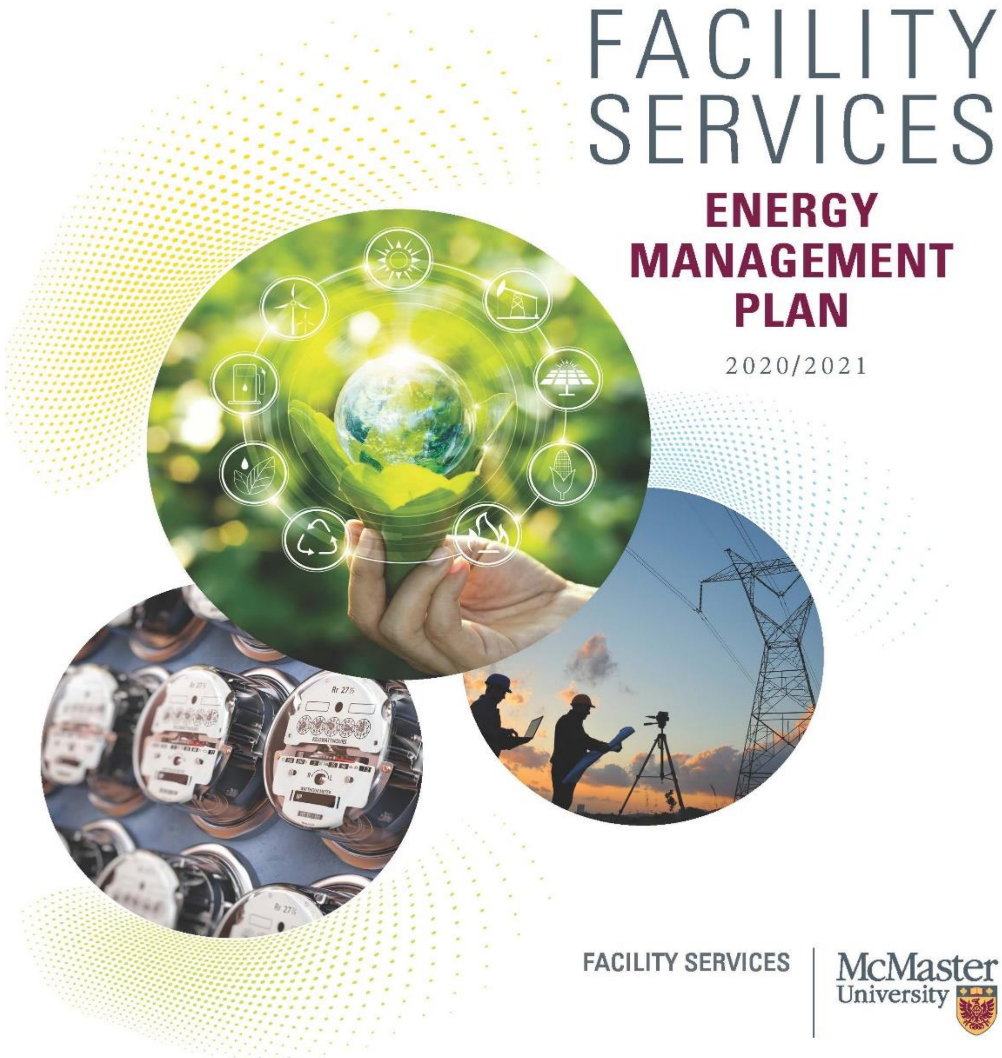


MAY 2020

**McMaster University**

# A Message from the AVP

## Debbie Martin, Assistant Vice President and Chief Facilities Officer, MBA, CPA, CGA

The sustainability of McMaster's campus is a priority for the University and for Facilities Services. Our utilities group continues to explore ways to achieve energy savings and sustainability opportunities across the entire campus.

McMaster has made a tremendous investment in sustainable energy projects since 2013. To date, we have completed over 22 projects campus-wide, with three currently in progress and plans for another 12 to begin over the coming year. These projects help the University meet its greenhouse gas emissions targets and reduce its carbon footprint. We continue to strive for ways to make the campus more sustainable, and will be working with a consultant this year to determine the feasibility of achieving net zero status over the next few decades.

For the first time, you will see that we are aligning our sustainability energy projects with the United Nations Sustainable Development Goals (SDG's). The universal symbols from the UN used throughout this report help us continue to align our work with global targets.

I am extremely proud of the work that our staff have done over the past few years, having developed and implemented an Energy Management Plan. We will continue to refine the plan, review and renew our energy savings targets, and strive to be a leader in the area of sustainability.

Debbie Martin
AVP and Chief Facilities Officer

**"At McMaster, we have always challenged our community to come up with big ideas to solve the world's greatest challenges, with a razor-sharp focus on the UN's Sustainable Development Goals"**
**David Farrar, President, McMaster University**

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# Executive Summary

McMaster is committed in maintaining a safe and sustainable campus. 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. With this approach, various projects have been evaluated in the past and new projects proposed in the hopes of creating a sustainable campus environment.

McMaster aims to reduce its utility consumption and GHG emissions with the following targets over the next 5 years, at which time our goals will be reviewed:

**2% annually for natural gas**
**2% annually for electricity**
**5% annually for water**
**2% annually for GHG emissions**

This will be accomplished through the various projects proposed in this updated EMP plan with a total investment of **$44,491,944** by 2025. McMaster currently emits **41,334 tonnes of CO2** from its district steam system and cogeneration system; it anticipates that its GHG emissions can be reduced by **25,192 tonnes of CO2** through the completed, ongoing and proposed projects highlighted in this report. This will require a significant investment over multiple years. Future versions of the Energy Management Plan will focus on our progress towards meeting these targets each year.

The progress of the energy management plan will be based on existing baselines, benchmarks with other Universities, and campus RETscreen models. A yearly analysis of the utility consumptions will be conducted to ensure that targets are met. Building performance can be compared and user groups within each building be made aware of how their buildings are performing in comparison to the others in the hopes of stimulating further energy conservation.

Many of the proposed projects are awaiting federal government funding, such as the Municipalities, Universities, Schools and Hospitals (MUSH) program. With the current changes in provincial policies concerning carbon pricing, McMaster aims to reduce its usage of natural gas for steam production by implementing various measures (i.e. electric boiler, demand control ventilation).

In keeping up with various global initiatives, McMaster has adopted Sustainable Development Goals from the United Nations and has identified three distinct SDGs met by the Energy Management Plan. They are as follows:

**7 – Affordable and Clean Energy**
**9 – Industry, Innovation and Infrastructure**
**13 – Climate Action**

Furthermore, McMaster is in the process of developing a long term net-zero carbon strategy. The university aims to position its community in an everchanging global environment by continue to meet the goals of its effective Energy Management Plan.

# Energy Management Plan Framework

## 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, world-renowned educational programs 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, just over 4,000 students occupy the university's 13 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.

# Energy Management Plan 2020/2021

The 2020 /2021, Energy Management Plan highlights the past successes of the previous energy management plans and creates a roadmap for a sustainable future. With an ever-increasing population of students and research-intensive strategic goal, McMaster is tasked with delivering a high-quality building environment while also striving for a sustainable, carbon-free campus.

Figure 1 highlights the student population trend from 2012/2013 to 2018/2019 school year.

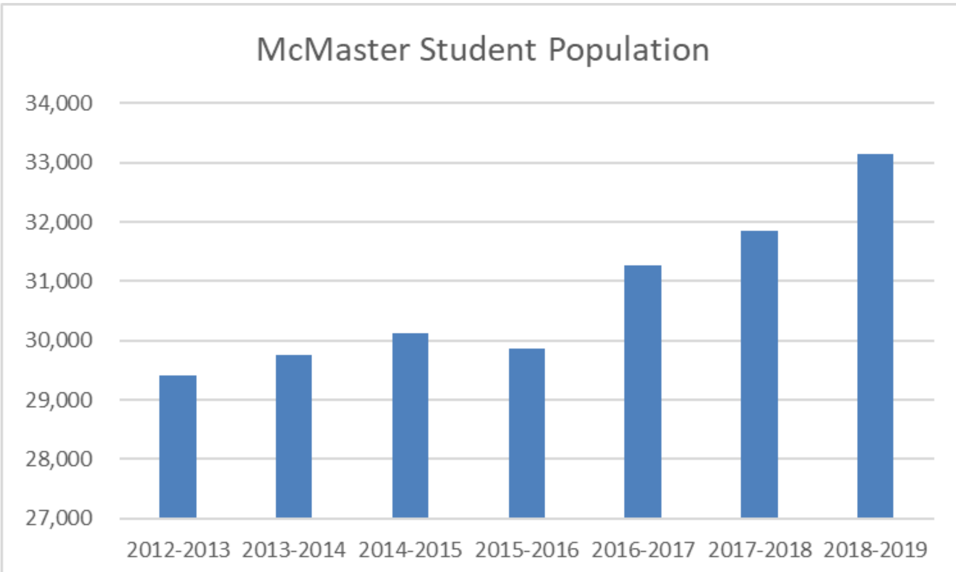


***Figure 1: McMaster Student Population***

To provide a state-of-the-art learning environment, McMaster has invested in increasing its academic and student residence buildings with the hope to provide 1st year students guaranteed accommodation, and quality academic learning space. Two buildings have been added since 2017 - AN Bourns Engineering Innovation Tower, and the Peter George Centre for Living and Learning. This has increased the campus building footprint from **396,474 $m^2$ to 433,543 $m^2$**

Figure 2 shows the uses of assigned spaces 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, which stresses the University's energy management systems. Custodial and maintenance staff in buildings later in the night and early in the morning also increase energy usage.

