# 8. ENERGY ACTION PLAN

The goal of the energy action plan is to reduce McMaster University's energy costs by reducing overall consumption, as well as by reducing the cost of purchase of utilities. These projects and initiatives aim to meet the cost and consumption targets as illustrated in Section 7.

## 8.1 Index of Initiatives


8.1.1 ENBALA pilot project

8.1.2 Nuclear Reactor Heat Recovery Plan

8.1.3 Co-generation Proposals

8.1.4 Building Exhaust Fans

8.1.5 Laboratory Air Balancing

8.1.6 Fumehood retrofits and upgrades

8.1.7 Schneider Dashboard

8.1.8 Renewable Energy Installations

8.1.9 Retro-Commissioning

8.1.10 Voltage correction

8.1.11 LED Lighting replacements

8.1.12 HHS-MUMC Window Coating

8.1.13 Plug Load Analysis

8.1.14 MiscellaneousControl Systems

8.1.15Chilled Water savings

8.1.16 Union Gas Contract

8.1.17 Chiller Replacements

8.1.18 Energy Manager

### *8.1.1 Grid Balancing (ENBALA) pilot project*

**Background and Proposed Solution**

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

In 2011, Enbala Power Networks proposed a pilot project that would exploit the flexibility of McMaster University's existing electrical equipment. Enbala operates a smart-grid platform that creates a network of large electricity users, and uses the inherent variations in their usage to balance the electricity system, thus providing system balance to the Independent Electricity Systems Operator (IESO).

The pilot project focuses solely on the university's use of electricity to produce chilled water, and involves changing the set points of the temperature of the water entering and leaving the system (within a defined temperature range) to compensate during higher and lower electricity demand periods. This grid balancing activity is anticipate to generate a revenue stream of $45 000 annually.

Enbala guarantees that participants experience no change in operational efficiency or costs of their electrical equipment, but receive payments from the IESO for improving the stability and efficiency of the regional electricity system, which reduces grid failures and greenhouse gas emissions. There is no capital cost for McMaster University associated with this project.

For a more detailed description of the proposed project please refer to the full Enbala report.

**Progress and Future Plans**

In order for the project to go through, there has to be potential to balance at least 1MW of power using the Enbala network. Estimation and inspection in order to assess the potential and install metering on the chilled water equipment is currently in progress.

### *8.1.2 Nuclear Reactor Heat Recovery Plan*

**Background and Proposed Solutions**

In March 2009, Atkinson Engineering was contracted to conduct a study on the heat recovery potential of the McMaster Nuclear Reactor (MNR).

The MNR currently operates at 3MW for 70 hours each week, with potential for upgrade to 5MW for 16 hours per week. As shown in the conceptual cooling circuit diagram below, no heat-recovery systems are currently in place. The secondary cooling circuit (consisting of the cooling tower and circuit pump) is the location being considered for the heat recovery system, as shown in Fig 24.

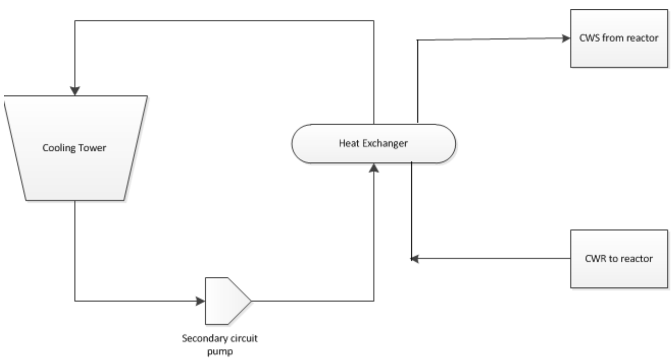


**Figure 24: Location of MNR heat recovery system**

The two heat recovery technologies considered were:

1. Low-temperature (30C) heat-exchanger based system for heating outdoor air in buildings adjacent to MNR.
2. High temperature (70C) heat pump based system for higher temperature applications such as hot water re-heating.

