McGill

Energy Management Plan

2016-2020 Implementation Phase

2017-08-01 Update



Produced by:

Utilities and Energy Management

Facilities Management and Ancillary Services

McGill University.

2017-08-01 Update

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The Arts Building’s cupola, McGill©

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Macdonald Campus’s North Powerhouse, McGill©

Students in a lab, McGill©

EXECUTIVE SUMMARY

McGill, as a world-class research and teaching institution, has a very high energy use intensity[1] and a sizeable carbon footprint. McGill uses more energy per square foot compared to peer institutions in Canada but compares favourably in terms of greenhouse gas emissions. Indeed, when normalized to gross building area or student enrolment, McGill's building-related greenhouse gas emissions are in fact 50% below the 1990 levels.

Since 2010, the University has invested $20M in energy conservation and managed to reduce energy use intensity and building-related greenhouse gas emissions respectively by 26% and 34% below the MEES[2]-defined 2002-2003 reference baseline. Utilities & Energy Management, a unit of Facilities Management & Ancillary Services, spearheaded the implementation of energy conservation measures in collaboration with a variety of stakeholders, both internal and external. McGill has gained recognition in energy management from its peers, utility companies, and the province. Among the lessons learned between 2010 and 2015, Utilities & Energy Management realized that smart tools and technologies deployed on campus don't obviate the need for brainpower: human resources are McGill's most valuable asset and long-term energy efficiency can only be achieved by changing mindsets and behaviours. Furthermore, the more McGill's energy efficiency increases, the more challenging it gets to make marginal savings. Figure 2 below gives an overview of investments and savings made with the first iteration of McGill's Energy Management Plan, as well as the impact on energy use intensity and greenhouse gas emissions, put in perspective with campus growth in terms of building area and student enrolment.

Recently, the provincial government set ambitious targets for institutions to reduce their energy use and carbon footprint which aligns well with McGill's ambition to become carbon neutral. A study of compliance requirements and McGill's institutional priorities shows there is a convergence in objectives to reduce energy consumption, reduce greenhouse gas emissions with a long-term goal of becoming carbon neutral, and manage peak power demand to reduce the strain on the province's utility infrastructure.

To respond to these requirements, Utilities & Energy Management is proposing a 2016-2020 iteration of the Energy Management Plan that will focus on the transition of buildings from discrete, static energy consumers to dynamic smart grids that make use of synergies between exothermic[3] and endothermic[4] buildings. This will be done by building the backbone for heat exchange between buildings on the downtown campus. Expected impacts include a 22% reduction in energy use intensity below the provincial government-newly defined 2012-2013 baseline as well as a 64% reduction in building-related greenhouse gas emissions below the 1990 levels. Investments in energy conservation in the order of $22M have been identified to reach these targets. Annual savings upon implementation are estimated at $3.99M for an overall payback of 4.3 years and a net present value calculated over 20 years of $14.89M.

The 2016-2020 action plan is articulated around five main areas of intervention:

- A set of projects motivated entirely by the Energy Management Plan which includes the deployment of smart grids downtown, recovering heat from the downtown powerhouse, and a demand-side management program.

[1] Energy use intensity: overall energy used in buildings to gross building area ratio.
[2] MEES: *Ministère de l'Éducation et de l'Enseignement supérieur du Québec*
[3] An exothermic building is a building in excess of heat, i.e. which needs cooling.
[4] An endothermic building is a building that needs heating.

- A set of mixed projects, so-called because they aren't solely motivated by the Energy Management Plan. These projects include major HVAC upgrades, deploying non-conventional renewable energy systems, and completing the deployments of smart grids downtown.
- A set of energy programs including building retro-commissioning, insulation, and systems optimization.
- A new section called "efficient operations" that aims to improve building operations, improve the efficiency of the energy generation and distribution systems, and ensure the continuity of energy savings.
- The last area of intervention is community engagement and includes: supporting McGill's Sustainable Procurement strategy, research and energy, applied student research, as well as increasing exposure by communicating McGill's ambitions and successes to the community.

Our analysis shows the proposed action plan will allow McGill to meet compliance requirements and institutional objectives for the years to come, as illustrated below.

Area of intervention	Reduce energy use intensity of building stock	Increase energy performance of new buildings incl. major renovations	Phase out use of heating oil in buildings	Reduce peak power demand	Reduce energy-related GHG emissions of buildings	Use renewable energy as the main source of heating buildings	Reduce overall GHG emissions (QC)	Work towards carbon neutrality (McGill)	Reduce GHG emissions related to transport
Smart grids DT	✓	✓			✓		✓	✓	
Increase DT powerhouse efficiency	✓				✓		✓	✓	
Peak demand management				✓					
Major HVAC upgrades	✓	✓		✓	✓	✓	✓	✓	
Non-conventional renewable energy systems			✓		✓	✓	✓	✓	
Retro-commissioning	✓	✓		✓	✓		✓	✓	
Insulation	✓				✓		✓	✓	
Buildings and systems optimization	✓				✓		✓	✓	
Efficient operations	✓	✓		✓	✓	✓	✓	✓	
Improve distribution efficiency	✓				✓		✓	✓	
Energy savings persistence	✓	✓		✓	✓	✓	✓	✓	
Community engagement	✓						✓	✓	✓

