University Services – Facilities Operations & Development – Utilities & Energy Management

Five-Year Energy Management Plan

2013 Update

2013-08-20

EXECUTIVE SUMMARY

McGill is a leading edge university recognized worldwide for the quality of its teaching and research. Due to its size and the research intensive activities it houses, the University is the largest energy consumer among Québec universities. In 2010, Utilities & Energy Management proposed a plan to reduce energy consumption and greenhouse gas emissions. By 2011-2012, investments made during the first years of the plan allowed the University to reach its 12% target reduction in energy intensity relative to the 2002-2003 baseline. Current annual savings total over $650,000 and the overall return on investment of the projects completed so far is 12.9 years. Additional benefits include reductions in greenhouse gas emissions of 3,400 tonnes of CO_2-equivalent per year.

The 2013 update of the Five-Year Energy Management Plan builds on lessons learned over the first three years of the plan. The updated plan is more diversified and comprises a lighting retrofit program and continuous use of the energy management information system, as in the first plan, as well as a revisited energy audit and building retro-commissioning program, new campus-wide programs (insulation, optimization, maintenance, etc.) and other softer measures meant to affect behavioural change. Utilities & Energy Management have identified $39.8 million worth of investments (including those made since 2010-2011) which will generate $5.3 million annual savings upon full implementation of the plan with an overall net return on investment of 7.0 years. Upon full implementation of the plan, McGill's annual energy consumption will be reduced by 480,000 GJ per year and greenhouse gas emissions will be reduced by 12,800 tons of CO_2-equivalent per year. On the overall, McGill's energy intensity will be 26% lower than the 2002-2003 reference.

Table 1 below summarizes the key performance indicators for each program and project of the plan. Grey font is used for past investments and black font for investments to come. For a more detailed version of the table, please refer to Section 9.

FIVE-YEAR ENERGY MANAGEMENT PLAN - 2013 UPDATE - KEY PERFORMANCE INDICATORS										
	Pre-FY11-12	FY11-12	FY12-13	FY13-14	FY14-15	FY15-16	FY16-17	FY17-18	OVERALL	R.O.I.
Investment	$ 2,627,954	$ 5,927,136	$ 1,720,262	$ 5,843,161	$ 12,885,402	$ 4,986,049	$ 3,172,757	$ 2,625,000	$ 39,787,720	
Incentives	$ 75,000	$ 495,809	$ 412,355	$ 267,523	$ 1,267,199	$ 288,226	$ -	$ -	$ 2,806,112	7.0
Annual Savings	$ -	$ 70,985	$ 1,281,518	$ 2,357,927	$ 3,686,005	$ 4,410,170	$ 4,940,856	$ 5,284,856	$ 5,284,856	
Annual Savings (GJ)	-	4,510	124,258	217,147	330,634	390,442	438,106	470,859	482,343	
GHG Emission Reduction (tCO2e)	-	3	4,007	6,195	8,904	10,298	11,613	12,552	12,842	

Table 1 - Energy Management Plan - 2013 Update - Key Performance Indicators

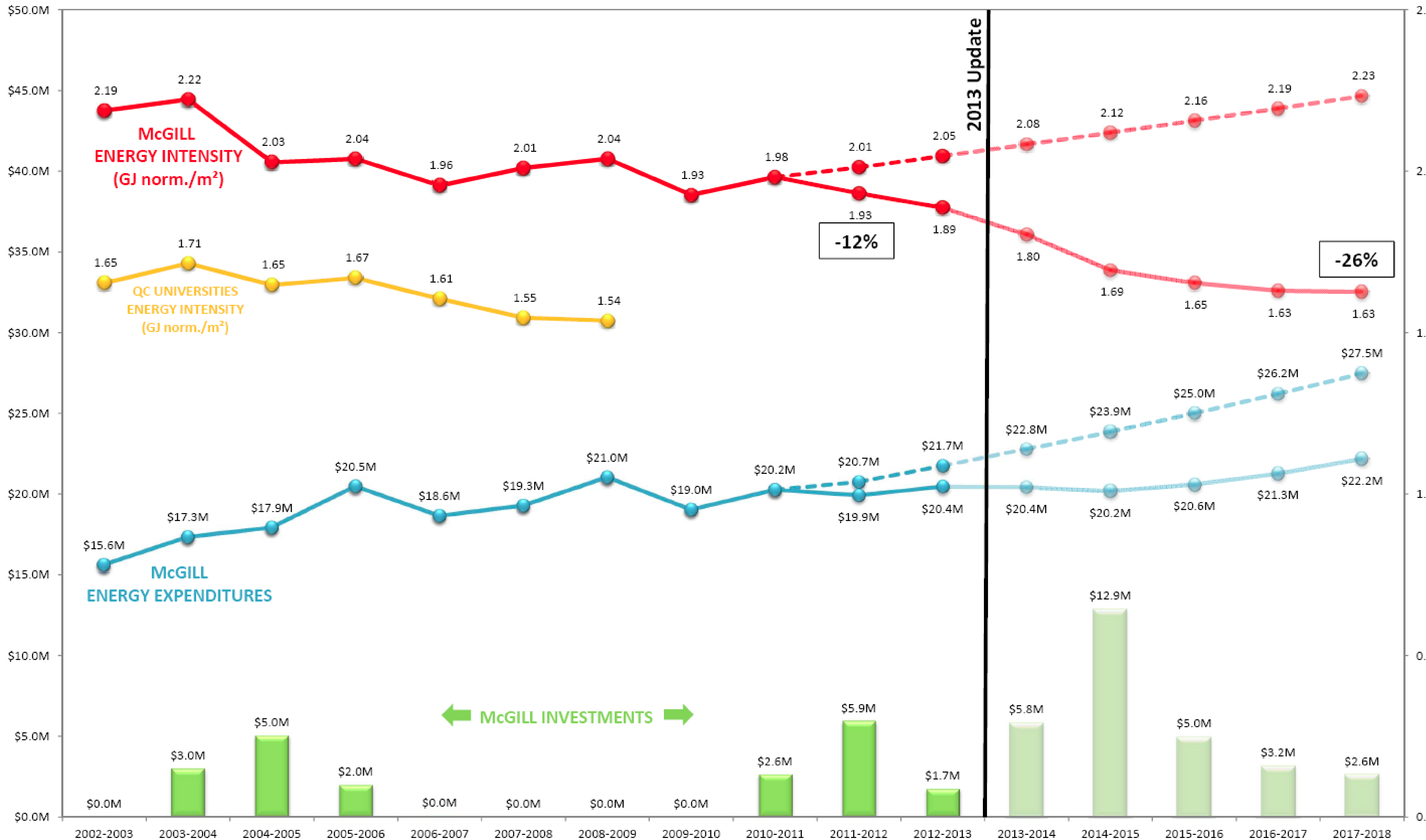

Figure 1 - Projected Impact of the Five-Year Energy Plan

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Baseline

In energy management, a baseline is a reference that allows to compare a building's energy use over different time periods assuming no major change in the building. A baseline is trained based on historical values comprising outputs (energy use data) and inputs (any influencing parameters such as weather data, occupation, day of the week, etc.) Baselines are used to estimate energy savings related to an energy conservation measure (e.g., lighting retrofit) or to estimate extra energy use resulting from nonconformities (e.g., undesired change in ventilation schedule).

Conversion Factors and Energy Units

Several units are used in energy management, as shown in the table below.

Fuel	Unit Symbol	Unit Name	Type
Chilled Water	BTU	British thermal units	Energy
Condensate	US gal	US gallons of condensate	Volume
Electricity	kWh	Kilowatt-hours	Energy
Energy (General)	GJ	Gigajoules	Energy
Hot Water	BTU	British thermal units	Energy
Natural Gas	m^3	Cubic meters of natural gas	Volume
Steam	lb	Pounds of steam	Mass

Table 2 - Energy Units

One can switch from one unit to the other using the following conversion factors below.

From	To	Multiply By
BTU	GJ	$1.055\ 10^{-6}$
GJ	BTU	$9.478\ 10^{5}$
kWh	GJ	$3.6\ 10^{-3}$
GJ	kWh	278
m^3 natural gas	GJ	$3.789\ 10^{-2}$
GJ of natural gas	m^3 of natural gas	26.39
US gal of condensate[1]	lb of condensate	8.081
lb of steam (Downtown)[2]	GJ of natural gas	$1.268\ 10^{-3}$
lb of steam (Macdonald)[3]	GJ of natural gas	$1.480\ 10^{-3}$

Table 3 - Energy Units and Conversion Factors

Energy Intensity

[1] At the temperature of 85°C, at atmospheric pressure, density of water from the US Geological Survey website http://ga.water.usgs.gov/edu/density.html

[2] 476,686,500 lb of steam generated for 604,294 GJ of natural gas consumed from May 2011 to April 2012, i.e. 789 lb of steam / GJ

[3] 61,406,500 lb of steam distributed for 90,885 GJ of natural gas consumed from May 2010 to April 2011, i.e. 676 lb/GJ

Energy intensity is the sum of all sources of energy used in a building over a 12-month period divided by the area of the building. Some benchmarks use net area while others use gross area. MELS uses gross area and unless otherwise specified, energy intensity is always calculated based on gross area in this document. The unit for energy intensity is GJ/m^2 (gigajoule per square meter). Energy intensity is also expressed in kWh/m^2 (kilowatt-hours equivalent per square meter) in Europe and in MMBTU/sq. ft. (millions of British thermal units per square foot) in the USA.

Fresh Air and Recycled or Recirculated Air

A lot of buildings on campus are ventilated to ensure an optimal work environment to building occupants. Heating, ventilation, and air conditioning (HVAC) systems treat outside air, supply it to the different building zones, and remove it from the building zones. The incoming air is referred to as fresh air. The air removed from the building zones can either be rejected to the atmosphere or, if clean enough, re-circulated to reduce energy use.

Normalized Energy Intensity

The calculation of normalized energy intensity derives from that of energy intensity. Energy consumption is highly dependent on weather conditions. If one wants to compare the impact of an energy conservation project, one must choose a reference year and use the weather conditions of this reference year to compare the energy consumption of the building year by year. MELS recommends a 30% portion of energy consumption independent of weather conditions and 70% dependent on weather conditions. Additionally, to compare all Quebec universities together, MELS normalizes all universities' energy intensities to Québec City heating degree days. That being said, analyses show that the fixed to variable split recommended by the MELS does not represent McGill's situation. For one thing, electricity does not correlate with heating degree days at McGill. Indeed, the two main campuses are heated with natural gas which makes more than 50% of McGill's energy consumption. Furthermore, though McGill's natural gas consumption is strongly correlated to heating degree days ($r^2 = 0.95$), a significant portion of it is fixed. Thus, the following equation is used to compute normalized energy intensity:

$$Normalized\ Energy\ Intensity = \frac{Electricity + Natural\ Gas \times \left(30\% + 70\% \times \frac{HDD_{Ref}}{HDD_{Montreal}}\right)}{Building\ Gross\ Area}$$

Equation 1- Calculating Normalized Energy Intensity

Heating Degree Days

Heating degree day (HDD) is a measure of how severe the weather is. Heating degree days are calculated as the difference between the outside temperature and 18°C, for each hour of the month. 18°C is considered as a balance point under which one must heat the building to maintain acceptable indoor conditions. A typical year in Montreal has 4,519 HDD; this reference used to normalize energy intensity. The same concept holds true for cooling degree days; however, due to the short cooling season in Quebec, cooling degree days are not used to normalize energy intensity.

MISSION STATEMENT

The role of McGill Utilities & Energy Management (MEUM) is to support the University's teaching and research mission. MEUM serves all 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 saving. We work closely with our stakeholders and give them tools to understand their energy use 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 have crafted a long-term strategy outlined in our rolling Five-Year Energy Management Plan 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. Energy conservation initiatives are 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 University Services and 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 and the McGill Energy Project in particular. 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 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 infuse these values into all our endeavours.

1. BACKGROUND

1.1. Context

In May 2010, University Services prepared a Five-Year Energy Management Plan to respond to the Minitry of Education's (MELS, i.e., *Ministère de l'Éducation, du Loisir et des Sports*) request that all post-secondary institutions in the province should reduce their energy intensity (GJ/m^2) by 14% relative to 2002-2003. MELS did not specify targets for individual institutions.

Prior to the 2010 Energy Management Plan, between 2002 and 2007, McGill invested over $10 million in various energy conservation projects. Before that, a major retrofit in the main power house implemented in 2000-2001 allowed major boiler and steam system improvements. As well, construction at McGill incorporates energy efficiency standards such as those advocated for by the Canadian Green Building Council (CaGBC). Buildings including Trottier, Génome, Music, and Life Sciences have all been built to energy-efficient standards. The most recent of these – the Life Sciences Complex – was awarded the LEED Gold certification in December 2011. More recently, several research buildings including McIntyre Medical, Maass Chemistry, and Macdonald Engineering have undergone major upgrades to bring their ventilation systems up to date and ensure optimal conditions for the leading-edge research activities they host. Although energy efficiency is one of the core components of these projects, the new indoor air quality standards often imply an increase in energy intensity for these buildings. These efforts have contributed to decreasing McGill's energy intensity in 2011-2012 by 12% relative to the 2002-2003 reference year. Figure 3 and Figure 4 show the main parameters that influence the University's energy consumption and energy expenditure..

