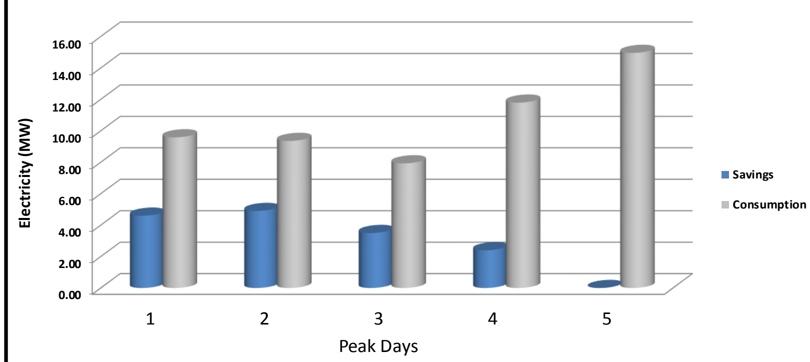

Table 14: Summary Results - Summer 2015

Table 15: Top 5 Peak Days' Savings - Summer 2015

Figure 27: Top 5 Peak Days - Summer 2015

Table 16: Electricity Performance for top Energy consuming buildings 2014									
Date	10-MML	16-JHE	24-IWC	25-ABB	34-PC	39-LSB	51-MUSC	52-MDCL	56-ETB
21-Jul-14	-35%	-10%	-26%	-9%	-11%	3%	5%	-34%	-18%
22-Jul-14	-28%	-9%	-26%	0%	-8%	4%	4%	-43%	-13%
11-Aug-14	-18%	-2%	-27%	-7%	-7%	-5%	-19%	-39%	-9%
25-Aug-14	-14%	0%	-20%	-8%	-4%	-1%	-19%	-37%	-14%
26-Aug-14	-1%	5%	-4%	9%	-1%	-10%	-11%	-25%	3%
5-Sep-14	-33%	9%	67%	0%	5%	-21%	6%	1%	29%
Average to date	-22%	-1%	-6%	-3%	-4%	-5%	-6%	-30%	-4%

Table 16: Electricity Performance for Top Energy Consuming Buildings in Summer 2014

Table 17: Electricity Performance for top Energy consuming buildings - Summer 2015								
Date	10-MML	16-JHE	24-IWC	25-ABB	34-PC	39-LSB	51-MUSC	56-ETB
7-Jul-15	3%	-14%	-10%	-13%	-21%	2%	-36%	-7%
13-Jul-15	-22%	-26%	-22%	-21%	-22%	9%	-19%	-5%
19-Jul-15	-27%	-39%	-37%	-22%	-33%	-12%	-41%	-7%
20-Jul-15	-3%	-12%	-20%	-8%	-25%	8%	-17%	-13%
27-Jul-15	-28%	-13%	-16%	-7%	-24%	4%	-39%	-13%
28-Jul-15	-23%	-15%	-17%	10%	-30%	5%	-34%	-12%
29-Jul-15	-35%	-9%	-13%	-16%	-24%	9%	-29%	-5%
30-Jul-15	6%	-12%	-18%	-11%	-27%	4%	-1%	-1%
17-Aug-15	-40%	-12%	-13%	3%	-27%	11%	-15%	-1%
19-Aug-15	-34%	-12%	-23%	-3%	-27%	8%	-9%	-18%
1-Sep-15	-32%	-10%	-18%	1%	-27%	5%	-20%	-6%
2-Sep-15	-31%	-11%	-25%	1%	-25%	9%	10%	-17%
8-Sep-15	-17%	-7%	-27%	7%	-27%	3%	16%	-2%
Average	-22%	-15%	-20%	-6%	-26%	5%	-18%	-8%

Table 17: Electricity Performance for Top Energy Consuming Buildings - Summer 2015

Note: Green denotes top performer with the most energy reduction achieved

Red denotes the lowest performer.

8.1.e Plug Load Analysis

The California Energy Commission describes plug load as “a term referred to equipment that are plugged into electrical outlets and it excludes heating, ventilation, and air conditioning loads as well as hard wired lighting loads.” Recent studies in several areas of the US have determined that plug loads are rapidly becoming one of the most energy intensive features of many buildings.

At McMaster University, plug loads typically involve small user devices such as printers, refrigerators, fax machines, phones and other office devices. There are two main methods of reducing this plug load in buildings: behavioural changes (unplugging or turning off devices when not in use, implementing management policies that limit the use of personal electronic devices etc.) and technical upgrades (energy efficient technology, occupancy sensors, motion sensors, etc.). A pilot project by the National Renewable Energy Laboratory, revealed that technical changes made the most impact, whereas user feedback and educational strategies made few or sporadic changes.