TIMELINE

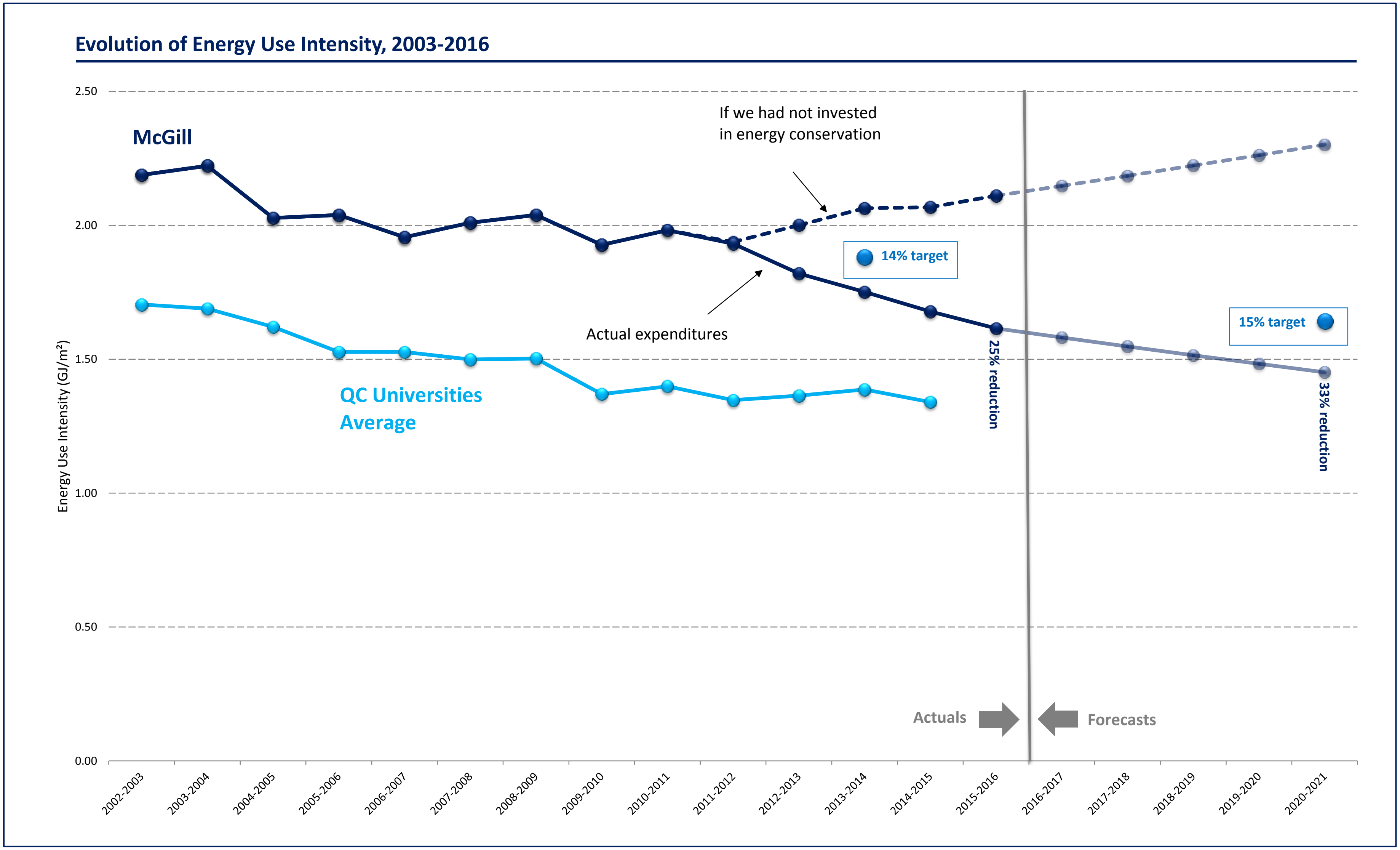

Figure 1 - Evolution of Energy Use Intensity, 2003-2016

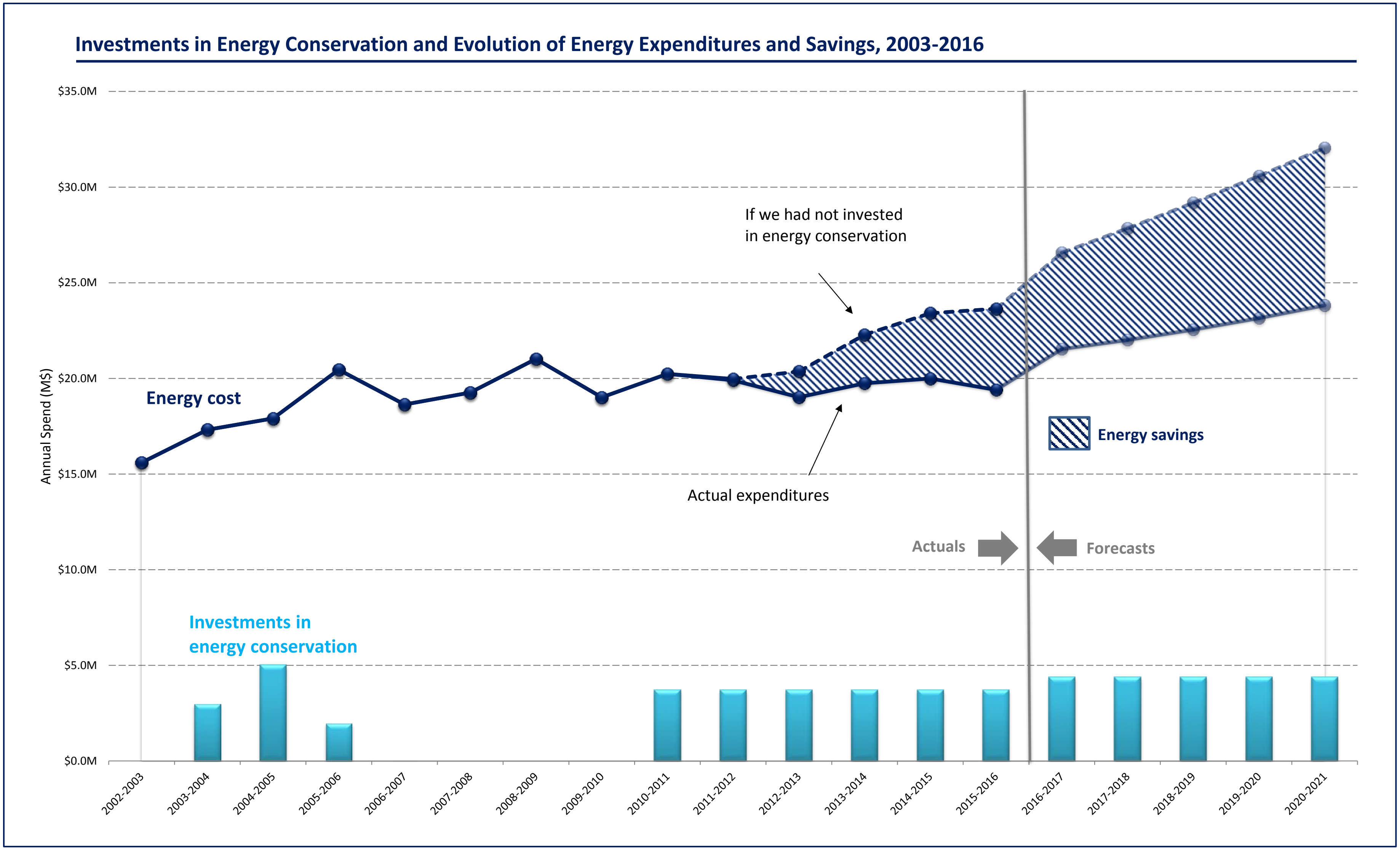

Figure 2 - Investments in Energy Conservation and Evolution of Energy Expenditures and Savings, 2003-2016