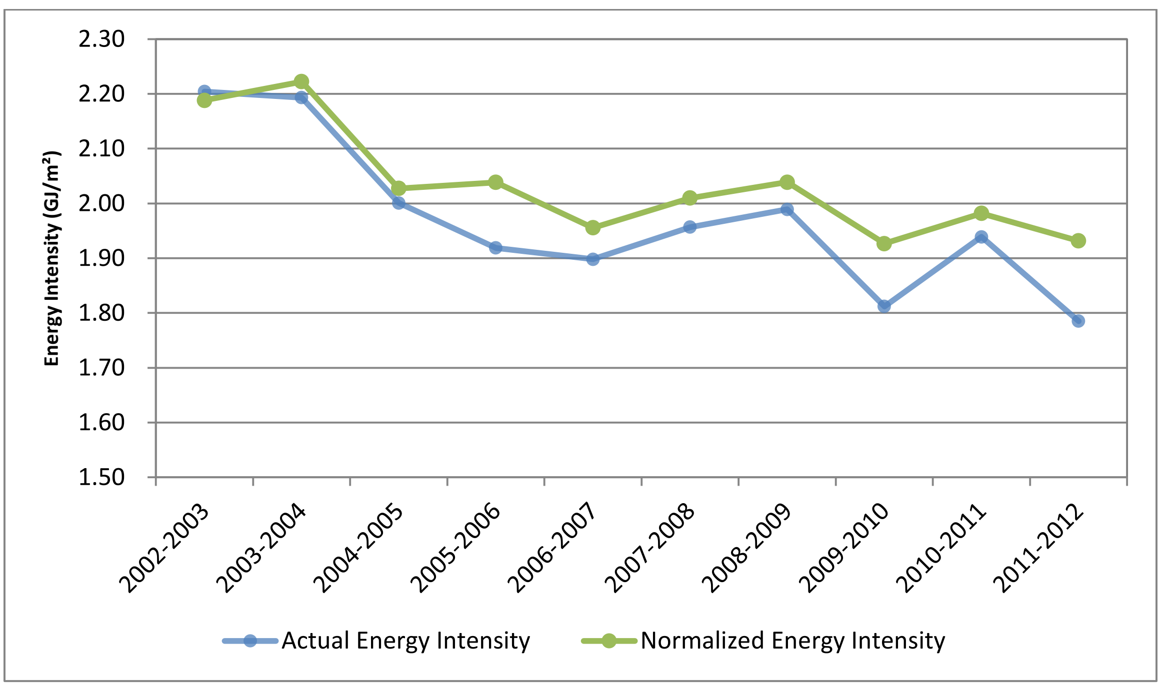

Figure 2 - Evolution of Actual and Normalized Energy Intensity

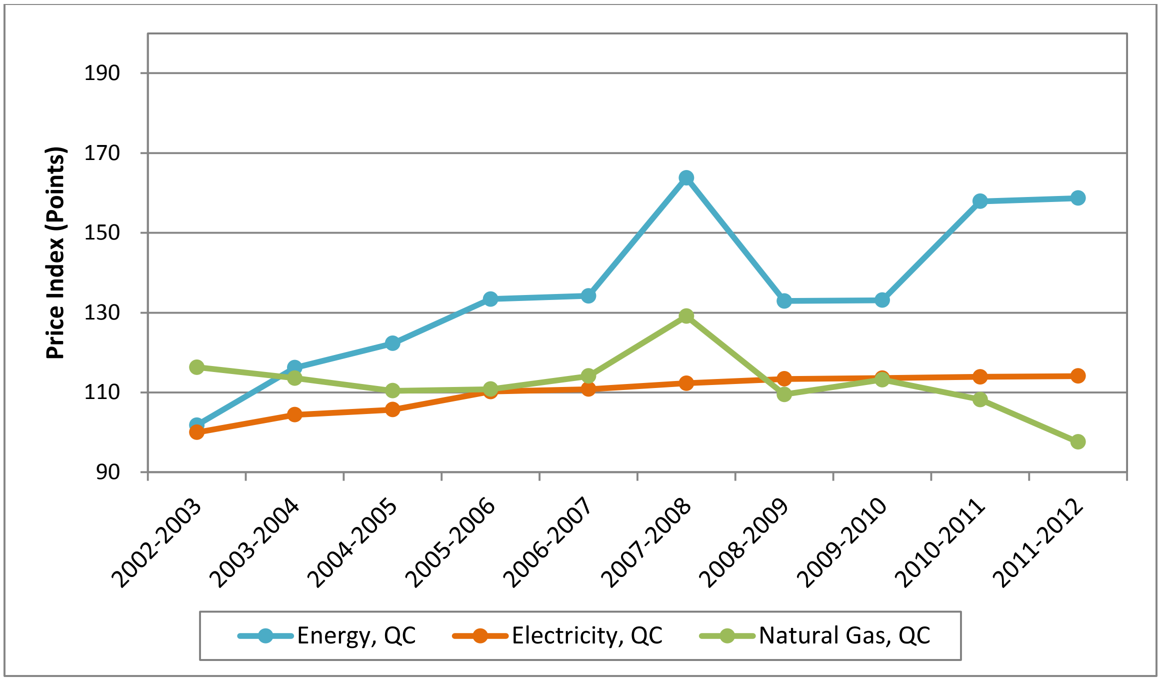

Figure 3 - Energy Price Indices for the Province of Québec, 2002-06 Reference Price Index

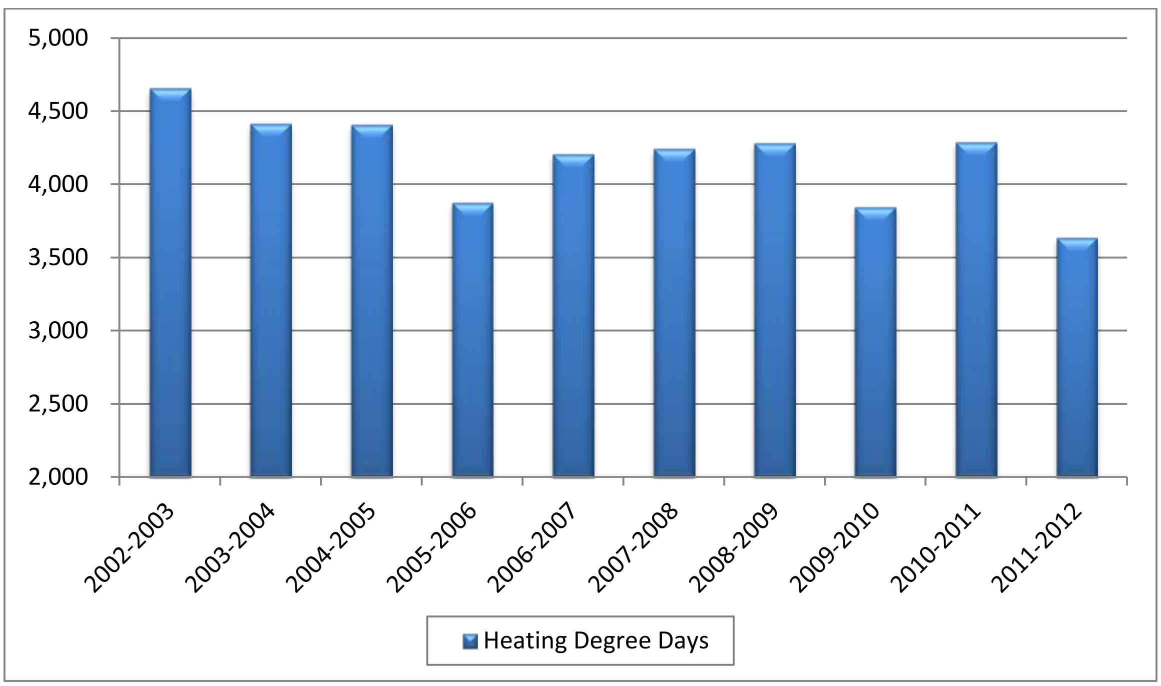

Figure 4 - Heating Degree Days, Montreal

1.2. The Energy Management Plan as Proposed in 2010

The first Five-Year Energy Management Plan as it was proposed in May 2010 proposed two targets: (1) to achieve a 12% reduction in energy intensity (relative to the 2002-2003 base year figures) by 2011-2012 and (2) to meet the Ministry of Education's (MELS) target of 14% energy intensity reduction by 2012-2013.

The 2010 proposal included:

- The implementation of an ***energy management information system*** (EMIS). The intent was to provide the necessary tools to monitor all aspects of energy consumption and pinpoint issues as they occur in real time.
- Building ***energy audit*** program to identify energy conservation measures with payback periods between three and ten years. Since the first Energy Management Plan, Hydro Québec's incentive for building audits was abrogated. Utilities & Energy Management thus decided to slow down the pace and focus on more interesting, low hanging fruit such as building re-commissioning and lighting retrofit projects. The program will be merged with the building re-commissioning program to save on consulting fees.
- A ***lighting retrofit*** program for all the main buildings on campus that includes the installation of occupancy sensors to maximize energy savings.
- A ***building re-commissioning*** program. Utilities & Energy Management adapted the original re-commissioning program to meet the requirements of *Le programme de remise au point des bâtiments*, an incentive program for re-commissioning projects jointly offered by Gaz Métro and Hydro Québec.
- And several ad-hoc ***energy conservation projects***.

Sections 2, 3, 4, and 6 of this report outline the status of each of these programs and the roadmap for the coming five years.

1.3. New Proposed Plan Structure

Since May 2010, Utilities & Energy Management has worked towards launching the four programs mentioned above. During this period, it has actively consulted with representatives of the *Régie du bâtiment du Québec*, Gaz Métro, Hydro Québec, *Programme bâtiment* (the entity that manages Hydro Québec's incentive programs), experts in energy conservation (including the *Association québécoise pour la maîtrise de l'énergie*), energy managers in other universities and public institutions, suppliers of energy conservation technologies, and service providers in energy efficiency. Utilities & Energy Management has also collaborated extensively with major institutional priority initiatives on campus including the Strategic Reframing Initiative (SRI) which set out to reduce recurring operational costs, and with Vision 2020, a community based plan to integrate sustainability in McGill's activities.

Based on this experience and network of knowledge, Utilities & Energy Management proposes to revise the different elements of the Energy Management Plan to better align with institutional priorities as follows:

- ***Lighting Retrofit Program.*** Due to technicalities, this program was put off one year and started in 2011-2012. Two buildings have successfully been retrofitted and seven more are under way. Savings demonstrated with the first two buildings are convincing and the performance of the occupancy detection sensors has been proven.
- ***Energy Audits and Re-Commissioning Program.*** Both programs are intertwined and many of the tasks required to conduct an energy audit are also required in building re-commissioning. Consequently, to

avoid duplicating consulting fees and McGill human resources, Utilities & Energy Management decided to merge both programs into one. Building re-commissioning will focus on easy to implement projects with short paybacks (typically less than three years) while building audits will address projects with longer paybacks and that require heavier capital investment.

- ***Energy Management Information System (EMIS).*** The installation of meters was completed in 2010-2011. Close to 400 meters now monitor all the energy flows in more than 67 buildings on the downtown and Macdonald campuses. McGill launched its online energy dashboard in April 2011. A taskforce was set up comprising staff from Utilities & Energy Management, Building Operations, and other ad-hoc guests to pinpoint issues as they occur, take action to correct these issues, and make recommendations to improve the energy performance of McGill's downtown buildings. This taskforce is essential to maintaining savings achieved through the different energy conservation measures implemented in campus.
- ***Campus-Wide Programs.*** Arising from the first wave of energy audits, these programs aim to address issues encountered in several buildings across campus that would be better dealt with on a systemic approach. Five areas of intervention have been identified: Maintenance, Insulation, Optimization, Building Upgrades, and Innovation.
- ***Other Energy Conservation Projects.*** The Otto-Maass retrofit and the McLennan – Redpath Library HVAC Upgrade, the New Summer Boiler, and Burnside Hall Heat Recovery Project outlined in the 2010 Energy Management Plan are completed. The Macdonald Campus Energy Project is its design phase. Other projects are proposed in the current report to complement this list.
- ***Other Measures not Included in the First EMP.*** While the Energy Management Plan covers hard measures, such as lighting retrofits, ventilation system upgrades, or building re-commissioning, Utilities & Energy Management also developed a range of soft measures such as the introduction of energy efficiency standards in all construction and renovation projects or the collaboration of Utilities & Energy Management experts on major deferred maintenance projects and other initiatives on campus.

2. Lighting Retrofit Program

Until 2011, the *Régie du bâtiment du Québec* requested that all retrofitted or otherwise modified lighting fixtures be certified by an authorized certification agency (such as CSA). Underlying this decision was the *Régie*'s concern about fire hazards related to inappropriate retrofits. This requirement from the *Régie* would have had a significant, negative impact on the payback of this project. Most of 2010 and 2011 was spent consulting with the *Régie* and certification agencies to find the most cost effective way to proceed with the program. After much ado, in August 2011, the *Régie* published an exception clause allowing retrofit programs without re-recertifying the retrofitted fixtures[4]. This resulted in a one-year delay in the implementation of the program.

In 2011, McGill launched two calls for tenders to retrofit the lighting systems of the Education and Rutherford Physics buildings. The intent of these two tenders was to determine the best business model that would then be applied to the whole campus. The two projects were completed in October 2011 (Education) and April 2012 (Rutherford Physics). Based on this experience, three calls for tenders were launched in 2012 to tackle seven more buildings in 2013.

2.1. Education and Rutherford

The table below sums up the total investment of the two projects (including equipment, labour, professional fees, management fees, and taxes).

Building	Project Start Date	Project End Date	Total Project Cost	Expected Savings (GJ)	Actual Savings (GJ)
Education	August 2011	October 2011	$372,000	2,923	1,201 – 2,486
Rutherford Physics	January 2012	April 2012	$237,000	2,152	2,024

Table 4 - Education and Rutherford Physics Lighting Retrofits

The actual payback for Education seems to be longer than originally estimated (10.8 years vs of 6.4 years). This holds true for Rutherford Physics (8.4 years vs 7.5 years). These figures do not include Hydro Québec's incentive estimated to $150,000 in total, which, once received, will bring both paybacks to 7.7 years and 6.3 years respectively.

Note on Project Costs:

As stated before, these two projects served to determine the optimal business model to be applied for all other lighting retrofits. Utilities & Energy Management expects smaller costs for the coming projects, with more interesting paybacks as buildings will be dealt with in lots rather than individually. This has been confirmed in 2012-2013 with bids much lower than expected (see Section 2.2 below).

Note on Savings:

The significant difference between the expected savings and the savings observed in the case of the Education building is due to different factors. First, there is just one meter on the electrical entrance of the building; it doesn't allow a breakdown of electricity per type of usage. Two temporary meters were installed before the

[4] Chronique 248 – Nouvelle approche – Modernisation de luminaires à lampes fluorescentes, Régie du bâtiment du Québec, August 2011.

project started in order to monitor the energy consumption of the lighting system on one floor of the building. These meters have shown an 80% decrease in energy consumption since project completion, which, extrapolated to the other floors, translates into savings of 2,486 GJ per annum. The meter on the main electrical entrance of the building, however, shows a 15% decrease in energy consumption, i.e., around 1,200 GJ per annum. From these facts, we can draw the following conclusions: 1) the energy consumption of the lighting system before project was overestimated mainly because no metering information on the lighting system only was available; 2) the current granularity of the metering system does not allow us to segregate the energy consumed by the lighting system from the energy consumed by the other systems, and therefore, we can only conclude we achieved substantial savings of at least 15% of the building's electricity with the project; 3) it is not possible to discriminate savings from additional energy use with meters at the building level; this is the main limitation of our metering system. That being said, it is common practice in other organizations to estimate savings based on fixture counts (ref. section 8 on Estimating energy savings.)

All these facts were taken into account to revise the estimated cost and savings for the coming years.