EMP version 1 identified four facilities (Building 2- Hamilton Hall, Building 20- Gilmour Hall, Building 23- Chester New Hall, Building 29- Togo Salmon Hall) as potential locations for implementing plug load solutions. These facilities were identified in a McMaster graduate student’s research work completed in collaboration with Facility Services.

Pilot projects in Building 2- Hamilton Hall revealed that significant employee buy in is required for implementing timers on individual staff devices (computers, monitors, fax machines, phones). A number of staff have no fixed times of office work and leave their devices on for remote access.

Recommendations from the plug load analysis include Energy Star equipment and energy efficient settings for desktop computers. These measures have been implemented corporate wide by the green procurement policy and University Technology Services (UTS).

On the same theme to reduce plug loads in facilities, a number of timers have been placed in facility electrical/mechanical rooms to ensure that the lights are off when not needed. Further, vending machines on campus have been installed with timers. Costs and energy savings are presented in Table 18 below.

	Capital cost	**Annual Savings**	**Energy Incentive**
Plug Load Retrofit	$10,650*	$2,891	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	26,280 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	3.3 metric tonnes	3.7 years	

Table 18: Plug load Analysis- Energy and Cost savings from Selective Implementation

** Funded under the Utilities budget*

8.1.f Miscellaneous Control Systems

i. University Hall Controls Retrofit

This project involved upgrading the existing pneumatic and mechanical control system to a digital control system, replacing control valves with two-way pressure dependant valves and installing variable speed drives.

The project was completed in 2015. Costs and energy savings are shown in Table 19 below.

	Capital cost	Annual Savings	Energy Incentive
University Hall Controls Retrofit	$217,269*	$10,075	$2,702
	Electricity Savings	**Gas Savings**	**Water savings**
	20,000 kWh	43,750 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	85 metric tonnes	21 years (<1 year using deferred maintenance funds)	

Table 19: University Hall Controls Retrofit

** Completed as part of larger facility deferred maintenance upgrade. No costs were incurred under the energy management budget*

ii. All Buildings Mechanical Fan Belt Upgrade

This project involved installing slip reducing fan belts on buildings ventilation and exhaust systems across campus and was completed in 2014.

The project was completed in 2014. Costs and energy savings are shown in Table 20 below.

	Capital cost	Annual Savings	Energy Incentive
Building Mechanical Fan Belt Upgrade	$90,223*	$14,270	$9,890
	Electricity Savings	**Gas Savings**	**Water savings**
	129,727 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	16 metric tonnes	5.6 years	

Table 20: Building Mechanical Fan Belt Upgrade Costs and Savings

** Funding: EMP loan*

iii. All Buildings Heating Systems Set-Backs After Hours

This initiative involved utilizing the outdoor air reset system to reduce all campus building ventilation and heating systems operation during low occupancy periods on campus (nights and weekends).

The cost and energy savings from this project are shown in Table 21 below.

	Capital cost	Annual Savings	Energy Incentive
All Buildings Heating System Set Back After Hours	$25,000*	$40,400	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	50,000 kWh	180,000 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	348 metric tonnes	<1 year	

Table 21: All building Heating System Set Back After Hours

** Funded under Utilities labour cost*

iv. Central Plant/Chilled Water Plant Operational Modifications

The project involved operational modifications to plant controls to improve central plant efficiencies and lower energy consumption. Cost and energy savings are presented in Table 22 below.

	Capital cost	Annual Savings	Energy Incentive
Central/Chilled Water Plant Operational Modifications	$20,000*	$11,790	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	30,000 kWh	0 m^3	3,000 m^3
	Annual GHG Avoidance	**Simple Payback**	
	9.4 metric tonnes	<1 year	

Table 22: Central/Chilled Water Plant Operational Modifications Costs and Savings

** Funded under Utilities labour cost*

8.1.g Demand Control Ventilation (DCV) – ABB Undergraduate Labs

This project was implemented in ABB Undergraduate labs beginning of 2015. The results of the project are listed in Table 19 below. The computerized system maintains an ongoing log of measurements. Access to this system has been provided to ABB lab staff and McMaster Health and Safety staff for real time monitoring. Cost and energy savings are presented in Table 23.

Project	Capital cost	Annual Cost Avoidance	Energy Incentives
ABB Undergraduate Laboratories Demand Control Ventilation	$427,427*	$90,805	$83,195
	Gas Savings	**Electricity savings**	**Water Savings**
	121,000 m^3	616,500 kWh	0 m^3
	GHG Avoidance		**Simple Payback Period**
	307 metric tonnes of CO_2 equivalent		3.7 years (< 1 year including deferred maintenance funding)

Table 23: ABB Undergrad DCV

* *The project costs included deferred maintenance initiatives to replace end of life equipment and upgrades in the undergraduate area. No costs were incurred from the Energy Management loan.*

8.1.h Fume Hood Retrofits and Upgrades Projects

On average a single fume hood costs McMaster approximately $4,000 in annual energy costs. There are a total of approximately 565 fume hoods on campus.