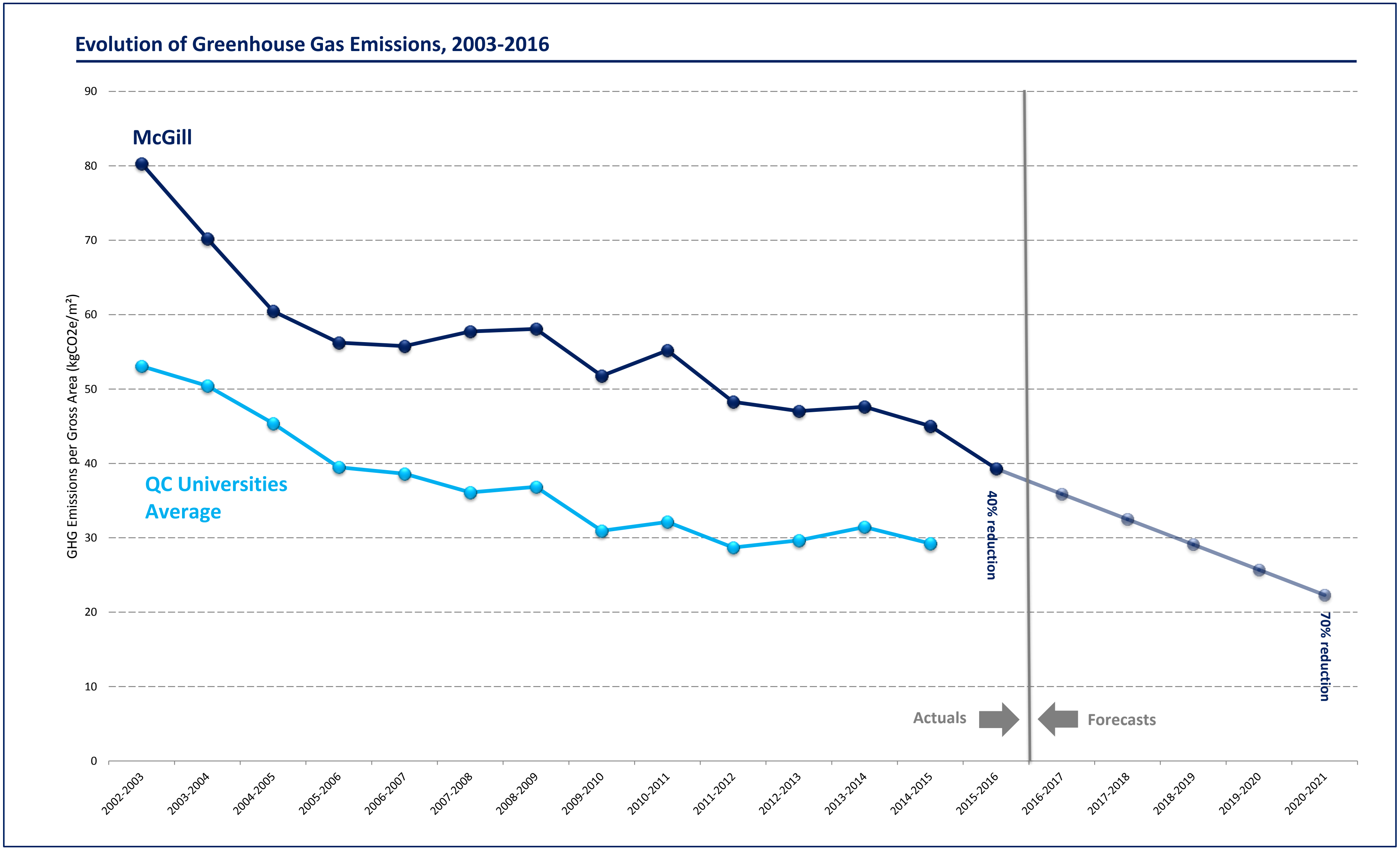

Figure 3 - Evolution of Greenhouse Gas Emissions, 2003-2016

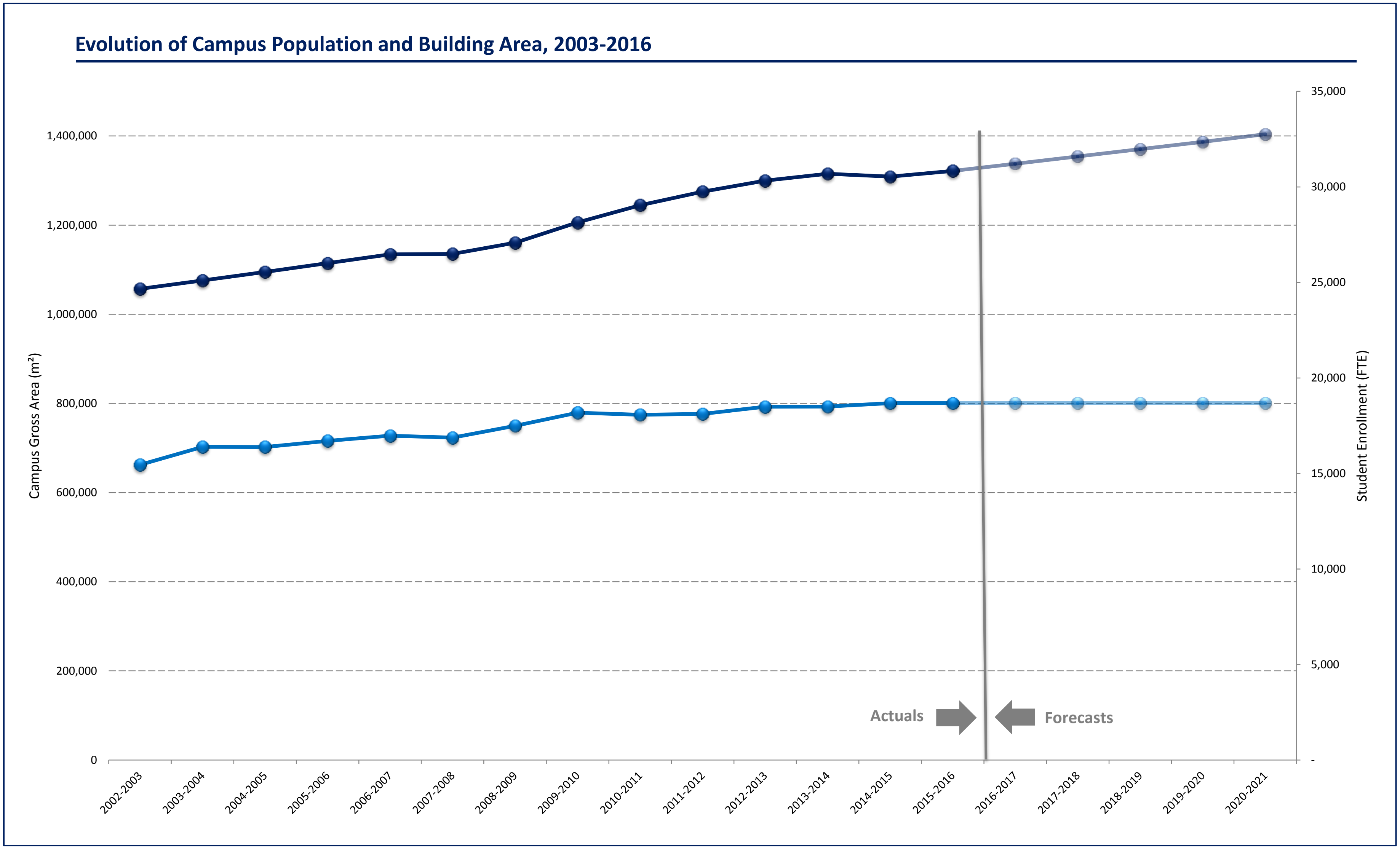

Figure 4 - Evolution of Campus Population and Building Area, 2003-2016

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MISSION STATEMENT

The role of McGill Utilities & Energy Management (UEM) is to support the University's teaching and research mission. UEM serves all McGill energy end-users by providing them with reliable energy. The Utilities Group efficiently operates and maintains energy generation and distribution systems on campus. The Energy Management Group is the authority on energy at McGill and strives to reduce energy consumption. Our team of knowledgeable and engaged individuals are empowered to foster initiatives geared toward energy savings. We work closely with our stakeholders and give them tools to understand energy use on campus and influence positive behavioural change. We collaborate with administrative units and faculties to inform decision-making processes in order to increase on-campus energy efficiency. To reach our goals, we follow a long-term strategy outlined in our rolling five-year Energy Management Plan which, we regularly update, that comprises capital investment, maintenance, and optimization programs as well as behavioural change programs. Our activities rely on three pillars: the expertise and technical background of our team, careful project scheduling, and sound funding and accounting. Energy conservation initiatives are mostly funded by loans and repaid with energy savings. We are committed to transparent, regular reporting on the progress of the plan to McGill's senior administration and community.

Looking beyond our core activities, we espouse the missions of the University and of Facilities Management and Ancillary Services and we actively engage with students, professors, and researchers by sharing knowledge on energy use at McGill and providing venues for academic and research projects. We nurture our relationship with academia. We recognize Vision2020 as a community vision and we pursue McGill's sustainability objectives by empowering change agents and supporting the University in the implementation of the Vision2020 Action Plan.

We work collaboratively and participate actively in a practice community and exchange with similar organizations such as universities and hospitals to keep abreast of the most recent trends in energy management.

We value reliability by ensuring optimal efficiency in all our activities, transparency which we seek to demonstrate through cooperation and proactive disclosure, and expertise which we maintain and enrich through continuous learning. We blend these values in all our endeavours.

1. Background

1.1. Narrative

McGill's first Five-Year Energy Management Plan and its 2013 update responded to the Ministry of Higher Education's (then *Ministère de l'Éducation, du Loisir et des Sports du Québec*) request that all post-secondary institutions in the province should reduce their EUI (GJ/m²) by 14% relative to 2002-2003 without specifying targets for individual institutions.

Since 2010-2011, McGill has invested $67M in energy conservation, $27M of which were funded through a loan repaid with the savings generated by the different projects. At the end of 2015-2016, annual savings reached $3.8M annually for an overall payback on energy loan-funded projects of 5 years.

As of May 2016, both EUI and greenhouse gas emissions related to stationary combustion were 26% and 34% below the 2002-2003 baseline.

1.2. Highlights

As of 2015-2016 Q3 and since 2010-2011, McGill has made **$19.1M investments** in energy conservation (out of a $27M budget) resulting in **$3.8M savings**. The University has received **$2.7M in incentives** from utility programs (Gaz Métro and Hydro Québec) and Québec's climate action incentive program (managed by Transition énergétique Québec). The plan has an **overall payback of 4.7 years**. These energy conservation measures have resulted in a **26% reduction in energy intensity** (see Figure 5) and a **34% reduction in greenhouse gas emissions** from stationary combustions, relative to the 2002-2003 levels. **43 buildings** were impacted by the program as illustrated on Figure 6. Table 1 below shows detailed financials for investments made between 2010-11 and 2015-16.

	EMIS	LIGHTING RETROFITS	ReCx & ENERGY AUDITS	MAJOR UPGRADES (PROJECTS)	INSULATION & OPTIMIZATION PROGRAMS
INVESTMENTS	$2.8M	$5.2M	$1.1M	$11.0M	$339k
INCENTIVES	$75k	$972k	$329k	$1.2M	N/A
SAVINGS	$384k	$581k	$1.3M	$1.2m	$355k
PAYBACK	7.1 yrs	7.3 yrs	0.6 yr	8.1 yrs	1.0 yr
BUILDINGS IMPACTED	80	45	15	11 (directly) 80 (indirectly)	10

Table 1 - Overview of 2010-2015 EMP Programs and Projects

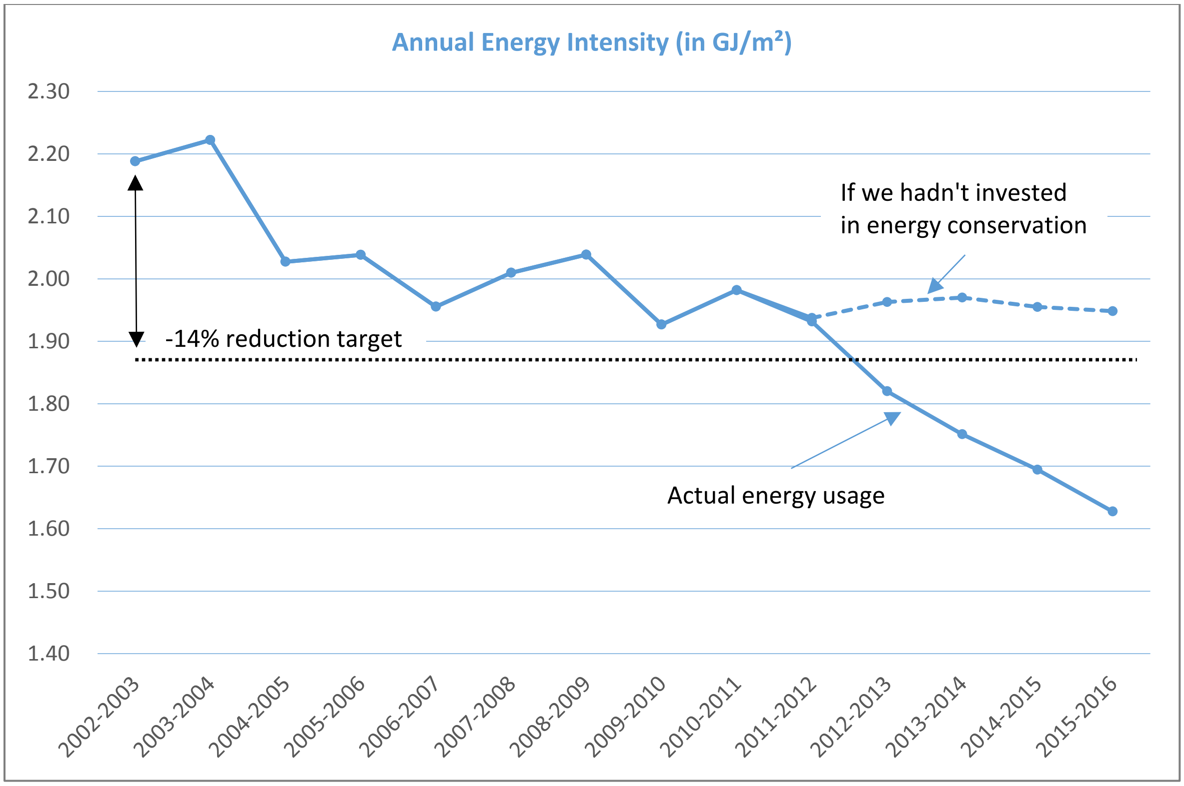

Figure 5 - Evolution of McGill's EUI

Downtown Campus **Macdonald Campus**

Figure 6 - Buildings Impacted by the 2010-2015 Energy Management Plan

McGill's Energy Management Plan is a collaborative effort that has involved scores of stakeholders, both on and off campus as illustrated by Figure 8 and Figure 7.