2.2. 2012 Lighting Retrofits

The following buildings will were retrofitted in 2012: Chancellor Day Hall, McConnell Engineering, Ferrier, Pulp & Paper, and the Raymond building on Macdonald campus. The total budgeted cost of the project for 2012 was $2.2 million with an expected payback of 14.3 years. The Leacock building had to be removed from the list; any intervention on the lighting fixture would require major code conformity upgrades to the ceiling which goes beyond the scope of a self-paying energy conservation measure. The Leacock lighting retrofit will be addressed in a deferred maintenance project. Actual project costs are also much lower than expected partly due to the removal of Leacock and mainly as a direct consequence of the different processes implemented further to the Education and Rutherford lighting retrofits including process management, better fixture counts, and purchasing strategy. McIntyre Garage will be retrofitted in 2013 but is included in the 2012 project cost. The payback of the 2012 lighting retrofit project is 10.7 years (7.4 including incentives).

Building	Project End Date	Total Project Cost	Expected Savings (GJ)	Actual Savings (GJ)
Chancellor Day Hall, McConnell Eng., Ferrier, Pulp & Paper, Raymond, McIntyre Garage	December 2012 *Sep 2013 for McIntyre Garage*	$999,183	6,714	3,604[5] – 6,714

Figure 5 - 2012 Lighting Retrofits

2.3. 2013 Lighting Retrofits

The following buildings will be retrofitted during the summer of 2013: Macdonald Stewart Library, James Administration, Redpath Library, Adams, McLennan Library, Bookstore, Peterson Hall, Redpath Museum, Burnside, and Arts. The estimated project cost is $1.6 million and expected savings in the order of 12,000 GJ. The expected payback is 9.6 years (8.8 including incentives to be confirmed.)

[5] Does not include McIntyre Garage savings. Retrofit postponed to summer of 2013 due to change of scope: garage will be retrofitted with LED fixtures..

2.4. Going Forward – 2014-2016

The graph below illustrates the coming investments for the next three fiscal years as well as the projects already completed or under completion (2011 to 2013). Installing detection sensors and retrofitting the 20 remaining main buildings on campus will require a further investment of $1.7 million and generate annual savings of over $126,000. The payback is estimated to 11.2 years including incentives.

At the end of the program, 39 buildings will have been retrofitted for a total project cost of $7.2 million, generating recurring annual savings of $600,000. Including incentives from Hydro Québec of $1.0 million and pending project costs for the final two years of the program, the overall payback of the program should be 10.2 years.

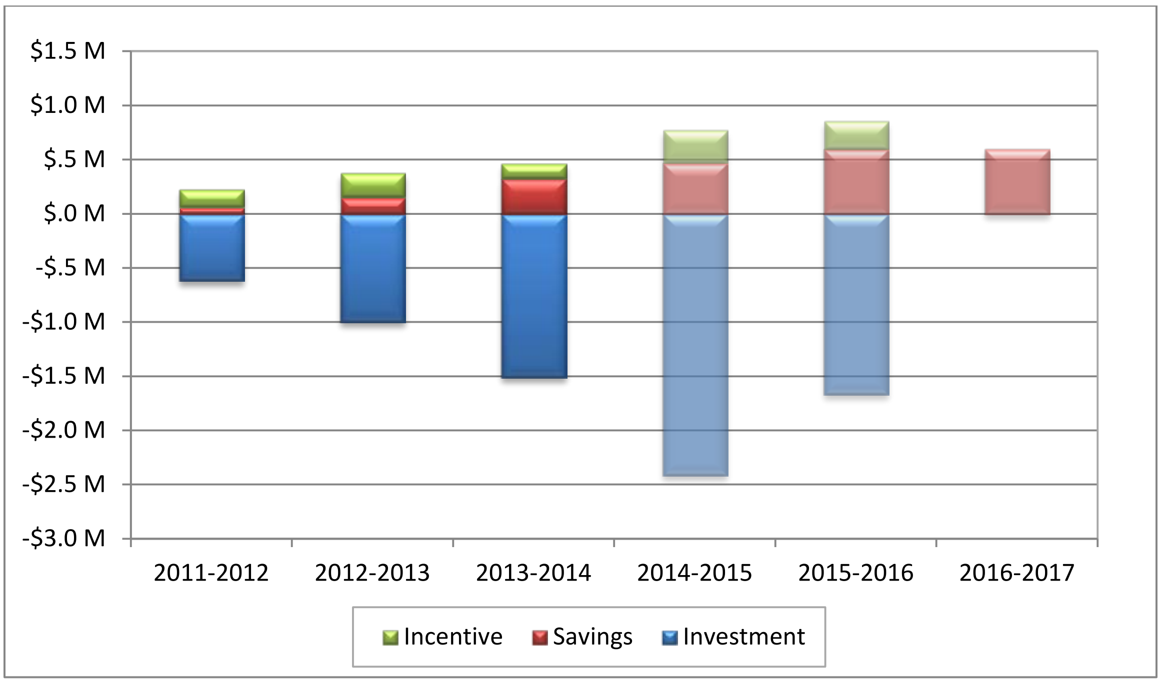

Figure 6 - Lighting Retrofits 2011 to 2016

3. Energy Audits and Re-Commissioning Program

3.1. Energy Audits – Education, Rutherford, and Burnside Hall

Several buildings have undergone an energy audit since the first Five-Year Energy Management Plan. Seven audit reports have been received between 2010-2011 and 2012-2013 (Education, Rutherford Physics, Burnside Hall, Bronfman Management, McConnell Engineering, Leacock, and Chancellor Day Hall).

Table 5 summarizes the auditors' recommendations for the Rutherford Physics building. Some recommendations are applicable to all buildings such as in Table 6; those recommendations will be dealt with through campus-wide programs. Section 5 outlines the plan Utilities & Energy Management proposes to enact these recommendations. For a complete list of recommendations, please refer Annex I. Note that the investment figures are very rough estimates (in the order of 30% - 50% error) and would need to be refined by McGill's Project Management before the recommendations are turned into projects.

Description of the Measure	Buildings Affected by the Measure	Investment ($)	Savings ($)	Savings (GJ)	Payback (Years)
Reduce fresh air intake by controlling dampers	Rutherford Physics	$48,000	$64,821	3,034	0.7
System #1 air handling heat recovery (enthalpy wheel in existing mixing duct)	Rutherford Physics	$55,000	$35,472	1,393	1.6
Air side free-cooling for server room	Rutherford Physics	$85,000	$23,262	2,006	3.7
Replace system #1 entirely w VFD unit, VAV boxes in rooms and DCV controller	Rutherford Physics	$675,000	$34,633	2,417	19.5
Install heat recovery unit for VA-1 (Clean room unit)	Rutherford Physics	$225,000	$14,261	560	15.8
Total		**$1,088,000**	**$172,449**	**9,409**	**6.3**

Table 5 - Examples of Recommendations from the 2010-2011 Audits

Description of the Measure
Install removable insulation on all steam traps, unions, valves, and condensate valves
Limit the hours of operation of lab hot water circulation pumps
Install temperature probes and humidity sensors to adjust actuation of ventilation systems
Change ventilation system schedules for summer hours
Stop toilet exhausts out of building hours

Table 6 - Example of Campus-Wide Opportunities Recommended in Energy Audit Reports

Additionally, fourteen buildings and the energy distribution network of Macdonald campus have also been audited in 2012-2013. These include Barton, Centennial Centre, C.I.N.E., Glenfinnan Rink, Laird Hall, Macdonald Stewart, Parasitology, Plant Research Greenhouse, Powerhouse, Raymond Building, Raymond Greenhouse, Sumerby Greenhouse, and the two Eco-Residences. Most of the recommendations of these audit reports are included in the Macdonald Energy Project. Figure 7the split of energy use of all the buildings located south of Autoroute 20 on Macdonald campus. Together, they represent over 80% of the total energy use of Macdonald campus.

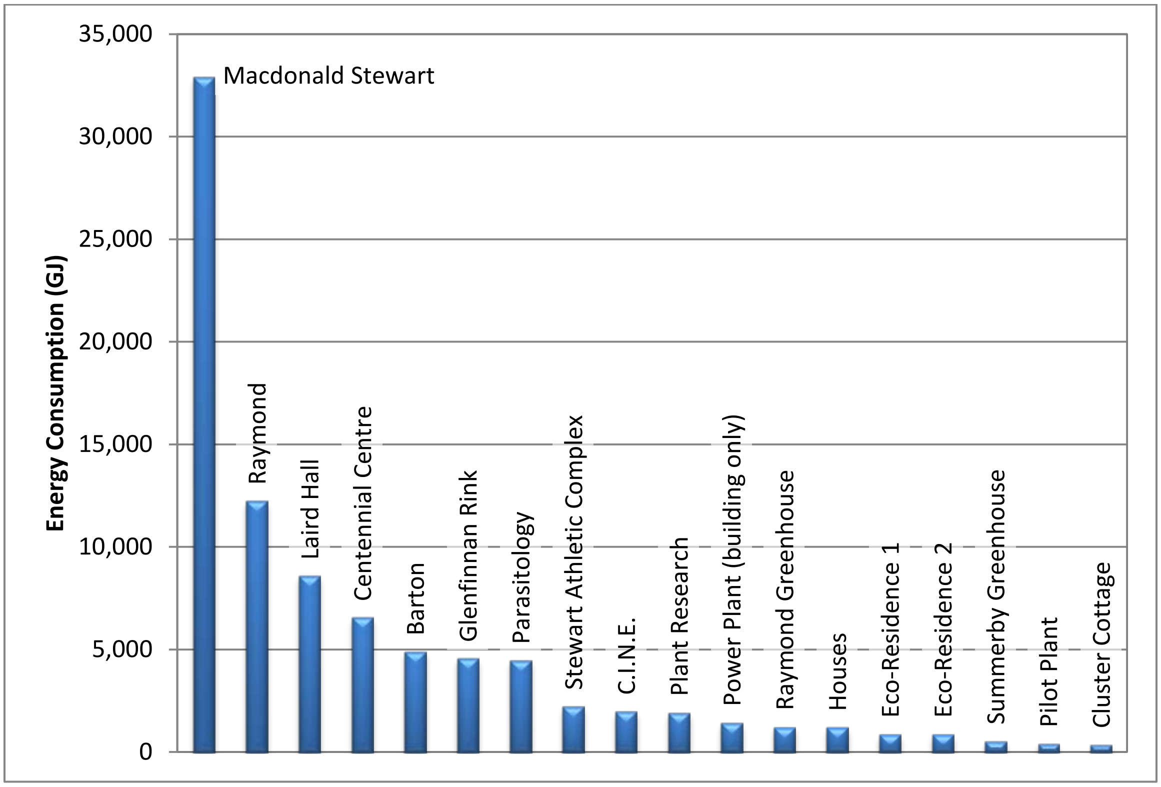

Figure 7 - Energy Use of Buildings on Macdonald Campus

During their audits of the buildings, the engineering firm investigated 42 energy conservation measures. The consultants categorized these energy conservation measures using parameters such as the potential for short paybacks, the risk associated with the technology, or the innovativeness of the measure. Table 7 sums up the most important measures that will be implemented as part of the Macdonald Campus Energy Project. Note that even though the payback of some measures does not look particularly appealing (e.g., *Generate domestic hot water with thermo-pumps*), these measures are necessary to implement other which will offer more interesting savings (in this case, shut off the steam lines during the summer and therefore greatly reduce network losses and energy consumption).

Description of the Measure	Buildings Affected by the Measure	Investment ($)	Savings ($)	Savings (GJ)	Payback (Years)
Convert multi-zone air handling units to variable air volume with terminal heating.	Barton	$ 111,599	$ 2,846	327	39.2
Convert double-duct, constant velocity systems to double duct, variable speed. Add variable frequency drive on supply and return fans.	Barton Macdonald Stewart	$ 439,769	$ 111,756	11,086	3.9
Generate domestic hot water with air to water heat	Barton Centennial Centre	$ 192,702	$ 7,562	680	25.5

exchangers. Modify existing systems to minimize steam use.	C.I.N.E. Laird Hall Macdonald Stewart Parasitology				
Recuperate heat from lab fume hoods to preheat fresh air.	C.I.N.E. Parasitology	$ 141,432	$ 4,432	474	31.9
Centralize lab fume hoods to reduce fresh air intake.	Macdonald Stewart	$ 192,606	$ 75,546	7,208	2.5
Convert air make-up system from 100% fresh air to system with economizer.	Parasitology	$ 35,794	$ 3,291	343	10.9

Table 7 - Examples of Recommendations from Macdonald Campus Energy Audit Reports[6]

3.2. Re-Commissioning – 2012 and 2013

Since the first Five-Year Energy Management Plan, Utilities & Energy Management has been working on defining the framework of a re-commissioning program that would be adapted to McGill's specific environment and meet the requirements of *Remise au point des systèmes mécaniques des bâtiments*, the incentive program jointly founded and funded by Hydro Québec and Gaz Métro for re-commissioning projects. Following Hydro Québec and Gaz Métro's requirements, the team met with consultants accredited by the *Agence de l'efficacité énergétique du Québec*. Three were finally chosen in 2012 (Genome, Education, and Rutherford Physics) and three more in 2013 (Leacock, Life Sciences, and Wong). These buildings were chosen because they represent most of the conditions found on campus: administrative and teaching spaces, as well as research spaces with dry labs and wet labs.

Re-commissioning as defined per the incentive program comprises several phases:

- A planning phase during which the consultant assesses the potential for savings and defines the scope of the re-commissioning.
- An investigation phase during which the consultant analyzes the different building systems in depth, studies the system control sequences, and tests how the systems respond under certain conditions. At the end of this phase, the consultant writes a report in which she outlines the results of the different functional tests and presents a set of low capital, short return on investment energy conservation measures.
- An implementation phase during which the recommendations of the re-commissioning report are implemented, using McGill staff or external contractors as required.
- A hand-off phase at which building operators receive a training to ensure they understand all the measures and why they were implemented. At this point, the consultant hands out her final report.
- A follow-up phase during which the energy use of the building is closely monitored to ensure re-commissioning benefits last. Annual reports will be submitted to McGill for a period of three years.

Utilities & Energy Management plans to go beyond compliance and requests that the investigation phase last eight months, this in order to capture the behaviour of the building systems over three seasons (winter, summer, and fall or spring) rather than three months only required by Hydro Québec and Gaz Métro.

The budget for these six projects is $660,000 with savings in the order of $210,000, which is around 5% of the total energy use of these buildings. The expected payback is 3.2 years, excluding incentives of $192,000.

[6] Bouthillete et Parizeau, Étude de faisabilité – Implantation d'une nouvelle chaufferie – Rapport final Rev2, February 2013

3.3. Other Projects Already Committed for 2013-2014

The Stewart Biology, Trottier, and New Music buildings are scheduled to be re-commissioned in 2013-2014 for a total budgeted cost of $547,000 and potential savings in the order of $150,000, i.e., 11,200 GJ.

