FACILITY SERVICES

ENERGY MANAGEMENT PLAN

2023/2024

FACILITY SERVICES | McMaster University

A Message from the AVP

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

In alignment with McMaster University's strategic vision, Facility Services is making a positive impact on our world by focusing on sustainability. Across McMaster's campus, our utilities group is initiating projects that conserve energy and reduce greenhouse gas emissions.

Since 2013, we have completed over 23 energy-savings projects campus-wide, with four currently in progress and plans for another 8 to begin over the coming years.

This year, our team is taking the next step in the university's Net Zero Carbon Roadmap. As part of this journey, we have set goals to completely negate the amount of greenhouse gases produced by human activity on campus. The team continues to work to accelerate the timelines for delivering this goal.

I would like to thank our team members who collectively worked to create the University's Net Zero Carbon Roadmap, developing business cases for the various components of the strategy, including some of the projects detailed in this report. For example, the current peak shaver and electric boilers project that produces behind the meter power generation and offsets natural gas steam production on campus will reduce McMaster's carbon footprint by over 21% from 2024 onwards.

Once again, we have illustrated how our sustainable energy projects align with the United Nations Sustainable Development Goals (SDG's). Learn more about this on page 19.

I am extremely proud of the work that our staff have done to develop this year's Energy Management Plan as we 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 to 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 with the aim of creating a more sustainable campus environment.

McMaster aims to reduce its utility consumption and GHG emissions in accordance with the targets outlined in the Net Zero Carbon Roadmap (Net Zero Roadmap). This currently means a reduction of 75% in GHG emissions by 2030 and 90% by 2050. Electricity, and natural gas consumptions will be reduced to meet these goals through various energy and carbon reduction projects. Water consumption will remain at a reduction of 5% annually as per the targets established in the 2019/2020 EMP.

These significant reductions will be accomplished through the various projects proposed in this updated EMP plan with a total investment required of over **$75M** by 2030. McMaster currently emits **40,400 tonnes of CO2e** annually from its district steam system, cogeneration system, emergency generators and fleet vehicles. It is anticipated that McMaster's GHG emissions can be reduced to **15,049 tonnes of CO2e** annually by 2030 through the completed, ongoing, and proposed projects highlighted in this report. Future versions of the Energy Management Plan will focus on progress towards meeting these annual targets. McMaster will continue to reduce its usage of natural gas for steam production by implementing various measures (for example, electric boiler installation and demand control ventilation).

McMaster recognizes that the provincial electrical grid faces several key challenges relating to decarbonization. As the demand for power increases due to electrification, there is not enough renewable generation available to support growth. This would result in the province requiring more natural gas generation or heavily relying on electricity imported from neighboring provinces and/or the United States to meet demand. This will require innovative local solutions to ensure a net-positive impact on carbon emissions in Ontario.

With several governmental policy changes, McMaster is also faced with increasing pressure on all fronts to reduce its carbon emissions. The economics of the carbon tax and implementation of a clean electricity credit system poses several challenges with decarbonization projects, which requires innovation.

McMaster is currently looking into accelerating the net-zero plan. This entails a thorough examination of new technologies as well as balancing cost-effective solutions. It is anticipated that an updated plan will be available in the 2023/24 academic year.

The progress of the energy management plan will be based on existing baselines and benchmarks with other Universities, rooted from utility consumption data. 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.

The federal government has released two carbon funding streams in the first quarter of 2022. Several projects were submitted to take advantage of this opportunity. McMaster was successful and will be receiving approximately $2M from the federal government through the Decarbonization Incentive Program.

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

With the completion of the net-zero carbon roadmap and an accelerated net-zero plan on the horizon, the university aims to position its community in an everchanging global environment by continuing to meet the goals in its Energy Management Plan.

Energy Management Plan Framework

McMaster University Profile

Founded in 1887, McMaster University is home to 36,450 students, 994 faculty members and 13,783 staff (McMaster Factbook 2020/2021). 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 individuals 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/cooling, lighting and ventilation, thus increasing energy costs, even with lower occupancy.

Basis for the Plan

McMaster has adopted a triple-bottom-line decision approach when considering new capital projects, policies, and initiatives. This means evaluating each decision based on its environmental, social, and economic impacts. Due to the COVID-19 pandemic, and governmental policy changes in 2020/2021 (federal and provincial), McMaster must strategically position itself when adopting new energy projects and initiatives, to ensure that it benefits its diverse and innovative campus community.

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.

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 1 shows the IESO's Electricity Sector GHG Emissions, Historical and 20-year forecast. This means that energy projects which reduce direct carbon emissions resulting from burning of fossil fuels must ensure that the indirect emissions are accounted for in the strategy.

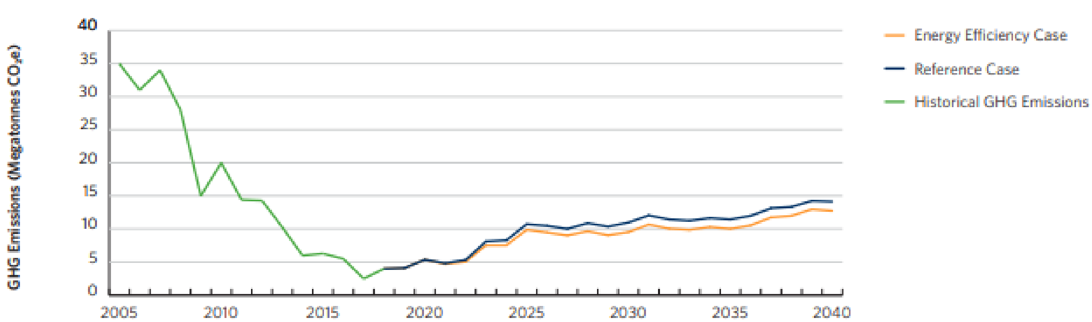

Figure 1: IESO Electricity Sector GHG Emissions, Historical and 20 year Forecast (Reference: IESO Annual Planning Outlook 2020)

This stresses the need for McMaster University to commit to further reducing its Green House Gas emissions. Figure 2 shows McMaster's current GHG emissions trend with no carbon reduction projects in place.

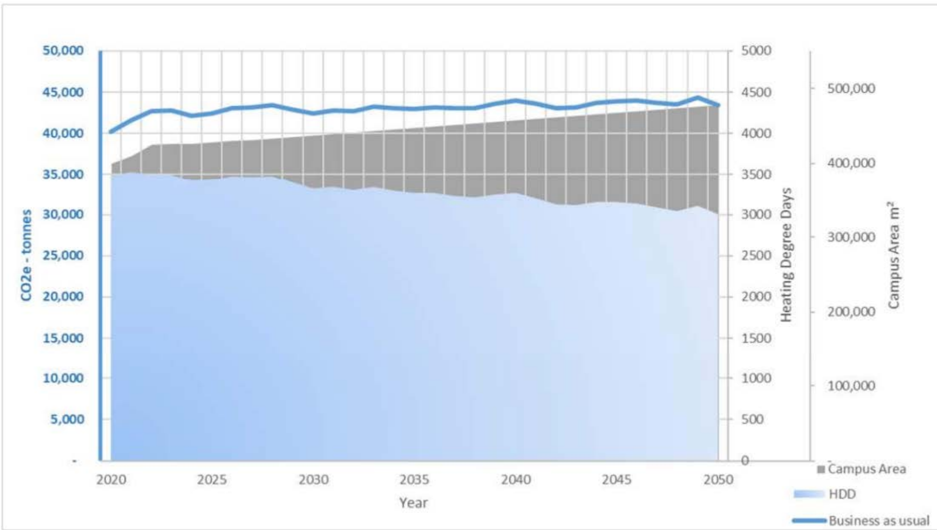

Figure 2: McMaster Baseline Emissions - Business as Usual [Source: Net Zero Carbon Roadmap]

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.

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 3), which drives the need for energy reduction projects.

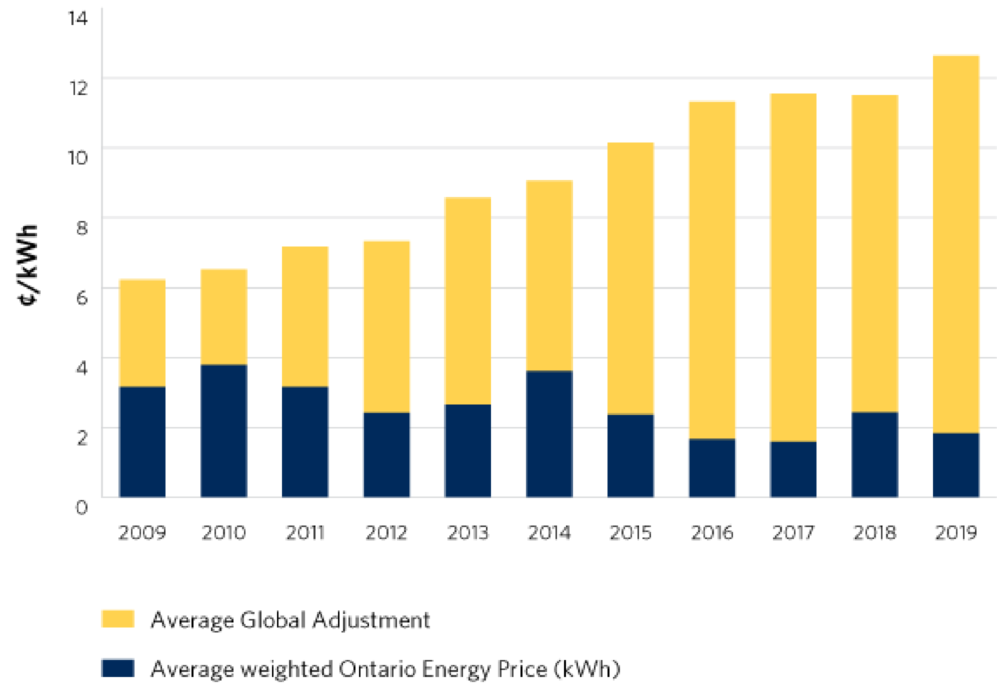

Figure 3: Hourly Energy Ontario Price Plus Average Global Adjustment Cost Graph (http://www.ieso.ca/Power-Data/Price-Overview/Global-Adjustment)

**** 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.

There have been several policy changes at both the federal and provincial level, affecting electricity and natural gas prices. McMaster must create a sound strategy to position itself for the next coming years, with the aim of maximizing carbon reduction and minimizing financial implications.