Few projects involving fumehood upgrades and retrofits on campus have been completed as presented above. In addition to that, the decommissioning of one obsolete fume hood in Building 29 Togo Salmon Hall (TSH) was completed in 2014.

The above measure and associated savings are presented in Table 24 below.

Project	Capital cost	Annual Cost Avoidance	Energy Incentives
Obsolete Fume Hood Removal (decommissioning) in 29 - TSH	$569*	$ 5,247	$ 0
	Gas Savings	**Electricity savings**	**Simple Payback Period**
	11,900 m3	27,000 kWh	
	GHG Avoidance		**Simple Payback**
	26 metric tonnes of CO_2 equivalent		<1 years

Table 24: Obsolete Fume Hood Decommissioning

** The project costs were covered from the Utilities budget*

8.1.i Indoor Corridors / Stairwells LED Lighting

Due to the long operating hours of lights in stairwells and corridors for safety reasons, LED lighting is a suitable solution for this application. Pilot projects in Building 20- Gilmour Hall, 29-Togo Salmon Hall, 23- Chester New Hall, 38- Kenneth Taylor Hall and 42- Thode Library stairwells produced encouraging results.

Building on the success of these pilots, the complete campus stairwells and corridors LED lighting project has been initiated and completed in 2014 (approximately 12,000 lamps). Cost and savings are presented in Table 25 below.

	Capital cost	Annual Savings	Energy Incentive
Interior Campus Corridor and Stairwells LED Lighting Retrofit	$452,311	$154,500	$45,950
	Electricity Savings	**Gas Savings**	**Water savings**
	1,403,750 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	176 metric tonnes	2.6 years	

Table 25: Interior Campus Corridor and Stairwells LED Lighting Retrofits (completed)

** Funded under an EMP loan*

8.1.j Conversion of City Water Cooling on Process Units to Chilled Water Loop:

The component to change city water cooled equipment to campus chilled water loop has been completed for all campus facilities and cafeterias in 2014/2015. This retrofit ensures compliance with the current potable water use regulations with the benefit of the reduction in fresh potable water consumption. Results are presented in Table 26 below.

	Capital cost	Annual Savings	Energy Incentive
Conversion of City Water Cooling on Process Units to Chilled Water Loop	$200,000*	$103,558	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	0 kWh	0 m^3	36,985 m^3
	Annual GHG Avoidance	**Simple Payback**	
	0 metric tonnes	2 years	

Table 26: Conversion of City Water Cooling on Process Units to Chilled Water Loop

** These costs were incorporated in the utilities budget.*

8.1.k Demand Control Ventilation and Retro Commissioning - JHE and MDCL

This project is to retro-commission two of McMaster's three highest energy cost and consumption facilities, MDCL and JHE, as identified in the 2013 McMaster Energy Management Plan. The proposed project, completed in 2017, included the fume hood and laboratory air balancing projects for these facilities from the 2013 Energy Management Plan in addition to upgrading the building strobic fans to be more energy efficient.

The total annual energy costs for these two facilities are approximately $2.8 million or approximately 20% of the academic buildings annual utilities cost. The majority of these costs are due to energy consumption in labs. This project includes newer lab control technologies which allow for better lab performance with lower energy consumption. In addition, mechanical and controls retrofits were implemented to improve facility performance and conserve energy.

Cost and energy savings are presented in Table 27 below.

	Capital cost	Annual Savings	Energy Incentive
JHE and MDCL Retro-Commissioning	$1,950,036*	$244,667	$150,000
	Electricity Savings	**Gas Savings**	**Water savings**
	866,000 kWh	250,110 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	760 metric tonnes	7.4 years	

Table 27: JHE and MDCL Facilities Retro-Commissioning

** Funded under an EMP loan*

8.1.l Co-Generation Proposals / Combined Heat and Power Project

Project Description

The proposed project envisioned implementing a co-generation facility to reduce campus energy costs. A detailed feasibility study on the initiative has been completed and approved by the Independent Electricity System Operator (IESO) for a project incentive of $7.74 million.

Following up on the McMaster Board of Governors direction, McMaster Facility Services completed a detailed feasibility study of the project with the help of external engineering, cost consultants and IESO's 100% feasibility study funding. Based on the University's actual electricity, heating and cooling loads, the detailed feasibility study recommended the implementation of a 5.7 MW capacity natural gas turbine with a steam producing capacity of 105,000 lbs/hour and 3,500 tons of cooling capacity. The above are name plate capacity numbers and the actual capacity would be lower.

The project has been approved by the McMaster Board of Governors and has been implemented. In service date was January 16, 2018.