3.4. Going Forward – 2013-2016

Figure 8 below illustrates the investments, savings, and incentives from 2011-2012 and five year into the future for the energy audit and building re-commissioning program. Note that the cost of the Macdonald campus energy audits is not included in this project as they were incurred under the Macdonald Energy Project. The budgeted cost for the whole program is $3.6 million with expected annual savings of $1.3 million upon completion for a global payback of 2.9 years, excluding incentives of $544,000.

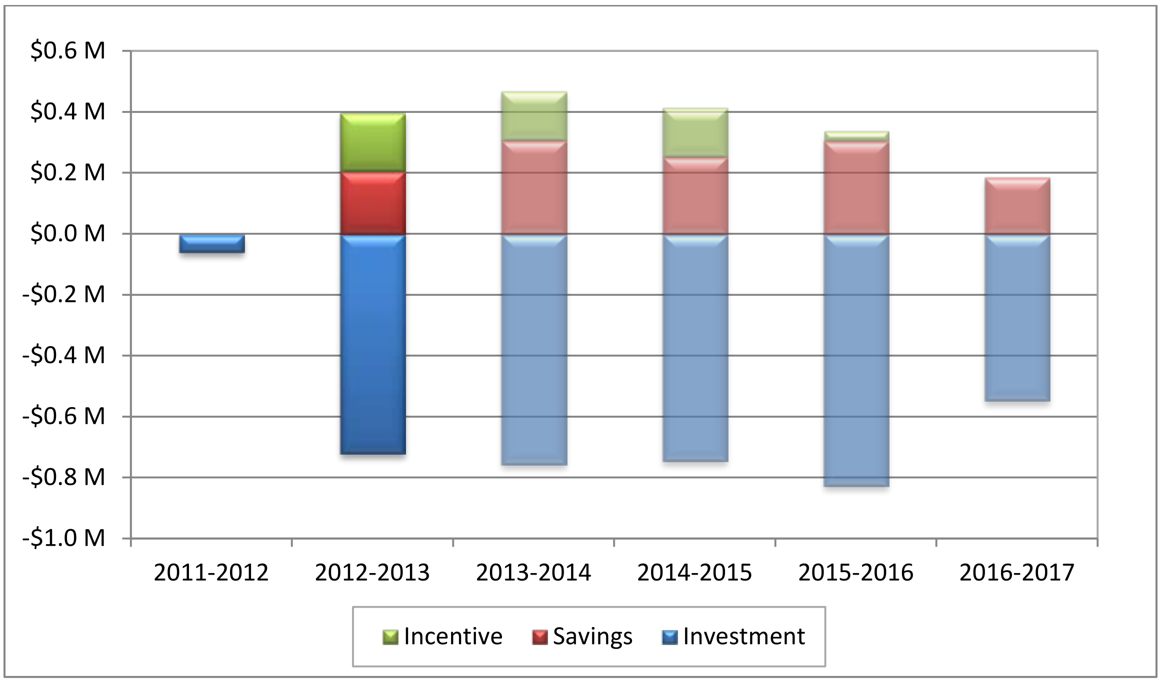

Figure 8 - Building Audits and Re-Commissioning 2011 to 2017[7]

[7] Investments for the energy audits on Macdonald campus are not included on this chart; they are included in the Macdonald Energy Project section.

4. Energy Monitoring and Information System

4.1. Installation of Meters

67 buildings on the McGill downtown and Macdonald campus are now equipped with close to 400 meters that keep track of electricity, steam and condensate return, chilled water, hot water, and natural gas consumption. Nine public calls for tenders were launched to purchase and install the meters for a total cost of $2.4 million compared to $3.2 million originally budgeted. Most of the meters were installed in the summer of 2011 according to standardized installation procedures defined by Utilities & Energy Management. Note that the actual investment is much lower than anticipated due to very competitive prices for equipment, installation, and the dashboard.

Utilities & Energy Management put in place a procedure to verify and calibrate each meter, newly installed and existing meters alike. The metering team verified and issued verification certificates for each of the 400 meters. When necessary, the team made modifications to the meters that did not pass the verification requirements. The team then integrated into a database to manage the data recorded by all the meters.

This massive task allowed Utilities & Energy Management to standardize its metering activities. The team is now working toward defining procedures to maintain and periodically control the pool of meters. For instance, all meters will be verified at least once every second year. This validation process is essential to several activities including the monthly billing of Utilities & Energy Management's clients and quarterly follow-ups of the performance of the projects described in this plan. Furthermore, consultants now have access to reliable data to identify areas of improvement whether in deferred maintenance project, HVAC upgrades, or re-commissioning projects.

4.2. McGill Energy Dashboard

As described in the first Energy Management Plan, an energy monitoring and information system (EMIS) requires an interface to visualize and organize the data read off the meters. Upon approval of the first Plan by McGill's Building and Property Committee, Utilities & Energy Management set out to enquire about the different solutions available on the market. A selection committee was created. The committee outlaid the needs and requirements of McGill and then approached several solution providers and compared their proposals. One of the main requests of the selection committee was for the software solution not only to be appealing for the members of the McGill community but also to be robust, flexible, intuitive, and to offer analytical solutions to the Utilities & Energy Management team. The selection committee then negotiated an agreement with Pulse Energy. Pulse Energy, Utilities & Energy Management, as well as students funded by McGill's Sustainability Projects Fund worked together to release the first public version of the dashboard in April 2011.

McGill's energy dashboard is accessible to anybody on the web in English and French at mcgill.pulseenergy.com. Community members can get a portrait of the energy consumption of campus buildings in real time and browse up to three months in the past. The dashboard also features a blurb on the history of the building, and a list of green features implemented therein, as well as equivalents of energy use (e.g., the Arts building consumed 22,354 kWh in the past week, which is equivalent to powering a typical home for 710 days).

According to recent surveys[8,9], the dashboard still lacks visibility on campus. Utilities & Energy Management will address this by partnering with several actors on campus such as the Libraries and student groups to show the dashboard on their public display. In spite of this, the energy dashboard gave rise to several student initiatives such as EnGage (a project to use the dashboard to educate residence students on sustainability issues) or Check Pulse (a group of MBA students who investigated how to best use the dashboard to maximize energy savings on campus) just to name a few.

4.3. Energy Management – Building Operations Taskforce

One of the keys to energy management is monitoring[10]. The purpose of this monitoring is manifold: not only does it allow benchmarking buildings' energy performance against that of similar buildings, but it also allows the detection of nonconformities. The purpose of the Energy Management – Building Operations Taskforce is to take action on these nonconformities by implementing corrective actions and preventive actions. The former are meant to solve issues as they arise while the latter aim to avoid these particular issues to occur again.

The members of the taskforce meet every second week. Utilities & Energy Management prepares a list of events to be reviewed by the taskforce. Events are defined as nonconformities such as seemingly unnecessary energy usage during unoccupied hours, abnormal trends in energy usage, random spikes in energy use, etc. The members discuss the event, look for its cause and propose a set of measures to be implemented by the Building Operations team. A follow-up period segues to make sure the nonconformity has been effectively dealt with, after which the event is documented and closed. During these meetings, the taskforce has reviewed over 30 events (14 solved; 7 in treatment; 6 cause found, no solution implementable; 4 no solution, no cause).

The taskforce is also spearheading three campus-wide energy conservation programs identified during the meetings:

- A review of operation schedules: the purpose of this program is to ensure that the operation schedule of the HVAC systems matches the occupancy schedule of each buildings, this to prevent the systems run during unoccupied hours when possible;
- The introduction of humidity probes to better control the fresh air intake and optimize free cooling;
- And seasonal reviews of operation which consists in a sort of post mortem of the season: what went right, what went wrong, how can we improve our operations in the future.

Three examples were chosen to illustrate the discussions of the taskforce.

Example #1: Bookstore, ventilation schedule

Description and analysis: During the November 2011 meeting, the Taskforce discussed why the Bookstore's energy demand profile looked the same throughout the week except on Sundays. The schedule of the HVAC system of the building did not match the opening hours of the building. There did not seem to be any particular reason why.

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[8] J. Singh, P. Tikasz, and A. Wu, Independent Study on Changing Student Behaviour to Increase Energy Sustainability and Efficiency at the Macdonald Campus of McGill University, McGill University, July 2012.

[9] McGill Business Consulting Group, Pulse Check – Final Report (a project funded by McGill's Sustainability Project Fund), August 2012

[10] ISO 50001:2011 – Energy Management Systems – Requirements with Guidance for Use, International Organization for Standardization, Geneva, 2011.

Proposed solution: Change the HVAC schedule to match the opening hours of the Bookstore and follow up with Bookstore occupants to ensure there will not be any negative impact on occupant comfort.

Savings: 882 GJ, i.e. 12% overall savings from November 2011 to April 2013. $10,000 savings on energy cost. Figure 9 is a snapshot of the Bookstore's energy demand taken from McGill's energy dashboard. The solid line plots the actual power demand while the dashed line plots the baseline power demand. The baseline here represents the power demand of the building if the change in HVAC schedule had not been implemented. Savings are achieved whenever the solid line is below the dashed line.

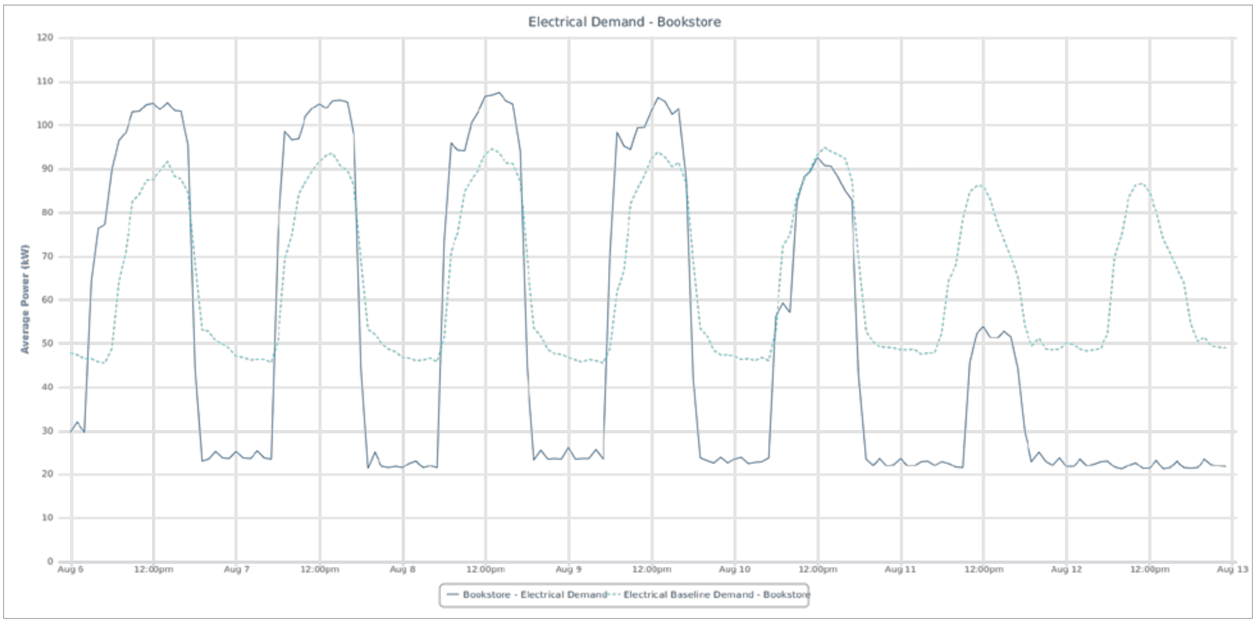

Figure 9 - Bookstore's Electrical Demand Before and After Schedule Optimization

Example #2: Several buildings on campus, HVAC system schedule

Description and analysis: during the last two weeks of January 2012, a number of buildings on campus showed abnormal energy demand trends (see Figure 10 below). The taskforce easily cornered the root cause of the problem: the schedule of the ventilation systems were changed from an automatic operation (i.e., weekdays vs weekends, day time vs night time) to a manual, 24/7 operation to adapt to the very cold temperatures on January 15, 2012.

Proposed solution: Change the ventilation schedules back to automatic and propose a method to avoid this happens again. Note: Building Operations have to change the ventilation schedules of the buildings occasionally to accommodate building users' special requests or to adapt to extreme weather conditions. Building Operations has made a lot of efforts over the past years toward fully integrating building controls into the online central control platform but several systems on campus are still operated manually. As a result, some systems are omitted when the time comes to get back to normal, automatic operations. Building Operations is aware of this situation and has put in place mechanisms to prevent such omissions happen again.

Savings: In this case, we should talk about avoided energy use instead of savings. The actual energy use per week was approximately 20 GJ greater than the baseline while the nonconformity lasted. Had this situation not been corrected, this would have resulted in an extra energy use of 1,040 GJ per year for electricity only. This represents an extra cost in the order of $10,000 per year for one building only – several buildings were in the same situation. Figure 10 shows the actual power demand of Chancellor Day Hall (solid line) and the baseline power demand (dashed line). In this case, the baseline was trained using the conditions prevailing before the event, i.e., based on an automatic operation rather than a 24/7, manual operation.