Social and Research Considerations

One of McMaster University's strategic goals is to develop a "distinctive, personalized, engaging, and sustainable student experience" (Source: McMaster Goals and Priorities, 2021).

This commitment suggests that one of the highest priorities of the university is to provide an enriching and transformative learning experience for all students. A part of this is 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, comfort and learning experience.** An effective energy management plan, and novel approaches to new building designs and refurbishments on campus can help to achieve this goal.

McMaster aims to support its academic faculties in delivering a personalized, engaging, and sustainable student experience by providing the utilities and infrastructure required to perform top notch teaching and 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 teaching and 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.

Governmental Policy Changes

There have been several changes in the federal and provincial policies regarding carbon and hydro pricing. Some of these changes are a direct result of the COVID-19 pandemic and Canada's commitment to the Paris Accord. A list of significant policy changes are listed below:

- **Increase in Federal Carbon Tax:** On December 2020, the Federal Government announced that it will increase the price on carbon from $10/tonne of CO2e to $15/tonne of CO2e after 2022. This announcement has affected the natural gas price model for the university.
- **New Federal Budget 2023**: The federal government has announced that it will offer a clean electricity investment tax credit worth $6.3 billion over four years and an additional $19.4 billion from 2028 to 2035 to completely transition Canada's electricity supply to green energy.
- **Implementation of Bill C-12**: Canada has officially passed the *Canadian Net-Zero Emissions Accountability Act* to improve the transparency and consistency around climate action.
- **Clean Electricity Credits**: Under O.Reg. 39/23, the regulations for CECs and registry were published. This entails a system to purchase and retire credits, which are also known as environmental attributes from power generation sources.

Clean Electricity Credit System: Impact to McMaster's Net-Zero Plan

With a market for environmental attributes, organizations have the option to buy CECs, which allows an organization the right to purchase and claim the power generated from Ontario's renewable sources. For instance, these credits certify that 1 MWh of clean energy has been generated and retired on behalf of an organization. As these credits are sold and retired, no other organization would be able to claim the clean energy from the Ontario grid. This poses several issues with electrification projects as they rely on clean energy. If that clean energy has been claimed and retired, the carbon intensity of the grid would increase as a result as those renewable assets would no longer be available.

This greatly impacts business cases for decarbonization projects as the assumed grid intensity for Ontario would not be reflective of the actual grid emissions resulting from the purchase of Clean Electricity Credits. This would have an impact on operational budgets as organizations would need to purchase CECs to ensure that their facility uses electricity generated from renewable sources.

IESO Outlook and Projections

The IESO published several reports outlining key studies focusing on demand growth and reliability of the electrical grid. The IESO has also undertaken a "Pathways to Decarbonization" study to determine the most effective way to decarbonize the electricity grid, given the reliance on natural gas as a flexible and response source type.

There are several key highlights from the various studies, which are outlined below:

- It was determined that without a limited amount of new natural gas generation, the IESO would be reliant on emergency actions such as conservation appeals and rotating blackouts to stabilize the grid.
- Natural Gas Generation provides flexibility by operating to meet changes in demand and can operate in extreme weather conditions.
- Due to the increasing demand in electricity as a result of decarbonization projects (electrification), the effort required to achieve net-zero by 2050 is daunting. Achieving a fully decarbonized grid by 2050 will require a system twice the current size, which will involve an investment of approximately $400 billion, with a need for emerging technologies to be developed.

Figure 5 highlights the gap between electricity demand and power generation supply in Ontario in the next 20 years, with the assumption that natural gas and current non-hydro renewable contracts expire.

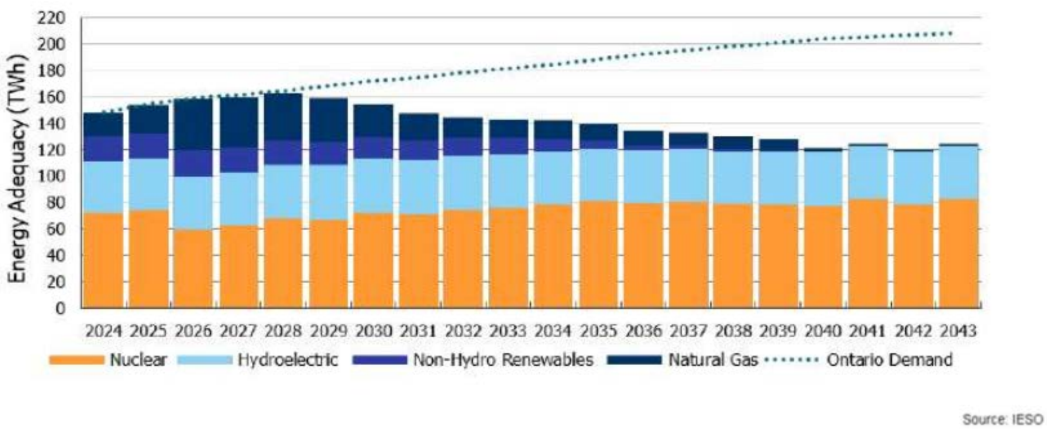

Figure 4: Energy Demand vs. Energy Supply in Ontario (Source: IESO)

If Ontario extends its current non-hydro renewables and Natural Gas generation, the gap between supply and demand reduces as shown in Figure 6 below.

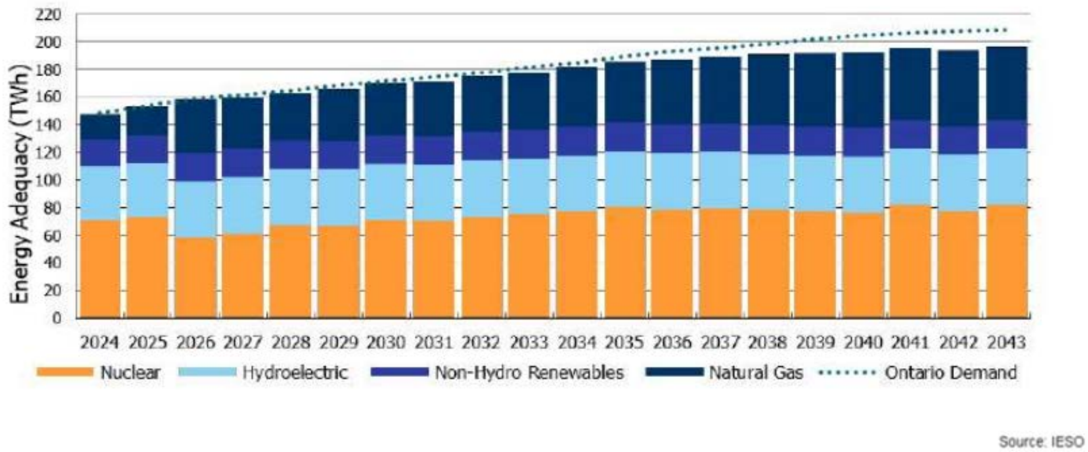

Figure 5: Energy Demand vs Energy Supply in Ontario with Natural Gas Generation (Source: IESO)

Without the extension of the current non-hydro renewables and Natural Gas generation, the supply would be filled by electricity import from neighbouring provinces/US states, as shown in Figure 7 below. There is an increase chance that the electricity that is imported to Ontario is produced from coal plants from neighbouring US states, such as Michigan, Minnesota, etc.

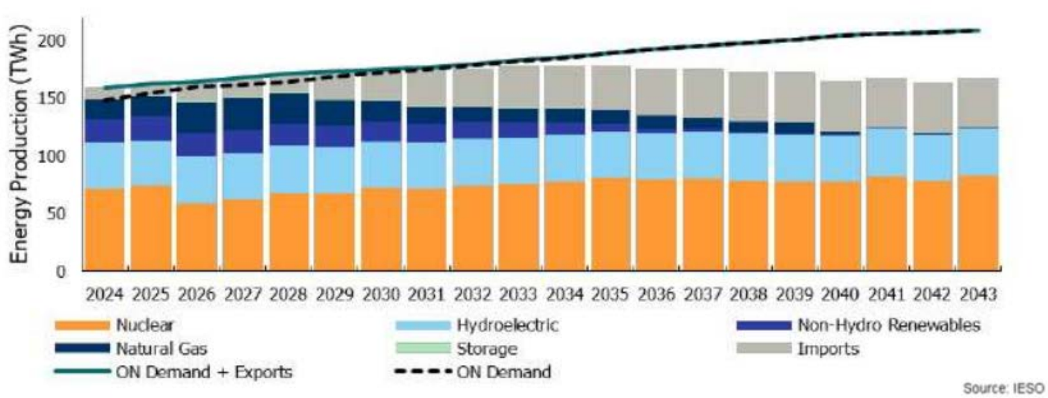

Figure 6: Energy Demand vs Energy Supply in Onatrio with Imports (Source: IESO)

Impacts to McMaster University Decarbonization Projects
Due to the challenges that the provincial electricity grid faces, McMaster is exploring different technologies to reduce its reliance on the provincial grid. With Ontario poised to use more natural gas generators to meet the projected electrical demands, the emissions factor of the Ontario grid will worsen over time. Any electrification projects would need to carefully consider Scope 2 emissions, in order to have a net positive impact on the environment.