	Capital cost	Annual Savings	Energy Incentive
CHP	$22,002,540*	$1,995,791	$7,737,261 **
	Electricity Savings	**Gas Savings**	**Water savings**
	0 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	0 metric tonnes	4.1 years	

Table 28: CHP Project

**Includes deferred maintenance funding of $ 6 million and 3.41% HST costs*
*** Includes $40,000 incentives from Union Gas*

8.1.m Chiller Replacement– Art Gallery

Project Description

This project involves replacement of the current Art Gallery Chiller and fine tuning the campus chilled water systems to provide more flexibility in operating the chiller on its own as well as while connected to the central plant.

The Art Gallery air conditioning is provided by a dedicated cooling machine which provides temperature and humidity control to the gallery. This chiller had a number of operational issues and is subject to occasional breakdowns. The project proposed the replacement of this chiller with a new high efficiency chiller, which would generate energy savings while ensuring required conditions in the Art Gallery are maintained. Chiller replacement was completed in 2016 and results are presented in Table 29 below.

Piping changes to enhance the operational flexibility has been completed in 2018.

Chiller Replacement / Retrofits	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$165,000 *	$25,190	$15,000
	Electricity Savings	**Gas Savings**	**Water savings**
	231,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	28 metric tonnes	5.5 years	

Table 29: Chiller Replacements / Retrofits

** Funded under a Utilities budget*

8.2 Projects Not Proceeding

8.2.a Nuclear Reactor Heat Recovery Plan

The proposed project involved recovering heat from the McMaster Nuclear Reactor for use in the surrounding facilities. The project was based on an engineering feasibility study completed by an external consultant in January 2013.

The financial feasibility of the project was estimated based on the utility rates at the time as shown in Table 30 below.

Utility	Rate (CAD)
Steam (per 1000lb)	$18.00
Natural gas (per m^3)	$0.3439
Electricity (per kwh)	$0.08

Table 30: McMaster Utility Rates

Since then, the natural gas rates have dropped by approximately 35% due to the US shale gas revolution which has brought large quantities of natural gas to the market. The lower natural gas rates led to an estimated project payback of approximately 18+ years. Further, the maintenance costs of the proposed system along with the mismatch of nuclear reactor operation (8 hours/5 days a week) with campus heat requirements extended the payback further. The project has been suspended from the Energy Management Plan.

8.2.b Voltage Correction

A pilot project to verify this technology was completed in 2014 at no costs to the university. The project results did not justify investing funds on the larger scale project. Thus, the project is not being pursued any further.

8.2.c HHS-MUMC Window Coating

EMP 2013 included this project as a joint collaboration with Hamilton Health Sciences (HHS) to implement window films for reducing solar related energy consumption in the McMaster campus hospital facility.

Further investigation and pilot implementation by the HHS staff revealed that proposed solution caused the older facility windows to shatter due to heat build up. The pilot testing of the proposed window film was completed utilizing HHS budget and this project has been removed from the EMP.

8.2.d Chilled Water Plant Optimization

The original proposed initiative involved replacing the 40-year-old Chillers 5 and 6 with ammonia chillers in order to reduce the power usage of the chillers.

Chiller 5 has now been scheduled for replacement within the Combined heat and power plant project. Further investigation of the initiative with the equipment vendors at McMaster site has revealed the ammonia plant efficiency levels to be comparable with the existing Chiller 1 to 3 using R134a refrigerant. With the chillers 1 to 3 typically running significant number of hours, the new ammonia chillers installation does not offer significant energy savings and requires extensive regulatory compliance requirements with the local authorities having jurisdiction. This project is not being proceeded with.

8.3 Partially Completed and Ongoing Projects

8.3.1 Laboratory Air Balancing / Demand Control Ventilation(DCV)

With McMaster being one of Canada's most research intensive universities, research labs are the biggest consumers of energy on campus. This is due to the high fresh air flows through the labs for maintaining safety and comfort. As there is no recirculation of air in labs, large amounts of heating and cooling energy is required for constantly air conditioning outdoor air (outside air temperature ranges from -30 to 40 degrees Celsius through the year) and maintaining comfortable indoor air temperature and humidity levels.

This project implemented a measurement based approach to lab ventilation. Typically, a lab ventilation system is designed to maintain constant air flows based on the maximum capacity of the equipment. The project implements lab air quality sensors, which measure air temperature, CO_2, volatile organic compounds, particulate matter and so forth. When the lab air quality is acceptable the system reduces the lab air flow to maintain comfort levels. If an accidental spill happens, the system ramps up the ventilation system to the maximum available capacity to try and drive out air contaminants and allow the occupant to take action. As the lab air quality system delivers air where required (as opposed to throughout the facility), the system enhances the lab safety by delivering the higher fresh air flows. With the lab air quality being acceptable 97%+ of the occupied hours, significant energy savings are possible with lab demand control ventilation. This initiative has been recognized by the US Department of Energy as best practices in labs.