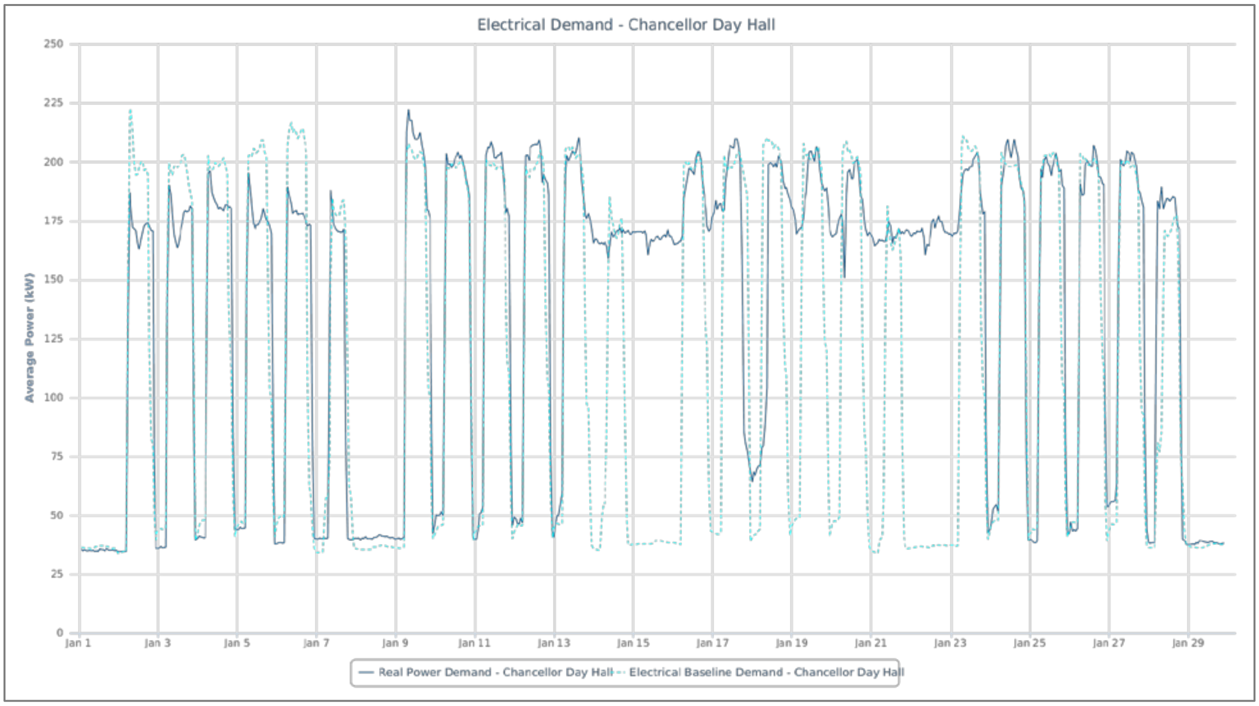

Figure 10 - Chancellor Day Electrical Demand Before and After Event

Example #3: Genome, high consumption during unoccupied hours

Description and analysis: The Genome building's power demand barely goes down during unoccupied hours unlike most other buildings on campus. The building comprises labs that need being ventilated with 100% fresh air all the time due to the type of research that takes place there. However, the building was designed with intelligent features to reduce the amount of fresh air in the labs during unoccupied hours, thus guaranteeing adequate conditions for research without jeopardizing energy efficiency. For unknown reasons, the controls of each room and system of the building have not been set up in such a way as to make advantage of the system's energy efficient features.

Proposed solution: Utilities & Energy Management mandated *Bouthillette Parizeau et Associés*, a consulting firm in building engineering, to re-commission the mechanical systems of the building. Part of their mandate is to revise the controls of the different systems in order to make use of the building's energy saving features.

Savings: Re-commissioning is under way. Re-commissioning projects typically yield savings in the order of 5% to 10% of the building's energy use, which would amount to 1,900 GJ to 3,800 GJ and somewhere between $25,000 and $50,000 annually.

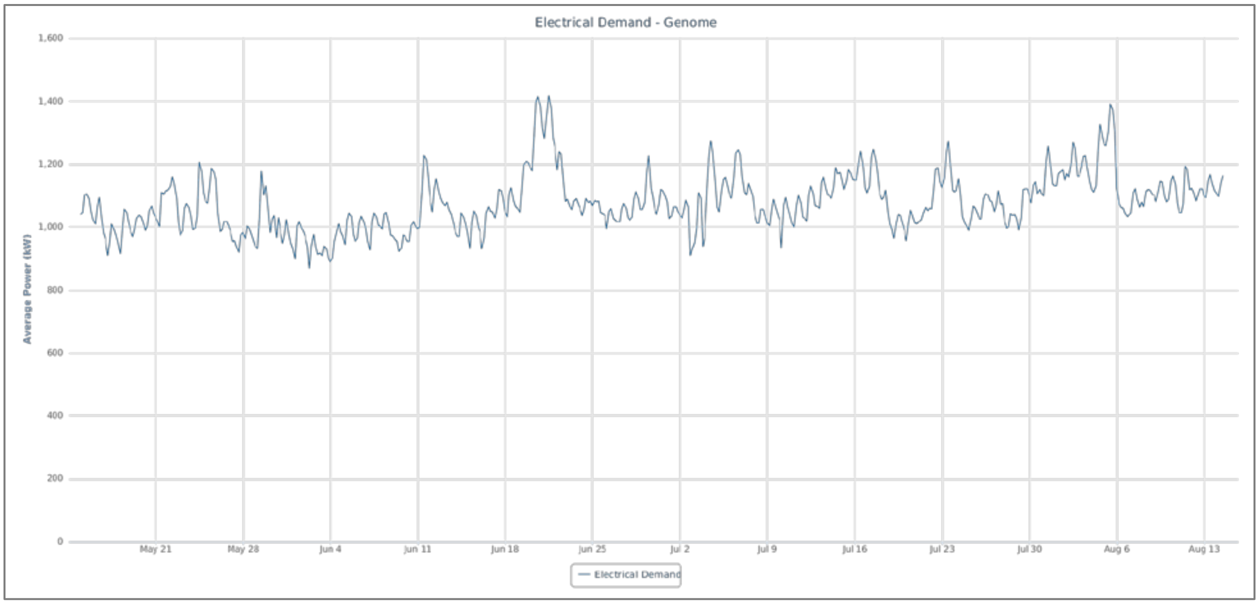

Figure 11 - Genome Electrical Demand

5. Campus-Wide Programs

Energy auditors and Utilities & Energy Management staff have identified several areas of intervention to improve building energy performance. Low investment, short payback programs such as the insulation, maintenance, and optimization programs proposed below will target obvious energy losses and process inefficiencies while building upgrades and innovation will require more investment to address facilities. For each of the programs proposed below, annual budget requests will be backed up with a detailed list of interventions.

5.1. Insulation

This program aims to reduce losses occurring on the network. During their visits, auditors identified steam pipes, union, and valves not insulated. Better insulating the seven buildings audited (McConnell Engineering, Bronfman, Burnside, Education, Leacock, Rutherford Physics, and Chancellor Day Hall) would yield annual savings of close to $50,000. In the case of union and valves, the auditor proposes removable insulation that allows trades to easily have access to the would-be insulated components for their maintenance activities. Utilities & Energy Management proposes to invest $250,000 per annum in the coming five years, yielding total savings of $250,000. Savings are conservative and the payback of this program is 5.0 years.

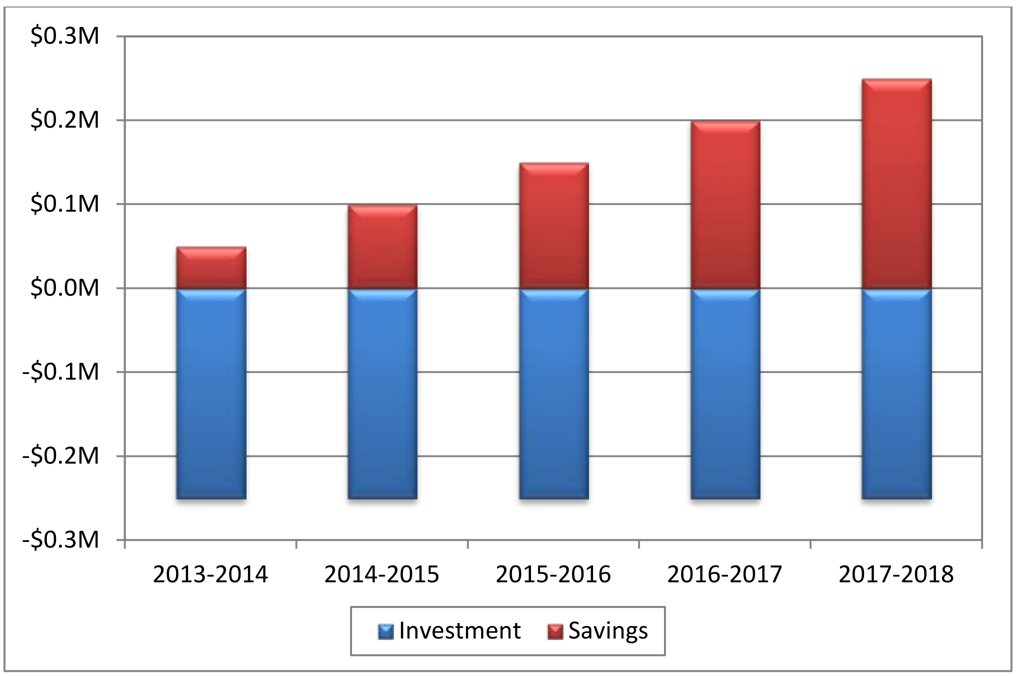

Figure 12 - Five-Year Insulation Program

5.2. Maintenance

Some HVAC system components are critical to the energy performance of the systems. Properly maintaining and cleaning heat exchangers, air dampers, and humidifiers ensures the systems remains efficient and easy to operate. Properly sealing windows to avoid air leakage is another measure that is all too often overlooked but has a significant impact on the operation and performance of a building. This program proposes to invest $25,000 annually for annual savings of $10,000. The payback is estimated to 2.5 years.

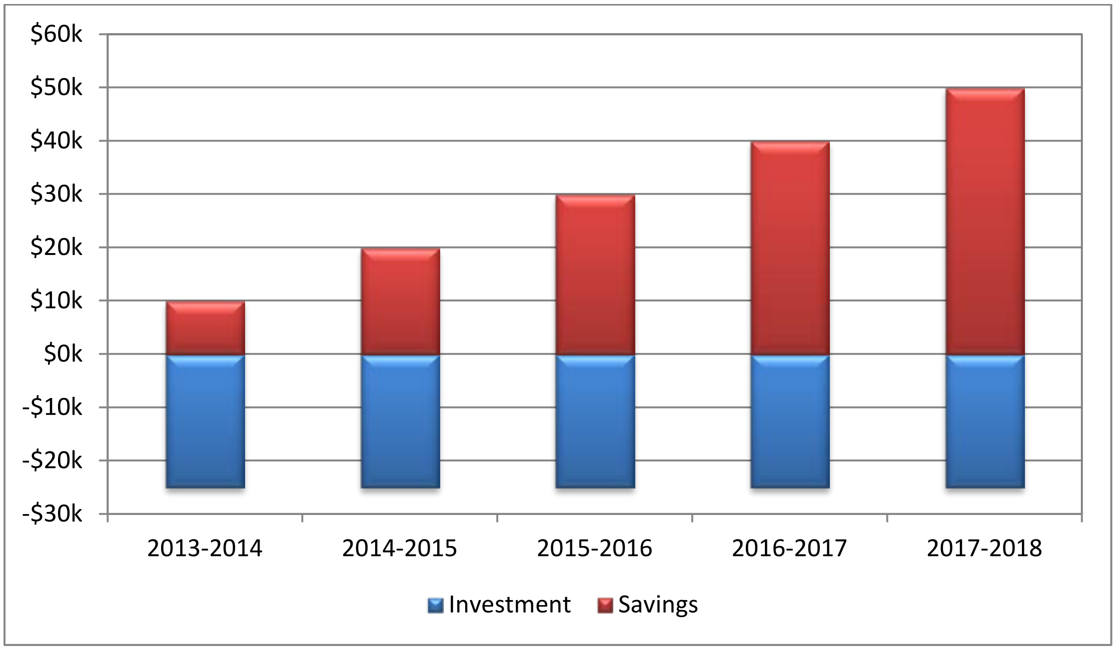

Figure 13 - Five-Year Maintenance Program

5.3. Optimization

Auditors as well as the Building Operations – Energy Management Taskforce have identified key elements that could substantially improve energy performance of building HVAC systems. While today's HVAC systems offer flexibility to building users and building operators by adjusting the level of ventilation and the temperature based on occupancy, systems designed before the '90s lack this flexibility. However, a few steps can be taken to render these systems more efficient. Most HVAC systems are equipped with heat recovery systems but there are still a few places on campus where heat recovery heat exchangers could be installed. Most air exhaust systems are not connected to the building automation systems; connecting them to the central system will allow for a better scheduling of their operation and to shut them off, if and when possible, during unoccupied hours. CO_2 sensors allow for a control of fresh air supply better aligned with building occupancy. High ventilation rates require a lot of energy to bring the air at the right temperature and humidity level, especially in Montreal's extreme climate.

Note that the decision to shut off or reduce the operation of a system at unoccupied times depends on three factors, listed by order of importance: building users' needs and comfort, building integrity, and energy efficiency. The goal of this program is to reduce energy consumption while maintaining ideal indoor air quality.

The program proposed here will required investment in the order of $250,000 for the next five years. Total savings have been evaluated to $420,000 with a global payback of 3.0 years.

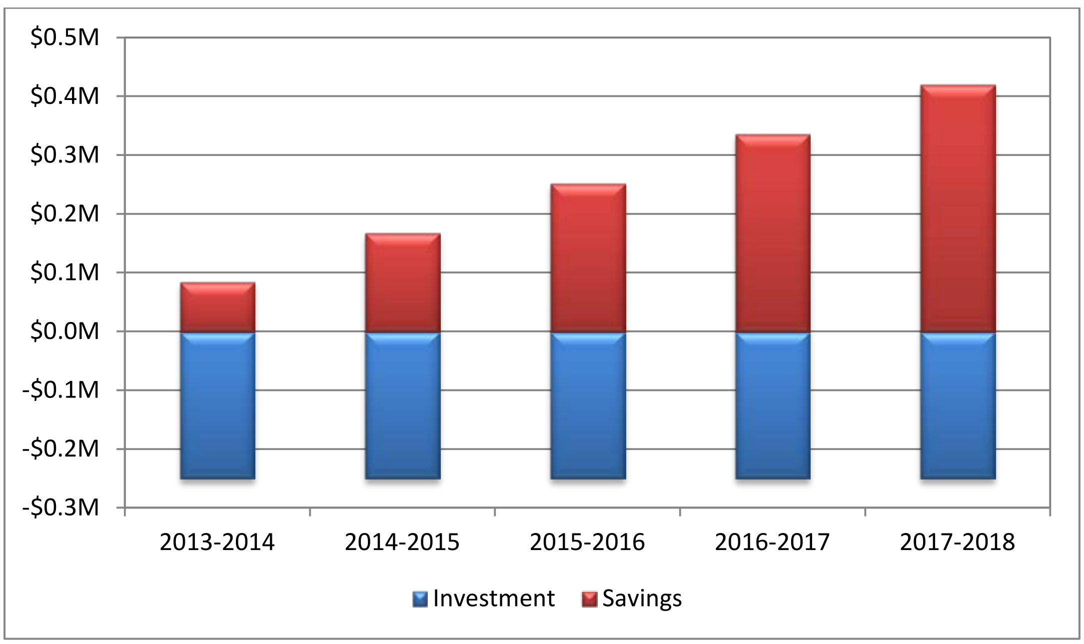

Figure 14 - Five-Year Optimization Program

5.4. Building Upgrades

While the short-payback programs will give building systems more flexibility in terms of operation, some systems designs are inherently inefficient and some system components are nearing their end of useful life. For instance, Chancellor Day Hall's HVAC system is "constant volume", i.e., it cannot modulate based on building occupancy. The solution would be to convert it with variable frequency drives on the supply and exhaust fans and variable air volume mixing boxes on the floors, not unlike what has been done in the McLennan Redpath Libraries (see section 6.3). These projects require heavier capital investment with typical payback periods of 10 years. Over the coming five years, Utilities & Energy Management proposes to invest $2.0 million to bring ventilation systems up to date.