Carbon Funding Streams

There were several opportunities announced by the Environment and Climate Change Canada (ECCC) regarding carbon funding initiatives that McMaster submitted applications for.

1. Low Carbon Economy Challenge – Champions Stream: This program will provide over $200 million in funding and will support the implementation of the Pan-Canadian Framework with the intent to promote clean growth and reduction of GHG emissions. The Champions stream focuses on projects with a direct reduction on GHG emissions which will contribute to Canada’s 2030 emissions reduction target. Eligible projects must have a Technology Readiness Level (TRL) scale of 8 or higher.

   McMaster submitted an expression of interest for the following projects:
   - Electric Boiler
   - Demand Control Ventilation (Lab systems)
   - Engineering Technology Building Cooling modifications.
   - Life Science Building Greenhouse – Heat Pump

   Detailed information about each project can be found under the projects section of the Energy Action Plan. Funding was not received for these initiatives.

2. Decarbonization Incentive Program (DIP) – Output Based Pricing System: This program is intended to promote decarbonisation and support Canada`s greenhouse gas (GHG) emissions reduction goals. Projects can receive funding amounts from $500,000 to $10 million with a cost-share arrangement.

McMaster was successful in its application for the Decarbonization Incentive Program (DIP) – Output Based Pricing System. The Government of Canada will contribute 40% of the cost of the electric boilers project, which amounts to about $2,087,600 in funding.

Net-Zero Carbon Road Map

McMaster's continuous commitment to sustainability and carbon reduction has led to the development of a Net Zero Carbon Roadmap. This report was developed by Footprint, an external consultant, which looked at McMaster's current operations and provided several recommendations to achieve net-zero by 2050. The comprehensive report is a culmination of McMaster's past project successes and progressive outlook towards the future. The report highlights the following key recommendations.

- Energy Conservations Measures: This focuses on implementing energy saving technologies, such as demand control ventilation (DCV), Energy and Heat Recovery, and Optimization of Building Automation Systems. These measures have been implemented in past projects and will be continually pursued in future renovation and infrastructure upgrades.
- Reduced Cogeneration Operation: The cogeneration plant comprises about 30% to 40% of McMaster's greenhouse gas emissions. Reducing its yearly operation will significantly reduce McMaster's campus carbon emissions.
- Electric Boiler Installation: McMaster's district steam system provides the heating for all the buildings on campus. With an aging infrastructure, the renewal of the steam system is critical to ensure campus operation resiliency. Instead of investing in traditional gas fired boilers, McMaster will invest in electric boilers to provide part of the campus steam requirements.
- Installation of Natural Gas Peak Shaving Generators: To minimize the increase in electricity costs by the electrification of the heating systems on campus, it was recommended to install 10 MW of peak shaving generators and participate in the Industrial Conservation Initiative (ICI) program by the IESO. This program will allow McMaster to realize cost savings from the Global Adjustment portion of its electricity bill.
- Ground Source Heat Pump – Closed Loop: A heat pump system uses the stable ground temperature as the source for building heating and heat sink for cooling. With a closed loop system, condenser water is circulated through several u-tube wells drilled to a certain depth. Through the circulation of the condenser water, heat is exchanged between the water medium and the ground.
- Waste-Water Heat Recovery: This solution utilizes the waste-water from buildings on campus as either a heat source or heat sink depending on the energy production requirements. The system uses heat exchangers and heat pumps to extract or expel heat from or to the waste-water stream. The conditioned water is then recirculated through a condenser water network using a set of heat pumps.
- Reactor Heat Recovery: The nuclear reactor on campus expels heat as part of the reaction process. This solution harnesses this waste heat for campus heating. This is done via a heat exchange system where heat from the reactor is recovered and transferred to a heating loop which is circulated in various buildings. This can be tied in into an overall water condenser loop serving the proposed ground source heat pump system and waste-water heat recovery systems.

Net-Zero Carbon Road Map (Update)

McMaster is currently undertaking a Geothermal Heat Pump Master Plan, which will provide a comprehensive plan to transition campus from its district energy system to a geothermal low temperature water loop. The master plan encompasses a detailed look of individual buildings and all the required HVAC system interventions to transition from steam systems to low temperature water systems. To determine the thermal capacity of the ground across campus, McMaster has engaged a contractor to perform borehole testing. Each location was carefully selected by the consultant to capture a wide array of ground conditions. A map of the borehole locations is shown in Figure 8 below.

Figure 7: Bore Hole Testing Locations

The bore hole testing will provide the thermal capacity of the ground to allow adequate sizing of wellfields across campus. The master plan is expected to be completed by end of summer 2023.

Once completed, McMaster will engage Footprint to develop an accelerated net-zero plan based on the results of the Geothermal Master Plan.

McMaster Net-Zero Carbon Roadmap Steering Committee

To accelerate McMaster's net-zero plan, several strategic projects would need to be completed in an accelerated timeline, which will require community consultation and a sound financial strategy. To facilitate these conversations, Facility Services will be establishing a Net-Zero Carbon Roadmap Steering Committee, comprised of key staff from Facility Services alongside members from other groups on campus who have a vested interest in McMaster's carbon reduction efforts. This committee would focus on the following:

- Review, on an annual basis, the contents of the Net Zero Carbon Roadmap
- Determine the performance of McMaster as compared to the Net Zero Carbon Roadmap's established goals and objectives
- Review any associated feasibility studies/strategies that would help implement solutions to reduce carbon emissions from corporate activities
- Update the Net Zero Carbon Roadmap with the most appropriate solutions/alternatives that are technologically, financially and socially feasible for implementation
- Prepare a business case for each identified solution/alternative being proposed for implementation, to support the request for internal/external funding and grants
- Identify the best change management strategy required to measure and gauge the level of interest and commitment from the overall McMaster community in following the identified solutions/alternatives

Alternative Paths to Net-Zero (Carbon Capture)

McMaster has engaged a consultant to look at carbon capture technology for natural gas equipment at the central plant (ET Clarke). The intent is for the Carbon Capture Units (CCUs) to be retrofitted to the existing gas plants, such as the natural gas boilers and Cogeneration unit, allowing the central plant to continue its operations while maintaining operational resiliency. The captured carbon can be stored in nearby storage areas in Southwestern Ontario or utilized to produce CO2 products for existing markets. As such, McMaster is also in discussion with utility companies for potential storage and re-use of the captured carbon. There are three major pathways for utilizing captured carbon, which includes mineralization, greenhouse gassing, and e-fuels.

There are several advantages with utilizing carbon capture technology:

- Less expensive than geothermal heat pump system
- No changes in central plant equipment
- No reliance on the provincial electrical grid, which can be beneficial especially with the current trajectory of electricity mix in Ontario.

There are also disadvantages associated with carbon capture technology:

- Conventional systems are space intensive. Modular systems are available but are cost prohibitive.
- Storage and transportation of stored carbon.
- Regulatory changes regarding CO2 utilization have not been approved, which is directly tied to carbon tax.

Alongside carbon capture, McMaster is also exploring blending hydrogen in its natural gas fired equipment. This will effectively reduce/eliminate the carbon emissions from the gas fired equipment depending on the amount of hydrogen that is used.

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 2021 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 decarbonization 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.

Electricity/Hydro

With covid precautions still in place which emphasized high ventilation rates within buildings, and remote and hybrid work options for staff, the consumption has relatively been similar to 2021-2022 academic year. Refer to Figure 9 for McMaster's monthly electrical profile for each academic year.

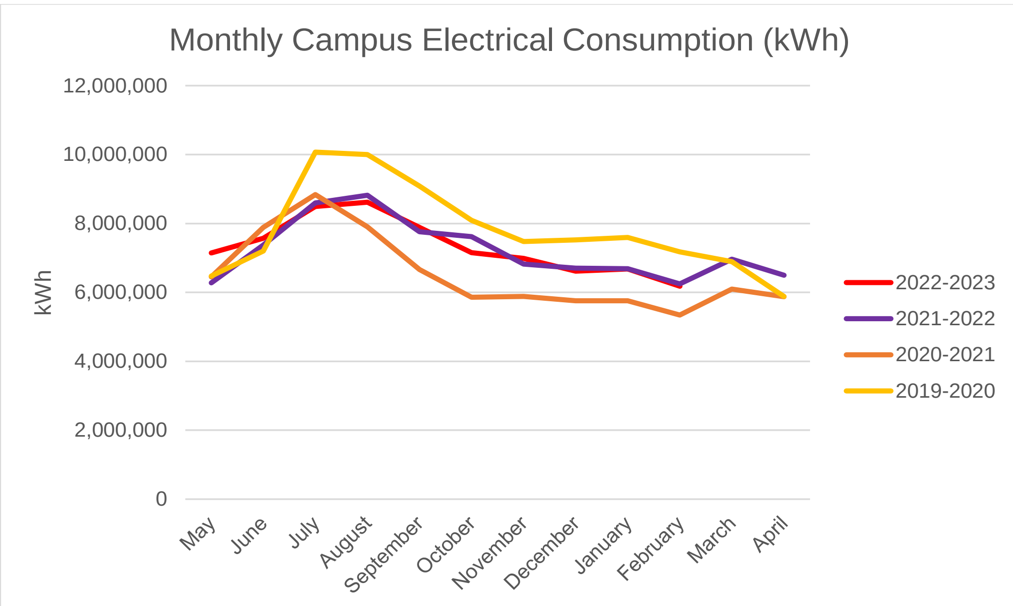

Figure 8: McMaster Campus Electricity Consumption

Steam

Steam production for 2022-2023 academic year is greater than the 2021-2022 academic year. This is attributed to McMaster campus providing steam to McMaster University Medical Centre (MUMC). Hamilton Health Sciences (HHS) has undergone upgrades on their cogeneration facility at the MUMC site, which severely reduced their on-site steam production. Refer to Figure 10 for McMaster's monthly steam production profile.