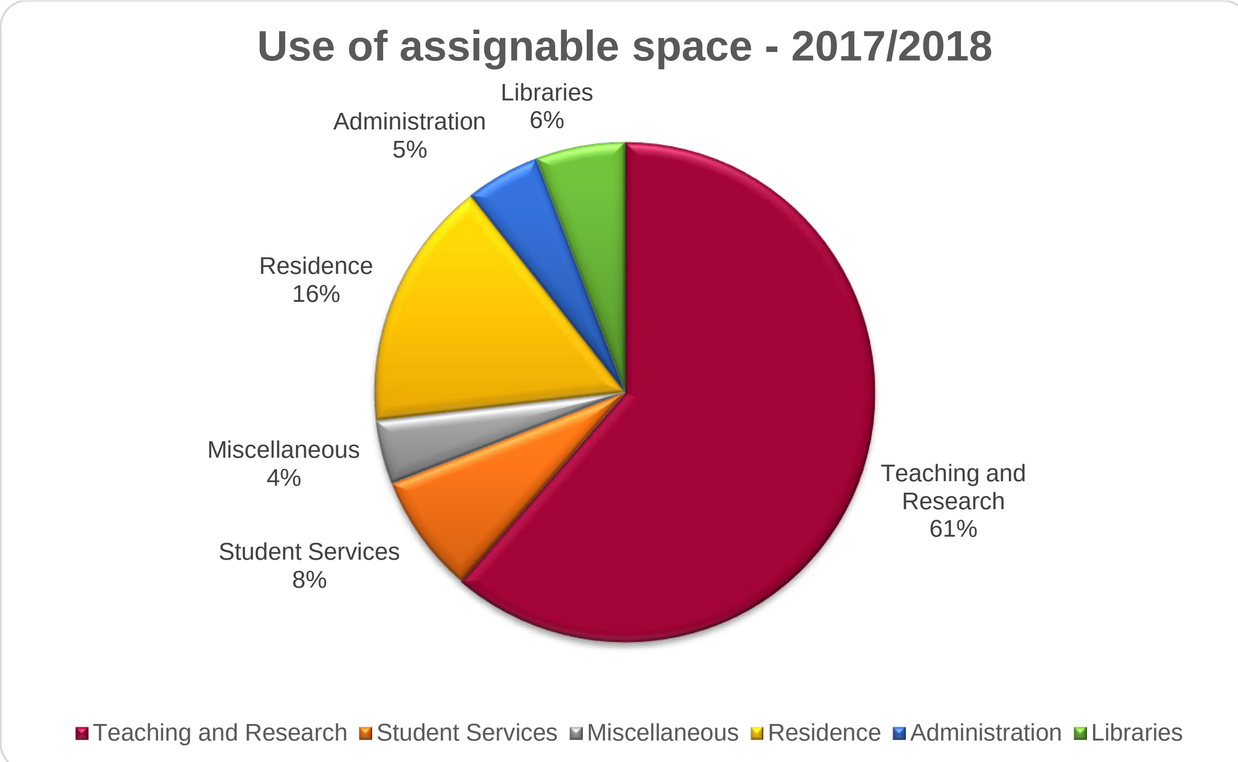


***Figure 2: Assignable Space***

# 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 for capital projects 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.

**Environmental**

Energy production and usage typically produces greenhouse gases, which contribute to global climate challenges. 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 and responsible energy production/usage. 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 reduced reliance on fossil fuels (natural gas). Organizations across North America are feeling the challenge of maintaining standards of service, and quality of life, while reducing energy consumption to remain cost competitive.

In accordance with these principles, the university signed the University and College Presidents' Climate Change Action Plan in October 2010, committing McMaster to reducing its greenhouse gas emissions. 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.

Other relevant documents include the Hamilton Climate Change Action Charter, the Ontario Regional Climate Change Consortium, President's Advisory Committee on Fossil Fuels Divestment, Sustainable Development Goals, and the UN Principles for Responsible Investment. These are each informing the sustainability targets that we are setting.

According to the Independent Electricity System Operator (IESO), the greenhouse gas emissions in Ontario are anticipated to increase to 11 megatonnes CO2e by 2030 because of a decline in nuclear production and an increased demand for electricity. This higher demand coinciding with a reduced nuclear generation capacity will partially be made up by an increase in usage of gas-fired generators across the province. Figure 3 shows the IESO's Electricity Sector GHG Emissions, Historical and 20-year forecast.

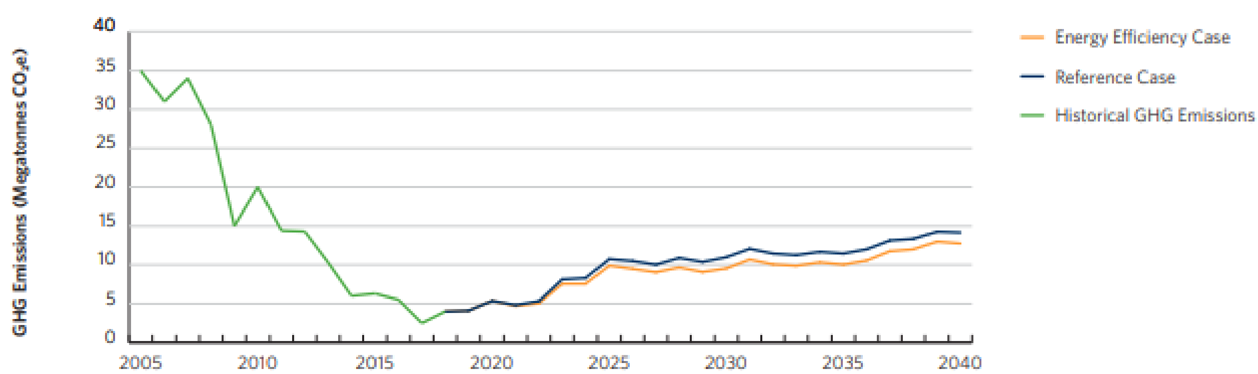


***Figure 3: IESO Electricity Sector GHG Emissions, Historical and 20 year Forecast (Reference: IESO Annual Planning Outlook 2020)***

**This stresses the need for McMaster University to commit to continuing to reduce its Green House Gas emissions.**


### 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 varying weather. Most importantly, it is driven by user behaviour.

Energy rates are driven by the provincial market, based on energy demand and government policies.

The price of electricity has increased since 2009 as shown in the **Hourly Ontario Energy Price (HOEP) Plus Average Global Adjustment (GA) Cost Graph (Figure 5), which drives the need for energy reduction projects.** (This table also demonstrates the comparative impact of government-inspired initiatives to the price of electricity in Ontario). **This version of the Energy Management Plan highlights past and future projects aimed at reducing McMaster`s overall electrical usage. This also highlights McMaster's financial responsibility to the students and campus community.**

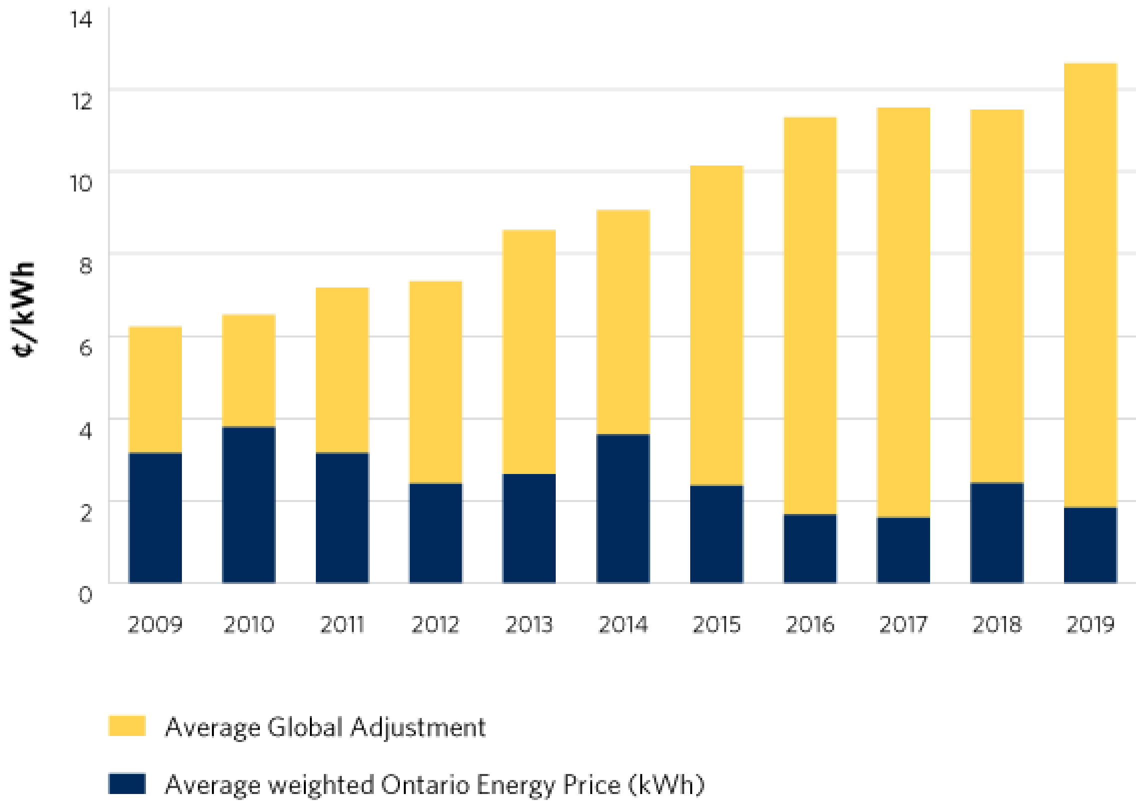


***Figure 4: Hourly Energy Ontario Price Plus Average Global Adjustment Cost Graph (http://www.ieso.ca/Power-Data/Price-Overview/Global-Adjustment)***