The heat recovery and cost savings for the two systems are shown in Tables 9 and 10:

| | Available Heat (Heating season) | Heat Recovered | CO2 reductions (MT) | Estimated cost (CAD) | Estimated annual savings (CAD) | Payback Period |
|---|---|---|---|---|---|---|
| 3MW, 70h/week | 5,077 MW | 4,243MW (84%) | 1,150 | $1,403,000 | $243,500 | 5.8 years |
| 5MW, 160h/week | 19, 544 MW | 14,018MW (72%) | 3,450 | $2,625,500 | $733,000 | 3.6 years |

**Table 9: Heat-exchanger based system analysis**

| | Available Heat (Heating season) | Heat Recovered | CO2 reductions (MT) | Estimated cost CAD | Estimated annual savings (CAD) | Payback Period |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 3MW, 70h/week | 5,545 MW | 4,850 MW (86%) | 1,300 | $2,453,000 | $228,000 | 10.8 years |
| 5MW, 160h/week | 20,995 MW | 15,800 MW (75%) | 3,900 MT | $3,728,000 | $704,000 | 5.3 years |

**Table 10: Heat-pump based system**

The analysis above was based on the following parameters:

1. Reclaimed heat estimate
   The heating requirements were calculated in 5°F increments (based on historical data). The airflows were calculated based on knowledge of each unit's operation, and a conservative estimate of how many hours each unit would be operating at varying airflows.

2. Estimated cost of system
   The system cost was estimated excluding annual maintenance costs and any government incentives that may become available. A 10% allowance to account for unknown costs and estimating errors was assigned to the total estimated value.

3. Estimate of utility costs/savings.
   Utility and steam rates were provided by McMaster Energy Management and Utilities, and are shown in Table 11:

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

**Table 11: McMaster Utility rates**

For more information, please see the full Atkinson report.

From the data tabulated above, the heat pump system appears to have marginally more energy savings but a longer Payback period than the heat exchanger system. The lower cost savings of the heat pump system are due to the estimated electrical consumption to operate the pumps. Furthermore, high-temperature heating applications were not dominant loads in

Based on the results of this Atkinson Engineering recommended the heat-exchanger system over the heat-pump system.

**Progress and Future Plans**

It is likely that the 3MW Heat Exchanger option will be implemented upon a follow up study.

#### *8.1.3 Co-generation Proposals*

**Background and Proposed Solutions**

In recent years, small-scale co-generation facilities on university campuses have become increasingly widespread. Institutions such as York University and Dartmouth College currently employ co-generation stations to generate heat for classrooms and student dorms, as it is a more thermodynamically efficient use of fuel.

In 2011, CEM engineering proposed the installation of an 8MW co-generation facility on campus that would produce 36,000lbs steam/hour and replace 8MW of power that would otherwise be purchased. It is anticipated that the installation of this plant would result in financial savings of $3,800,000 annually, (with an initial investment of $11,326,000 and a Payback Period of about 3 years). While the co-generation does not strictly reduce consumption, it does allow for the purchase of electricity at a cheaper rate than buying from the grid, thus while not an energy savings measure, it does produce substantial cost savings.

**Progress and Future Plans**

The next steps in implementing this initiative is to issue an RFP for a consultant to perform a more detailed feasibility study to determine if McMaster has the loads and infrastructure available for the successful implementation of a co-generation plant. Facility Services is currently working with CEM (Co-generation and Energy Management) Engineering to assess the potential for the McMaster co-generation plant. The project will most likely commence in the 2015-16 academic year

Presently on campus there is an embedded cogeneration plant that is owned by Bay Area Health Trust(BAHT). The University purchases energy from BAHT under an Energy Service Agreement (ESA). The University and BAHT have been in negotiations to further expand the purchase of energy to balance campus production but the cost of purchased steam presently is too expensive and offsets any savings for campus balance.

### *8.1.4 Building Exhaust Fans*

1. Building exhaust fan control
   This project involves connecting all building exhaust fans that are not currently interconnected with Building HVAC to the Building Automation System (BAS). To date, inventory of existing fans has been completed and the project is scheduled to begin in the 2012-13 year.