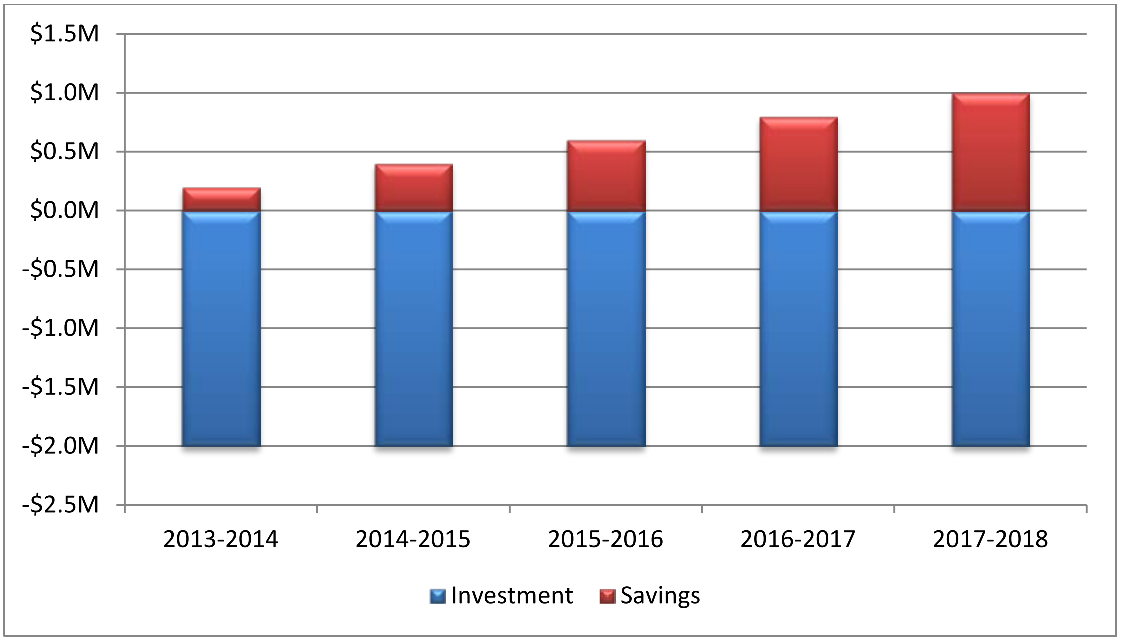

Figure 15 - Five-Year Building HVAC Upgrades

5.5. Innovation

Innovation in building operations guarantees sustained energy performance. The programs proposed above will render building systems more flexible and efficient but ultimately, new technologies will bring McGill's facilities up to the next level. High end technologies such as solar walls or photovoltaic panels are interesting for their environmental benefits but they remain quite expensive and the payback periods remain quite long. On the other end, some low key technologies also have potential but need to be tested on large scale projects before they can be implemented on a full scale. For instance, a new technology based on air flow rate monitoring was tested in the McLennan – Redpath libraries. This technology looks promising but there is a learning curve as much for consultants designing building systems and controls as for building operators. In the coming five years, Energy Management proposes to test new technologies and approaches in cooperation with Building Operations. Accepting a longer payback for these tests, the investment level should be around $100,000 per annum with a payback in the order of 8.0 years.

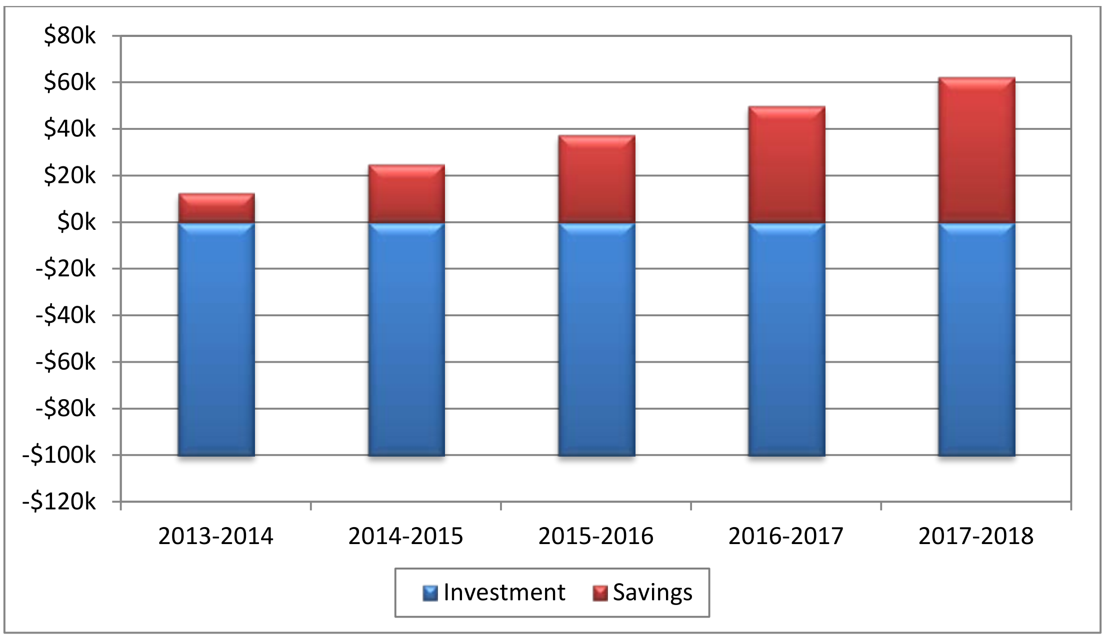

Figure 16 - Five-Year Innovation Program

6. Energy Conservation Projects

6.1. Otto-Maass Retrofit and Burnside Hall Heat Recovery Project

The retrofit consisted in replacing the ventilation systems of three of the four blocks of the Otto Maass Chemistry building. This project was completed in July 2011 for a total cost of $4.6 million. Estimated savings for the project were in the order of $720,000. Actual savings are closer to $480,000. Indeed, the savings on electricity have not materialized (actual savings in the order of $75,000 instead of the $185,000 announced in the consultant's report[11]). Including incentives of $350,000 from Hydro Québec, the payback for the project is 8.8 years.

The project to recover heat from the Burnside Hall server room to heat the Otto Maass Chemistry building had to be delayed because of conflicts with other projects in Burnside Hall. The heat exchanger started operation in April 2013. The total investment for this project is $2.5 million with expected savings of $120,000 (revised to today's 12-month average cost of natural gas on downtown campus). Based on the first month of operation, the savings should be closer to $85,000. The calculated payback is 29 years. Note that the scope of this project goes beyond the installation of a heat exchanger and includes a major upgrade the NCS Data Centre's HVAC system.

These two projects were not funded through the Energy Fund but are presented because they will save substantial amounts of energy.

Project	Savings ($)	Savings (GJ)
Maass Chemistry Ventilation Upgrade	$480,000	56,700
Heat Recovery from Burnside Hall Server Room	$85,000	10,900

Table 8 - Maass Ventilation Upgrade and Heat Recovery - Key Performance Indicators

6.2. Macdonald Campus Energy Project

Timeline

A workgroup was created in April 2010 for the project. An energy consulting firm was hired in November 2010 to guide the workgroup through the process, to challenge the design team, and to ensure savings materialize. A design team was selected in May 2011 through a public tender process favouring innovation and expertise in leading-edge energy technologies. The design team collected data and proposed integrated solutions in fall 2011. These solutions included "innovative" solutions such as a bio-digester to offset natural gas consumption on campus, a heat exchanger to use the thermal mass of Lake Saint-Louis, and a new low temperature water network to exchange energy between buildings on campus. In January 2012, the workgroup sought feedback from the Macdonald community with an open presentation[12]. Though the bio-digestion and heat exchanger solutions looked interesting at first glance, neither of them offered enough benefits to offset the upfront capital investment and the future recurrent operational cost they would entail. Besides, the this exercise showed that the implementation of energy conservation measures and renewable energy would require a major upgrade of the campus energy infrastructure which would monopolize the allocated budget, either leaving little room for energy conservation and innovation, or going over the allocated budget. The project objectives were changed to focus on

[11] Pageau Morel, Simulation énergétique – Pavillon Otto Maass, Report #2477-001-W8, Montreal, July 2012
[12] www.mcgill.ca/facilities/utilities/macdonald-campus-energy-project

the campus energy infrastructure and energy conservation. In order to stay within the budget limits and to have an acceptable payback, innovation was left aside. Note that this infrastructure step-up is a necessary transition toward the integration of renewable energy.

Technology Watch

The design team investigated over 40 energy conservation measures, half of which considered as standard conservation measures with the other half considered as more innovative. See Annex II for a comprehensive list of the technologies investigated. The team also audited the main buildings on campus to determine the most promising energy conservation measures (see Table 7 for a list of recommendation from the audits).

Key Performance Indicators

Based on the new project objectives, the design team proposed a solution to the University that has yet to be adopted. The solution includes energy conservation measures, the reconfiguration of the energy distribution network, re-commissioning of existing ventilation systems. Budget is evaluated to $7.1 million, including design, construction and all soft costs. Savings are estimated to $560,000 per annum which, along with expected incentives worth $800,000, would bring the payback to 12.7 years.

Investment	Annual Savings	Annual Savings
$7,099,074	$560,647	49,051 GJ

Table 9 - Key Performance Indicators, Macdonald Campus Energy Project

6.3. McLennan – Redpath Library HVAC Upgrade

This project consisted in a major retrofit of the air handling units of the ventilation systems as well as a retrofit of the mixing boxes on all the floors of the two libraries. Variable frequency drives (VFDs) were installed on most of the supply and exhaust fans to reduce energy use during unoccupied hours. Furthermore, an economizer was installed to recover heat from the return air of the ventilation systems. This project also encountered major challenges and it was demonstrated there were significant differences between what the system the consultant designed, the system built by the HVAC contractor, and the controls programmed by the control contractor. To ensure the system work as intended and to guarantee the expected savings materialize, Utilities & Energy Management decided to have the project commissioned by a third-party consultant. The commissioning process is not unlike the re-commissioning process described above with the exception that it goes much more in depth to analyze the difference between what the consultants designed, what the HVAC contractor delivered, and how it the control contractor programmed it. Utilities & Energy Management also requested that the design consultant re-evaluate its calculations of savings bearing in mind the recommendations of the commissioning consultant.

The final cost of the project is $3.5 million. The project was completed in April 2012 but the commissioning thereof is still under way. Savings are somewhat smaller than announced ($300,000 vs $470,000) mainly because the libraries have longer hours than before the project was implemented. Including incentives of $330,000 received from Hydro Québec and Gaz Métro, the payback period is 12.7 years.

Investment	Annual Savings	Annual Savings
$3,491,580	$249,258	20,800GJ

Table 10 - Key Performance Indicators, McLennan Redpath Libraries HVAC Upgrade

6.4. Chiller Sequencing Project

There are more than 30 mechanical chillers on downtown campus, representing a total output of approximately 15,000 tons of cooling. Hydro Québec's rate for downtown campus is Rate L (Large Client); under this particular rate, McGill pays not only for its energy use (in kWh) but also for the peak power demand during each billing period (in kW). During hot and humid summer days in the summer, the demand for cooling reaches its peak. This means that all of the 30 chillers might work at full capacity at the same time, resulting in a hefty cost of power demand (in the order of $300,000 vs $200,000 for the winter months). The rationale of this project is to better sequence the different chillers on campus.

Also included in this project is the installation of capacitors to improve the overall power factor of the downtown campus. As most other utilities in North America, Hydro Québec charges a penalty fee to clients that have a power factor below 95%. The installation of capacitors aims to maximize the overall power factor of the downtown campus in order to save on this penalty fee. Figure 17 shows a decrease in the penalty paid for the main Hydro Québec downtown. Expected annual savings (chiller sequencing and installation of capacitors) were evaluated to $70,000. Measured savings for the capacitor part of the project amount to $30,000. Savings from the chiller sequencing part of the project cannot be measured since there isn't enough information at the chiller level.

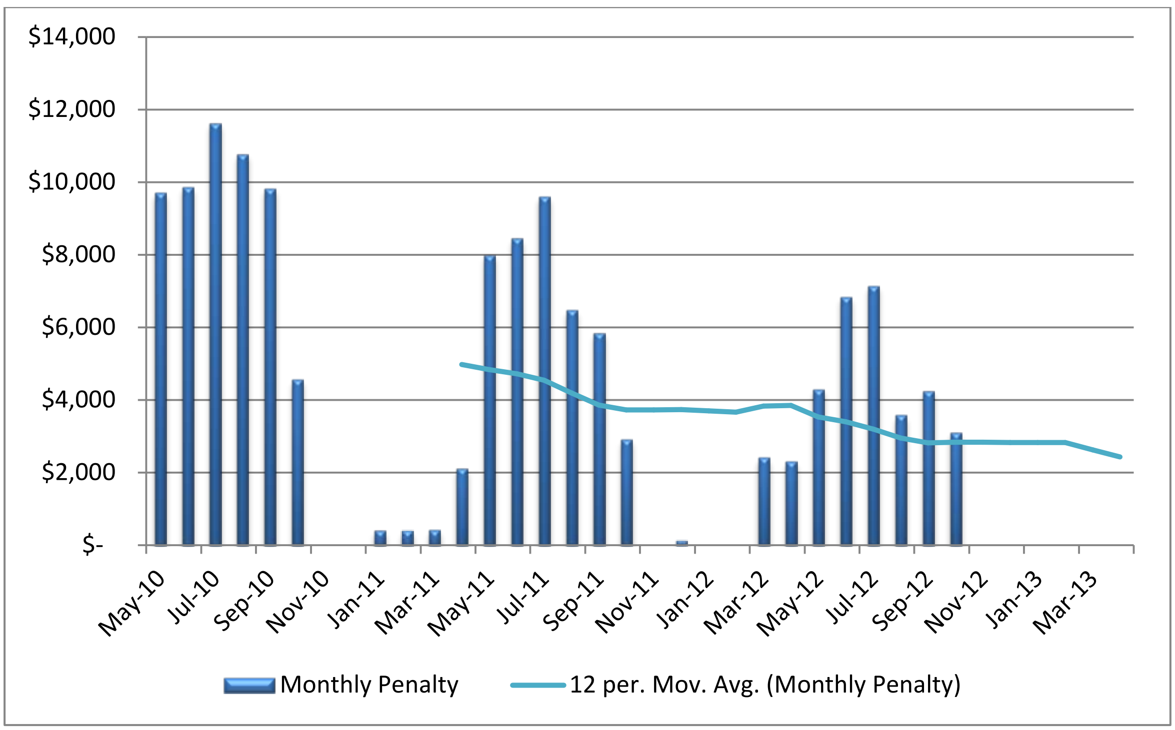

Figure 17 - Monthly Power Factor Penalty, Downtown Campus

6.5. New Boiler for Summer Steam Production and Replacement of the Power House Absorption Chiller

Until 2011, an absorption chiller and a mechanical chiller supplied chilled water for the chilled water network that supplies cooling to a dozen buildings on lower campus. Two other absorption chillers were also used in Burnside

Hall until 2011; they were replaced by two 500-ton mechanical chillers in 2012. This project aimed to solve three issues:

- First, absorption chillers are used in situations where extra heat or steam is available. This used to be true at McGill; however, the demand for steam in the summer is steadily decreasing. It became clear that the majority of the demand for steam in the summer was due to absorption chillers. Demand in the summer is much lower than in the winter and operating the big boilers that are sized for winter use has become highly inefficient.
- Second, absorption chillers are far less efficient than mechanical chillers. Indeed, the coefficient of performance of an absorption chiller is 1:1 while for an electric chiller it is 3:1 (meaning 1 Watt of input is required to produce 3 Watts of cooling).
- Finally, there are very few absorption chillers left in North America. Finding parts and qualified contractors to maintain them is getting critical.