**** Mid to large businesses pay hourly wholesale prices, also known as Hourly Ontario Energy Price (McMaster University is included in this group), as opposed to time-of-use rates (residential and small business consumers). The total commodity cost of electricity is comprised of the HOEP and the Global Adjustment (GA) cost. The GA cost is intended to cover new electrical infrastructure, maintenance of existing ones and delivery of conservation programs. The GA cost is calculated each month and varies depending on market revenues. For residential and small business consumers, the GA cost is incorporated into time-of-use rates.***

***The cost of electricity for time-of-use rate users are determined when the electricity is used. The Ontario Energy Board (OEB) has provided set rates for off-peak, mid-peak and on-peak hours. These rates are adjusted by the OEB twice a year.***

***As universities no longer qualify for the Ontario Electricity Rebate program as of November 1, 2019 (which provides an electricity rebate of 31.8 percent of the base invoice amount), there will be a stark contrast in electricity rates between residential consumers and the universities across Ontario.***

Currently, under the federal backstop announcement, it has been mandated that pollution will no longer be free as of 2019. Ontario has proposed its own carbon tax plan, but it is currently under review by the Environment and Climate Change Canada (ECCC). As a result, Ontario is currently under the federal backstop jurisdiction and therefore subjected to federal carbon pricing (\$30/tCO2e as of January 1, 2020).

As per natural gas usage, effective January 1, 2019, a carbon pollution pricing program was implemented in Ontario and is comprised of two components:

- Output-based pricing system (OBPS) for industrial facilities – January 1, 2019
- Federal Carbon charge applied to fossil fuels

**This stresses the need for McMaster University to also consider reducing its reliance on natural gas in the operation of its facilities.**

There are several programs and initiatives available for projects that reduce electrical and natural gas consumption on campus. 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. McMaster is positioning itself to be able to take full advantage of the opportunities offered in these programs.

- **Climate Action Incentive Fund (CAIF)** – funds projects that decrease energy usage and reduce greenhouse gas emissions. Under the current CAIF, McMaster is eligible to participate in the MUSH Retrofit stream. The Municipalities, Universities, Schools and Hospital (MUSH) stream has allocated \$41 million in available funding to various schools and universities (Reference: Climate Action Incentive Fund). Details of the program are yet to be released by the federal government (as of March 1, 2020). McMaster is positioned to take advantage of this incentive fund once they are released.
- **Grid Innovation Fund** - considers applications for projects based on significant cost savings achieved by better electricity management or maintaining a reliable electricity system. This program is always available but will involve different requirements throughout the year.
- **SaveOnEnergy –** offers a wide range of incentives based on the energy efficiency measures (LED-lighting replacements, VFD retrofits, etc.)
- **Enbridge Energy Rebate Program** - rebates can be offered through a broad range of measures, such as replacement of more gas efficient equipment, reducing energy consumption during off hours (i.e. lecture halls, etc.).

### Social and Research Considerations

One of McMaster University's goals is to "provide and maintain healthy and safe working and learning environment for all employees, students, volunteers and visitors" (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.** 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.

Finally, McMaster aims to support its academic faculties by providing the utilities and infrastructure required to perform energy intensive research. Energy projects such as demand control ventilation allow for a reduction of heating, cooling and ventilation demand in buildings while maintaining the required conditions for proper laboratory use. Other projects, such as solar panel heating, and rainwater harvesting allow for renewable sources of energy, which reduces the need for district heating and water from McMaster central plant.

# Sustainable Development Goals (SDGs)

McMaster is committed to helping in the development of a sustainable and prosperous future. One of the ways McMaster is at the forefront of this initiative is through its adoption of the United Nations' Sustainable Development Goals (SDGs). Twelve of the SDG's focus on various aspects related to energy, such as clean water, climate action, sustainable communities, etc.

The 2020 Energy Management Plan has incorporated three of the 17 SDGs:

7 – Affordable and Clean Energy: Through proposed projects, such as solar panels (refer to Proposed Projects section); McMaster is able to provide clean energy within its campus grounds.

9 – Industry, Innovation and Infrastructure: A number of past projects and proposed projects involves varying innovation for green and sustainable technologies. Some of these include demand control ventilation projects, new fume hood technologies, solar panel roofs, etc.

13 – Climate Action: McMaster recognizes the need for climate action. Through various decarbonisation projects, as highlighted in this Energy Management Plan, McMaster is committed to lowering its overall carbon footprint. Some project examples include but not limited to: electric boiler installation, demand control ventilation, etc.

# Utility Trends and Monitoring

## Utility Baselines

To determine the effectiveness of the Energy Management Plan, proper baselining must be implemented. This entails recording previous Utility trends and actively monitoring changes in Utility consumption/costs to ensure that target goals are met.

Natural gas, Hydro and Water consumptions are shown in Figures 5 to 7. Utility intensities are also shown on the graphs, which factors in student population. Currently, the data for the Cogeneration plant is being logged separately and collected for detailed analysis. Data and trends for the Cogeneration plant will be available in the fall of 2020. For the purposes of this report, the Cogen emissions have been omitted until this analysis is complete.

Based on past data, the campus natural gas consumption has steadily increased, despite the implementation of various energy efficiency measures such as demand control ventilation and the replacement to higher efficiency HVAC equipment. This can be attributed to the addition of several buildings and spaces from 2016 to 2019. This list includes L.R Wilson building, Hatch building, and ABB EIT Tower. Furthermore, as research becomes more energy intensive, the university is faced with the challenge of providing the required utilities while also conserving energy and reducing carbon emissions.

Similarly, electricity consumption has also increased over the years, despite energy reduction projects. More notably, there is a sharp increase in consumption from 2017 to 2019, which can be attributed to the following reasons:

- McMaster delivered more chilled water to the hospital during the summer of 2018 and onwards (increased the kWh consumption from the chillers) as It is more economical for the hospital to purchase chilled water and steam from McMaster central plant as the efficiency of their system is less than that of McMaster's. This translates to better energy efficiency for the hospital.
- Extended occupant schedules drove increased demand on existing buildings.
- Additional buildings coming in operation (Gerald Hatch Centre - 2017 and ABB EIT Tower - 2019).

Finally, the water consumption on campus saw an increase especially in 2018 and onwards as McMaster started producing more chilled water and steam for the hospital and newly constructed buildings (increased steam consumption resulted in increase in make-up water).

To effectively track the progress of the Energy Management Plan, McMaster has employed a rigorous monitoring and metering program. In addition, it is advantageous for the following reasons:

- 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

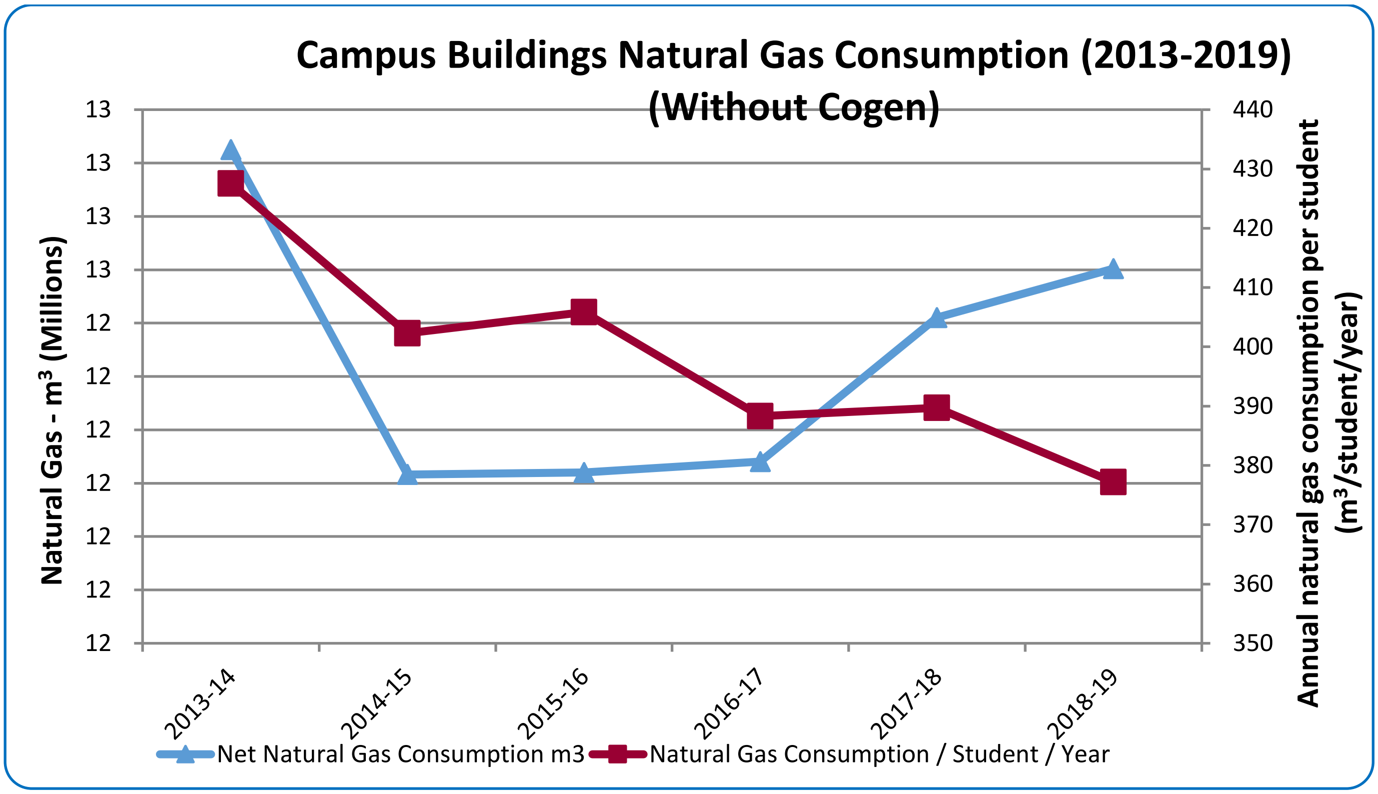


***Figure 5: Natural Gas Consumption without Cogen***

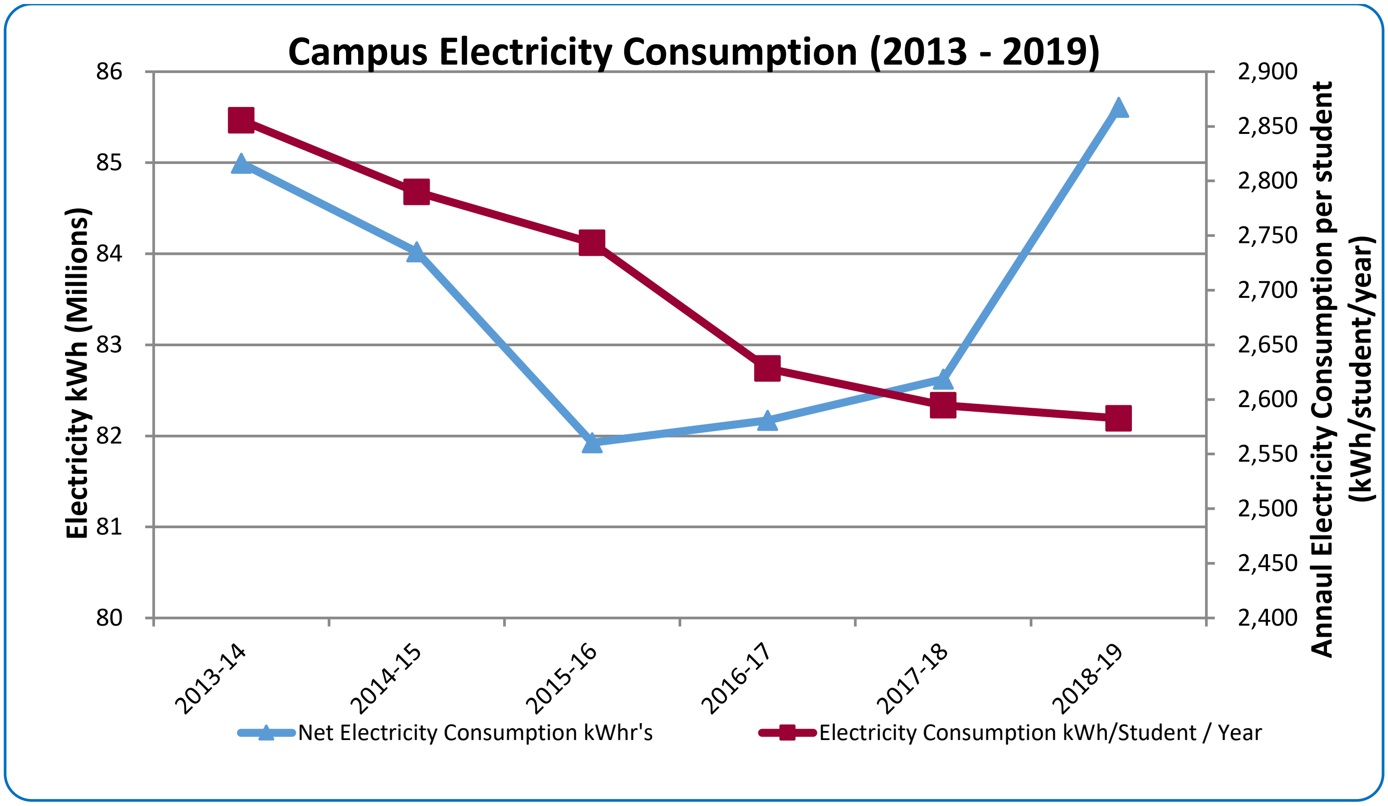


*Figure 6: Electricity Consumption*

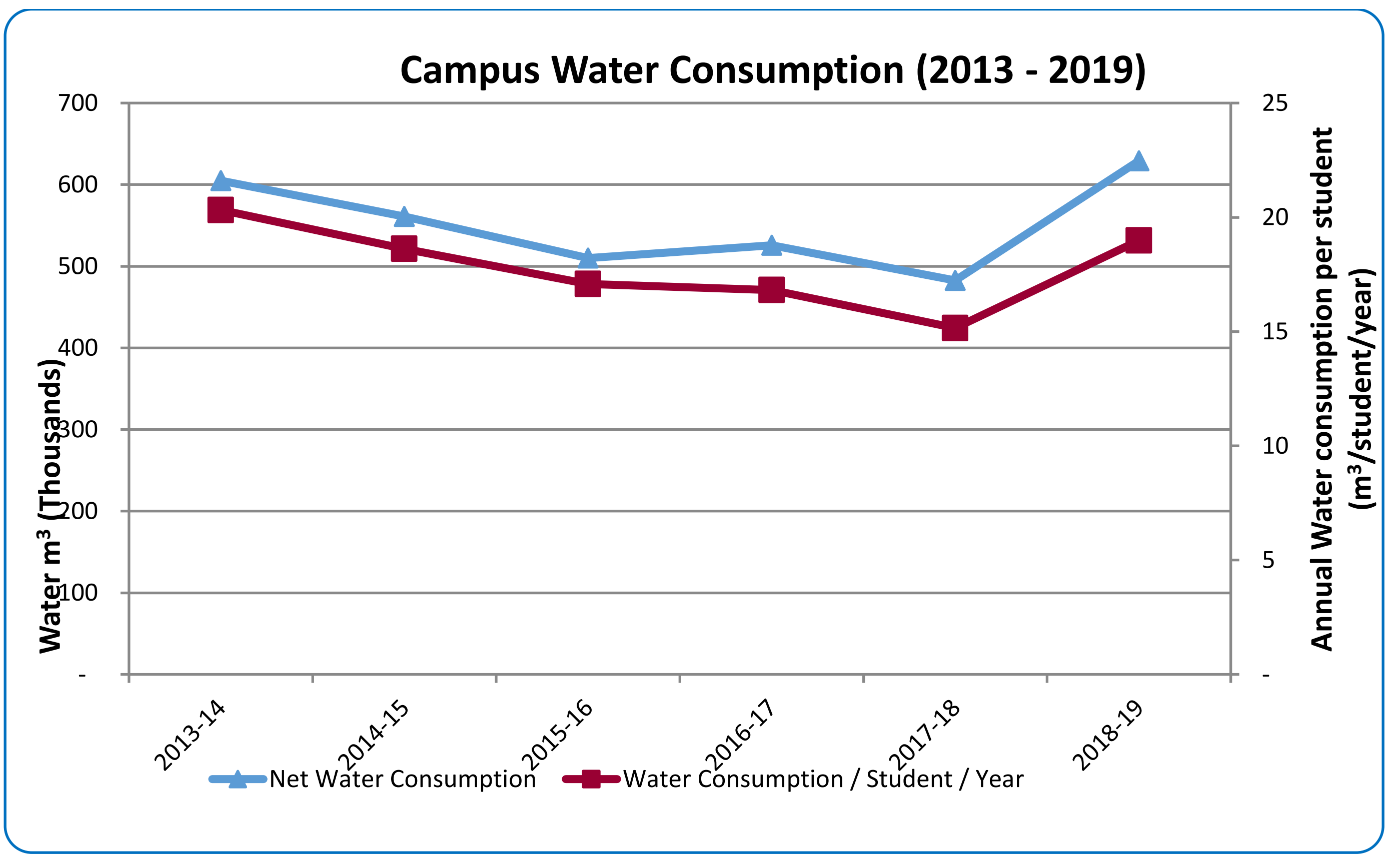


*Figure 7: Campus Water Consumption*

The utility consumption per square meter of the campus buildings has also been quantified in Table 1 below and will serve as another metric to gauge McMaster's energy and emission targets from 2020 and beyond.

| 2018-2019 | |
|---|---|
| **Electricity (kWH/Sq.M)** | 198 |
| **Natural Gas (m3/Sq.M)** | 45.7 |
| **Water (m3/Sq.M)** | 1.45 |

***Table 1: Utility per square meterGreen House Gas Emissions Trend***

Over the years since the inception of the Energy Management Plan 2013, McMaster has decreased its greenhouse gas emissions through various projects, and programs. The addition of several new buildings/spaces, and extended occupant schedules contribute to an increase in greenhouse gases, but due to the increasing student population, the greenhouse gas emission intensity has shown a steady decline. Figure 8 highlights McMaster's carbon footprint intensity from 2002 to 2019.