   The costs and energy savings of this project are shown in Table 12

| Project | Capital cost | Annual Savings | Payback Period |
|---|---|---|---|
| **Building exhaust fan control** | $115,500 | $38,500 | 3 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 87,164 $m^3$ | 167,090 kWh | 0 $m^3$ |

**Table 12: Building exhaust fan savings**

### *8.1.5 Laboratory Air Balancing*

The Air Genuity project, proposed in June 2012, is a project intended to improve the efficiency of the air circulation systems in the laboratory rooms in ABB. Currently, university policy states that laboratory rooms require 20 air changes per hour, which is a very energy intensive process. However, the Air Genuity project proposes that instead of 20 air changes per hour (ACH), samples of air will be drawn back to a central station for analysis. Depending on whether contaminants are present, the number of air changes can be increased or decreased accordingly, thus reducing the need for excessive air changes.

Air Genuity suggests that it would be possible to have as few as 5ACH when air quality in the laboratory is good, thus dramatically reducing energy usage in ventilation for laboratories. Furthermore, it would not interfere with fumehood air changes, but only air changes in the external room environment.

A schematic diagram of the proposed system is shown in Fig. 25:

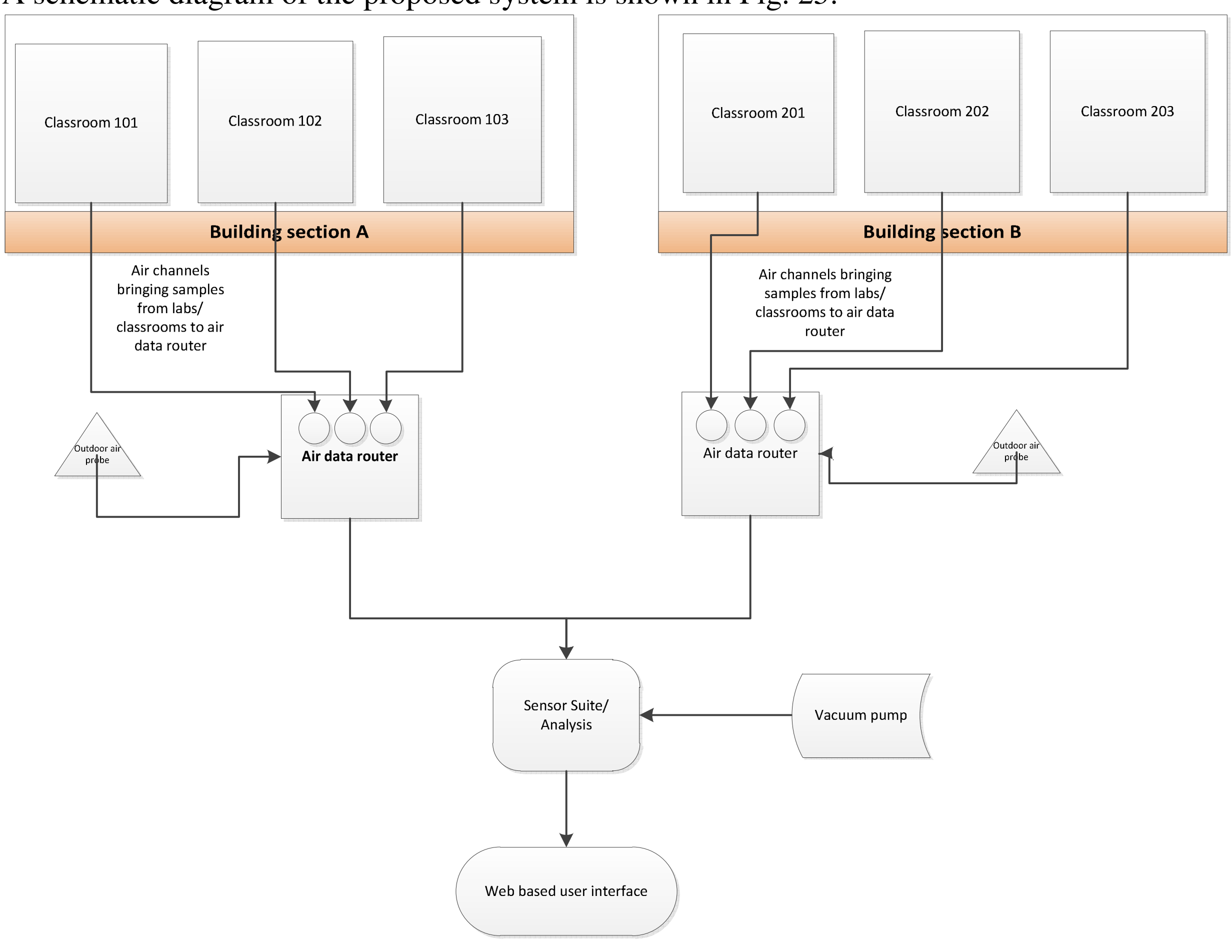


**Figure 25: Schematic diagram of Air Genuity System**

The costs and energy savings associated with this project are shown in Table 13:

| Project | Capital cost | Savings | Payback Period |
|---|---|---|---|
| **ABB Undergraduate Laboratories** | $200,000 | $219,733 | 1.04 years |
| **MDCL Laboratories** | $350,000 | $153,750 | 2.3 years |
| **ABB West Wing Laboratories** | $175,000 | $86,250 | 2.02 years |
| **JHE Annex Laboratories** | $200,000 | $77,500 | 2.6 years |

**Table 13: Cost of Air Genuity projects**

The energy savings from the project are shown in Table 14:

| Project | Electricity savings | Gas savings | Water savings |
|---|---|---|---|
| **ABB laboratories** | 454,828 kWh | 585,000 $m^3$ | 0 $m^3$ |
| **MDCL Laboratories** | 350,000 kWh | 475,000$m^3$ | 0 $m^3$ |
| **ABB West Wing Laboratories** | 175,000 kWh | 275,000 $m^3$ | 0 $m^3$ |
| **JHE Annex Laboratories** | 150,000 kWh | 250,000 $m^3$ | 0 $m^3$ |

**Table 14: Energy savings from Air Genuity project**

### *8.1.6 Fumehood retrofits and upgrades projects*

There are several ongoing projects involving fumehood upgrades and retrofits on campus. These projects address fumehoods in the research intensive buildings on campus such as ABB, JHE, NRB and MDCL. Some of these projects involve fine tuning the fumehood controls systems to saving energy, or installing variable air flow controls to reduce energy consumption. Other projects involve removing obsolete fumehoods in old or converted laboratory spaces on campus. These projects are all schedules to commence between 2012 and 2015.

The projects and associated savings are described in Tables 15-21.

| **Project** | **Capital cost** | **Savings** | **Payback Period** |
|---|---|---|---|
| **General Retrofits JHE Annex** | $264,000 | $91,700 | 2.9 years |
| | **Electricity Savings** | **Gas Savings** | **Water savings** |
| | 387,890 kWh | 211,644 $m^3$ | 0 $m^3$ |

**Table 15: JHE Annex fumehood retrofits**

| **Project** | **Capital cost** | **Annual Savings** | **Payback Period** |
|---|---|---|---|
| **Fumehood controls fine tune ABB, JHE, NRB** | $0 | $9,750 | <1 year |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 22,080 $m^3$ | 42,300kWh | 0 $m^3$ |

**Table 16: Fumehood controls fine tune in ABB, JHE, NRB labs**

| **Project** | **Capital cost** | **Annual Savings** | **Payback Period** |
|---|---|---|---|
| **Variable air flow controls on MDCL fumehood** | $225,000 | $42,065 | 5.35 years |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 162,500$m^3$ | 54,600kWh | 0 $m^3$ |