Similar initiatives have previously been implemented in top labs across North America, including:

- University of Ottawa
- Carleton University
- MaRS Discovery District
- Environment Canada
- University of California, Irvine– these measures were implemented at 11 labs and were profiled by US Department of Energy as best practices in labs
- Harvard University Medical School, Beth Israel Deaconess Medical Centre
- University of Pennsylvania

8.3.1.a Demand Control Ventilation (DCV) - ABB Chemistry Wing

Following up on the success of ABB Undergraduate labs project, a feasibility study to implement this measure in ABB (Chemistry and Physics Wing) has been completed and the project is now in the implementation stage. Cost and savings data is presented in Table 31 below.

ABB Chemistry Wing Demand Control Ventilation	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$1,260,000 *	$172,800	$152,520
	Electricity Savings	**Gas Savings**	**Water savings**
	1,260,000 kWh	198,000 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	510 metric tonnes	7 years	

Table 31: ABB - Chemistry Wing Lab Demand Control Ventilation

** Funded under an EMP loan*

8.3.1.b Demand Control Ventilation (DCV) – ABB Physics Wing

Following up on the success of ABB Undergraduate labs project, a feasibility study and detailed engineering to implement this measure in ABB Physics Wing has been completed. Project is now in the bidding stage and planned to be completed in 2019. Cost and savings data is presented in table 32 below.

ABB Physics Wing Demand Control Ventilation	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$887,000 *	$60,000	$54,300
	Electricity Savings	**Gas Savings**	**Water savings**
	311,400 kWh	131,700 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	348 metric tonnes	14 years	

Table 32: Demand Control Ventilation (DCV) – ABB Physics Wing

** Requires external funding*

8.3.2 Lighting Retrofits

Background and Proposed Solutions

LED light bulbs are amongst the most energy efficient commercially available lighting technology, with longer life spans and significantly lower energy usage compared to traditional incandescent and CFLs. LED lamps also cost significantly more than traditional lamps.

Campus lighting LED retrofits have been broken up into three categories:

- Residences Lighting Retrofits: More lighting retrofits were implemented in the Student Residence buildings. Cost and energy savings are presented in Table 33b below.

	Capital cost	Annual Savings	Energy Incentive
Student Residences (9 buildings)	$792,431 *	$108,397	$96,838
	Electricity Savings	**Gas Savings**	**Water savings**
	985,427 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	123 metric tonnes	7 years	

Table 33a: Residences Lighting Retrofits (completed)

** Funded under an Residence deferred maintenance*

- Indoor corridors / stairwells LED lighting installation (Completed, see 8.1.i above for details).
- Outdoor / Street lighting

Lighting retrofits were implemented in various outdoor areas including Parking Lot M, and in indoor areas in MDCL, Burke Sciences Building and Hamilton Hall in 2018. Table 33a below present the cost and energy savings.

	Capital cost	Annual Savings	Energy Incentive
Various Indoor Areas in MDCL, Burke Sciences Building and Hamilton Hall, and Outdoor Areas including Parking Lot M	$241,000 *	$55,274	
	Electricity Savings	**Gas Savings**	**Water savings**
	526,416 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	66 metric tonnes	4.4 years	

Table 34a: Various Areas Lighting Retrofits (completed)

** Funded under maintenance budget for material and executed by maintenance team*

8.3.3 Chilled Water Loop Modifications

A number of campus facilities connected to the central campus chilled water system have systems which result in inefficient chilled water operations. This is because of cooling systems, which require a constant supply of chilled water regardless of the actual need for cooling in the facility. The constant supply of chilled water results in the chilled water pumping energy penalty as well as chiller plant inefficiency. The project involves retrofitting the existing building chilled water systems for enhancing the efficiency of the campus chilled water system and was completed in 2013.Results are presented in Table 34 below.

Chiller Replacement / Retrofits	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$150,000	$24,750	$15,000
	Electricity Savings	**Gas Savings**	**Water savings**
	223,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	28 metric tonnes	5.5 years	

Table 35: Chilled Water Loop Modifications

** Funded under an deferred maintenance*

8.3.4 Energy Manager

This initiative is a carry over from 2013 EMP.

McMaster Facility Services in the past has been in touch with OPA/IESO regarding the Energy Manager incentive stream for funding an incremental, dedicated resource for campus energy management.

The program now provides $50,000 of the funding for an incremental position for a period of two years. McMaster University has been advised by the IESO of the availability of this funding and has moved to capitalize on this funding source. An invoice for the amount above has been issued to IESO in 2016.

8.3.5 Water Conservation - Water System retrofit on Life Sciences Building Fish Tank Room

The Building 39 Life Sciences Facility has a fish research room which currently utilizes potable water through fish tanks and drains it to the sewage system. The current annual consumption of city water is approximately 50,000 m^3 or $164,000 in annual costs at current water rates. This is a significant potable water consumption area on campus.