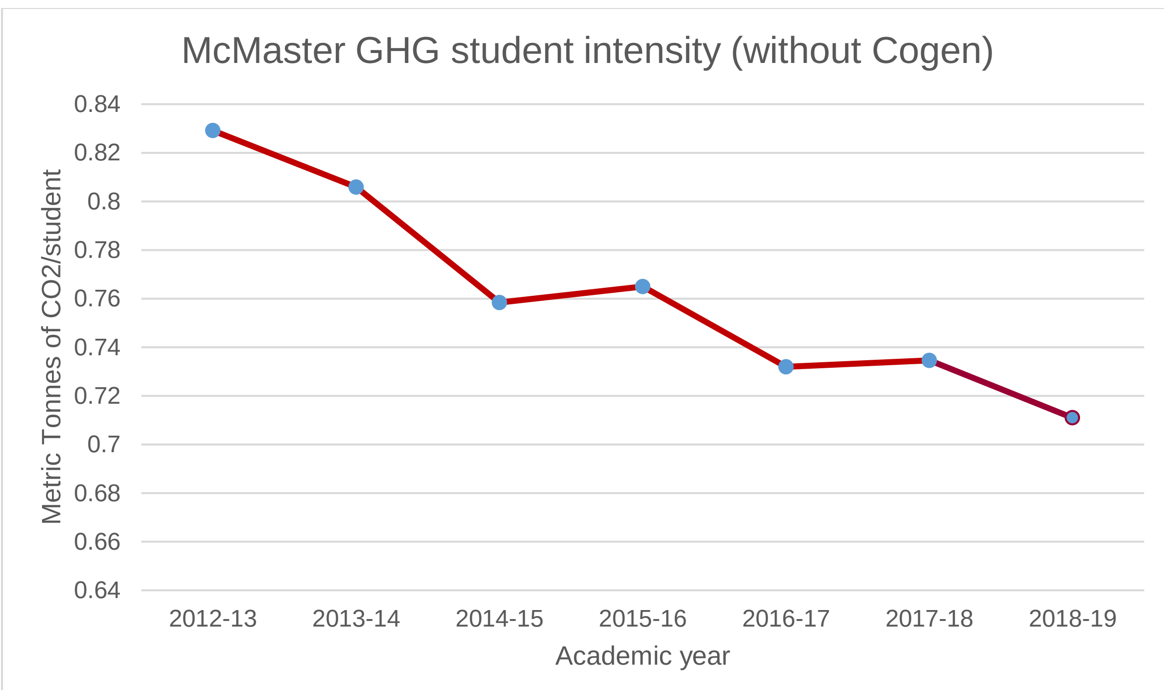


***Figure 8: McMaster Green House Gases Student Intensity (metric tonnes of CO2/student) – without Cogen***

# Utility Cost Unit Rates

In order to conduct a proper financial analysis of the projects proposed in the Energy Management Plan, utility costs are tracked over the years. This ensures that projects are financially feasible. Refer to Table 2 for natural gas, water and electricity costs from 2013 to 2019.

| Year | Natural Gas ($/cu.m) | Water ($/cu.m) | Average Electricity (cents/kWh) | Class A or Class B Classification |
|---|---|---|---|---|
| 2013-2014 | **0.16** | 2.56 | 8.57 | Class A |
| 2014-2015 | **0.17** | 2.76 | 9.06 | Class A |
| 2015-2016 | **0.13** | 3.00 | 10.14 | Class A |
| 2016-2017 | **0.10** | 3.00 | 11.32 | Class A |
| 2017-2018 | **0.19** | 3.10 | 11.55 | Class B |
| 2018-2019 | **0.14** | 3.22 | 11.50 | Class B |

***Table 2: Utility unit rates (Source: Ontario Energy Board – Union Gas rates, McMaster Water data, and IESO)***

# Energy Procurement Policy

McMaster University's Energy Procurement policy aims to reduce the cost of purchasing utilities. This is accomplished by hedging energy prices when optimal; 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, can protect 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, as of recently, unit prices have been low and as such, McMaster purchases at index instead of hedging for both natural gas, and hydro as of March 2020.

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.

# Benchmarking with Other Institutions

Aside from implementing an internal utilities baselining to track usage rates, it is also important to track how McMaster compares to other institutions in energy reduction and decarbonisation targets.

One benchmark for comparison is the financial investment of each university based on square footage. A high-level costing Information pertaining to this is highlighted in the recent Energy benchmarking report provided by NRCan (2018/2019).

NRCan in conjunction with 21 universities in Ontario (including McMaster University) has provided an Energy benchmark and Pre-Feasibility Analysis Report with RETScreen Expert. This report is a portfolio-wide approach towards decarbonisation. NRCan worked with the Ontario Association of Physical Plant Administrators (OAPPA) and Council of Ontario Universities (COU) from September 2018 to December 2019 to determine energy benchmarks and provide pre-feasibility studies for all facilities across all 21 universities, which is done through NRCan's RetScreen Expert Clean Energy Management Software. The initiative was partially funded by the Independent Electricity System Operator (IESO)'s Education Capacity Building Fund.

One of the most important pieces of information included in the report is a cost information for various energy-efficiency measures. Although the analysis is at a high level, the archetype used to calculate the cost information serves as a start to benchmarking McMaster's progress in comparison to other universities in Ontario. This established model can be further refined once projects are more concrete and this may decrease the cost per efficiency measures.

| University Name | # of Facilities | Size of Facilities (m2) | Cost of Proposed Efficiency Measures | $/m2 |
|---|---|---|---|---|
| Algoma University | 11 | 32,447 | $1,423,701 | $43.88 |
| Brock University | 55 | 264,672 | $11,745,329 | $44.38 |
| Carleton University | 48 | 426,026 | $18,446,930 | $43.30 |
| Lakehead University | 52 | 208,558 | $7,679,702 | $36.82 |
| Laurentian University | 32 | 181,052 | $6,228,605 | $34.40 |
| McMaster University | 55 | 599,892 | $28,954,859 | $48.27 |
| Nipissing University | 13 | 153,764 | $5,844,444 | $38.01 |
| OCAD | 12 | 59,217 | $1,471,608 | $24.85 |
| Ontario Tech University | 31 | 247,050 | $9,685,350 | $39.20 |
| Queen's University | 198 | 661,039 | $21,322,259 | $32.26 |
| Royal Militarry College of Canada | 29 | 189,255 | $6,259,138 | $33.07 |
| Ryerson University | 35 | 347,740 | $9,328,299 | $26.83 |
| Trent University | 41 | 140,187 | $5,072,582 | $36.18 |
| University of Guelph | 105 | 574,700 | $25,871,854 | $45.02 |
| University of Ottawa | 74 | 625,354 | $18,050,873 | $28.87 |
| University of Toronto - Mississauga | 28 | 218,010 | $8,550,057 | $39.22 |
| University of Toronto - Scarborough | 37 | 188,831 | $8,334,698 | $44.14 |
| University of Toronto - St. George | 146 | 1,394,156 | $54,807,751 | $39.31 |
| University of Waterloo | 91 | 789,076 | $27,858,634 | $35.31 |
| University of Western Ontario | 116 | 915,085 | $31,637,397 | $34.57 |
| University of Windsor | 47 | 295,909 | $10,897,286 | $36.83 |
| Wilfrid Laurier University | 56 | 349,290 | $11,626,754 | $33.29 |
| York University | 74 | 642,379 | $21,755,759 | $33.87 |

*Table 3: Ontario University Portfolio RETScreen Expert Results*

$28,954,859

**McMaster potential financial investment for decarbonisation**

## Reduction Targets

Facility Services researched relevant literature to aid in the development of meaningful energy conservation targets.

Some relevant targets are discussed below:

1. The provincial government has set electricity conservation targets in the Ontario Long Term Energy Plan (LTEP) issued at the end of 2013 (updated for 2016-2020). The newest version of the plan involves an 80% reduction in GHG by 2050.
2. In 2009, the Council of Ontario Universities have made a pledge to go “greener”, which involved developing multi-pronged strategies to reduce energy consumption. Every year, the Council of Ontario Universities (COU) releases a report titled “Going Greener”, which outlines general expectations for universities to invest in green energy and cut carbon emissions over the next decade. It also highlights yearly accomplishments of the various universities in energy management and sustainability. The latest version was released in 2018.

Facility Services recommends reducing absolute **electricity consumption on campus by 2%, gas consumption by 2%, water consumption by 5% and GHG emissions by 2% on a yearly basis** over the next five years to contribute to the overall culture of sustainability and energy conservation in Ontario.

# Energy Action Plan

The goal of the energy action plan is to reduce McMaster University’s energy costs and carbon footprint by reducing overall consumption, as well as reducing the cost of purchase of utilities. This section has been updated based on 2019 EMP performance to date, current utility rate forecasts, and market conditions.

## Completed (pre-2020)

**Grid Balancing Pilot Project**
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)

**Building Exhaust Fans and Domestic Hot Water Pumps**

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 switch 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)

## 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 behavioral energy conservation.

## Chasing the Peak (2014-2015. Discontinued)

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 stand-by 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.

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). In 2015, Ivor Wynne Centre achieved the top performance (20% peak reduction).

**McMaster saved $2M annually during Chasing the Peak. However, due to a negative impact to research laboratories and feedback from the campus community, the program was terminated.**

### Plug Load Analysis (2015)

The California Energy Commission describes plug load as "a term referred to equipment that is 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 (Hamilton Hall, Gilmour Hall, Chester New Hall, 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 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.

**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 independent valves and installing variable speed drives. The project was completed in 2015.

**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. With slip reducing fan belts, there will be operating savings due to better runtime efficiency. The project was completed in 2014.

**All Buildings – Heating System 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).

**Central Plant/Chilled Water Plant Operational Modifications**
The project involved operational modifications to plant controls to improve central plant efficiencies and lower energy consumption.