**Table 17: Variable airflow controls in MDCL labs**

| **Project** | **Capital cost** | **Annual Savings** | **Payback Period** |
|---|---|---|---|
| **LSB Lab ventilation retro-fit** | $450,000 | $183,750 | 2.45 years |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 575,000$m^3$ | 400,000kWh | 0$m^3$ |

**Table 18: Lab ventilation retrofit/upgrade- LSB**

| **Project** | **Capital cost** | **Annual Savings** | **Payback Period** |
|---|---|---|---|
| **ABB Physics wing lab ventilation retro-fit** | $200,000 | $123,750 | 1.62 years |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 385,000 $m^3$ | 275,000 kWh | 0$m^3$ |

**Table 19: Lab ventilation retrofit/upgrade-ABB Physics wing**

| Project | Capital cost | Annual Savings | PAYBACK PERIOD |
|---|---|---|---|
| **JHE North Wing Lab ventilation retro fit** | $200,000 | $115,000 | 1.74 years |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 350,000$m^3$ | 275,000 kWh | 0$m^3$ |

**Table 20: Lab ventilation retrofit/upgrade- JHE North wing**

The fumehood removal project involves creating an inventory of the (approximately) 600 fumehoods currently operating on campus, and uninstalling those which are no longer in use. Currently, the inventory is complete and removals are ongoing

| Project | Capital cost | Annual savings | PAYBACK PERIOD |
|---|---|---|---|
| **Removing obsolete fumehoods** | $1,000/fumehood | $7,000/fumehood | < 1 year |
| | **Gas savings** | **Electricity savings** | **Water savings** |
| | 16,156 $m^3$ | 29,610 KWh | 0 $m^3$ |

**Table 21: Obsolete fumehood removal**

### *8.1.7 Schneider Dashboard*

The Schneider Dashboard project is a collaborative effort between Schneider Electric and McMaster University to develop, customize and implement an interactive information dashboard that will track real time energy consumption, waste generation and fuel usage in buildings and vehicles across campus. Preliminary research shows potential for up to 5% energy reduction by communicating energy usage data to building occupants.

*Static Dashboard*

The static dashboard will compile historical and real-time information about the University's water, gas and electricity consumption and price data. This information will be accessible to Energy Management &Facility Services employees and will be used to forecast energy costs, and set conservation targets.

*Interactive Dashboard*

The interactive dashboards will be on display on screens in campus residences and buildings. These dashboards will display information about McMaster University's real-time energy usage, dependent on weather, user behaviour and building use, thereby providing users with feedback as to how their behaviour affects energy consumption on campus. Schneider's claims that the highlights of this dashboard are as follows:

- Highlights the building energy consumption with an informative daily display
- Allows users and building occupants to be active players by illustrating the impact of their behaviour and energy consumption.

It is anticipated that energy savings will result from users' consciously changing behaviours in response to the information available, and projects are currently being considered for two residence and two non-residence buildings.

Anticipated costs savings are in Table 22; based on a realistic estimate of 3% of building energy savings:

| Cost Savings | Capital cost | Annual Savings | Payback Period |
|---|---|---|---|
| | $100,000 | $401,385 | <1 year |
| **Energy Savings** | **Electricity Savings** | **Gas Savings** | **Water savings** |
| | 2,659,653kWh | 307,763$m^3$ | 24,364 $m^3$ |

**Table 22: Schneider dashboard savings**

#### *8.1.8 Renewable Energy Installations*

Several renewable energy projects are being considered to save electricity and heating costs across campus. The three most significant include:

- Ground source heat pumps to aid in the production of campus heating and cooling
- Photovoltaic and Thermal solar panels on building rooftops to produce electricity as well as building hot water.
- Wind turbines to produce electricity on campus.

These renewable energy installations could be used to power campus facilities or sold back to the grid to offset electricity already purchased. They are set to be reviewed in the upcoming year (2012-13) along with potential funding sources such as the Ontario Power Authority's Feed in Tariff program.