The project involves implementing best practices from fish research labs at University of Guelph, Aqua Lab and Environment Canada and implementing a filtration and circulation system which would have the capability to reduce potable water consumption by 80-95%. Detailed engineering of the project has been completed and bidding preparation is currently underway. Project is planned to be completed in 2019. Cost and savings data is presented in table 35 below.

LSB Fish Tank Water System Retrofit	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$300,000*	$134,000	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	0 kWh	0 m^3	41,000 m^3
	Annual GHG Avoidance	**Simple Payback**	
	0 metric tonnes	2.25 years	

Table 36: LSB Fish Tank Water System Retrofit

** Funded under an EMP loan*

8.3.6 Outdoor / Street Lighting Retrofit

Facility Services is currently testing LED lighting solutions for street/parking lot lighting and facility outdoor lighting.

LED lighting offers the promise of better quality lighting, energy savings and long life with low replacement costs. The project's intention is to replace all out doors lighting fixtures with new energy efficient LED lighting.

Parking Lot, Street Lighting, Exterior Facility Lighting LED Retrofit	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$850,000*	$85,250	$95,000
	Electricity Savings	**Gas Savings**	**Water savings**
	775,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	97 metric tonnes	8.9 years*	

Table 37: Parking Lot, Street Lighting, Exterior Facility Lighting LED Retrofit

** Funded under an EMP loan*

Note: The paybacks for both these projects has been calculated based solely on energy savings. Significant maintenance savings would also result from longer LED life requiring less frequent replacements of these expensive to maintain lighting fixtures.

8.3.7 Strobic Fan System Upgrade

This project is to upgrade building strobic fans (in NRB and ABB buildings) to be more energy efficient.

Strobic Fans Systems Upgrade	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$10,000*	$5,000	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	22,000 kWh	12,000 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	25 metric tonnes	2 year	

Table 38: Strobic Fans Systems Upgrade

** Funded under an Utilities budget*

8.3.8 Chiller Plant Re-commissioning

Project Description

This project involves re-commissioning the campus central chilled water plant and improving the operational efficiency. Equipment efficiency drops over time with use. An ongoing performance measurement and tracking system allows for early identification of energy efficiency loss and potential maintenance requirements. The project is currently being implemented based on the IESO's chilled water plant re-commissioning incentive and the performance measurement and tracking phase is planned to be completed in October 2018. It will be followed by a set of recommendations and measures to save energy that will be implemented in 2019. Data is presented in table 38 below.

Chiller Re-commissioning	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$150,000	$22,320	$40,000
	Electricity Savings	**Gas Savings**	**Water savings**
	180,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	22 metric tonnes	5 years	

Table 39: Chiller Recommissioning

8.3.9 Window Replacement

8.3.9.a Window Replacement – JHE South Facade

Window Replacement – JHE South Facade	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$350,000	$449	
	Electricity Savings	**Gas Savings**	**Water savings**
	1,177 kWh	1,505 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	3 metric tonnes		

Table 40: Window Replacement in JHE South Façade

** Funded under deferred maintenance*

This project was completed in 2018.

8.3.9.b Window Replacement – Gilmour Hall

	Capital cost	Annual Savings	Energy Incentive
Window Replacement – Gilmore Hall	$750,000	$2,323	
	Electricity Savings	**Gas Savings**	**Water savings**
	5,191 KWh	8,200 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	15 metric tonnes		

Table 41: Window Replacement in Gilmour Hall

** Funded under deferred maintenance*

8.3.9.c Window Replacement – McKay Hall

	Capital cost	Annual Savings	Energy Incentive
Window Replacement – McKay Hall	$1,700,000	$1,125	
	Electricity Savings	**Gas Savings**	**Water savings**
	0 KWh	5,115 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	10 metric tonnes		

Table 42: Window Replacement in McKay Hall

** Funded under Residences deferred maintenance*

Project was divided into two phases. One was completed in 2018 and the second phase is planned for completion in 2019.

8.4 New Projects – Energy Efficiency

8.4.1 Steam Traps Replacement

	Capital cost	Annual Savings	Energy Incentive
Steam Traps Replacement	$1,050,000	$7,382	
	Electricity Savings	**Gas Savings**	**Water savings**
	0 kWh	33,557 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	63 metric tonnes		

Table 43: Steam Traps Replacement

8.4.2 Window Replacement

	Capital cost	Annual Savings	Energy Incentive
Ivor Wynne Centre Commons Building Campus Services Building Tandem Accelerator Life Sciences Building Moulton Building Mills Memorial Library Nuclear Research Building	$7,615,000	$7,646	
	Electricity Savings	**Gas Savings**	**Water savings**
	15,865 kWh	28,854 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	54 metric tonnes		

Table 44: Window Replacement in Various Buildings

8.4.3 Facilities Dorm Competition and Behaviour Report Cards

Under the same theme of behavioural-based initiatives above, Facilities Dorm Competition and Behaviour Report Cards has been identified as a best practice by the US Business Executive Roundtable report. The project scope is to ensure that facility systems are scheduled per requirement and 24/7 scheduling across campus is minimized.