INTERNAL STAKEHOLDERS: Building Operations | Project Management | Design Services | Macdonald Campus Operations | Procurement | McGill Energy Project | Vision 2020 | Vision 2020 Sustainable Labs Work Group | Environmental Health and Safety | Financial Services | McGill Athletics | Student Housing and Hospitality Services | Student Services | Sustainability in Engineering at McGill (SEAM) | Students' Society of McGill University (SSMU) | the Post-Graduate Students' Society (PGSS) | Macdonald Campus Students' Society (MCSS)| the Sustainability Project Fund (SPF) | Faculty of Management | Faculty of Medicine | Faculty of Agriculture and Environmental Sciences | Faculty of Science | Faculty of Law | Gault Nature Reserve | McGill School of Environment | CFI Office | VP Research & International Relations Office | scores of SPF project, CFI projects, and renovation projects across campus

Figure 7 - Internal Stakeholders

EXTERNAL STAKEHOLDERS: Gaz Métro | Hydro Québec | Ministère de l'Éducation supérieure et de la recherche du Québec | Ministère des Ressources naturelles du Québec | Bureau de l'efficacité et de l'innovation énergétiques | Association québécoise pour la maîtrise de l'énergie | Groupe DATCH | Natural Resources Canada | Office of Energy Efficiency | Statistics Canada | UQÀM | Université de Montréal | Université de Sherbrooke | Polytechnique Montréal | ÉTS | Concordia | Université Laval | University of Toronto | UBC | Harvard | Ville de Montréal | Office municipal d'habitation de Montréal | Association of Energy Engineers | ASHRAE | Sustainable Labs Canada (SLCan) | AGPI | and more...

Figure 8 - External Stakeholders

The first implementation phase of McGill's Energy Management Plan was also an opportunity for Utilities & Energy Management to test the reception of energy conservation programs within the organization and the community. Some of the main projects outcomes are:

- Smart tools and technologies don't obviate the need for brainpower.
- Human resources are our best and most valuable asset. Operators and technicians can assimilate new skills and develop knowledge essential to the proper operation of ever more complex systems and technologies that are becoming the new norm.
- Actively involving building operations staff early in the process is crucial to success.
- Long-term energy efficiency isn't achieved by energy conservation projects but by changing mindsets and habits.
- Improving energy performance is achieved through a constant collaborative process involving energy staff, building operations staff, decision makers, and building users.
- The more on-campus energy performance increases, the harder it is to make incremental savings.

2. Regulatory and Policy Context

2.1. Compliance Framework

The Province of Québec has long been committed to climate action. The Province demonstrated leadership with its *Plan d'action 2013-2020 sur les changements climatiques* whose targets for the institution sector are outlined in the *Mesures d'exemplarité de l'État* document. The targets are:

- A 15% reduction in greenhouse gas emissions for institutional buildings by 2020 with reference to 2009-2010;
- As of 2016, all new buildings and buildings undergoing major renovation must use renewable energy as primary source of heating: fossil fuels cannot meet more than 25% of the heating requirements of the building; during their operation phase, fossil fuels can only make up to 20% of the building's total annual energy use.
- Buildings on heat distribution networks such as McGill's do not have to meet this requirement; however, should heat generation equipment be upgraded in any way (capacity increase, equipment upgrade or replacement), the network would have to comply with this requirement.
- All new constructions and major renovations must be 20% more efficient than the 2011 National Energy Code of Canada for Buildings
- Institutional buildings whose heating oil usage represents more than 20% of the building's total annual energy use must be converted by 2020; after conversion, fossil fuels can only make up to 20% of the building's total energy use and no more than 30% of the building's heating requirements can be met with fossil fuels.

In the wake of COP21, Québec unveiled its *Politique énergétique 2030* in early 2016. The strategy sets the roadmap for energy management and climate action to meet the Province's commitment to reduce GHG emissions 37.5% below the 1990 levels.

A few facts from this policy of interest to McGill's operations include:

- An overarching goal of 37.5% reduction in greenhouse gas emissions and reaching 61% renewable energy in the province's energy mix by 2030;
- The reduction of petroleum-based fuel consumption and, as a cleaner alternative, the use of natural gas;
- A 50% increase in the use of energy from biomass;
- Transport electrification with the target of 1 million electric vehicles on the roads by 2030 and the use of natural gas for commercial transport;
- A reduction in energy intensity of 15% below the 2012 levels for institutional buildings by 2021;
- The requirement that renewable energy be the main source of heating and cooling for new institutional buildings.

The policy has yet to be turned into action plans by each Ministry including the *Ministère de l'Éducation et de l'Enseignement supérieur*, however, it is safe to assume that ministry action plans should use the same targets and overarching goal as the *Politique énergétique 2030*.

2.2. UTILITIES TARIFFS AND PROGRAMS

Further to developing programs to help meet energy efficiency and climate action targets set by the provincial government, the two main utilities in Québec, Hydro Québec and Gaz Métro, also report to the Québec Energy Board (*la Régie de l'énergie*) which has lately focused on the cost of peak demand on end-users. The two utilities have historically driven market changes through their tariff offers and incentive programs. It is essential that McGill's Energy Management Plan leverage these programs to maximize opportunities on campus.

2.2.1. Hydro Québec

The utility hasn't yet developed an action plan to respond to the *Politique énergétique 2030*. Rather, it appears Hydro Québec will maintain its energy conservation incentive program as is. Also, the utility spearheaded a demand-side management program during peak hours in the winter (Dec 1st through March 31st) in 2015-2016. Québec has an untypical profile when it comes to electricity usage. While power demand peaks on hot, humid days, typically in the summer in the rest of North America, peak demand hours occur on cold, windy days in Québec due to the widespread use of electricity for space heating. On extremely cold days, Québec doesn't generate enough electricity and must purchase some from its neighbours (mainly Ontario and New England) at a very high cost. To reduce the burden, Hydro Québec launched a demand-side management program that incentivizes clients who willingly reduce their power demand during these hours. The utility has indicated the pilot year was a success and the program is now recurring. Hydro Québec also launched an incentive program for the replacement of heating oil-fueled heating systems which could be used to convert the last buildings burning heating oil on campus, namely the Gault Nature Reserve and a few buildings on the Macdonald Campus.

2.2.2. Gaz Métro

Much like Hydro Québec, Gaz Métro's energy efficiency incentive programs will remain in place for the time being to support the *Politique énergétique 2030* and shift the market. The 50% increase in biomass target set in the *Politique énergétique 2030* as well as the use of natural gas as a cleaner alternative to heating oil and diesel both poise Gaz Métro in a favourable position to diversify its activities and broaden its offer of renewable energy solutions. Gaz Métro is also working actively in the field of renewable natural gas, i.e. methane from biomass, which is considered a renewable energy source and part of the equation to decarbonize energy systems.

2.3. INSTITUTIONAL ORIENTATIONS

2.3.1. Vision 2020:

In 2010, the McGill Office of Sustainability engaged in a broad community process that resulted in Vision 2020, the University's sustainability strategy. Vision 2020 identifies five categories where change needs to happen to bring about the community's vision for a more sustainable McGill. Among the actions[5] of interest to our energy management plan are:

[5] See actions 3 (Sustainable Labs), 8 (Green Building), and 11 (Energy & Climate) in Vision 2020 Priority Action Briefs

- **Sustainable Labs** under the Research category. This action focuses on how we do research at McGill. Utilities & Energy Management is collaborating with several stakeholders under the leadership of Environmental Health and Safety to introduce change in the labs.
- **Energy & Climate** and **Green Building** both under the Operations category. McGill's Energy Management Plan is a key component of the Energy & Climate action as well as GHG quantification. Utilities & Energy Management has also been instrumental to McGill's Green Building Standards and the hiring of a sustainable construction officer.

The second implementation phase of Vision 2020 will also focus on climate action which will seek to make McGill become carbon neutral in the future. This plan will bring McGill closer to its vision that "renewable energy sources supply the vast majority of McGill's energy needs and McGill is progressively increasing the share of its energy coming from renewable sources while minimizing non-renewables" and "McGill's natural and built environment supports resilient ecosystems, strong communities and individual well-being"[6].

2.3.2. Principal's priorities:

Principal Fortier, installed as McGill's principal in 2013, has developed five priority areas among which the two priorities below echo with Utilities & Energy Management's mission:

- **Unleashing McGill's full potential of research**[7]: research is the most energy-intensive activity on campus and Utilities & Energy Management will continue to engage with the research community and with Facilities to find innovative solutions to ensure that researchers have access to leading-edge facilities that are also energy efficient.
- **Transforming our Campus**[8]: McGill needs more space to fulfill its mission. Numerous projects are on the table and Utilities & Energy Management will ensure that energy conservation and sustainability be at the core of each project.