Currently, only solar PV installations are being pursued. It is generally estimated that solar panel installations cost between $9,000 and $11,000 per kW. In southern Ontario, weather conditions dictate a generation capacity of 1,150kWh-1,300kWh/$m^2$.

The Ontario Power Authority offers the micro FIT program that buys electricity from small scale producers at a rate of $0.71/kWh. Assuming an average electricity cost of $0.71/kWh, the costs and associated savings of a 10kW installation are shown in table 23 with the following assumptions:

- Installation costs: $10,000/kW
- Generation Capacity: 12,000kWh/year

| **Cost Savings** | **Initial Investment** | **Annual Savings** | **Payback Period (years)** |
|---|---|---|---|
| | $160,000 | $8,520 | 18.8 |
| **Energy savings** | **Electricity (generated)** | **Gas savings** | **Water savings** |
| | 12,000 kWh | N/A | N/A |

**Table 23: Solar PV estimated costs and savings**

### *8.1.9 Retro-Commissioning*

The building retro-commissioning initiative involves surveying existing campus buildings to identify potential areas for energy savings. Primarily, the projects being considered are those with an up to five year Payback period.

The Building retro-commissioning initiatives often involve working with external energy audit firms to identify key projects and investments in campus buildings. These initiatives may involve upgrading existing equipment to newer, energy-efficient models, tuning control systems to improve performance, improving HVAC systems to optimize the amount of outdoor air used, or simply re-evaluating the building purpose (i.e. energy usage of lab space turned into office space, etc.)

Listed below are some of the projects suggested:

**1. Building 19: Whidden Hall retrofit**

- Install new fan coil units to replace hot water radiators and upgrade the controls system.
- Connect the building to chilled water district plant, to improve efficiency of heating and cooling systems (install air-conditioning), and upgrade the building envelope.
- Upgrades to the HVAC system, controlling exhausts in each washroom/bathroom individually via an occupancy sensor and on/off switch.
- Install motion sensors for room lighting.
- Replace domestic hot water storage tank with instantaneous steam to hot water system.
- Make up air handling unit installed in basement.

**2. Building 52: MDCL retrofit**

- Upgrading the building exhaust system to account for change in space usage. i.e. the building was primarily designed for lab space that requires significantly more air changes per hour than office space, which is what much of the building is currently used for. Re-evaluating the ventilation system, noting the change in space-use has huge energy savings potential
- Heat recovery systems on exhaust systems.

**3. Building 38: Kenneth Taylor Hall (KTH) retrofit**

- Convert constant volume systems to VAV systems.
- Install digital controls on reheat coils in basement and ground floor.
- Examine control system for cut back opportunities such as operational schedules.

**4. Building 16: JHE Building**

- Revise HVAC system initially designed for laboratory space into a system optimized for office space.

Overall, the costs and energy saving of these proposed retrofits are outlined in Table 24, and it will likely commence in 2013-14.

| **Cost Savings** | **Initial Investment** | **Annual Savings/Income** | **Payback Period** |
|---|---|---|---|
| | $1,250 000 | $668,975 | 1.9 years |
| **Energy savings** | **Electricity (generated)** | **Gas savings** | **Water savings** |
| | 4,432,832 kWh | 512,737 $m^3$ | 40, 603$m^3$ |

**Table 24: Retro-commissioning costs and savings**

### *8.1.10 Voltage correction*

The Voltage Correction initiative was developed by Legend Power. The project involves the Harmonizer-AVR, which Legend Power guarantees reduces electrical energy consumption in commercial buildings, saves money and ultimately lowers greenhouse gas emissions.

According to Legend Power, the product works as follows:

"The Harmonizer-AVR is installed in a facility's electrical room at the point where power enters a building and regulates incoming voltage. By operating equipment at a reduced and controlled voltage level, equipment runs with greater efficiency, saving energy (up to 12% of peak consumption), while reducing costly premature equipment failure and also extending a products life expectancy.