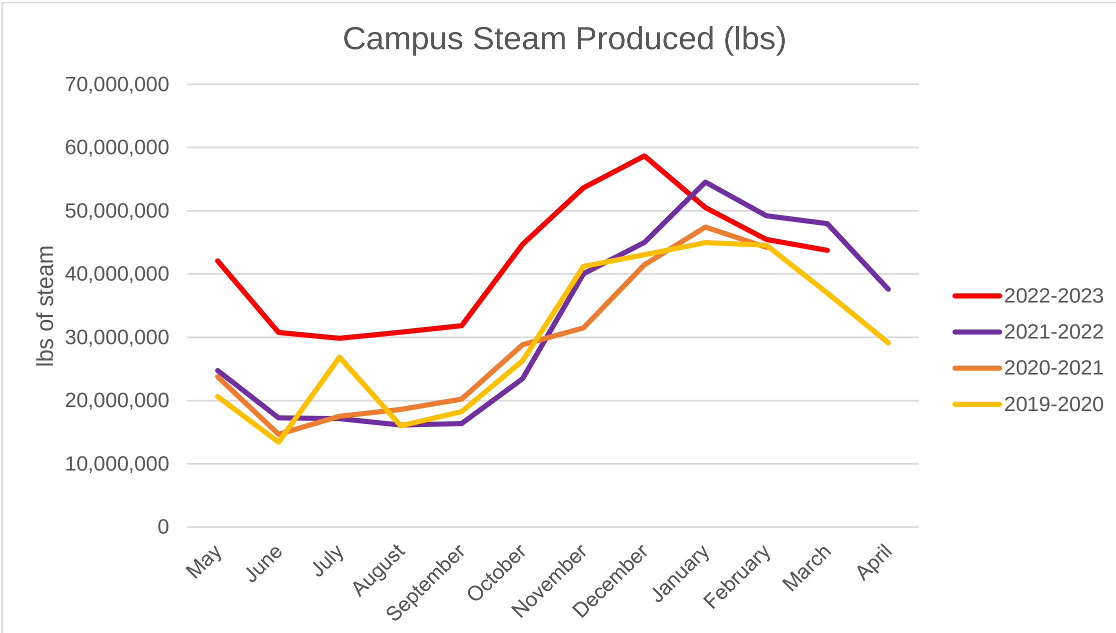

Figure 9: McMaster Campus Steam Production Profile

Steam consumption during the spring and fall season are dependent on ambient conditions. Due to the ongoing cogeneration system upgrades at MUMC, HHS has heavily relied on McMaster central plant in providing steam to its facility. During the cooling season, HHS operates its absorption chillers, which require steam to operate. This has increased the steam demand at central plant during the 2022-2023 cooling season.

Natural Gas

Natural gas consumption is predominantly influenced by steam production from Boilers 3/5 and power/steam production from the Cogeneration Plant. Refer to Figure 11 for McMaster's monthly natural gas consumption profile. In 2022-2023 academic year, the cogeneration plant saw a reduction in operating hours to reduce campus GHG emissions. However, this was offset by the temporary steam demands of MUMC resulting from the upgrades on their cogeneration facility; resulting in an increased in usage of Boilers 3 and 5. Figure 12 and Figure 13 highlights the campus boilers and cogeneration gas consumption which supports the above points.

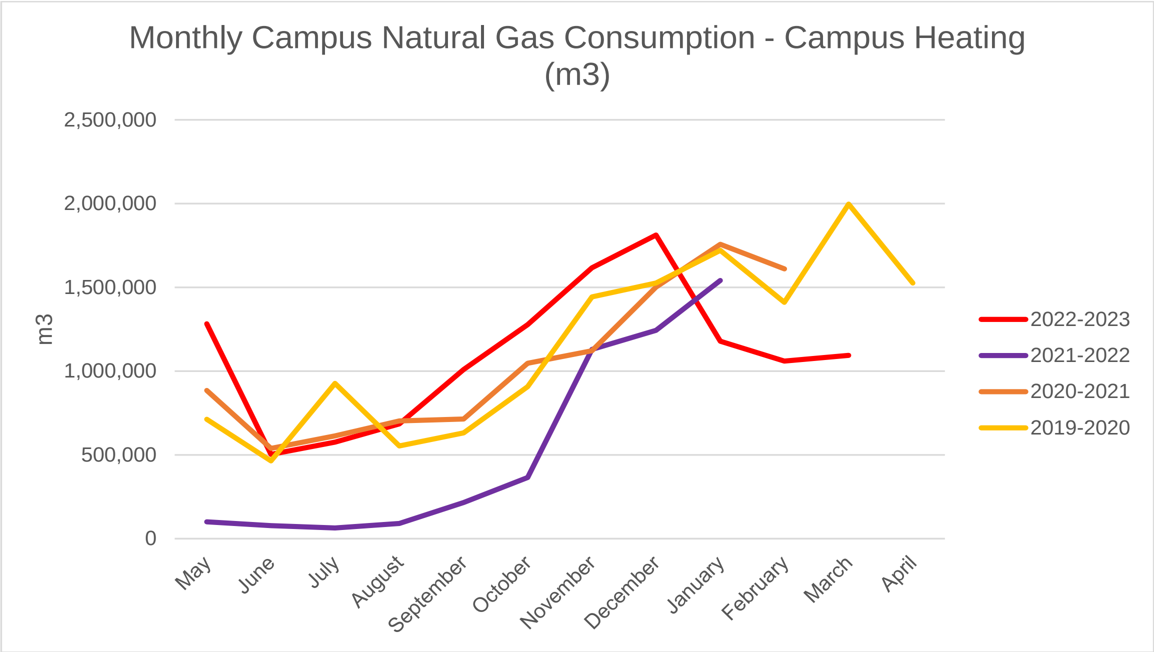

Figure 10: McMaster Campus Natural Gas Consumption - Boilers and CHP

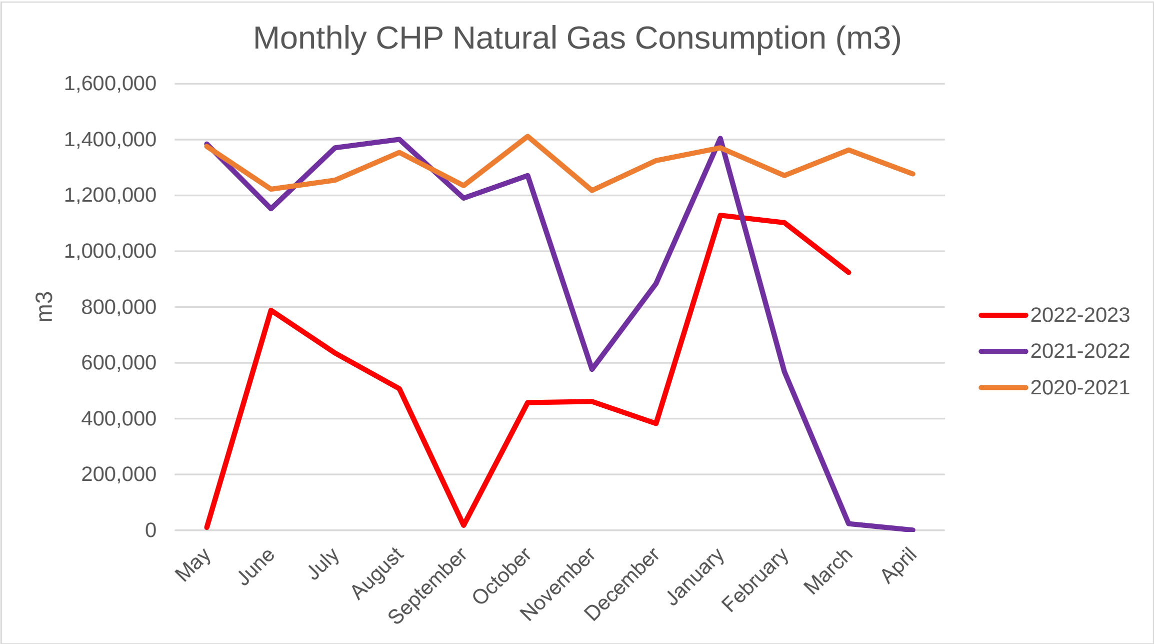

Figure 11: McMaster Monthly Cogeneration (CHP) Natural Gas Consumption (m3)