2.4. OTHER BEST PRACTICES

2.4.1. Universities in Québec and Canada

Utilities & Energy Management fosters ongoing relationships with the main universities in Québec including Université de Montréal, UQÀM, Concordia, HEC Montréal, Université de Sherbrooke and Université Laval. All have slightly different approaches to energy management. Université Laval and Université de Sherbrooke are the most engaged in climate action: Laval claims to be the first university to have become carbon neutral in Québec in November 2015[9] while Sherbrooke has the ambitious goal to reduce greenhouse gas emissions between 80% and 95% below the 1990 levels by 2050[10]. Among the interesting projects recently implemented are the conversion of energy systems to work with low-temperature hot water at Université de Sherbrooke, extremely-efficiency heat recovery from servers at Université Laval, or fresh air and ventilation management in research buildings at UQÀM.

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[6] See Operations category in Vision 2020 Sustainability Strategy
[7] Unleashing McGill's Full Research Potential
[8] Transforming our Campus
[9] Plan de lutte aux changements climatiques de l'Université Laval
[10] Budget carbone de l'Université de Sherbrooke

In Canada, UBC has a long proven track record of achievements in sustainability. UBC aims at reducing its greenhouse gas emissions 100% and becoming a net positive energy producer by 2050. Among the many initiatives it implemented, UBC replaced aging steam infrastructure with more efficient hot water heating systems, made major lighting and ventilation upgrades, and put in place a continuous building optimization program. UBC is presently working on a Community Energy and Emissions Plan to meet the UBC's ambitious targets.

Performance Metrics and Units		McGill	Université de Montréal	Université Laval	Université de Sherbrooke	UBC *Vancouver Campus*	University of Toronto *St George Campus*
Site EUI	GJ/m²	1.75	1.51	1.48	1.39	1.30	±1.69
Energy per student enrolment	GJ per FTE	44	26	32	30	42	39
Energy use per sponsored research income	GJ per M$	2,903	2,227	3,216	4,621	3,397	1,901
GHG emissions per student enrolment	tCO2e per FTE	1.18	0.55	0.97	0.56	0.90	2.04
GHG emissions per sponsored research income	tCO2e per $M	78	47	98	88	73	101
GHG emissions per gross area	tCO2e per m²	0.047	0.032	0.045	0.028	0.028	±0.085

Table 2 - Energy Performance Metrics - McGill vs Research-Oriented Canadian Universities

Table Legend: Lowest value | Highest value

2.4.2. Universities in the USA

The table below shows how McGill compares with three of the most research-intensive universities in the US.

Performance Metrics and Units		McGill	Harvard	MIT	Stanford
Site EUI	GJ/m²	1.75	1.47	±2.93	±2.65
Energy per student enrolment	GJ per FTE	44	181	306	230
Energy per sponsored research income (CAN) or R&D expenditures (USA)	GJ per M$	2,903	3,348	3,421	3,852
GHG emissions per gross area	tCO2e per m²	0.047	0.096	0.178	0.148
GHG emissions per FTE	tCO2e per FTE	1.18	11.77	18.57	12.85
GHG emissions per sponsored research income (CAN) or R&D expenditures (USA)	tCO2e per M$	78	218	208	216

Table 3 - Energy Performance Metrics - McGill vs. US Research Universities

The energy management and climate action context that prevails south of the border is very different from Canada. For one thing, most electricity in the US is generated from fossil fuels, driving up scope 2 emissions. This combined with a strong leadership to make university campuses greener has led to the creation of several policies at the national and state level as well as incentive programs to shift paradigms. These mechanisms help boost the payback of renewable energy systems and traditional energy conservation measures.

Most universities have implemented traditional energy-conservation measures the like of which McGill has been implementing on campus since 2010. Harvard stands out with its green building program whereby most of the renovations made on campus are LEED® certified, thereby ensuring optimal energy performance and a minimum environmental impact. Scores of universities have installed solar panels on their campuses and most of them purchase RECs (renewable energy certificates). Universities located in areas where power grids are overused, such as California and New England, have been implementing power demand management strategies and are starting to deploy smart grids.

2.5. Summary of Compliance Requirements and Institutional Orientations

The table below summarizes the many compliance requirements and institutional orientations McGill's Energy Management Plan must address.

Description	Target	Compliance date	Reference	Metric	Scope	Framework
Reduce energy use intensity of building stock	-15%	2021	2012	Energy use intensity (GJ/m²/yr.)	All buildings	QC PP V2020
Increase energy performance of new buildings incl. major renovations	-20%	2016	National Energy Code of Canada for Buildings (2011)	Total energy use (GJ/yr.)	Per building, applicable to new constructions and major renovations	QC PP Vision2020
Phase out use of heating oil in buildings	≤20%	2020	Current	Heating oil use to total energy use ratio	Per building, applicable to buildings whose ratio is over threshold	QC V2020
Reduce peak power demand	N/A	N/A	Current	Peak demand (kW(	Applicable to buildings enrolled	HQ
Reduce energy-related GHG emissions of buildings	-15%	2020	2009-2010	Scope 1 building-related GHG emissions (tCO2e/yr.)	All buildings	QC PP V2020
Use renewable energy as the main source of heating buildings	≤20%	2016	Current	Fossil fuel use to total energy use ratio	Applicable to new stand-alone construction, existing stand-alone buildings undergoing major renovation, and McGill's distribution should it undergo changes	QC
Reduce overall GHG emissions (QC)	-37.5%	2030	1990	Total GHG emissions (tCO2e/yr.)	All buildings	QC
Work towards carbon neutrality (McGill)	-100%	TBD	current	Total GHG emissions (tCO2e/yr.)	All sectors identified in McGill's GHG inventory	QC V2020
Reduce GHG emissions related to transport	N/A	N/A	Current	Transport-related emissions (tCO2e/yr.)	McGill-owned vehicles and Macdonald shuttle	QC V2020

Table 4 - Summary of Compliance Requirements and Institutional Orientations

HQ: utilities orientation (Hydro Québec)

QC: provincial compliance requirements

PP: Principal's Priorities

V2020: Vision 2020 orientations

3. Situational Analysis of Energy Management at McGill

3.1. Key Performance Indicators

UEM tracked down information from 1990 and was able to estimate with reasonable accuracy McGill's performance then. The table below shows key performance indicators as well as the relative change between 1990 and 2015-2016. The 1990 baseline was chosen to align McGill's targets with those of Québec's *Politique énergétique 2030* and other international climate change agreements such as COP21.

The use of EUI (energy use intensity) as the main key performance indicator in energy management is debatable. Indeed, this metric doesn't take into account how efficiently space is used. For instance, areas only used part of the time (e.g. weekdays 9 am to 5 pm) are allegedly used less efficiently than similar areas that are also used weeknights and weekends or even 24/7; however, intensely-used areas have a greater EUI and therefore appear be less energy efficient when they are in fact used more efficiently. A more meaningful metric could be energy use intensity per working hour for instance. Utilities & Energy Management is working toward defining another indicator that would account for occupancy.

Performance indicator	1990	2016	Relative change
Gross area	549,421 m²	791,140 m²	+44%
FTEs	22,616[11]*	30,535[11]*	+35%
Total energy use	1,284,809 GJ[11]*	1,223,675 GJ	-5%
Renewable energy	28%	49%	+21%
Normalized EUI – McGill	2.34 GJ/m²	1.63 GJ/m²	-30%
Normalized EUI – QC average	1.71 GJ/m²	1.39 GJ/m²*	-19%
McGill vs. QC average	37% higher	18% higher	-19%
Total spend	$8.8M	$18.6M	+113%
Total spend per area	$15.95/m²	$23.56/m²	+48%
Energy rate (overall)	$6.82/GJ	$15.23/GJ	+123%
GHG emissions[12] (absolute)	48,501 tCO2eq	31,110 tCO2eq	-36%
GHG emissions12 per area	88.3 kg CO2eq/m²	39.32 kg CO2eq/m²	-55%
GHG emissions[12] per FTE	2.14 tCO2eq/FTE	1.02 t CO2eq/FTE	-52%
GHG emissions[12] per energy unit	37.8 kg CO2eq/GJ	25.42 kg CO2eq/GJ	-33%

Table 5 - Key Performance Indicators, 1990 vs 2016

[11] Estimates

[12] Scope 1 emissions from stationary sources only

SWOT Analysis

The table below shows how well McGill is positioned to meet the targets set out in Québec's *Politique énergétique 2030* and the opportunities to go even further in energy management and climate change action.

Strengths

GHG emission reduction target 96% met

Energy use reduction target already met

Solidly established energy mgmt. practices

Strong cooperation with McGill Operations

Solid partnerships with utilities & tech experts

Weaknesses

Inertia typical of big organizations

End-users don't pay for energy charges

Old heritage buildings with high facilities condition index (i.e. requiring major investment)

Lack of clear campus plan

Opportunities

Hydro Québec's new demand-side mgmt. and heating oil conversion programs.

Province to develop/revamp climate action incentive programs

Gaz Métro's new orientations to diversify operations incl. renewable natural gas

Canada Strategic Infrastructure Fund pgm.