	Capital cost	Annual Savings	Energy Incentive
Facilities Dorm Competition and Behaviour Report Cards	3 FTE *	$9,200	$0
	Electricity Savings	**Gas Savings**	**Water savings**
	80,000 kWh	5,000 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	12metric tonnes	< 1 years	

Table 45: Facilities Dorm Competition and Behaviour Report Cards

** Funded under Utilities budget*

8.5 New Projects – Renewable Energy

8.5.1 Car Parking Solar PV

	Capital cost	Annual Savings	Energy Incentive
Car Parking Solar PV	$4,135,000	$204,400	
	Electricity Savings	**Gas Savings**	**Water savings**
	2,044,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	87.9 metric tonnes		

Table 46: Car Parking Solar PV

8.5.2 Rooftop Solar PV

Rooftop Solar PV	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$4,050,000	$254,000	
	Electricity Savings	**Gas Savings**	**Water savings**
	2,540,000 kWh	0 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	109 metric tonnes		

Table 47: Rooftop Solar PV

** Requires external funding*

8.5.3 Solar Water Heating

Solar Water Heating System Re-Design, Repair and Recommissioning	**Capital cost**	**Annual Savings**	**Energy Incentive**
	$219,609	$3,412	$11,611
	Electricity Savings	**Gas Savings**	**Water savings**
	0 kWh	15,509 m^3	0 m^3
	Annual GHG Avoidance	**Simple Payback**	
	29 metric tonnes		

Table 48: Solar Water Heating

8.6 Energy Action Plan Conclusion

Appendix B summarizes the proposed projects and initiatives to be included in the Energy Management Plan that were discussed in the previous section. The updated plan extends to 2019/2020 and includes several projects with a total anticipated investment of around $20 million (excluding deferred maintenance funding) over around four years, and a total anticipated annual savings of around $ 2.5 million.

9. AWARENESS CAMPAIGNS AND MILESTONE CELEBRATIONS

Energy management awareness will be approached in several ways: formal education, public awareness strategies and campus competitions.

Formal educational strategies involve integrating sustainability issues into course curricula that allows students to work on energy management projects in a form of experiential education. These courses/projects will allow students to gain hands on experience with implementing energy management strategies and understand the challenges involved with energy conservation. Ideally, such courses will have a ripple effect by allowing other students, even those not enrolled in the course to understand the need for such projects on campus. Facility Services contribute to courses with experiential learning ideas and initiate projects that help students in these courses.

Public awareness strategies range from posters and educational videos to more involved strategies such as the energy management dashboard that displays real time energy consumption to building users, and has the potential to reduce overall energy consumption by up to 3%.

Campus competitions include events such as Chasing the Peak, Shut the Sash and Residence Wide Energy challenge that puts residences against one another in a friendly challenge to see which one can achieve the highest energy savings in a given window of time. The winners of this challenge are typically rewarded with prizes to encourage continued conservation measures. Similar projects could be implemented between other campus buildings to incentivize energy conservation and make it more appealing and fun for the general public.

10. PROGRAM ASSESSMENT

In order to determine the success of the Energy Management Plan (EMP), the planned initiatives and progress will be assessed annually. To ensure that the Energy Management Plan development team is kept up-to-date on new and emerging issues and energy management strategies, the team will read similar plans developed by other universities and comparable institutions. The targets and strategies set by these institutions will be studied carefully and McMaster University's progress evaluated in comparison to identify potential for improvement.

The EMP, as well as benchmarks, progress and targets met will be communicated to all University staff, students and faculty and made available online. Annual reports may be developed if deemed necessary, in order to alert the Energy Management team and campus users of issues or goals achieved in a timely manner and to raise awareness and maintain enthusiasm for sustainability and energy management initiatives.