**Demand Control Ventilation (DCV) – ABB Undergraduate Labs**
This project was implemented in ABB Undergraduate labs beginning of 2015, which reduced the air changes per hour based on lab activities. 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.

**Fumehood Retrofits and Upgrade Projects**
On average a single fume hood costs McMaster approximately $4,000 in annual energy costs. There is a total of approximately 565 fume hoods on campus.

A 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.

**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 Gilmour Hall, Togo Salmon Hall, Chester New Hall, Kenneth Taylor Hall and Thode Library stairwells produced encouraging results.

Building on the success of these pilots, the complete campus stairwells and corridors LED lighting project was initiated and completed in 2014 (approximately 12,000 lamps).

**Chilled Water Savings - Conversion of City Water Cooling on Process Units to Chilled Water Loop:**

This component changes the city water-cooled equipment to campus chilled water loop and 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.

**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. This is achieved through changing the air changes per hour in the labs depending on usage.

**Co-Generation Proposals / Combined Heat and Power Project**

The proposed project envisioned implementing a co-generation facility to reduce campus energy costs. A detailed feasibility study on the initiative was 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 nameplate capacity numbers and the actual capacity would be lower.

The project was approved by the McMaster Board of Governors and has been implemented. In-service date was January 16, 2018. A comprehensive review of this project is underway.

**Chiller Replacement – Art Gallery**

This project involves replacement of the current Art Gallery Chiller and fine-tuning the campus chilled water systems to provide operational flexibility, while connected to the central plant.

The Art Gallery air conditioning is provided by a dedicated cooling unit which provides temperature and humidity control to the gallery. This chiller had a number of operational issues and occasional breakdowns. The project proposed the replacement of this chiller with a high efficiency one, which would generate energy savings while ensuring that the required conditions in the Art Gallery are maintained. Chiller replacement was completed in 2016, while the piping changes to enhance the operational flexibility has been completed in 2018.

### Window Replacements

A number of window replacements were completed in the past years:

1. JHE South Façade (2018)
2. Gilmour Hall (2018)
3. McKay Hall (2018)

With higher efficiency windows, heating savings (gas) can be realized which reduces the steam demand at central plant.

### Chiller Plant Recommissioning

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. A study and measurement were conducted in 2018/2019 and it was deemed that the chiller plant operation is already optimized. There was no savings realized from this initiative.

### Lighting Retrofit – Student Residence

In conjunction with the student residence, the lighting in various residences has been replaced with LED lighting. Savings were calculated based on energy consumption of the LED lightings only.

### Lighting Retrofit – Indoor and Outdoor Lighting

LED lighting offers the promise of better-quality lighting, energy savings and long life with low replacement costs. This project replaced the majority of the outdoor lighting fixtures with new energy efficient LED 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. Savings were calculated based on energy consumption of the LED lightings only.

**Table 5 summarizes all the completed projects based on their savings, incentives, payback and GHG reductions.**

| *Completed Projects* | *Year Completed* | *Cost ($)* | *Energy Incent.* | *Annual Gas Savings (m3)* | *Annual Electricity Savings (kWhr)* | *Annual Water Savings (m3)* | *Annual Savings $* | *Simple Payback* | *Funding Source* | *GHG Emissions Reduction (tonnes of CO2e)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Grid Balancing Project** | 2014 | Staff time | $0 | $0 | 0 | 0 | $3,961 | < 1 | IESO | 0 |
| **Building Exh Fans & Dom. HW pumps** | 2013 | $118,316 | $17,406 | 29,500 | 90,052 | 0 | $16,600 | 6.1 | EMP | 56 |
| **Energy Dashboard** | 2013 | $575,000 | $124,000 | 104,500 | 304,500 | 15,500 | $99,300 | 4.5 | MTCU & PIF Grant | 197 |
| **Chasing the Peak** | 2014-2017 | $165,000 | $0 | varies | Varies | 0 | $2,000,000 | < 1 | U.B. (14-15), EMP (17) | varies |
| **Plug Loads Analysis** | 2015 | $10,650 | $0 | 0 | 26,280 | 0 | $2,891 | 3.7 | U.B. | 0 |
| **University Hall Controls Upg** | 2015 | $217,269 | $2,702 | 43,750 | 20,000 | 0 | $10,075 | 21 | D.M | 82 |
| **Mech Fans Belt Upgr. (All buildings)** | 2014 | $90,314 | $9,890 | 0 | 129,727 | 0 | $14,455 | 5.6 | EMP | 0 |
| **Heating Set back (All Buildings)** | 2015 | $25,000 | $0 | 180,000 | 50,000 | 0 | $40,400 | < 1 | U.B. | 339 |
| **Cent. CHW Plant Oper. Modification** | 2015 | $20,000 | $0 | 0 | 30,000 | 3,000 | $11,790 | < 1 | U.B. | 0 |
| **DCV – ABB Undergrad** | 2015 | $427,427 | $83,195 | 121,000 | 616,500 | 0 | $90,805 | 3.8 | D.M. + IESO | 228 |
| **Decommiss/Fumehood Retrofits (TSH)** | 2014 | $5,000 | 0 | 11,900 | 27,000 | 0 | $5,247 | <1 year | U.B. | 22 |
| **Lighting Retrofits – Campus Indoor/Outd** | 2014 | $452,311 | $45,950 | 0 | 1,403,750 | 0 | $154,500 | 2.6 | EMP Loan | 0 |
| **Chilled Water Savings** | 2015 | $200,000 | $0 | 0 | 0 | 36,985 | $103,558 | 2 | U.B. | 0 |
| **DCV – JHE & MDCL** | 2017 | $1,950,036 | $150,000 | 250,110 | 866,000 | 0 | $244,667 | 7.4 | EMP Loan | 471 |
| **Co-Generation Proposals** | 2018 | $22,002,540 | $7,737,261 | 0 | 0 | 0 | $1,995,791 | 7.1 | EMP, IESO and | 0 |

Union Gas

| Completed Projects | Year Completed | Cost ($) | Energy Incent. | Annual Gas Savings (m3) | Annual Electricity Savings (kWhr) | Annual Water Savings (m3) | Annual Savings $ | Simple Payback | Funding Source | GHG Emissions Reduction (tonnes of CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Chiller Replacement (Art Gallery)** | 2018 | $165,000 | $15,000 | 0 | 231,000 | 0 | $25,190 | 5.5 | U.B. | 0 |
| **Window Replc. – JHE** | 2018 | $350,000 | 0 | 1,505 | 1,177 | 0 | $449 | > 20 | D.M. | 3 |
| **Window Replc. - Gilmour Hall** | 2018 | $750,000 | $0 | 8,200 | 5,191 | 0 | $2,323 | > 20 | D.M. | 15 |
| **Window Replc. - McKay Hall** | 2018/2019 | $1,700,000 | $0 | 5,115 | 0 | 0 | $1,125 | > 20 | D.M. | 10 |
| **ET Clarke – Chiller Recommissioning** | 2018 | $131,800 | $0 | 0 | 0 | 0 | $0 | N/A | EMP Loan | 0 |
| **Lighting Retrofit – Student Res** | 2016 | $792,431 | $96,838 | 0 | 985,427 | 0 | $108,397 | 6.4 | IESO | 0 |
| **Lighting Retrofit – Indoor/Outdoor** | 2018 | $241,000 | $0 | 0 | 526,416 | 0 | $55,274 | 4.4 | D.M. | 0 |
| ***Total*** | | ***$30,384,790*** | ***$8,282,242*** | ***755,580*** | ***5,313,020*** | ***55,485*** | ***$4,986,798*** | | | ***1,424*** |
| ***EMP Investments*** | | ***$24,910,444*** | ***$7,960,507*** | ***279,610*** | ***2,489,529*** | ***0*** | ***$4,426,013*** | | | ***527*** |

***Legend:**
**EMP – Energy Management Plan**
**U.B. – Utilities Budget**
**D.M. – Deferred Maintenance**
**MTCU – Ministry of Training, Colleges and Universities**
**PIF – Productivity and Innovation Fund**
**IESO – Independent Electricity System Operator**

## Table 4: Completed Projects Summary

# Ongoing Projects

**Demand Control Ventilation – Physics Wing**

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 airflows 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 airflow to maintain comfort levels. If an accidental spill happens, the system ramps up the ventilation system to the maximum available capacity to 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

Following the success of ABB Undergraduate labs project, a feasibility study to implement this measure in ABB (Physics Wing) has been completed and the project is awaiting government carbon reduction funding to be implemented.

**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 m3 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 was planned to be completed in 2019 in conjunction with the Faculty of Science and the Central Animal Facility. Delays in procurement of fish tanks and the recent pandemic have slowed construction. This project is expected to be completed in 2020.

**Strobic Fan Upgrades**

The strobic (high plume fans) in NRB and ABB are still operating with old pneumatic dampers. This project intends to replace the old pneumatic dampers to DDC electronic and is expected to be completed in 2020.

| *Ongoing Projects* | *Year Completed* | *Cost ($)* | *Energy Incent.* | *Annual Gas Savings (m3)* | *Annual Electricity Savings (kWh)* | *Annual Water Savings (m3)* | *Annual Savings ($)* | *Simple Payback* | *Funding Source* | *GHG Emissions Reduction (tonnes of CO2e)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lab Air / DCV – ABB Physics Wing** | 2020-2021 | $887,000 | $0 | 131,700 | 311,400 | 0 | $112,000 | 8 | EMP | 248.3 |
| **Water Conservation in Fish Lab** | 2020 | $425,000 | $0 | 0 | 0 | 41,000 | $134,000 | 3 | EMP | 0 |
| **Strobic Fan Systems Upgrade** | 2020 | $10,000 | $0 | 12,000 | 22,000 | 0 | $5,000 | 2 | U.B. | 22.6 |
| ***Total*** | | ***$1,322,000*** | ***$0*** | ***143,700*** | ***333,400*** | ***41,000*** | ***$251,000*** | | | ***270.87*** |
| ***EMP Investments*** | | ***$1,312,000*** | ***$0*** | ***131,700*** | ***311,400*** | ***41,000*** | ***$246,000*** | | | ***248.25*** |

***Table 5: Ongoing Projects Summary***

# Proposed Projects

### Steam Traps Replacement

The steam distribution system at McMaster relies on stream traps to ensure operation. Aside from an operational standpoint, steam traps play a vital role in fuel efficiency. Leaking traps are a major cause of energy and condensate loss. This project focuses on replacing these old and leaky steam traps for better efficiency and energy savings.