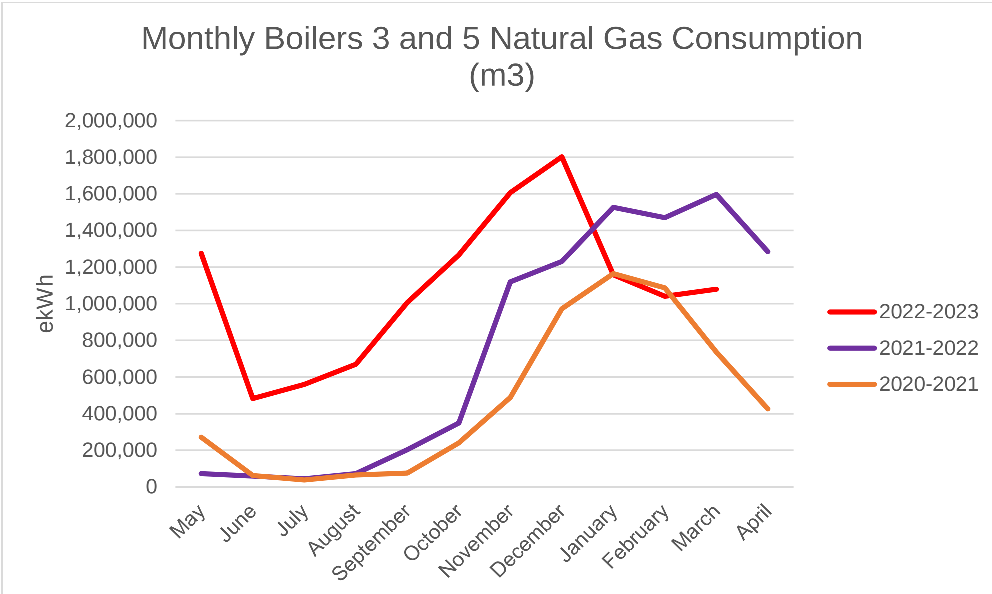

Figure 12: McMaster Monthly Boilers 3 and 5 Natural Gas Consumption (m3)

Domestic Water

The domestic water usage for 2022-2023 has decreased in comparison from the previous year.

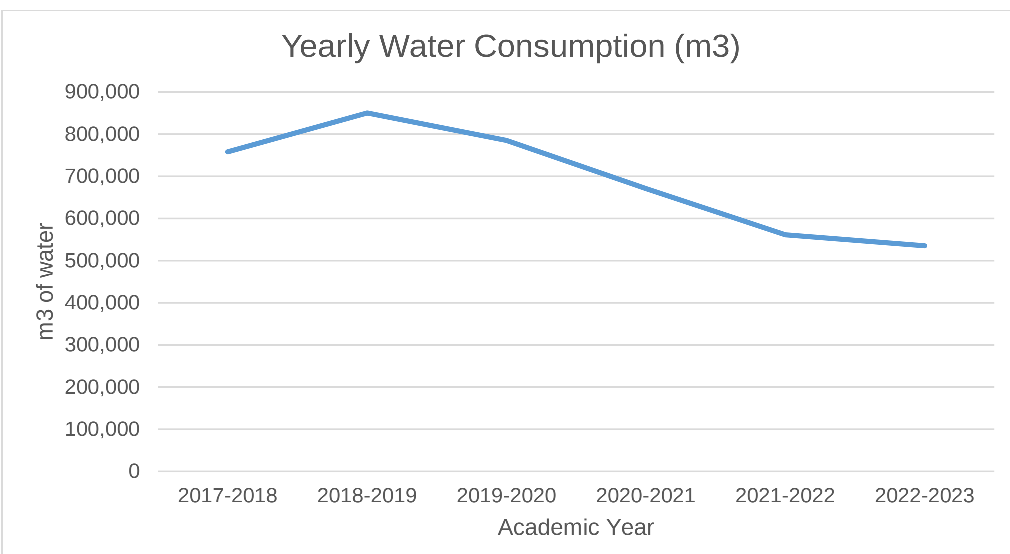

Figure 13: McMaster Domestic Water Consumption

Utility Intensities

There has not been an increase in net building area on campus between 2021-2022 and 2022-2023 academic years. The change in utility consumption is reflected on the utility intensity graphs, as shown in Figure 15, 16 and 17.

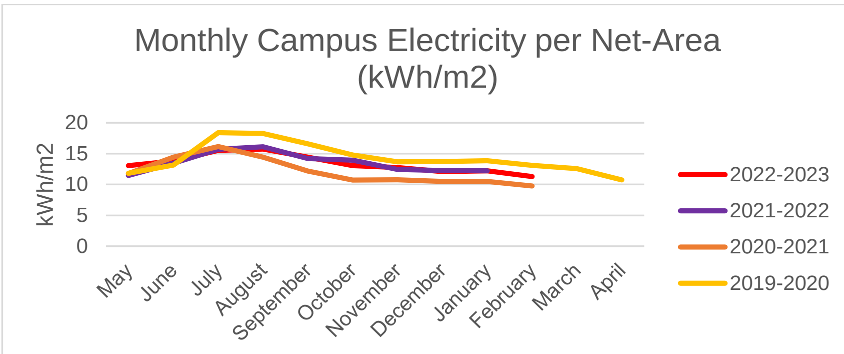

Figure 14: Monthly Campus Electricity per Net-Area (kWh/m2)

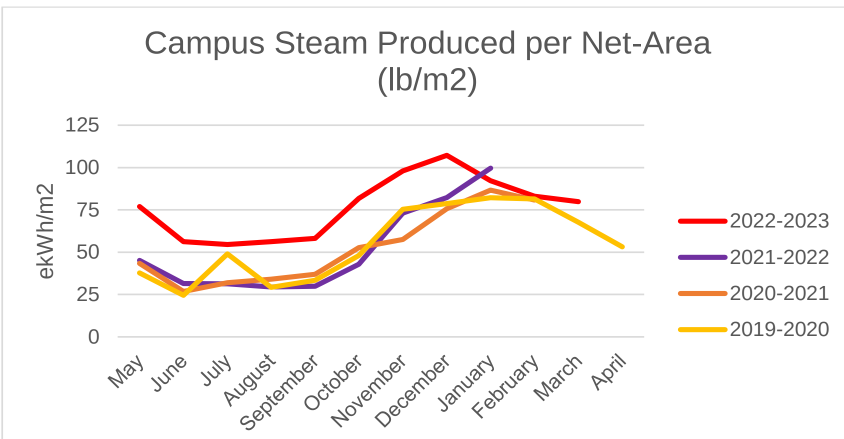

Figure 15: Monthly Steam Produced per Net-Area (lb of steam/m2)

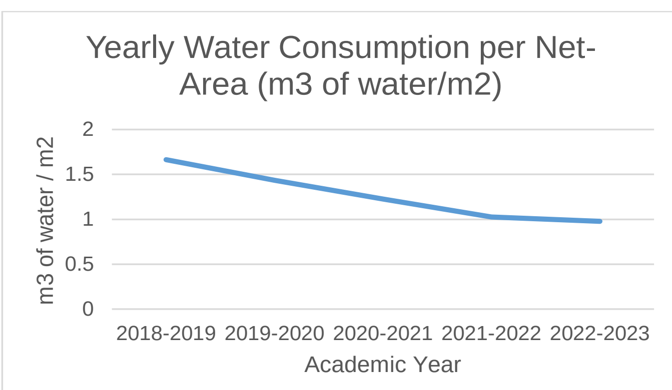

Figure 16: Yearly Water Consumption per Net-Area (m3 of water / m2)

McMaster GHG Emissions

As part of the Net Zero Carbon Roadmap, an energy model was created to determine the most energy and carbon intensive buildings. Figures 18 and 19 shows the campus models created by Footprint. These models will help McMaster University in prioritizing energy projects in the future.

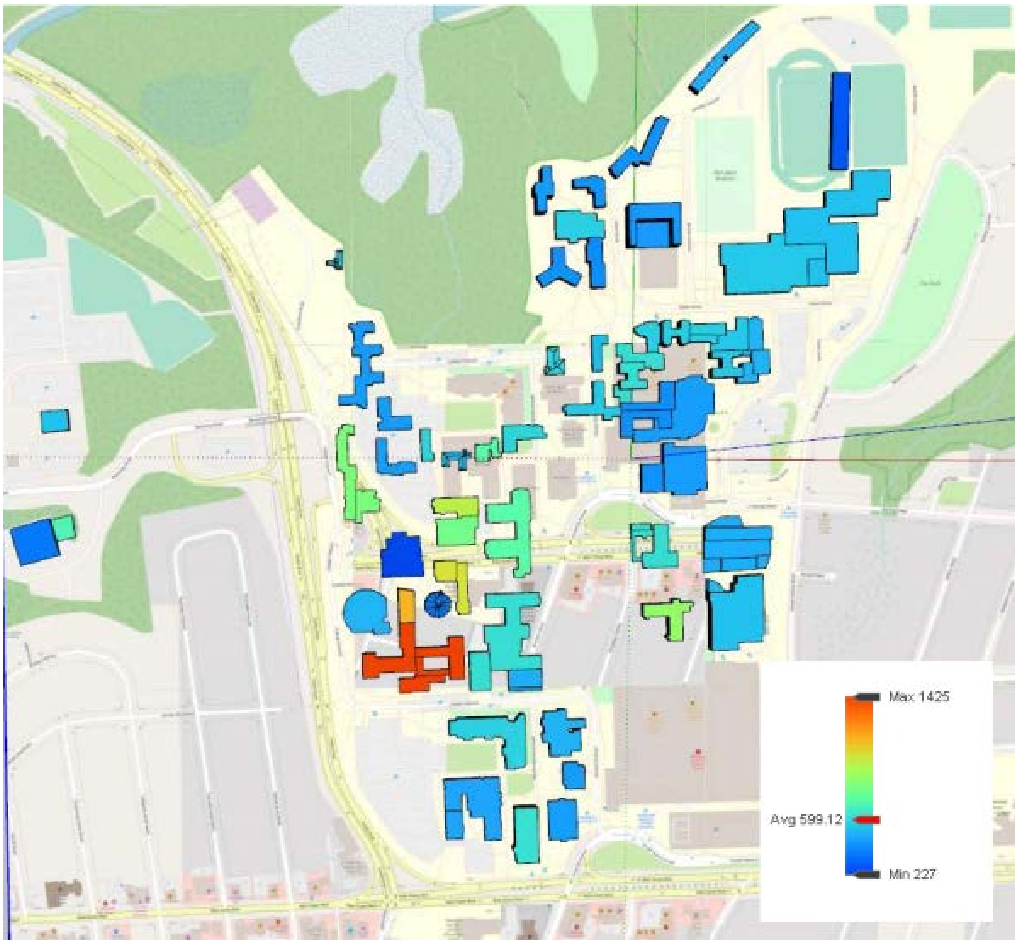

Figure 17: Campus Energy Model [Source: McMaster Net-Zero Carbon Roadmap Report]