Redevelopment of the Royal Vic

Threats

Incentive programs from utilities & agencies can be suspended at any time

McGill competes with private sector for climate action incentive monies

Low energy prices penalize energy conservation and renewable energy projects

Emission rights: federal & provincial regulations, international agreements, market forces.

Figure 9 - SWOT Analysis of Energy Management at McGill

4. 2016-2020 Strategy

4.1. Vision

Our long-term vision is that McGill's campuses are net-zero energy consumers and carbon neutral. Energy performance is embedded in the culture of operation staff and building users as part of a more global sustainability mindset.

4.2. Goal for the 2016-2020 Period

The 2016-2020 implementation phase will see to the transition of McGill's energy systems from discrete static "consumers" to dynamic smart grids that make use of synergies between endothermic and exothermic systems. Renewable energy systems will be deployed and connected to these smart grids.

4.3. Objectives

- Build backbone for heat exchange between buildings on downtown campus
- Deploy renewable energy systems on Macdonald, Campus building on the new low-temperature distribution network
- Continue investing in energy conservation and push for greater energy efficiency in renovation and construction projects
- Ensure achieved savings are sustained

4.4. Activities

- 100% energy conservation projects
- Mixed projects (energy conservation + alternative sources of funding)
- Energy programs
- Efficiency in Operations
- Community Engagement

4.5. Impacts

- Reduction of energy intensity on campus 22% below 2012-13 level | 35% below 2002-03 level
- Absolute reduction of GHG emissions from stationary combustion of 13,500 tons of CO_2e, i.e. 64% below 1990 level
- 53% renewable energy in McGill's overall energy mix, 68% for Macdonald Campus
- 1.6 MW of peak demand charge avoided on average

5. Action Plan

5.1. 100% Energy Conservation Projects

Most of the success of McGill's Energy Management Plan relies on an innovative funding mechanism: projects are funded by internal loans repaid with the savings generated by the said projects. We are calling this section 100% Energy Conservation Projects not because funding comes entirely from an energy conservation loan but because the only drive behind the project is energy conservation and cost savings.

One of our challenges is that we have grabbed the low-hanging fruit during the first implementation phase of the Energy Management Plan. We must now tackle projects with longer paybacks that require heavier upfront capital investment. Climate action and energy efficiency incentive programs must be leveraged to maximize opportunities. Table 6 summarizes key figures of this project.

	Investment	of which energy loan	Savings	Incentives	Net payback	GHG reduction (tCO2e)
Deploy smart grids on DT campus	$4.59M	0.0%	$194k	$0.87M	19.2	1,101
Heat recovery from DT powerhouse stacks	$1.33M	100.0%	$266k	$0.53M	3.0	1,417
Peak demand management	$8.28M	14.3%	$179k	$0.00M	6.6	-52
Total	$14.20M	17.7%	$639k	$1.40M	8.9	2,466

Table 6 - 100% Energy Conservation Projects

5.1.1. Deploy smart energy grids on downtown campus

In 2015, Utilities & Energy Management mandated a firm of consultants to develop a strategy to deploy a heat recovery loop linking together the buildings of the southeast quadrant of downtown campus. The consultants identified short- and medium-term measures that could save 14% of the quadrant's energy use and reduce greenhouse gas emissions 38%. Measures are broken down into two categories: those that can benefit from synergies with upcoming infrastructure projects in this sector and the remaining measures, including looping the buildings together, which will be implemented in a single overarching project. Multiple incentive programs are considered to help fund this strategy.

5.1.2. Improve powerhouse and distribution networks efficiency

The downtown powerhouse has a total output capacity of 470,000 lb/h (i.e. 120 MW). It supplies most of the downtown campus buildings with steam used for space heating, humidification, and sterilization. It burns 13 to 15 million m³ of natural gas every year with an overall combustion efficiency of 80%. This means that 20% energy is lost, i.e. around 100,000 GJ per year or ±8% of McGill's annual energy use. Investments will be made to install economizers on boiler stacks. There are scores of examples of facilities that have installed boiler stack economizers and McGill will carefully review the pros and cons, dos and don'ts of such a measure.

5.1.3. Manage peak demand

Peak demand management has become a stake for Gaz Métro and for Hydro Québec for slightly different reasons. While natural gas supply greatly exceeds demand in North America at this time, transport from gas fields in Western Canada to end-users in Central Canada has reached capacity and extra transport, especially during cold winter days, has become extremely costly. As for Hydro Québec, the utility has to purchase power from neighbouring states and provinces during extremely cold winter days at a great cost. Both utilities have been instructed by the Québec Energy Board to develop solutions to minimize the cost on end-users. Gaz Métro is revising its interruptible offer and Hydro Québec spearheaded a demand-side management program in the winter of 2015-2016. McGill took part in the pilot project and implemented load shedding measures in the Genome Building. Note that, unlike McGill, most organizations that participated in the program used their emergency power generators to reduce their power demand. Critics voiced concerns over the environmental impact of running diesel generators to replace electricity purchased from neighbouring utilities. According to Hydro Québec, taking into account the much greater emission factors of neighbouring utility networks[13] (e.g. the overall emission factor for New England is 145, Ontario is 38 times greater, etc.) and transmission losses, it still makes sense to use onsite emergency generators in Québec rather than importing electricity.

Further to these offers, McGill also has an incentive to manage its peak demand in the summer. Indeed, power demand reaches its apex on campus during the summer. The downtown distribution is at Hydro Québec rate LG which charges for energy consumed (in kWh) and peak power demand (kW). In FY15-16 for instance, the downtown power distribution cost $4.7M in energy charges and $3.2M in demand charges. Monthly demand charges are on average $70,000 greater during the summer months.

The proposed strategy consists in:

- Implementing demand-side management measures in the main buildings on downtown campus including running emergency generators when Hydro Québec calls for peak demand hours and implementing load shedding measures such as the ones implemented in the Genome building.
- Relocate and convert the downtown powerhouse generator from diesel to a co-generation, natural gas engine. The powerhouse generator is temporarily located close to the James Administration building. A project is on the table to relocate it behind the powerhouse. Instead of replacing it with a traditional diesel engine, Utilities & Energy Management is looking into installing a co-generation system fueled by natural gas. This system is proposed for two reasons: natural gas as a greenhouse gas emission factor per unit of energy 32% less than that of diesel and emits 90% less nitrous oxides which is the main source of urban smog and acid rain. The second reason is that traditional engines have an overall efficiency of 20 to 30%. Co-generation systems, also called combined heat and power (CHP), make use of the heat lost by the engine and the stack and convert it to hot water to be used for space heating or other purposes. CHP can reach 50 to 75% efficiency[14].

[13] Table 2 – Québec's Default Emission Factors for Electricity Imports
[14] US EPA – Combined Heat and Power Benefits

5.2. Mixed Projects (Energy Conservation + Alternative Sources of Funding)

Some project do not offer reasonable paybacks or net-present values for Utilities & Energy Management to undertake on its own. However opportunities exist and Utilities & Energy Management will seek to create synergies to grab each opportunity.

	Investment	of which energy loan	Savings	Incentives	Net payback	GHG reduction (tCO2e)
Major HVAC System Upgrades	$40.00M	25.0%	$1.00M	$2.65M	7.3	3,991
Deploy non-conventional renewable energy systems	$1.50M	100.0%	$120k	$0.69M	6.7	978
Deploy smart grids on DT campus	$6.47M	77.3%	$445k	$0.00M	11.2	57
Total	$47.97M	34.4%	$1.56M	$3.35M	8.4	5,035

Table 7 - Mixed Projects (Energy Conservation + Alternative Sources of Funding)

5.2.1. Major HVAC system upgrades

With a building portfolio fifty years of age on average, McGill manages anywhere between $20M and $100M worth of major renovations every year. Major buildings will be upgraded in the years to come. Utilities & Energy Management is mostly interested in building HVAC systems as they drive anywhere between 50 to 80% of a building's consumption. When appropriate, Utilities & Energy Management will participate technically and financially to such projects in order to increase energy efficiency on campus and to grab opportunities that would otherwise be missed in a generally very tight budget context.

5.2.2. Deploy non-conventional renewable energy systems

In a retrofit context, and even more so in McGill's context, most renewable energy technologies don't have acceptable paybacks or a positive net present value over the expected lifetime of the systems. Installing any such system must therefore be financed in part by alternate sources of funding such as donations to a fund to make McGill energy systems greener or by climate action incentive programs. In support of McGill's Vision 2020, Utilities & Energy Management will seek to increase the presence of renewable energy systems on campus. It should also be noted that the cost of renewable energy is decreasing at an accelerated pace relative to the cost of traditional energy; renewable energy technologies should thus become much more affordable in a near future.

5.2.3. Deploy smart energy grids on downtown campus

Synergies will be created between the smart grid deployment project and other infrastructure projects so as to leverage capital investments already required to update HVAC and mechanical systems. The idea is to influence these project designs and contribute in part to their funding so as to implement the long-term network strategy developed for the four quadrants of the downtown campus.

5.2.4. Propose a strategy for the deployment of charging stations

Utilities & Energy Management along with Transportation & Parking Services are the two main stakeholders in this project. McGill must adapt to changing market conditions. Québec has set ambitious goals to increase the market penetration of electric vehicles and real estate owners and managers such as McGill must prepare for the market shift. UEM will be strongly involved in the selection of the appropriate technology to charge electric vehicles on campus.