11. APPENDICES

Appendix A: Projects Completed

	Project Name	Description/Building	$ Cost	Energy Incentive	Annual Savings	Simple Payback	Funding Source
8.1.a	Grid Balancing Pilot Project (Enbala)	Demand side regulation	Staff time	0	$3,961	<1 year	IESO
8.1.b	Building Exhaust Fans and Domestic Hot Water Pumps Controls	Connect all building exhaust fans and domestic hot water pumps that are not currently interconnected with building HVAC controls in ABB, JHE, GH, CNH, Mills Library, MDG School of Business, TSH, University Hall	$118,916	$17,406	$15,511	6.5	EMP Loan
8.1.c	Energy Dashboard	Informative interactive screen, giving building occupants information about building energy consumption trends	$575,000	$124,000	$99,300	<1 year	MTCU PIF Grant
8.1.d	Energy Competitions	Chasing the Peak	Staff time		$2,000,000	<1 year	Utilities Budget
8.1.e	Plug Loads Analysis	GH, CNH, HH, TSH	$10,650	$0	$2,891	3.7	Utilities Budget
8.1.f	Miscallaenous Controls Upgrades	University Hall Controls Retrofit	$217,269	$2,702	$10,075	<1 year	Deferred Maintenance Budget
		All Building Mechanical Fans Belt Upgrade	$90,223	$9,890	$14,270	5.6	EMP Loan
		All Buildings Heating Set Back	$25,000	$0	$40,400	<1 year	Utilities Budget
		Central Chilled Water Plant Operational Modifications	$20,000	$0	$11,790	<1 year	Utilities Budget
8.1.g	Laboratory Air Balancing	Demand Control Ventilation at ABB Undergraduate Labs	$427,427	$83,195	$90,805	<1 year	Deferred Maintenance
8.1.h	Fume Hoods Retrofits	Decommissioning of one obsolete fumehood in TSH	$569	$0	$5,247	<1 year	Utilities Budget
8.1.i	Lighting Retrofits	LED Lighting Retrofit in Campus interior corridors and stairwells	$452,311	$45,950	$154,412	2.6	EMP Loan
8.1.j	Chilled Water Savings	Convert city water cooling to chilled water cooling	$200,000	$0	$103,558	2 years	Utilities Budget
8.1.k	Laboratory Air Balancing	Demand Control Ventilation and Retro commissioning JHE and MDCL	$1,950,036	$150,000	$244,667	7.4	EMP Loan
8.1.l	Co-generation Proposals	Installation of a heat engine on campus to simultaneously generate both electricity and useful heat	$22,002,540	$7,737,261	$1,995,791	4.1	Deferred Maintenance, IESO and Union Gas
8.1.m	Chiller Replacement	Chiller Replacement of the Art Gallery	$165,000	$15,000	$25,190	5.5	Utilities Budget
Total			**$26,254,941**	**$8,185,404**	**$4,817,868**		
EMP Investment			**$2,611,486**	**$223,246**	**$428,860**		

Appendix B: Partially Completed, Ongoing and Future Projects

Project #	Project Name	Description	Cost ($)	Energy Incentives	Annual Savings ($)	Simple Payback (including incentives)	Funding Source
8.3.1.a	Laboratory Air Balancing/Demand Control Ventilation	Demand Control Ventilation - ABB Chemistry Wing	$1,260,000	$152,500	$172,800	7	EMP Loan
8.3.1.b	Laboratory Air Balancing/Demand Contro Ventilation	Demand Control Ventilation - ABB Physics Wing	$887,000	$54,300	$60,000	14	TBD
8.3.2	Lighting Retrofits	Student Residence lighting retrofit	$792,431	$96,838	$108,397	7	Deferred Maintenance
8.3.2	Lighting Retrofits	Lighting Retrofits - various indoor and outdoor areas	$241,000		$55,274		Deferred Maintenance
8.3.3	Chilled Water Loop	Chilled water loop modifications	$150,000	$15,000	$24,750	5	Deferred Maintenance
8.3.4	Energy Manager	Utilize IESO funding to hire an additional energy manager for completing campus initiatives	$0	$50,000	Included		IESO
8.3.5	Water conservation in Fish Lab	Water recirculation system of the Life Sciences Building fish tanks	$300,000	$0	$134,000	2	Deferred Maintenance/ Rennovation
8.3.6	Outdoor Street Lighting	Parking Lot, Street Lighting, Exterior Faciligy LED Lighting	$850,000	$95,000	$85,250	9	EMP Loan
8.3.7	Stobic Fans System Upgrades	Strobic Fan System Upgrade - NRB and ABB	$10,000	$0	$5,000	2	Utilities Budget
8.3.8	Chiller Plant Re-Commissioning	Central Plant Re-commissioning	$150,000	$40,000	$22,320	5	TBD
8.3.9.a	Window Replacement	Window Replacement - JHE South Façade	$350,000	$0	$449		Deferred Maintenance
8.3.9.b	Window Replacement	Window Replacement - Gimour Hall	$750,000	$0	$2,323		
8.3.9.c	Window Replacement	Window Replacement - McKay	$1,700,000	$0	$1,125		
8.4.3	Facilities Dorm Competition + Behaviour Report Cards + Chasing the Peak*	Annual energy competitions on campus, residence facilities + energy report cards for labs	FTE / Energy Manager	$0	$9,200	< 1 year	TBD
TOTALS			**$7,440,431**	**$503,638**	**$680,888**	**10**	
Total excluding deferred maintenance and utilities budget funding			**$5,947,000**	**$391,800**	**$343,142**	**16**	