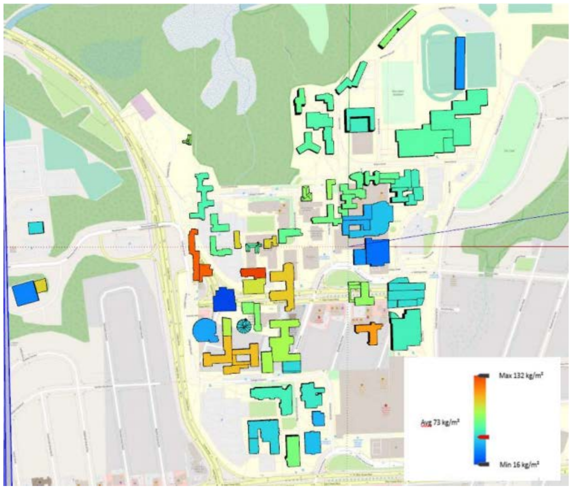

Figure 18: Campus Carbon Emissions Model [Source: McMaster Net-Zero Carbon Roadmap Report]

Based on the energy model in Figure 18, A.N. Bourns Building (Building 25) is one of the highest energy consuming buildings on campus (red/orange colour), followed by Tandem Accelerator (Bldg 32), and General Science Building (Bldg 22), which are yellow in colour. Table 1 summarizes the highest energy consuming buildings on campus and associated action plan to reduce energy consumption.

Building	Energy Consumption (red/orange/yellow)	Action Plan
AN Bourns Building (Bldg 25)	Red/Orange	Recent renovation in ABB has installed Demand Control Ventilation in the Undergraduate Chemistry Wing. There are several other laboratories that could be retrofitted with a DCV system. This will be part of the campus wide DCV project.
Burke Science Building (Bldg 11)	Yellow	Lab systems to be retrofitted with demand control ventilation as part of campus wide DCV project.
Tandem Accelerator (Bldg 32)	Yellow	Lab systems to be retrofitted with demand control ventilation as part of campus wide DCV project.

Table 1: Highest Energy Consuming buildings

Currently, McMaster emits approximately 40,400 tonnes of CO2e annually. 95% of the emissions are direct emissions stemming from the district steam, cogeneration plant, emergency generators and fleet vehicles. The remaining 5% are indirect emissions from electricity imported from the grid. Figure 20 highlights the amount of carbon emissions resulting from the direct use of natural gas and grid electricity consumption.

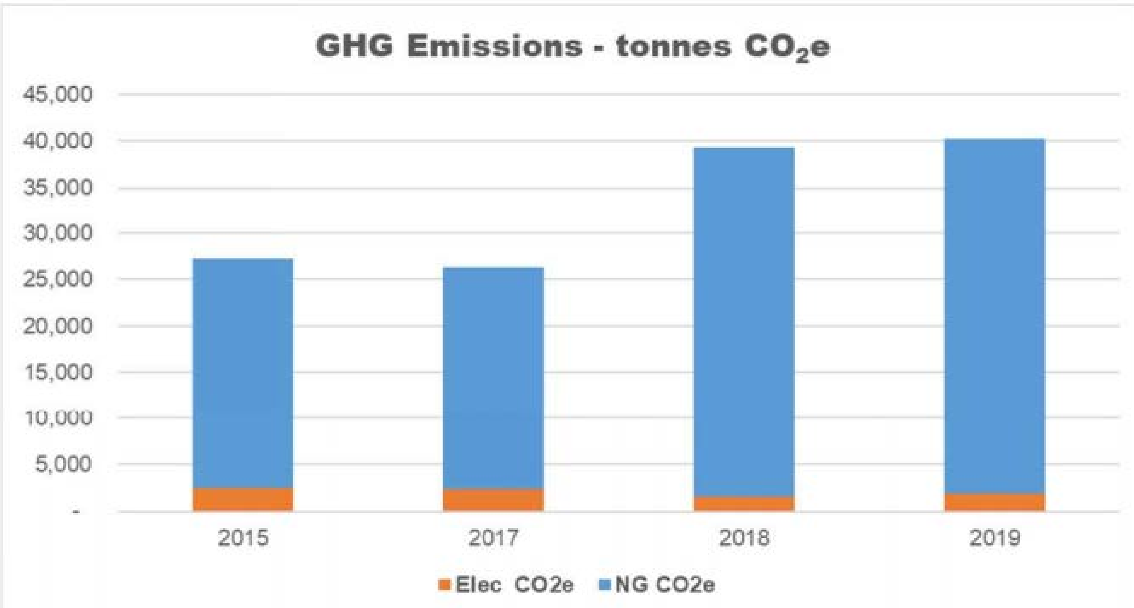

Figure 19: McMaster GHG Emissions [Source: McMaster Net-Zero Carbon Roadmap Report]

This highlights the need for McMaster to actively reduce its carbon emissions through various carbon reduction projects. The suggested carbon pathway to 2050 is shown in Figure 21.

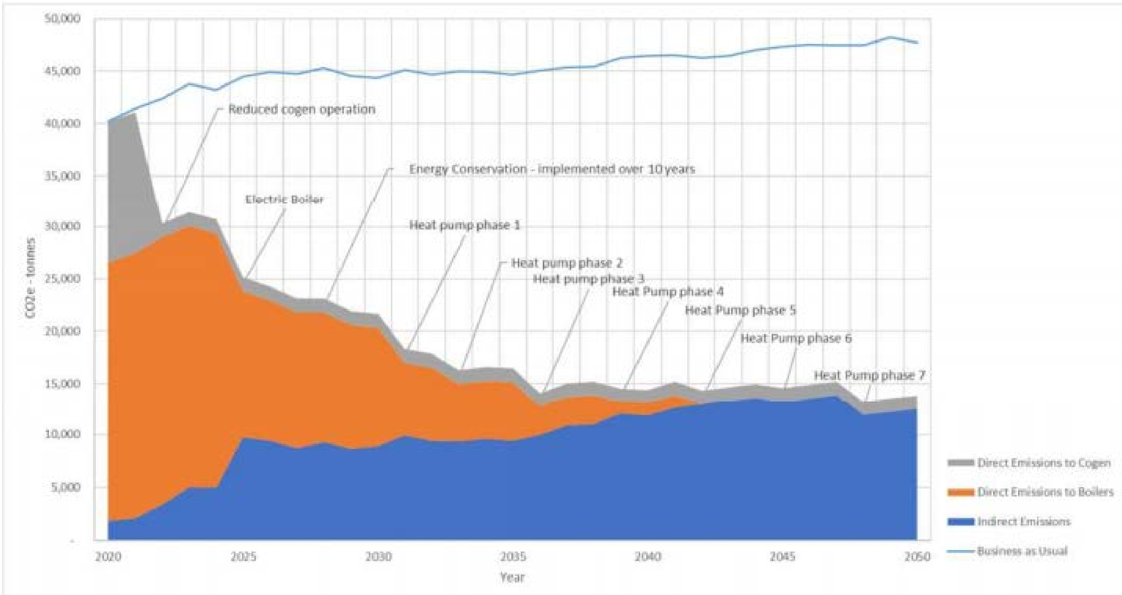

Figure 20: McMaster Carbon Reduction Path [Source: McMaster Net-Zero Carbon Roadmap Report]

The main theme in McMaster's carbon road map is the electrification of the heating systems on campus. McMaster's district heating system utilizes high energy steam and this has proven to be cost effective throughout McMaster's history due to the low cost of natural gas. However, with the yearly increase in carbon tax, the true cost to operate the district system becomes significant. As such, McMaster is pursuing the installation of two electric boilers to renew its aging steam infrastructure while also avoiding future carbon cost.

To operate the electric boilers without an increase in electricity cost, McMaster intends to participate in the ICI program as a Class A customer. This will be accomplished by installing 10 MW of peak shaving at the NF 91 transformer lot. As a Class A customer, McMaster will be able to reduce the Global Adjustment portion of its annual electricity cost, making it financially feasible to operate the electric boilers. A Utility Cost impact graph shown in Figure 22, highlights what it would cost McMaster on an annual basis to implement all the carbon reduction recommendations with and without peak shaving.