### Window Replacements

A culprit for a building's energy losses are from the building's façade, with old leaky windows being the top contributor. Replacing the windows would ensure that there are minimal leakages allowing conditioned air to escape. The following buildings have been identified for potential candidates for window replacements:

- Ivor Wynne Centre Commons Building
- Campus Services Building
- Tandem Accelerator
- Life Sciences Building
- Moulton Building
- Mills Memorial Library
- Nuclear Research Building

### Variable Speed Pumping

The pumping and distribution system at LSB is currently designed for constant volume. Retrofitting the system to variable speed operation will result in electrical savings due to variable flow. This would entail new VFD pumps and conversion of all three-way valves to two-way valves (energy valves).

### Demand Control Ventilation – Campus Wide

In order to reduce the steam demand, the heating demand of a building must also be reduced. The most common way to accomplish this is through demand control ventilation.

Laboratories have the highest energy usage out of all the spaces on campus and as such have the most potential for energy savings. The proposed demand control ventilation system monitors the concentration of the effluent in the exhaust air stream and effectively increases/decreases the speed of the exhaust fan in response. The energy savings occur when there is minimal fume hood activity/usage, as the system reduces the fan speed in order to conserve energy. This reduces the air changes per hour required in the laboratory, which reduces the heating load in the building. This translates to less steam demand from central plant, effectively reducing the GHG of the gas boilers. In the past, McMaster has implemented the demand control ventilation system across many labs on campus (JHE Chemistry Wing, ABB Undergraduate Chemistry, MDCL, etc.), with great success (refer to past projects section).

Building on previous success, the DCV system can also be used in non-lab spaces; in the case of non-lab areas such as office spaces, meeting rooms, etc., the sensor suite/system can be configured to detect CO2, TVOC's, and particulates. This will give an indication of the occupancy levels in each of the spaces, which can be used in real-time to adjust ventilation requirements and reduce fan operations.

Table 7 highlights all the potential buildings (both laboratories, non-laboratories, and animal facilities) that can be retrofitted with Demand Control Ventilation with accompanying savings and GHG reductions as indicated in study completed by Airgenuity.

| | | Capital Cost | Incentive | Net Capital | Electrical Savings (kWh) | Therms | CO 2 (Metric Tonnes) |
|---|---|---|---|---|---|---|---|
| 9 | Nuclear Research building | $165,000 | $27,084 | $137,916 | 174,823 | 34,291 | 230 |
| 10 | Mills Memorial Library | $209,550 | $26,069 | $183,481 | 164,053 | 34,515 | 222 |
| 11 | Burke Science Building | $529,600 | $73,066 | $456,534 | 471,683 | 92,490 | 617 |
| 16 | John Hodgins Engineering | $687,475 | $146,809 | $540,666 | 950,946 | 184,696 | 1238 |
| 17 | Divinity College | $97,166 | $5,794 | $91,372 | 36,423 | 7,685 | 51 |
| 22 | General Sciences | $165,000 | $22,690 | $142,310 | 148,961 | 27,834 | 188 |
| 23 | Chester New Hall | $91,100 | $15,208 | $75,892 | 97,241 | 19,586 | 132 |
| 24 | Ivor Wynne Centre | $155,925 | $49,058 | $106,867 | 310,065 | 64,471 | 429 |
| 25 | ABB - Arthur Bourns Building | $856,040 | $126,436 | $729,604 | 847,776 | 148,779 | 1009 |
| 29 | Togo Salmon Hall | $155,930 | $33,158 | $122,772 | 210,503 | 43,243 | 289 |
| 30 | Biology Greenhouse | $105,300 | $11,305 | $93,995 | 74,097 | 13,911 | 94 |
| 32 | Tandem Accelerator Building | $131,115 | $27,807 | $103,308 | 179,581 | 35,175 | 236 |
| 33 | Applied Dynamics Lab | $132,500 | $18,860 | $113,640 | 124,398 | 22,927 | 155 |
| 34 | Psychology Building | $437,558 | $84,466 | $353,092 | 540,345 | 108,686 | 724 |
| 38 | Kenneth Taylor Hall | $253,389 | $18,459 | $234,930 | 121,851 | 22,405 | 147 |
| 39 | Life Science building | $721,500 | $146,023 | $575,477 | 1,003,008 | 163,294 | 1080 |
| 42 | Thode Library of Science & Engineering | $118,450 | $31,698 | $86,752 | 200,660 | 41,543 | 276 |
| 43 | Communications Research Laboratory | $119,971 | $9,935 | $110,036 | 69,105 | 10,801 | 71 |
| 46 | DeGroote School of Business | $97,200 | $5,325 | $91,875 | 33,503 | 7,051 | 46 |
| 48 | Institute for Applied Health Sciences | $306,763 | $50,867 | $255,896 | 329,514 | 63,983 | 424 |
| 49 | Information Technolog Building | $209,600 | $14,270 | $195,330 | 89,963 | 18,836 | 123 |
| 51 | McMaster University Student Centre | $197,400 | $28,706 | $168,694 | 181,430 | 37,725 | 250 |
| 52 | Michael Degroote Centre for Learning & Discovery | $438,016 | $89,670 | $348,346 | 614,290 | 100,860 | 667 |
| 54 | David Braley Athletic Centre | $144,750 | $13,884 | $130,866 | 86,027 | 18,862 | 120 |
| 56 | Engineering Technology Building | $324,491 | $72,753 | $251,738 | 501,507 | 80,724 | 530 |
| 57 | Ron Joyce Centre | $162,940 | $10,240 | $152,700 | 64,630 | 13,489 | 88 |
| 58 | MIP MARC | $363,725 | $62,998 | $300,727 | 408,183 | 79,215 | 531 |
| 59 | MIP Atrium Building | $165,000 | $27,152 | $137,848 | 179,168 | 32,982 | 23 |
| 74 | LR Wilson Hall | $209,600 | $32,551 | $177,049 | 206,042 | 42,669 | 284 |
| 83 | David Braley Athletic Centre | $97,170 | $12,862 | $84,308 | 83,949 | 5,954 | 104 |
| 85 | One James North | $97,170 | $4,940 | $92,230 | 31,264 | 6,478 | 43 |

***Table 6: Airgenuity - McMaster Campus Review***

**Electric Boilers and Peak Shaving Generators (Natural Gas Generators)**

The most significant and meaningful way to reduce the University's carbon footprint is to employ electric boilers as oppose to the conventional natural gas boilers. The electric boilers will generate the required steam to provide the heating across campus. However, to make electric boilers financially feasible to operate, McMaster will need to be a Class A participant. Class A participants pay global adjustment (GA) based on their percentage contribution to the top five peak hours (the ICI - Industrial Conservation Initiative). In order to participate as a Class A, customers must have a peak demand above the nominal threshold of 5 MW; McMaster currently operates between 9 to 11 MW but is currently participating as a Class B. We participated as Class A during the Chasing the Peak initiative. When that initiative ended, we moved back to being Class B because it wasn't financially viable to continue as Class A with lower volumes (Co-gen is generating between 45%-55% of power on campus).

In order to make this effective, the electric boiler must only operate during times when the Hourly Ontario Energy Price(HOEP) is favourable; this is when the price of the HOEP is less than $.03. At this price, operating an electric boiler is cheaper than burning gas in a conventional boiler to produce steam. A feasibility study of an electric boiler was conducted in 2017 and was determined that a 40,000 lb/hr electric boiler would offset approximately **9,531 carbon tonnes of CO2e**. The capital cost to implement this electric boiler is around **$4 million**. There are no cost savings associated with the implementation of an electric boiler; it is simply a greenhouse gas emission reduction strategy.

McMaster will return to Class A classification if the decision is made to employ **electrical peak shavers**, which are dedicated natural gas generators that operate during anticipated peak hours only. This will allow McMaster to participate in the ICI program. Based on total GA from previous years, it can be estimated that Class A customers would pay $550,000 per MW of load. This means that if McMaster is able to reduce its net load by 2 MW through the peak shavers for all 5 Ontario coincident peaks then about $1.1 million of savings can be realized.

Another benefit of having **electrical peak shaving natural gas generators** is that the emergency load can be shifted to these generators. With the completion of Peter George Centre for Living and Learning Building, the remaining capacity of the emergency generators at ET Clarke have been exhausted, which leaves no capacity for future expansion. Having additional natural gas generators, will allow for emergency load requirements of the boilers and chillers to be shifted from the emergency generators to the peak shaving natural gas generators, allowing for spare capacity to be used for campus. An investment in an emergency generator will have to be made if electrical peak shaving natural gas generators are not pursued and implemented. A rough equipment cost for an emergency generator is around **$1,500,000**; this does not include engineering and construction cost.