5.3. Energy Conservation Programs

Building on the success of the first implementation phase of McGill's Energy Management Plan, Utilities & Energy Management proposes to carry on with the programs listed below. These programs require minimum investment, light interventions, and have a very short payback.

	Investment	of which energy loan	Savings	Incentives	Net payback	GHG reduction (tCO2e)
Retro-Commissioning	$1.05M	100.0%	$386k	$0.21M	2.2	1,540
Insulation	$0.50M	100.0%	$500k	$0.00M	1.0	2,661
Building and Systems Optimization	$2.00M	50.0%	$458k	$0.00M	2.2	1,829
Total	$3.55M	71.8%	$1.34 M	$0.21M	1.7	6,030

Table 8 - Energy Conservation Programs

5.3.1. Retro-commissioning

Retro-commissioning is one of the plan's programs with the shortest payback. It is much like doing a health check-up of a building's systems and fixing what ought to be fixed. A team of consultant do a walk-through of the building, review the sequence of operation of the different systems, analyze energy logs and identify inefficiencies. The goal is to make sure that the systems work as efficiently as possible to deliver optimal conditions for building users. 15 buildings were retrofitted during the first implementation phase for an overall payback of 1 year. 15 smaller buildings including student residences have been identified for the new implementation phase.

5.3.2. Insulation

Insulating uninsulated pipes is the program with the shortest payback, i.e. less than one year. With more than 15 km of main distribution pipes, more than 1,000 HVAC systems on campus and countless interventions, there are always sections of pipes to be re-insulated.

5.3.3. Building and systems optimization

This program is for short payback, limited-scale interventions that either fall out of scope of Utilities & Energy Management's regular programs (e.g. Retro-commissioning) or are competing with other more urgent interventions in Building Operations' budget. A good example would be heat recovery systems: a malfunctioning heat recovery coil wouldn't impede the normal operation of a system and wouldn't be treated as an emergency by Building Operations. In the meantime, every day the said heat recovery coil is out of function can cost thousands of dollars to the University. This program, in partnership with Building Operations, is meant to fund such interventions.

The program is divided into two categories: project with a two- to three-year payback (e.g., installation of CO2 sensors for demand control ventilation) and projects with a six- to eight-year payback (e.g., installation of variable frequency drives).

5.4. Efficient Operations

In any organization, operations staff are crucial to the longevity of savings. The first implementation phase of McGill's Energy Management Plan saw the birth and strengthening of the relationship between Utilities & Energy Management and Building Operations. Utilities & Energy Management will continue to nurture this relationship and develop new relationships with other operations areas in the organization.

	Investment	of which energy loan	Savings	Net payback	GHG reduction (tCO2e)
Efficient operations	$0.03M	0.0%	$68k	0.4	74
Improve powerhouse and distribution networks efficiency	$0.38M	100.0%	$377k	1.0	0
Ensure continuity of energy savings	$0.65M	0.0%	$0k	--	0
Total	$1.05M	35.8%	$445k	0.8	74

Table 9 - Efficient Operations

5.4.1. Empower building operators

As mentioned times and again, operations staff are critical to energy efficiency. Utilities & Energy Management has actively collaborated with building control technicians during the first implementation phase of the plan. We now wish to develop a new partnership with building operators, to empower them with the tools and knowledge they need to increase energy performance on campus. The plan is to:

- Offer the Building Operators Certification (BOC) training to interested building operators. This certification program was launched in the mid '90s in the USA where over 10,000 building operators have been certified since. The certification program seeks to empower building operators to operate HVAC systems more efficiently and consists of training sessions around building engineering, systems controls, etc. Surveys show BOC-certified operators save on

average 2.5% of their building's energy. The different modules were mostly designed and are taught by senior building operators.
- Offer Lean white- and yellow-belt training to interested building operators. This phase of the program is meant to supply basic problem-analysis and solution-seeking tools to building operators.
- Organize Kaizen workshops with trained operators, ideally in buildings that have already been retro-commissioned. During this final step, trained operators will use the knowledge and skills they have honed in to participate in workshops animated by Lean experts along with staff from Building Operations and Utilities & Energy Management. The goal is to pinpoint inefficiencies and collectively find solutions to improve building energy performance.

5.4.2. Improve powerhouse and distribution networks efficiency

McGill's downtown and Macdonald campus powerhouses represent 45% of McGill's overall energy and 90% of McGill's thermal energy. Energy is extracted from natural gas to generate steam and hot water for space heating, humidification, and sterilization. Over 15 km of networks link the powerhouses with the main buildings on the downtown and Macdonald campuses. Losses and inefficiencies can occur in many places and have an exponential impact on McGill's overall energy performance. Much as building operators, the powerhouse staff are critical to energy efficiency. Utilities & Energy Management proposes to review activities and analyze opportunities for improvement using a Lean – Six-Sigma approach with expertise of key resources from McGill's central administration.

5.4.3. Ensure continuity of energy savings

Monitoring performance is a *sine qua non* condition to sound management. Back in 2010, hundreds of energy meters were installed in more than 70 buildings downtown, on the Macdonald campus, and in off-campus residences. These meters monitor 80% of the University's overall demand in real time. A software solution was deployed to visualize data, analyze trends, and generate reports. The 400 and more meters now installed must be inspected at regular intervals and around 2% of them need to be replaced at any time. This set of tools allows tracking savings and detecting deviation from normal trends.

5.5. Community Engagement

5.5.1. Sustainable Procurement

McGill procures hundreds of millions of dollars of goods and services every year. New equipment, particularly research equipment, has a major impact on energy usage on campus and contributes to an ever-growing demand. Procurement Services assumes its leadership and has developed a five-year sustainability strategy to influence purchases on campus and make sure McGill lives up to its aspirations. Utilities & Energy Management is an active stakeholder in this process and collaborates with Procurement Services to change purchasing habits of researchers, decision-making parameters (e.g. consider total cost of ownership instead of lowest upfront cost), and requirements from granting agencies.

5.5.2. Research and Energy

The Sustainable Labs workgroup was set up in response to Vision 2020. Research represents more than 40% of McGill's energy use while research space only covers around 25% of the University's total square footage. There are more than 1,300 research fume hoods on campus. Fume hood users and lab users in general have a significant impact on McGill's energy and sustainability performance. Utilities & Energy Management is an active stakeholder of the Sustainable Labs workgroup which strives to continuously educate a high-turnover population on energy conservation in labs via trainings, the inclusion of energy criteria in the lab inspection process, awareness campaigns, etc.

A student-led initiative called Shut Your Sash[15] in the Life Sciences Complex in 2011 showed the impact of lab users on energy use: savings in the order of 5% of the building's overall energy use were observed at the end of the project. In 2013, Utilities & Energy Management, supported by the Sustainability Projects Fund[16], experimented different prompts and messages to nudge lab users to shut their sash. The results were manifold: such programs only have an impact in labs with high fume hood to square footage ratios; dynamic messages based on gamification principles led to greater savings than static messages such as the ones installed in Life Sciences; fume hood users get used to static messages and their effect wears off with time, making it necessary to relaunch an awareness campaign, train incoming lab users, or use dynamic prompts.

We will continue those efforts, work with stakeholders on campus to develop trainings for all new lab users, and support change leaders in the research community to push for newer, more environmentally-friendly and energy-efficient practices.

5.5.3. Applied Student Research

Applied Student Research *is an opportunity for students to address the needs of their community for academic credit in a hands-on way, bridging the gap between theories taught in the classroom and their practical application*[17]. For Utilities & Energy Management this means tapping into the knowledge of McGill's student population to investigate technologies in development and how to deploy them on campus while offering students the opportunity to learn more about these technologies and energy systems in general.

There are many challenges to ASR: finding the right students with enough background and an understanding of systems thinking, finding projects that work well with students timeline (typically one or two terms), or getting staff's buy-in on the project output.

5.5.4. Communications

McGill has several success stories to tell when it comes to energy management. Over the course of 2010-2015, energy use veered sharply downward and greenhouse gas emissions were cut down. The University is at the forefront of energy management in the province and in Canada. Our communications strategy will be twofold. We will share positive stories with the McGill community to raise awareness on McGill's achievements in energy conservation and seek the participation of the community to the different programs and projects on campus. We will also work with external stakeholders to better disseminate our successes which will contribute to reaffirm McGill's image.