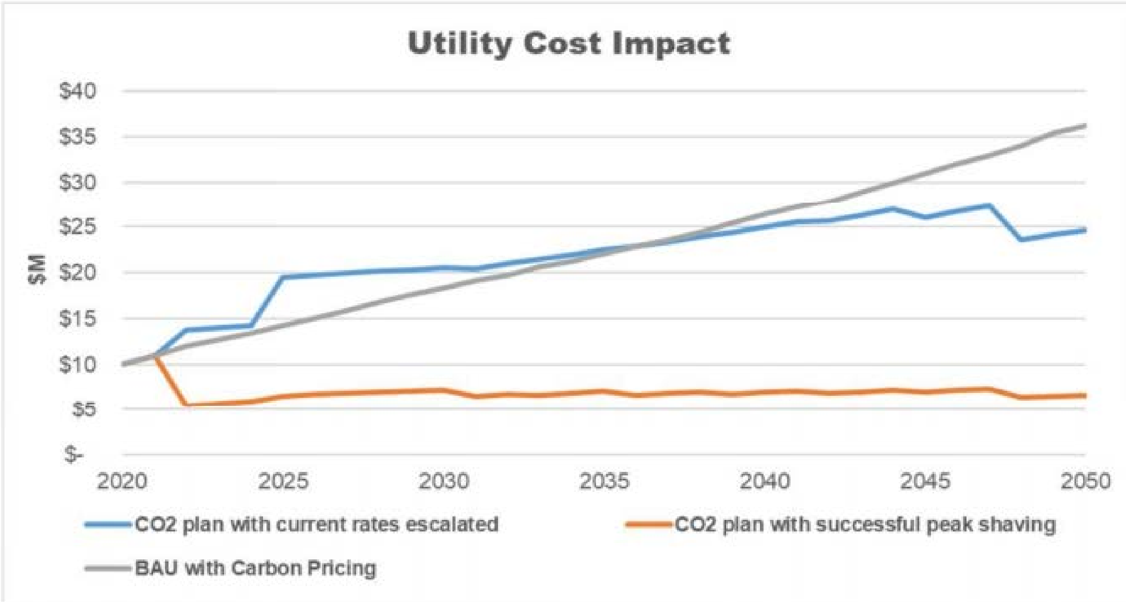

Figure 21: McMaster Utility Cost Impact [Source: McMaster Net-Zero Carbon Roadmap Report]

Benchmarking with Other Institutions

McMaster energy and GHG intensities were favourable prior to 2017. Due to the installation of the cogeneration plant (CHP), McMaster's energy and GHG intensities have significantly increased as shown in Figure 23 and 24.

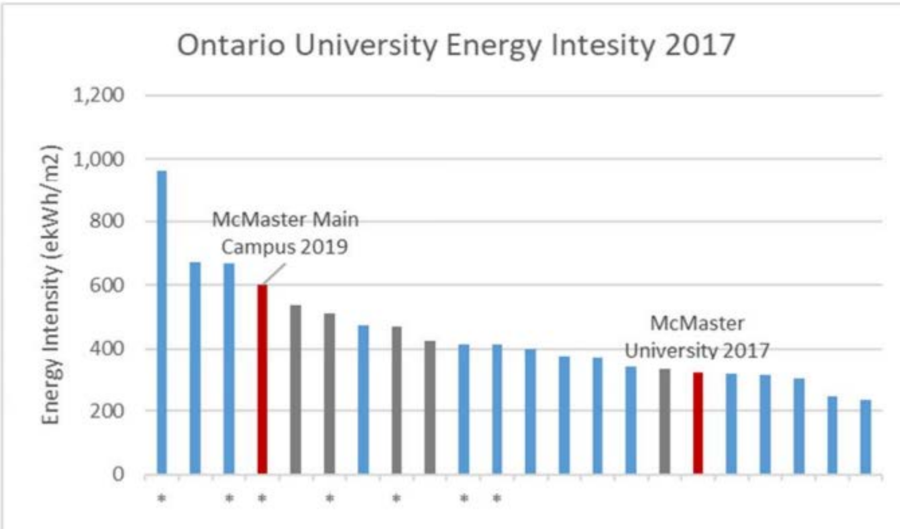

Figure 22: Ontario University Energy Intensity 2017 in ekWh/m2 [Source: Source: McMaster Net-Zero Carbon Roadmap Report]

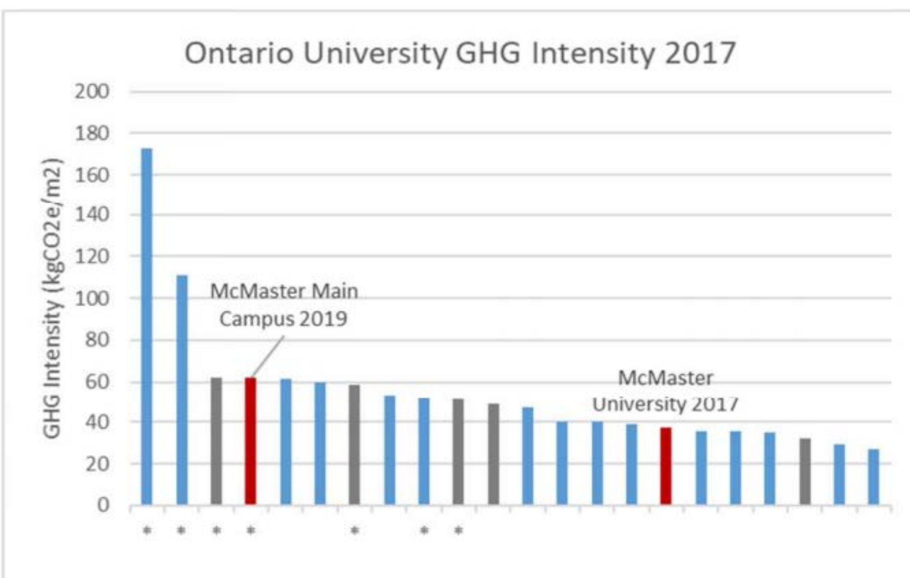

Figure 23: Ontario University GHG Intensity 2017 in kgCO2e/m2 [Source: McMaster Net-Zero Carbon Roadmap Report]

Reduction Targets

McMaster's Net-Zero Carbon Road Map has outlined comprehensive targets from 2021 to 2050, reducing campus carbon emissions by **75% in 2030** and **90% in 2050**, with a net reduction of **36,360 tonnes of CO2 per year**. The remaining 10% of campus carbon emissions are to be addressed by utilizing carbon offsets, or production of renewable energy on campus.

McMaster is committed to meeting its 2030 carbon reduction targets through the implementation of projects that focus on energy conservation, ventilation heat recovery, and BAS optimization.

McMaster will also alter its current electrical infrastructure by implementing peak shaving generators to reduce the financial cost of future carbon reduction projects, which heavily rely on electrification of heating systems. This becomes important as McMaster moves forward with the proposed projects, beginning with the installation of electric boilers at ET Clarke in 2022.

As of Fall of 2021, McMaster University is exploring solutions that will accelerate the Net-Zero roadmap, with a focus on cost-effective solutions. McMaster is also exploring other technologies, such as solar PV, hydrogen blending and carbon capture due to the challenges facing the provincial electrical grid. McMaster University recognizes that there are environmental impacts associated with the production of natural gas. To minimize impacts, McMaster University is exploring Renewable Natural Gas as an option.

Energy Action Plan

McMaster's Net Zero Carbon Roadmap has successfully laid out McMaster's carbon reduction pathway to 2050. The goal of the energy action plan is to highlight projects that will assist McMaster in achieving its reduction targets with an emphasis on carbon and financial impacts.

Due to COVID-19, the initiation of a few projects has been delayed. This is a direct result of changes in governmental policies, and funding streams. Economic changes have also led to uncertainty with pricing and construction scheduling.

Government funding can also alter the execution of projects based on program rules. Projects submitted for federal/provincial carbon funding will need project key dates assessed and re-evaluated to meet the conditions of the funding program.

Past projects before 2019 can be found in previous iterations of the Energy Management Plan.

Completed Projects (post 2019)

Strobic Fan Upgrades

The strobic (high plume fans) in NRB and ABB are still operating with old pneumatic dampers. This project has replaced old pneumatic dampers to DDC electronic and has been successfully completed.

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.

Update: Project is now completed with minor deficiencies to be addressed. It is now awaiting regulatory approval.

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.

Update: All defective steam traps have been replaced in 2022.

Ongoing Projects

LSB Mechanical Upgrades / 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).

Update: This project has been included in the new Greenhouse project at LSB, where majority of the mechanical systems in the building are to be replaced and renewed as part of deferred maintenance. Project is scheduled to be completed in 2023 and overall project funding for the mechanical systems upgrade is approximately **$2.5M.** Amount of carbon reduction resulting from the upgrades to be determined once selection of equipment have been finalized.

LSB Greenhouse Geothermal Heat Pump System

One of the key recommendations in the Net Zero Carbon Roadmap is the transition to a geothermal heat pump system to provide heating on campus. To verify the effects of the proposed campus geothermal heat pump systems, it was decided that a pilot system would be implemented as part of the Life Science Building Greenhouse project.

This involves drilling thermal wells below the new greenhouse addition and installing a closed-loop system with circulation pumps. It is estimated that the pilot geothermal system would displace **100 kW** of heating and cooling from the district energy system. This amounts to a reduction of **98.5 tonnes of CO_2e annually**.

The implementation of the pilot geothermal system would cost approximately **$500K** with no financial payback; it is intended for carbon reduction. McMaster Facility services hopes to gain more understanding of the financial implications of geothermal heat pump systems to operations and utilities through this pilot project.

Update: This project will be included in the submission for the Low Carbon Economy Challenge fund and Decarbonization Incentive Program.