In summary, the University's carbon footprint generated by the gas boilers can be reduced by implementing electric boilers. However, this will require McMaster to invest in peak shaving generators in order to participate as a Class A. An additional benefit of investing in peak shaving generators is that there will be extra capacity in the emergency generators for future expansion, which eliminates the need for a separate investment in an additional emergency generator at ET Clarke.

Currently, there are different ways to implement the peak shavers, each with its distinct financial implications. These will be thoroughly investigated, and a comprehensive proposal brought forward through governance in the fall of 2020 for potential approval.

***Solar Panels (Electricity)***

A solar panel farm produces sustainable renewable energy. This design works by photovoltaic cells/panels that absorb the energy from the sun and convert it to electricity via solar inverters.

McMaster is through the planning stages of designing and constructing a multi-level parking lot in Lot K. This provides the opportunity for a solar panel array on this structure's roof. A feasibility study was conducted by a consultant to assess the viability of integrating a solar panel farm/array on this proposed multi-level parking structure. It was determined that this solar roof could yield approximately 400 kW of power, with a construction cost of approximately $1.09 million.

The cost savings for the solar roof originate from two sources:

1. With McMaster potentially being a Class A participant in the future, McMaster will be able to participate in the ICI program. McMaster can save approximately $550K per MW when chasing the 5 top peaks as discussed in previous sections. If a battery storage system was implemented in conjunction with the solar panel farm/array, McMaster is able to utilize the electricity generated through the solar panels and offset the electricity taken from the grid by 400 kW during peak hours, resulting in potential savings of around **$220K**. Implementing a battery storage system in Parking Lot K will require physical space and additional electrical infrastructure. It will add approximately $2 million in cost to the project.
2. During non-peak hours, the savings can be realized by offsetting the power taken from the grid during the day. The savings from the daily operation is approximately **$70,000 annually**.

***Capital Cost: $1.09 million (Solar Panel Array) + $2 million (Battery Storage system – BESS)***
***Annual Savings $290K***
***Annual Electricity Savings: 400 kW (approx. 1.5 million kWh)***
***Payback:  11 years***
***Annual GHG Avoidance: 0 tonnes of CO2***

### Demand Control Ventilation – MUMC

There are many opportunities at MUMC for energy reduction. Demand control ventilation across labs and offices offers significant energy savings, and the University has implemented this in various locations on campus. A payback analysis is shown below (also summarized in Table 10). The University would need to do this project in coordination with Hamilton Health Sciences, who maintains the building per the current lease.

***Capital Cost: $850K***
***Annual Savings $100K***
***Annual Gas Savings: 31,334 m3***
***Payback: 7 years***
***Annual GHG Avoidance: 59 metric tonnes of CO2***

### Metering Upgrades Project

With an aging campus infrastructure, many of the existing meters are outdated and difficult to service. This project will look at upgrading old meters (chilled water and steam mostly). It is estimated that the project will cost approximately $250K (equipment and install). Upgrading the existing meters will help in better monitoring and tracking of Utility services, which will facilitate verification measures for the EMP plan.

### Irrigation Control System / Water Monitoring System

There are currently 28 irrigation systems on campus that the McMaster Grounds maintains and operates. Ninety percent of the irrigation systems are operated based on a schedule, which is not the most efficient way to operate. With advancement in control systems, today's irrigation technology allows for a demand response operation whereby the water monitoring system will track weather data and make adjustments to the irrigation demand. For instance, during days when there is precipitation, the water monitoring system will close the valves to the sprinkler system to conserve water. The water monitoring system also tracks the integrity of the irrigation lines/heads by actively monitoring any pressure drops caused by leaks or damaged sprinkler heads.

As a test case, the ten-acre field was used to determine the potential water savings from retrofitting a water monitoring to an existing irrigation system. There are 15 zones in this area and the test results were very positive. Savings targets are being developed. **With 15 zones, the total water consumption is around 3,839,616 million gallons per year (14,547 m3/year).**

**Rainwater Harvesting**

Rainwater harvesting involves harvesting rainwater via a water collection system; rooftops are the most viable location for collection to avoid water contamination by ground elements. Currently, McMaster has a number of rainwater collectors spread across campus (DBAC, IWC, JHE, ETB, etc.). There are already cistern tanks in place to take advantage of this. A capital investment would have to be made to install new pipelines and pumps to extract rainwater from the cisterns and to be used for irrigation. This project is being researched.

**Campus City Water Audit**

This project involves identifying all sources of water leaks, such as taps, pump seals, and once-through cooling systems. Once the campus is audited, the amount of water loss for each is identified and repairs are prioritized accordingly. This involves hiring two summer students to audit the campus and to complete a follow-up inspection. The expected savings are based on the industrial savings of 5%. Cost of repairs is to be determined based on the results of the initial audit.

**Wastewater Abatement Program**

Participation in this program will allow the University to reduce their water cost by diverting a minimum of 25% of the purchased potable water from the sewer works. Examples of diverted water includes ground irrigation, evaporative water from cooling towers, etc.

There are potential savings in pursuing this program as a high volume of water is diverted from the sewer works by the cooling towers and water irrigation. The City of Hamilton will have to be engaged to determine if McMaster will qualify for this program.

| *Proposed Projects* | *Target Completion Date* | *Cost ($)* | *Energy Incent.* | *Annual Gas Savings (m3)* | *Annual Electricity Savings (kWhr)* | *Annual Water Savings (m3)* | *Annual Savings* | *Simple Payback* | *Funding Source* | *GHG Emissions Reduction (tonnes of CO2e)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Steam Trap Replacement** | 2021 | $1,050,000 | $50,000 | 33,557 | 0 | 0 | $7,382 | > 20 | D.M. | 63 |
| **Window Replacements (various)** | 2022 | $7,615,000 | $0 | 28,854 | 15,865 | 0 | $7,646 | > 20 | D.M. | 54 |
| **Variable Speed Pumping** | 2021 | $200,000 | $0 | 0 | 48,000 | 0 | $5,237 | > 20 | D.M. | 0 |
| **Demand Control Vent (Campus Wide)** | 2025 | $14,300,000 | $2,900,000 | 9,436,400 | 19,189,000 | 0 | $780,000 | 15 | EMP | 13,789 |
| **Electric Boiler (40,000 lbs/hr)** | 2022 | $4,000,000 | $0 | 0 | 0 | 0 | $0 | N/A | MAC Loan | 9,531 |
| **Solar Panels (Lot K)** | 2022 | $3,090,000 | TBD | 0 | 1,460,000 | 0 | $290,000 | 11 | EMP | 0 |
| **Metering Upgrades** | 2021 | $250,000 | TBD | 0 | 0 | 0 | $0 | N/A | D.M. | 0 |
| **Irrigation Control/Water Monitoring** | 2020 | $6,500 | $0 | 0 | 0 | 7,274 | $24,700 | < 1 year | EMP | 0 |
| **Rainwater Harvesting** | 2020 | $23,000 | $0 | 0 | 0 | 648 | $2,400 | 10 | EMP | 0 |
| **Campus City Water Audit** | 2020 | TBD | TBD | 0 | 0 | 31,000 | $105,000 | <1 year | EMP | 0 |
| **Wastewater Abatement Program** | 2020 | TBD | TBD | 0 | 0 | TBD | TBD | TBD | EMP | 0 |
| **MUMC – Demand Control Ventilation** | 2021 | $850,000 | $100,000 | 31,334 | 581,808 | 0 | $102,000 | 7 | EMP | 59 |
| ***Total*** | | ***$31,384,500*** | ***$3,050,000*** | ***9,530,145*** | ***21,294,673*** | ***38,922*** | ***$1,324,365*** | | | ***23,497*** |
| ***EMP Investments*** | | ***$18,269,500*** | ***$3,000,000*** | ***9,467,734*** | ***21,230,808*** | ***38,922*** | ***$1,304,100*** | | | ***13,848*** |

***Table 7: Proposed Projects Summary***

***Table 8: EMP Projects & Sustainable Development Goals***

# Energy Action Plan Conclusion

This energy action plan extends to 2025 and includes 12 essential projects with a total anticipated Energy investment $18.3M. This will bring the total investment to **$44,491,944** by 2025. Table 9 below summarizes the EMP investment breakdown from the past projects, current projects and future projects.

| Project | EMP Investment |
|---|---|
| **Completed Projects** | $24,910,444 |
| **Ongoing Projects** | $1,312,000 |
| **Proposed Projects** | $18,269,500 |
| **Total (by 2025)** | **$44,491,944** |

***Table 9: EMP Investment up to 2025***

With the current and ongoing projects, the GHG emission is targeted to be reduced by the following values. McMaster's annual carbon footprint of **41,334 tonnes of CO2 is projected to be reduced to an annual carbon footprint of 16,142 tonnes of CO2** from 2020 to 2025.

| Year | Annual GHG Emission Reductions (tonnes of CO2) |
|---|---|
| **2013 to 2020** | 1,695 |
| **2020 to 2025** | 23,497 |
| **Total** | **25,192** |

***Table 10: GHG reductions up to 2025***

EMP projects will be individually approved by the appropriate executives or governance process on the basis of a business case. The EMP progress will be tracked by comparing monthly and yearly utility and GHG intensities. Baseline, benchmarks, progress and targets met will be tracked and recorded. Annual reports will be developed in order to alert any stakeholders of any issues and milestones achieved. The hope is to raise awareness and maintain enthusiasm for sustainability and energy management initiatives.

To further its efforts to reduce campus GHG emissions, McMaster is in the process of hiring carbon management consultants to produce a net zero carbon strategy that will allow campus to be net-zero in the long-term.