[15] Shut Your Sash
[16] The Fume Hood Experiment
[17] Definition of ASR from the McGill Office of Sustainability website

5.6. Meeting Compliance Requirements and McGill's Objectives

Area of intervention	Reduce energy use intensity of building stock	Increase energy performance of new buildings incl. major renovations	Phase out use of heating oil in buildings	Reduce peak power demand	Reduce energy-related GHG emissions of buildings	Use renewable energy as the main source of heating buildings	Reduce overall GHG emissions (QC)	Work towards carbon neutrality (McGill)	Reduce GHG emissions related to transport
Smart grids DT	✓	✓			✓		✓	✓	
Increase DT powerhouse efficiency	✓				✓		✓	✓	
Peak demand management				✓					
Major HVAC upgrades	✓	✓		✓	✓	✓	✓	✓	
Non-conventional renewable energy systems			✓		✓	✓	✓	✓	
Retro-commissioning	✓	✓		✓	✓		✓	✓	
Insulation	✓				✓		✓	✓	
Buildings and systems optimization	✓				✓		✓	✓	
Efficient operations	✓	✓		✓	✓	✓	✓	✓	
Improve distribution efficiency	✓				✓		✓	✓	
Energy savings persistence	✓	✓		✓	✓	✓	✓	✓	
Community engagement	✓						✓	✓	✓

Table 10 - Meeting Compliance Requirements and Institutional Orientations

5.7. SUMMARY TABLE

	100% ENERGY PROJECTS	MIXED PROJECTS	ENERGY PROGRAMS	OPERATIONS	TOTAL
INVESTMENTS	$14.20M	$47.97M	$3.55M	$1.05M	**$66.78M**
OF WHICH ENERGY LOAN	17.7%	34.4%	71.8%	35.8%	**32.9%**
INCENTIVES	$1.40M	$3.35M	$0.21M	$0k	**$4.96M**
SAVINGS	$639k	$1.56M	$1.34M	$445k	**$3.99M**
PAYBACK ON ENERGY LOAN	8.9	8.4	1.7	0.8	**4.3**
NPV	$2.94M	$6.45M	$3.96M	$1.54M	**$14.89M**

Table 11 - Summary of 2016-2020 EMP Programs and Projects

APPENDICES

Five-Year Energy Management Plan

2016-2020 Plan Proposal

	GHG Savings (tCO2eq)	Savings (GJ)			Savings ($)			Investment ($)			Incentives ($)					Payback (yrs.)	Payback (yrs.)	20-yr NPV
		Natural gas	Electricity	Total	Natural gas	Electricity	Total	Energy Loan	Other	Total	HQ	GM	BEIE	MESRS	Total			
1. 100% ENERGY CONSERVATION PROJECTS	**2,466**	**54,115**	**- 3,500**	**47,495**	**$ 527,478**	**$ 145,182**	**$ 639,021**	**$ 2,513,860**	**$ 11,690,000**	**$ 14,203,860**	**$ -**	**$ 244,551**	**$ 1,007,930**	**$ 148,089**	**$ 1,400,570**	**8.9**	**11.1**	**$ 2,935,383**
1.1. Deploy smart grids on downtown campus	1,101	25,697	- 3,500	19,077	$ 273,173	-$ 45,428	$ 194,106	$ -	$ 4,590,000	$ 4,590,000	$ -	$ 169,551	$ 550,386	$ 148,089	$ 868,026	19.2	23.6	-$ 643,751
1.2. Improve powerhouse and distribution networks efficiency	1,417	28,418	-	28,418	$ 266,272	$ -	$ 266,272	$ 1,331,360	$ -	$ 1,331,360	$ -	$ 75,000	$ 457,544	$ -	$ 532,544	3.0	5.0	$ -
1.3. Manage peak load	- 52	-	-	-	-$ 11,968	$ 190,610	$ 178,642	$ 1,182,500	$ 7,100,000	$ 8,282,500	$ -	$ -	$ -	$ -	$ -	6.6	6.6	$ 294,949
2. MIXED PROJECTS (ENERGY CONSERVATION AND OTHER SOURCES OF FUNDING)	**5,035**	**96,402**	**15,249**	**96,613**	**$ 917,966**	**$ 232,718**	**$ 1,564,667**	**$ 16,500,000**	**$ 31,471,500**	**$ 47,971,500**	**$ -**	**$ 615,141**	**$ 2,484,276**	**$ 246,332**	**$ 3,345,749**	**8.4**	**10.5**	**$ 6,446,949**
2.1. Upgrade HVAC systems	3,991	80,043	16,545	96,588	$ 750,000	$ 250,000	$ 1,000,000	$ 10,000,000	$ 30,000,000	$ 40,000,000	$ -	$ 528,125	$ 1,995,500	$ 130,089	$ 2,653,714	7.3	10.0	$ 7,221,630
2.2. Deploy non-conventional, renewable	978	13,188	- 815	12,373	$ 134,256	-$ 14,202	$ 120,054	$ 1,500,000	$ -	$ 1,500,000	$ -	$ 87,016	$ 488,776	$ 116,243	$ 692,035	6.7	12.5	-$ 86,838
2.4. Deploy smart grids on downtown campus	57	3,171	- 433	985	$ 33,710	-$ 2,354	$ 444,613	$ 5,000,000	$ 1,471,500	$ 6,471,500	$ -	$ -	$ -	$ -	$ -	11.2	11.2	-$ 687,843
2.5. Propose strategy for deployment of charging stations	10	-	- 48	- 13,333	$ -	-$ 725	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-	-	$ -
3. ENERGY PROGRAMS	**6,030**	**120,935**	**13,968**	**134,903**	**$ 1,133,162**	**$ 211,054**	**$ 1,344,216**	**$ 2,552,172**	**$ 1,000,000**	**$ 3,552,172**	**$ -**	**$ 60,000**	**$ 152,731**	**$ -**	**$ 212,731**	**1.7**	**1.9**	**$ 3,964,969**
3.1. Retro-commissioning	1,540	30,887	6,385	37,272	$ 289,412	$ 96,471	$ 385,883	$ 1,052,172	$ -	$ 1,052,172	$ -	$ 60,000	$ 152,731	$ -	$ 212,731	2.2	2.7	$ 1,400,411
3.2. Insulation	2,661	53,362	-	53,362	$ 500,000	$ -	$ 500,000	$ 500,000	$ -	$ 500,000	$ -	$ -	$ -	$ -	$ -	1.0	1.0	$ 1,359,006
3.3. Building and systems optimization	1,829	36,686	7,583	44,270	$ 343,750	$ 114,583	$ 458,333	$ 1,000,000	$ 1,000,000	$ 2,000,000	$ -	$ -	$ -	$ -	$ -	2.2	2.2	$ 1,205,552
4. OPERATIONS	**74**	**1,477**	**3,600**	**5,077**	**$ 390,587**	**$ 54,396**	**$ 444,983**	**$ 376,750**	**$ 675,300**	**$ 1,052,050**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**0.8**	**0.8**	**$ 1,539,857**
4.1. Improve powerhouse and distribution networks efficiency	-	-	-	-	$ 376,750	$ -	$ 376,750	$ 376,750	$ -	$ 376,750	$ -	$ -	$ -	$ -	$ -	1.0	1.0	$ 1,833,247
4.2. Empower building operators	74	1,477	3,600	5,077	$ 13,837	$ 54,396	$ 68,233	$ -	$ 25,300	$ 25,300	$ -	$ -	$ -	$ -	$ -	0.4	0.4	$ 377,150
4.3. Ensure continuity of energy savings	-	-	-	-	$ -	$ -	$ -	$ -	$ 650,000	$ 650,000	$ -	$ -	$ -	$ -	$ -	--	--	-$ 670,540
TOTAL	**13,605**	**272,928**	**29,317**	**284,087**	**$ 2,969,192**	**$ 643,350**	**$ 3,992,886**	**$ 21,942,782**	**$ 44,836,800**	**$ 66,779,582**	**$ -**	**$ 919,692**	**$ 3,644,938**	**$ 394,421**	**$ 4,959,051**	**4.3**	**5.5**	**$ 14,887,158**

Appendix B – Key Performance Indicators – 1990 vs. 2016

Performance indicator	1990	2015-2016	Relative change	
			Total (%)	Average annual (%)
Gross area	549,421 m^2	791,140 m^2	+44%	+1.4%
FTEs	22,616[18]	30,535[18]	+35%	+1.2%
Total energy use	1,284,809 GJ[18]	1,223,675 GJ	-5%	-0.2%
- electricity	28%	49%	+21%	--
- natural gas	66%	50%	-16%	--
- heating oil & other	6%	0%	-6%	--
Normalized EUI – McGill	2.34 GJ/m^2	1.63 GJ/m^2	-30%	-1.4%
Normalized EUI – QC average	1.71 GJ/m^2	1.39 GJ/m^2*	-19%	-0.8%
McGill vs. QC average	37% higher	18% higher	-19%	--
Total spend	$8.8M	$18.6M	+113%	+2.9%
- electricity	54%	64%	+10%	--
- natural gas	41%	36%	-5%	--
- heating oil & other	5%	0%	-5%	--
Total spend per area	$15.95/$m^2$	$23.56/$m^2$	+48%	+1.5%
Energy rate (overall)	$6.82/GJ	$15.23/GJ	+123%	+3.1%
- electricity	$13.20/GJ	$19.58/GJ	+48%	+1.5%
- natural gas	$4.22/GJ	$10.05/GJ	+159%	+3.7%
- heating oil & other	$6.01/GJ	$15.73/GJ	+162%	+3.8%
GHG emissions[19] (absolute)	48,501 tCO2eq	31,110 tCO2eq	-36%	-1.7%
GHG emissions per area	88.3 kg CO2eq/m^2	39.32 kg CO2eq/m^2	-55%	-3%
GHG emissions per FTE	2.14 tCO2eq/FTE	1.02 t CO2eq/FTE	-52%	-2%
GHG emissions per energy unit	37.8 kg CO2eq/GJ	25.42 kg CO2eq/GJ	-33%	-2%

[18] Estimated data
[19] Scope 1 emissions from stationary combustion only