Electric Boilers and Peak Shaving Generators (Natural Gas Generators)

Installation of electric boilers as opposed to the conventional natural gas boilers will significantly reduce McMaster's GHG emissions. Based on the recommendations in the Net Zero Carbon Roadmap, the installation of one 30,000 lb/hr steam boiler would reduce McMaster's carbon emissions by 35%. There are no cost savings associated with the implementation of an electric boiler; it is simply a greenhouse gas emission reduction strategy.

McMaster will be installing two 50,000 lb/hr electric boilers in the last quarter of 2022. This will require a capital investment of approximately $3.6M. These two boilers will be operated in partial loads to achieve the carbon reduction target in the Net-Zero Carbon Roadmap. It is possible to achieve greater carbon reduction by operating the two electric boilers at a higher capacity. An operational review will be conducted once the electric boilers are in place.

To minimize the financial impacts on the operational budget of the electric boilers, McMaster will need to participate in the Industrial Conservation Initiative with the IESO and participate as a Class A customer. Class A participants pay global adjustment (GA) based on their percentage contribution to the top five peak hours. As a perquisite to the program, the facility must have a peak demand above the nominal threshold of 5 MW; McMaster currently operates between 9 to 11 MW.

To maximize the financial savings from the program, McMaster will be installing 10 MW of peak shaving generators at the NF91 transformer lot and ET Clarke. With behind-the meter generation, McMaster will be able to significantly reduce its global adjustment cost, minimizing the operational costs of the proposed electric boilers. The natural gas generators are expected to operate 100 hours/year, in order to meet the peak days, which happen mostly in the summer months. With this, the natural gas generators will be producing approximately 700 tonnes of CO2e locally on campus. In essence, this displaces 700 tonnes of CO2e from the province as the province would be operating natural gas generators during peak periods.

Based on McMaster's electricity load profile over the years, and current market conditions, it is estimated that approximately $4M in Global Adjustment savings can be achieved through peak shaving.

The installation of the two electric boilers, 10 MW of peak shaving generators and refurbishment of existing steam assets will cost McMaster approximately $31.5M. With an estimated $4M in annual savings, a payback of 13 years is expected; this factors in operational and maintenance costs.

<u>Update</u>: This project has been separated into two projects due to the location of the equipment.

1. **NF91 Peak Shaver Project – includes installation of the 4 x 2 MW generators at NF91 site**
2. **2.5 MW Peak Shaver/Emergency Generator and Electric Boilers – includes the installation of the fifth generator at ET Clarke (2.5 MW) and installation of the two electric boilers.**

The NF91 project is nearing construction completion and will be operational by end of summer 2023. Meanwhile, the 2.5 MW generator and electric boilers project is expected to be completed by the spring of 2024.

Due to the project delays, the financial savings projected from the ICI program (peak shaving) will not be realized until 2025-2026 fiscal year.

Please note that the application for the Decarbonization Incentive Program for the electric boilers was successful, and McMaster will receive $2M in contribution from the federal government.

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.

<u>Update</u>: This project is nearing completion with 90% of the buildings completed.

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, and particulate matter. 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 exhaust 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

This particular project will target the Physics Wing of AN Bourns Building.

Update: The project is awaiting funding before contractor bids are solicited. This project was not successful in its application for the Low Carbon Economy Challenge fund and Decarbonization Incentive Program.

Geothermal Heat Pump Master Plan / Bore Hole Drilling and Testing

To fully understand the scope and challenges associated with transitioning campus from its district energy system to a geothermal heat pump system, Facilities Services has undertaken a comprehensive geothermal heat pump master plan. The scope includes the following:

- Assessment of required mechanical system interventions at the building level to transition from steam systems to low temperature water. This encompasses all main Air Handling Systems, secondary steam heating systems, etc.
- An in-depth look of the service tunnels to determine routing requirements for the low temperature piping required to transport the energy harvested from the ground.
- Review of ground conditions to ascertain thermal capacity available for campus heating. McMaster has acquired a geothermal drilling company to perform bore hole tests across campus with the guidance from the geothermal consultant.
- A review of required construction phasing to minimize campus impacts.
- A detailed review of capital costs to implement a campus wide geothermal system conversion and operating costs after implementation.

The master plan is slated to be completed by the Fall of 2023.

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)*
LSB Greenhouse – Mech	2023	$2,500,000	$0	TBD	TBD	0	TBD	TBD	D.M	TBD
LSB - Geothermal HP	2023	$500,000	$250,000	**	**	0	**	TBD	EMP	99
Peak Shaver & Electric Boiler	2022	$31,222,530	$1,707,602	4,880,637	1,570,000	0	$4,000,000	13	EMP	9200
Lab Air / DCV – ABB Physics Wing	2022 - 2023	$887,000	$443,500	131,597	311,393	0	$112,000	4	EMP	248
Metering Upgrades	2022	$1,800,000	$0	0	0	0	N/A	N/A	D.M.	0
Geothermal Heat Pump Master Plan	2023	$777,500	$0	0	0	0	N/A	N/A	EMP	0
Total EMP Investments		***$33,387,029***	***$2,401,102***	***5,012,233***	***2,131,758***	***0***	***$4,112,000***			***9,547***

DM – Deferred Maintenance
EMP – Energy Management Plan (Energy Budget)

*All projects under EMP to be submitted for government funding (Low Carbon Economy Fund & Decarbonization Incentive Fund)

****** *The annual gas savings achieved from the geothermal heat pump system is negated by the increased electricity cost form the operation of the heat pumps*

Table 2: Ongoing Projects Summary

Proposed Projects

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

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 emissions 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 CO_2, 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 3 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 3: Airgenuity - McMaster Campus Review

Engineering Technology Building – Demand Control/Cooling Modifications

Lab spaces typically have very high energy usage due to the increased ventilation rates. Therefore, it is beneficial to ensure that the main fan systems only condition the right amount of outside air to minimize energy consumption. This can be accomplished by using terminal units, such as fan coils, to provide the required thermal conditioning of the space. This will then allow for the reduction of ventilation rates based on occupancy/demand. By implementing both strategies, the thermal requirements at the main fan systems will be reduced, resulting in energy savings.

This project focuses on reducing the thermal loads on the main fan systems by installing chilled water/hot water fan coil units across the various labs/rooms in the Engineering Technology Building. The intent is for the fan coils to provide the thermal conditioning, in order to reduce the energy demand at the main fan systems.

The design of this project has been completed and is ready to be tendered for contractor pricing. It is anticipated that this project will be completed in the summer of 2023 due to the size and magnitude of the scope. A detailed outline of the project, along with funding sources will be submitted through governance for approval. This project will also be included in the submission for the Low Carbon Economy Challenge fund and Decarbonization Incentive Program.

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.

Cooling Tower Make-Up Source Change

The cooling towers in ET Clarke use city water for make-up. This introduces calcification in the system increasing water usage. By switching the make-up water source from city water to Reverse Osmosis (RO) water, contamination will be kept at a minimal and will provide a reduction in make-up water consumption.

McMaster Utilities is currently exploring this option. Potential water savings will be calculated once the new RO system is fully operational.

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)*
Window Replacements (various)	2022-2030	$7,615,000	$0	28,854	15,865	0	$7,646	> 20	D.M.	54
Demand Control Vent (Campus Wide)	2025	$14,300,000	$0	9,436,400	19,189,000	0	$780,000	18	EMP	13,789
ETB DCV/Cooling Modification	2023	$2,550,000	$0	141,161	250,365	0	$87,565	29	EMP	266
Irrigation Control/Water Monitoring	2022	$6,500	$0	0	0	7,274	$24,700	< 1 year	EMP	0
Rainwater Harvesting	TBD	$23,000	$0	0	0	648	$2,400	10	EMP	0
Campus City Water Audit	**	TBD	TBD	0	0	31,000	$105,000	<1 year	EMP	0
Wastewater Abatement Program	2022	TBD	TBD	0	0	TBD	TBD	TBD	EMP	0
Cooling Tower Make-Up Water Source Change	2022	TBD	TBD	0	0	TBD	TBD	TBD	EMP	0
Total		***$24,494,500***	***$0***	***9,606,415***	***19,455,230***	***38,922***	***$1,007,311***			***14,109***
Total EMP Investments		***$16,879,500***	***$0***	***9,577,561***	***19,439,365***	***38,922***	***$999,665***			***14,055***

Table 4: Proposed Projects Summary

DM- Deferred Maintenance
EMP – Energy Management Plan (Energy Budget)

** This is a continuous project where the city water audit is done on a yearly basis.

Energy Action Plan Conclusion

This energy action plan extends to 2030 and includes 4 ongoing energy projects with a total energy investment of **$33,387,029**. There are 22 completed projects with a total investment to date of **$25,372,944** and another 8 proposed projects with a total anticipated energy investment of **$16,879,500**. This will bring the total investment to **$75,639,473** by 2030. Funding sources for each of these projects are being considered, along with timelines and business case development. Projects will be brought through governance for consideration based on the total project value. Table 5 below summarizes the EMP investment breakdown from the past, current and future projects.

Project	EMP Investment
Completed Projects	$25,372,944
Ongoing Projects	$33,387,029
Proposed Projects	$16,879,500
Total (by 2030)	**$75,639,473**

Table 5: EMP Investment up to 2030

With the current and proposed projects, the GHG emission is targeted to be reduced significantly. McMaster's annual carbon footprint of **40,400 tonnes of CO_2 is projected to be reduced to an annual carbon footprint of 15,049 tonnes of CO_2** by 2030.

Year	Annual GHG Emission Reductions (tonnes of CO_2)
2013 to 2020	1,695
2020 to 2030	23,656
Total	**25,351**

Table 6: GHG reductions up to 2030

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 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.