For all these reasons, it was decided to 1) change the Powerhouse and Burnside Hall absorption chillers for more efficient mechanical chillers, 2) to install a smaller boiler for summer use, and 3) to shut down the Southwest steam distribution line during the summer. The 8,000 lb/h absorption chiller in the Powerhouse was changed for a 1,200 ton[13] chiller with an estimated gain in efficiency of 233%. Along with the installation of the new chiller, the sequence of operation of the two Powerhouse chillers and of the Trottier chiller was revised to optimize energy use and reduce peak power demand on campus. These three chillers feed the same network. The chiller was commissioning in late June 2012 and the summer boiler in mid-July 2012.

Table 11 below presents the payback of the project. Note that the estimated savings assume that the Southwest and Southeast steam lines will be shut down during most of the summer (mid-May until mid-October). During the months of July and August 2012, the Southwest distribution line was shutdown yielding estimated savings of 2,500 GJ. However, the demand on the three remaining lines fluctuated greatly every day, often surpassing the summer boiler capacity, and thus forcing the Powerhouse to operate one the bigger, less efficient boilers. With the energy dashboard, Utilities & Energy Management identified that a number of buildings consume far too much steam during the summer months. This point has been brought to the Building Operations – Energy Management Taskforce for discussion. An action plan will be implanted to reduce demand for steam from the building and maximize the operation of the summer boiler.

Investment ($)	Savings ($)	Payback (years)	Savings (GJ)
$2.7 million	$585,000	4.6	43,600

Table 11 - Powerhouse Summer Boiler - Key Performance Indicators

Note that the chiller replacement project was not funded as an energy conservation project but as a differed maintenance project, and thus, there is no loan associated with this project. Savings are presented for information only.

Type of Chiller	Annual Energy Use[14] (GJ)	Annual Energy Use ($)
Absorption Chiller	6,508	$56,000
Mechanical Chiller	1,905	$16,000
Savings	4,603	$40,000

Table 12 - Powerhouse Absorption Chiller Remplacement - Savings

[13] 1 ton of cooling = 12,000 BTU/h
[14] Primary energy use estimated using 900 hours of operation per year for both cases.

7. Other Measures not Included in the EMP

This section features a few initiatives in which Utilities & Energy Management is involved. These initiatives are more people and process oriented. With these initiatives, Utilities & Energy Management wishes to raise awareness on energy efficiency within the organization, engage stakeholders, and deal with processes that have an impact on energy at McGill.

7.1. Energy Efficiency Design Standards

Facilities Operations and Development has a set of design standards to guide consultants in any construction, renovation or demolition projects. Design Services is the watchdog of these standards deemed to be more than 75% in accordance with LEED standards. The energy efficiency standards proposed by Utilities & Energy Management are more stringent than the building codes in force. They can be accessed from www.mcgill.ca/facilities/design/standards Divison 01-47-00.

7.2. Energy Fiche

Hundreds of projects are managed by Facilities Operations and Development every year for hundreds of million dollars. The scope of these projects varies from ventilation upgrades, lab renovations, or installation of new research equipment, to overall building upgrades. More often than not, these projects result in an increase in energy demand. To ensure that all projects accounts for energy efficiency, the director of the department sits on a committee that reviews projects as they are created. He assesses whether or not a project should have a focus on energy conservation and attributes an expert from Utilities & Energy Management to accompany the project team.

An energy fiche has also been made available to project managers for them to evaluate the impact of their project on McGill's global energy demand, be it an increase or decrease. This fiche helps Utilities & Energy Management in its accounting of energy add-ons and savings on campus.

7.3. Five-Year Energy Management Reports

Self-funded units (Athletics, Residences, student associations, the Bookstore, and Student Services) are charged for the energy they consume. Money being a straight forward incentive, Utilities & Energy Management has been producing annual reports to help these stakeholders better understand their energy charges. The goal is for them to make educated choice as to how they decide to operate their buildings.

7.4. White Book on Utility Billing

As a service provider, Utilities & Energy Management redistributes energy charges to several clients on campus. A software solution was deployed in 2012 to generate monthly invoices whose calculation is anchored in Utilities & Energy Management Conditions Part 1 – Billing Structure and Part 2 – Clients and Meters. These invoices include detailed information on the rates, the calculations, and energy consumption. Along with the McGill Energy Dashboard, these are tools to help decision makers reduce energy consumption and spending at McGill.

Sending virtual invoices to other building users on campus is on the roadmap of Utilities & Energy Management. Even though most users are not charged for the energy they consume (academics and research), having a better idea of how much their buildings costs and consumes will hopefully help contribute to raise their awareness on energy and will influence the decisions they make regarding the ventilation hours of a building, for instance.

7.5. Energy Procurement – Natural Gas Portfolio

McGill's energy portfolio is essentially split between natural gas (53%) and electricity (47%). In terms of spending, the split is the opposite (59% for electricity and 40% for natural gas). Electricity is a state monopoly in Quebec. As for natural gas, though the sole authorized distributor in Montreal is Gaz Métro, McGill has the option to buy its physical natural gas directly on the commodity market. Utilities & Energy Management along with Procurements manage McGill's natural gas portfolio to ensure the lowest cost while minimizing risk exposure.

7.6. Energy Managers Committee

Since the beginning of 2012, Utilities & Energy Management has been taking part to an energy managers committee comprising Université de Montréal, UQÀM, Concordia, the City of Montreal, *l'Office municipal d'habitation de Montréal* (Montréal Social Housing), and other institutional building managers. The purpose of this group is to share knowledge and experience on energy conservation and energy management practices.

7.7. Building Directors Committee

Building Directors act as interface between building occupants and Facilities; they receive privileged information from Facilities and consequently are more aware than building occupants of the ins and outs of their building. However, they have little power or incentive to influence building occupants to be more energy conscious. In the coming year, Utilities & Energy Management will set out to create a venue to share information with Building Directors, seek their active participation in energy conservation initiatives, and empower them to change building occupant behaviour.

7.8. Mock Bills

Energy expenditures are managed by McGill's central administration; energy end-users consequently have no idea as to how much energy they use and how much it costs. Utilities & Energy Management, following a proposal from the Faculty of Medicine, will produce mock bills for lab users of the McIntyre Medicine and Life Sciences buildings. The intent is to provide information to lab users and influence them in their decision making, whether it be for day-to-day activities or when purchasing new equipment. Depending on the success of this campaign, Utilities & Energy Management will spread this campaign to other faculties and departments on campus.

7.9. Better Practices for Energy Management Workgroup

This workgroup was appointed by Human Resources to work on better practices for energy management. The team is made of representatives from Human Resources, the Faculty of Management, Building Operations, and Utilities & Energy Management. The purpose of the workgroup is to identify, explore, recommend and support the implementation of practical means to reduce energy consumption at McGill. The group will concentrate its actions toward modifying the behaviour of groups and individuals in the McGill community in order to accelerate energy reduction initiatives. The group will suggest means to motivating, recognizing, and sustaining behavioural change to this end. The group started meeting in the summer of 2013 and will address energy use in research labs for its first initiative.

8. Lessons Learned

A few lessons can be drawn from the implementation of the first Five-Year Energy Management Plan.

Estimating energy savings: with little monitoring available at the beginning of this plan, Utilities & Energy Management had to make assumptions to estimate project savings. Project loans are repaid with the savings generated by energy conservation measures, directly from the central energy budget. Correctly estimating energy savings is, therefore, of the essence. A careful quarterly review of the performance of each energy conservation measure has allowed Utilities & Energy Management to crosscheck calculated savings with measured savings and to refine its estimation methods.

Difference between savings announced by designers and materialized savings: in the same spirit, the quarterly follow-up of energy conservation projects has demonstrated that there is often a significant difference between the savings calculated by consultants and the savings measures once projects are completed. Aware of its mandate to meet this plan's objectives, Utilities & Energy Management is working with Project Management and Procurements to frame a contractual binding for consultants to guarantee the performance of their design, and therefore, the announced savings.

Testing different business models: working on smaller case projects before launching campus-wide programs (e.g., lighting retrofits) has paid off. Different business models were tested for the lighting retrofit program and the final model has generated costs much lower than what consultants have predicted.

Maintaining project benefits: the best energy conservation project can be a failure unless there is a commitment to maintain the savings. Bearing this in mind, Utilities & Energy Management and Building Operations are strongly committed to ensure that objectives are met and maintained. As an example, the two teams have coordination meetings to minimize steam demand on campus specifically during the summer time; this will allow the powerhouse to operate its smallest boiler all summer long regardless of outdoor temperatures, thus generating savings of 30% natural gas for the period.

9. SUMMARY

FIVE-YEAR ENERGY MANAGEMENT PLAN - 2013 UPDATE - FINANCIAL KEY PERFORMANCE INDICATORS	Pre-FY11-12	FY11-12	FY12-13	FY13-14	FY14-15	FY15-16	FY16-17	FY17-18	OVERALL	R.O.I.
Programs										
Lighting										
Investment	-	$ 529,255	$ 999,183	$ 2,595,000	$ 2,416,150	$ 1,668,775	$ -	$ -	$ **8,208,363**	**$**
Incentives	-	$ 162,750	$ 220,355	$ 139,523	$ 299,394	$ 256,226	$ -	$ -	$ **1,078,248**	**$ 9.6**
Annual Savings	-	$ 70,985	$ 176,662	$ 429,662	$ 599,304	$ 744,487	$ 744,487	$ 744,487	$ **744,487**	**$**
Building Retro-Commissioning and Audits										
Investment	-	$ 59,522	$ 721,079	$ 623,161	$ 745,178	$ 692,274	$ 547,757	$ -	$ **3,388,970**	**$**
Incentives	-	$ -	$ 192,000	$ 128,000	$ 160,000	$ 32,000	$ -	$ -	$ **512,000**	**$ 2.6**
Annual Savings	-	$ -	$ 205,969	$ 443,970	$ 697,759	$ 932,741	$ 1,119,427	$ 1,119,427	$ **1,119,427**	**$**
Insulation										
Investment	-	$ -	$ -	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ **1,250,000**	**$ 5.0**
Annual Savings	-	$ -	$ -	$ 50,000	$ 100,000	$ 150,000	$ 200,000	$ 250,000	$ **250,000**	**$**
Maintenance										
Investment	-	$ -	$ -	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ **125,000**	**$ 2.5**
Annual Savings	-	$ -	$ -	$ 10,000	$ 20,000	$ 30,000	$ 40,000	$ 50,000	$ **50,000**	**$**
Systems Optimization										
Investment	-	$ -	$ -	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ **1,250,000**	**$ 3.0**
Annual Savings	-	$ -	$ -	$ 84,000	$ 168,000	$ 252,000	$ 336,000	$ 420,000	$ **420,000**	**$**
Building Upgrades										
Investment	-	$ -	$ -	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ **10,000,000**	**$ 10.0**
Annual Savings	-	$ -	$ -	$ 200,000	$ 400,000	$ 600,000	$ 800,000	$ 1,000,000	$ **1,000,000**	**$**
Innovation										
Investment	-	$ -	$ -	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ **500,000**	**$ 8.0**
Annual Savings	-	$ -	$ -	$ 12,500	$ 25,000	$ 37,500	$ 50,000	$ 62,500	$ **62,500**	**$**
Projects										
EMIS										
Investment	2,354,954	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ **2,354,954**	**$**
Incentives	75,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ **75,000**	**$ 5.7**
Annual Savings	-	$ -	$ 219,142	$ 400,000	$ 400,000	$ 400,000	$ 400,000	$ 400,000	$ **400,000**	**$**
McLennan & Redpath Libraries HVAC Upgrade										
Investment	-	$ 3,515,757	$ -	$ -	$ -	$ -	$ -	$ -	$ **3,515,757**	**$**
Incentives	-	$ 333,059	$ -	$ -	$ -	$ -	$ -	$ -	$ **333,059**	**$ 12.8**
Annual Savings	-	$ -	$ 369,828	$ 249,258	$ 249,258	$ 249,258	$ 249,258	$ 249,258	$ **249,258**	**$**
Capacitors and Chiller Sequencing Optimization										
Investment	273,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ **273,000**	**$ 7.8**
Annual Savings	-	$ -	$ 32,717	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ **35,000**	**$**
Summer Boiler										
Investment	-	$ 1,822,602	$ -	$ -	$ -	$ -	$ -	$ -	$ **1,822,602**	**$ 3.7**
Annual Savings	-	$ -	$ 309,917	$ 491,037	$ 491,037	$ 491,037	$ 491,037	$ 491,037	$ **491,037**	**$**
Macdonald Campus Energy Project										
Investment	-	$ -	$ -	$ -	$ 7,099,074	$ -	$ -	$ -	$ **7,099,074**	**$**
Incentives	-	$ -	$ -	$ -	$ 807,805	$ -	$ -	$ -	$ **807,805**	**$ 11.2**
Annual Savings	-	$ -	$ -	$ -	$ 560,647	$ 560,647	$ 560,647	$ 560,647	$ **560,647**	**$**
Overall Energy Management Plan										
Investment	2,627,954	$ 5,927,136	$ 1,720,262	$ 5,843,161	$ 12,885,402	$ 4,986,049	$ 3,172,757	$ 2,625,000	$ **39,787,720**	**$**
Incentives	75,000	$ 495,809	$ 412,355	$ 267,523	$ 1,267,199	$ 288,226	$ -	$ -	$ **2,806,112**	**$ 7.0**
Annual Savings	-	$ 70,985	$ 1,281,518	$ 2,357,927	$ 3,686,005	$ 4,410,170	$ 4,940,856	$ 5,284,856	$ **5,284,856**	**$**
Other Projects										
Maass Chemistry HVAC Retrofit										
Investment	4,590,670	$ $ -	$ -	$ -	$ -	$ -	$ -	$ -	**4,590,670**	**$**
Incentives	350,000	$ $ -	$ -	$ -	$ -	$ -	$ -	$ -	**350,000**	**$ 8.8**
Annual Savings		482,501	$ 482,501	$ 482,501	$ 482,501	$ 482,501	$ 482,501	$ 482,501	$ **482,501**	**$**
Burnside Hall Heat Recovery Project										
Investment	-	$ $ -	2,491,096	$ $ -	$ -	$ -	$ -	$ -	**2,491,096**	**$ 29.3**
Annual Savings	-	$ -	$ -	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ **85,000**	**$**

Table 13- Five Year Energy Management Plan - 2013 Update - Financial Key Performance Indicators

FIVE-YEAR ENERGY MANAGEMENT PLAN - 2013 UPDATE - ENERGY SAVINGS AND GHG EMISSION REDUCTION	Pre-FY11-12	FY11-12	FY12-13	FY13-14	FY14-15	FY15-16	FY16-17	FY17-18	OVERALL
Program									
Lighting									
Annual Savings (GJ)	-	4,510	11,224	29,743	40,522	49,746	49,746	49,746	**49,746**
GHG Emission Reduction (tCO2e)	-	3	6	17	23	28	28	28	**28**
Building Retro-Commissioning and Audits									
Annual Savings (GJ)	-	-	16,839	35,515	56,420	74,251	89,162	89,162	**89,162**
GHG Emission Reduction (tCO2e)	-	-	425	896	1,423	1,872	2,248	2,248	**2,248**
Insulation									
Annual Savings (GJ)	-	-	-	4,594	9,187	13,781	18,375	22,968	**22,968**
GHG Emission Reduction (tCO2e)	-	-	-	229	458	687	916	1,145	**1,145**
Maintenance									
Annual Savings (GJ)	-	-	-	919	1,837	2,756	3,675	4,594	**4,594**
GHG Emission Reduction (tCO2e)	-	-	-	23	46	69	93	116	**116**
Systems Optimization									
Annual Savings (GJ)	-	-	-	7,717	15,435	23,152	30,869	38,587	**38,587**
GHG Emission Reduction (tCO2e)	-	-	-	195	389	584	778	973	**973**
Building Upgrades									
Annual Savings (GJ)	-	-	-	18,375	36,749	55,124	73,499	91,873	**91,873**
GHG Emission Reduction (tCO2e)	-	-	-	463	927	1,390	1,853	2,317	**2,317**
Innovation									
Annual Savings (GJ)	-	-	-	1,148	2,297	3,445	4,594	5,742	**17,226**
GHG Emission Reduction (tCO2e)	-	-	-	29	58	87	116	145	**434**
Projects									
EMIS									
Annual Savings (GJ)	-	-	21,325	36,609	36,609	36,609	36,609	36,609	**36,609**
GHG Emission Reduction (tCO2e)	-	-	538	923	923	923	923	923	**923**
McLennan - Redpath Libraries - HVAC Upgrade									
Annual Savings (GJ)	-	-	35,951	20,810	20,810	20,810	20,810	20,810	**20,810**
GHG Emission Reduction (tCO2e)	-	-	1,098	343	343	343	343	343	**343**
Capacitors and Chiller Sequencing Optimization									
Annual Savings (GJ)	-	-	-	-	-	-	-	-	**-**
GHG Emission Reduction (tCO2e)	-	-	-	-	-	-	-	-	**-**
Summer Boiler									
Annual Savings (GJ)	-	-	38,919	61,717	61,717	61,717	61,717	61,717	**61,717**
GHG Emission Reduction (tCO2e)	-	-	1,941	3,077	3,077	3,077	3,077	3,077	**3,077**
Macdonald Campus Energy Project									
Annual Savings (GJ)	-	-	-	-	49,051	49,051	49,051	49,051	**49,051**
GHG Emission Reduction (tCO2e)	-	-	-	-	1,237	1,237	1,237	1,237	**1,237**
Overall Energy Management Plan									
Annual Savings (GJ)	-	4,510	124,258	217,147	330,634	390,442	438,106	470,859	**482,343**
GHG Emission Reduction (tCO2e)	-	3	4,007	6,195	8,904	10,298	11,613	12,552	**12,842**
Other Projects									
Maass Chemistry HVAC Retrofit									
Annual Savings (GJ)	-	-	49,976	49,976	49,976	49,976	49,976	49,976	**49,976**
GHG Emission Reduction (tCO2e)	-	-	2,566	2,566	2,566	2,566	2,566	2,566	**2,566**
Burnside Hall Heat Recovery Project									
Annual Savings (GJ)	-	-	-	10,928	10,928	10,928	10,928	10,928	**10,928**
GHG Emission Reduction (tCO2e)	-	-	-	545	545	545	545	545	**545**

Table 14 - Five-Year Energy Management Plan - 2013 Update - Energy Savings and GHG Emissions

10. Basis for Quarterly Follow-up

Utilities & Energy Management reports to McGill's senior administration on the advancement of the energy management plan on a quarterly basis. The following table is used to monitor budget, track savings, and document the difference between expected and observed savings.

2013-06-05 Update	Project Description		Project Advancement				Savings										Financials			Energy Fund	Reviewed	Notes for SRI
Savings	Project #	Project Description	Project Completion Status	Budget Spending (%)	Project Start Date (YYYY-MM)	Project Completion Date (YYYY-MM)	2012-2013 Savings ($)	2013-2014 Savings ($)	2014-2015 Savings ($)	2015-2016 Savings ($)	2016-2017 Savings ($)	2017-2018 Savings ($)	Annual Savings upon Payback	Payback²	% actual savings vs expect'd savings PROJECT IN PROGRESS	% actual savings vs expect'd savings PROJECT COMPLETED	Investment (Budget) ($)	Investment (Actual)¹ ($)	Incentive ($)			
Objective	08-37-005	EMIS and metering (176 buildings)	Meters Installation Completed	74%		2011-12	$ 400,000	$ 400,000	$ 400,000	$ 400,000	$ 400,000	$ 400,000	$ 400,000	5.7	--	--	$ 3,203,000	$ 2,354,954	$ 75,000	YES	NO	Savings generated by actions taken by Energy & Operations Taskforce. E.g., review of building ventilation schedules under implementation etc. Though the hardware and software parts of the project were completed in 2011-12, the actions to achieve savings are gradually being implemented.
Actual (vs Pulse baslines)							$ 231,203	$ -	$ -	$ -	$ -	$ -	$ 219,142	10.4	55%	--						
Objective	09-37-003	Capacitors for Chillers	Completed	64%		2010-09	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	$ 35,000	7.8	--	--	$ 425,000	$ 273,000	n/a	YES	YES	
Actual (vs meters)							$ 32,717	$ -	$ -	$ -	$ -	$ -	$ 32,715	8.3		93%						
Objective	09-37-003	Chillers Sequencing	Under Way			2012-05	$ -	$ -	$ -	$ -	$ -	$ -			--	--						
Actual vs Baseline							$ -	$ -	$ -	$ -	$ -	$ -										
Objective	09-37-001	Lighting Retrofit - Education	Completed	79%		2011-10	$ 45,949	$ 45,949	$ 45,949	$ 45,949	$ 45,949	$ 45,949	$ 45,949	#REF!	--	--	$ 410,000	$ 325,039	$ 106,307	YES	YES	
Actual (vs temporary meters)							$ 34,849	$ -	$ -	$ -	$ -	$ -	$ 34,849	#REF!		76%						
Objective	09-37-002	Lighting Retrofit - Rutherford Physics	Completed	80%		2012-03	$ 30,066	$ 30,066	$ 30,066	$ 30,066	$ 30,066	$ 30,066	$ 30,066	#REF!	--	--	$ 255,000	$ 203,753	$ 58,250	YES	YES	
Actual (vs survey of # of fixtures)							$ 28,113	$ -	$ -	$ -	$ -	$ -	$ 28,108	#REF!		93%						
Objective	08-29-122	McLennan Redpath Library HVAC Retrofit	Commissioning	102%		2012-02	$ 273,331	$ 273,331	$ 273,331	$ 273,331	$ 273,331	$ 273,331	$ 273,331	#REF!	--	--	$ 3,439,580	$ 3,515,757	$ 333,059	YES	YES	When objectives were set, libraries working hours used to be different (no 24/7 operations). Savings re-evaluated by consultant @ 16,956 GJ - $135,000 for nat gas and 2,311 to 5,640 GJ - $32,000 to $78,000 for elec.
Actual (against 2009-2010 baseline)							$ 369,828	$ -	$ -	$ -	$ -	$ -	$ 249,258	#REF!	--	91%						
Objective	11-273	Lighting Retrofit - McConnell Engineering, ~~Leacock~~, McIntyre Garage, Ferrier, Chancellor Day Hall, Raymond, Pulp and Paper	Completed excpt McIntyre Garage	31%		2012-12	$ 32,071	$ 102,019	$ 110,936	$ 110,936	$ 110,936	$ 110,936	$ 110,936	4.5	--	--	$ 2,244,500	$ 704,007	$ 203,853	YES	YES	Leacock not retrofited (para sismic upgrade required.) McIntyre Garage Lighting Retrofit scheduled for FY13-14. Final project cost will be closer to $893k.
Actual (vs survey of # of fixtures)							$ 26,265	$ -	$ -	$ -	$ -	$ -	$ 79,872	6.3	72%	--						

Table 15 - Quarterly Follow-up Spreadsheet

ANNEX I – LIST OF RECOMMENDATIONS FROM THE 2011 ENERGY AUDIT REPORTS

Description of the Measure	Buildings Affected by the Measure	Electrical Savings (GJ/year)	Steam Savings (GJ/year)	Savings (GJ)	Investment ($)	Savings ($)	Payback (Years)
Reduce fresh air intake by controlling dampers	Rutherford Physics	489	2,545	3,034	$48,000	$64,821	0.7
System #1 air handling heat recovery (enthalpy wheel in existing mixing duct)	Rutherford Physics		1,393	1,393	$55,000	$35,472	1.6
Air side free-cooling for server room	Rutherford Physics	2,006		2,006	$85,000	$23,262	3.7
Replace system #1 entirely w VFD unit, VAV boxes in rooms and DCV controller	Rutherford Physics	1,568	848	2,417	$675,000	$34,633	19.5
Install heat recovery unit for VA-1 (Clean room unit)	Rutherford Physics		560	560	$225,000	$14,261	15.8
Sub Total – Rutherford Physics	**Rutherford Physics**	**4,063**	**5,346**	**9,409**	**$1,088,000**	**$172,449**	**6.3**
Air handling damper controls, VFD and DCV for systems 1, 2, and 3 and VAV boxes	Burnside Hall	1,413	6,851	8,264	$848,000	$186,227	4.6
Air handling heat recovery and system controls upgrade to eliminate left over waste heat	Burnside Hall		718	718	$235,000	$18,280	12.9
Preventative maintenance of filters and heat exchangers	Burnside Hall	104	832	936	$10,000	$22,055	0.5
Control valves for steam unit heaters	Burnside Hall	-8	406	399	$12,000	$10,285	1.2
Exhaust fan BAS controls	Burnside Hall	25	5	30	$16,000	$331	48.3
Sub Total – Burnside Hall	**Burnside Hall**	**1,534**	**8,812**	**10,346**	**$1,121,000**	**$237,178**	**4.7**
Isolate the 1st floor library zone and install a standalone HVAC unit with high efficiency cooling and gas heating	Education	381	1,046	1,427	$150,000	$29,982	5
Complete retrofit of HVAC system to VFD VAV with DCV controls	Education	1,144	3,716	4,860	$950,000	$113,959	8.3
Replace supply fan #3 and controls for garage	Education		5,400	5,400	$350,000	$147,351	2.4
Sub Total – Education	**Education**	**1,927**	**10,162**	**11,687**	**$1,450,000**	**$291,292**	**5.0**
Air handling unit damper controls, VFD and DCV	Bronfman	863	5,241	6,104	$747,400	$141,045	5.3
Upgrade motors to premium efficiency	Bronfman	46		46	$43,500	$900	48.3
Ultrasonic reverse osmosis for humidification	Bronfman	-57	562	505	$72,000	$13,816	5.2
Control valves for steam unit heaters	Bronfman		712	712	$12,000	$18,135	0.7
Upgrade flat V-belts to cogged	Bronfman	50		50	$1,280	$442	3.1
Sub Total – Bronfman	**Bronfman**	**852**	**6,515**	**7,417**	**$876,180**	**$173,338**	**5.1**
Total – All Four Buildings		**8,376**	**30,835**	**38,859**	**$4,535,180**	**$874,307**	**5.2**

Annex II – List of Measures Investigated for the Macdonald Campus Energy Project

Standard Energy Conservation Measures		Innovative Energy Conservation Measures	
Convert ventilation system to Variable Air Volume	Install variable frequency drives on fan motors of cooling towers	Preheat ventilation air with solar walls	Noveko air filters
Control fresh air with CO2 sensors	Install efficient boiler in power plant	Heat buildings with solar collectors	Solar adsorption chillers
Convert heating and chilled water pumps from constant to variable flow	Dehumidify using desiccant technology	Install combined PV-solar thermal panels	Building envelop (hybrid electrochromic and photochromic windows, on-demand insulation)
Night setback temperature control	Convert 100% fresh air unit into economizer ("H") ventilation system	Install transparent PV film	Heat recovery from waste water drains
Produce domestic hot water with heat pumps	Install economizer on stack of power plant	Preheat domestic hot water in the residence halls with solar panels	Humidify using compressed air atomizer
Heat recovery on fume hoods and air exhaust systems	Shut down power plant in summer	Heat and irrigate seedlings in greenhouses with heating carpets	Generate marine current power
Install a floating head compressor	Upgrade make-up air units	Convert hydronic network from high to low temperature	Geothermal energy
Install variable frequency drives on fan motors	Control room temperature individually	Install autonomous exterior lighting systems (wind + solar)	Areo-thermal energy
Heat recovery chille r(economizer)	Install economizer on flue gases	Refrigeration system using CO2 in arena	Wind power (micro turbines, etc.)
Upgrade insulation on piping		Biomethanation using organic waste	Biomass (cogeneration, combined solar biomass plant, psychrophile anaerobic digestion)
Heat recovery on ammonia		Use thermal mass of Lake Saint-Louis + low temperature network	Thermal energy storage (mitigated water network, thermal mass, molten salt)
Operate power plant and distribution network seasonally		Ground-to-air heat exchanger	