If excess power is supplied to a building in the form of high voltage, the Harmonizer-AVR will automatically adjust voltage to an efficient level to save energy and money. Power and voltage delivered to a facility will typically vary by up to 10% throughout the year. Because of this, most buildings receive more power than needed, and this directly impacts a building's overall electrical energy consumption. Legend Power eliminates this hidden energy waste and provides guaranteed energy savings. "

Table 25 summarizes the anticipated costs and savings, for the John Hodgin's Engineering Building (JHE).

| **Cost Savings** | **Initial Investment** | **Annual Savings/Income** | **Payback period** |
|---|---|---|---|
| | $750,000 | $150,000 | 5 years |
| **Energy savings** | **Electricity (generated)** | **Gas savings** | **Water savings** |
| | 1,500,000kWh | 0 | 0 |

**Table 25: Voltage correction cost and energy savings**

### *8.1.11 LED Lighting replacements*

**Background and Proposed Solutions**

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

McMaster University received a proposal from EcoLight, which suggested the replacement of a total of 27,792 T8 4' lamps to the same number of 18W LED 4' lamps. Currently, there are several initiatives underway to improve lighting efficiency even further by implementing LED fixtures in classrooms, parking lots and offices across campus. The savings and costs of these projects are shown in Table 26.

| Project Description | Electricity savings | Capital Cost ($CAD) | Annual Savings ($CAD) | Payback period (years) |
|---|---|---|---|---|
| Parking Lot C initiative | 4,555 kWh/year | $1,360 | $456 | 2.9 |
| Robinson Theatre (Togo Salmon Hal) initiative | 3,285 kWh/year | $1,185 | $329 | 3.6 |
| Campus-wide replacement initiative | 1,704,205 kWh/year | $1, 528, 560 | $170,421 | 8.9 |

**Table 26: Savings and costs from LED projects**

### *8.1.12 HHS-MUMC Window Coating*

McMaster University is working on a partnership with Hamilton Health Sciences (HHS) to utilize E-time Energy concerning the windows on the McMaster Hospital Building.

The double paned windows with no additional heat blocking capacities led to several concerns with the existing condition of the building, including:

- High heat gain/loss leading to user discomfort during certain periods of the day
- HVAC systems cannot meet building demands
- Glare through windows makes it difficult to view LCD screens
- UV radiation damaged finishing's.

An analysis of the building concluded that significant savings could result from the application of the HPS Heat Shield to the windows in the building. These heat shields have the following attributes and capacities:

- Block 40-60% of heat transfer
- Block 90% of UV radiation while maintaining visual transmittance

These effects will have the effect of maintaining a more consistent interior environment, reducing the load on the HVAC system (thereby conserving energy) and increasing user comfort. Furthermore, eTime Energy guarantees that the product will not significantly affect the aesthetic appearance of the building and does not create any landfill waste or emissions.

A RET Screen analysis performed by eTime Energy yielded financial investments and returns for the project, shown in Table 27.

| Project | Capital Cost ($CAD)<br>without SaveOnEnergy incentives | Annual energy saved ($CAD) | Payback Period (years) |
|---|---|---|---|
| **eTime Energy Heat Shield windows** | $330,000 | $99,000 | 3.3 years |
| | Annual Electricity Savings | Lower HVAC operation costs | Steam Heat reduction |
| | 90,000 KWh | 24% | 8% of total spend |

**Table 27: Window Coating energy savings**

With the proposed SaveOnEnergy incentives offered by the Ontario Power Authority, the capital cost of the project is even lower. The proposed incentives amount to approximately 21% of the project cost, reducing the total capital cost to $260 000, and a payback period of 2.6 years.

### *8.1.13 Plug Load Analysis*

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

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

At McMaster University, a study was conducted on four buildings to determine a Base load energy profile and develop solutions to reduce this energy load.

### Gilmour Hall

An analysis of Gilmour Hall revealed a total electricity usage of 1,899,498 KWh per year, with a total area of 7,660m$^2$ for electricity intensity of 248 KWh/m$^2$.

Fig. 26 below shows the building energy usage by a % of the total KWh, thus demonstration that Equipment load is a significant source for energy savings.

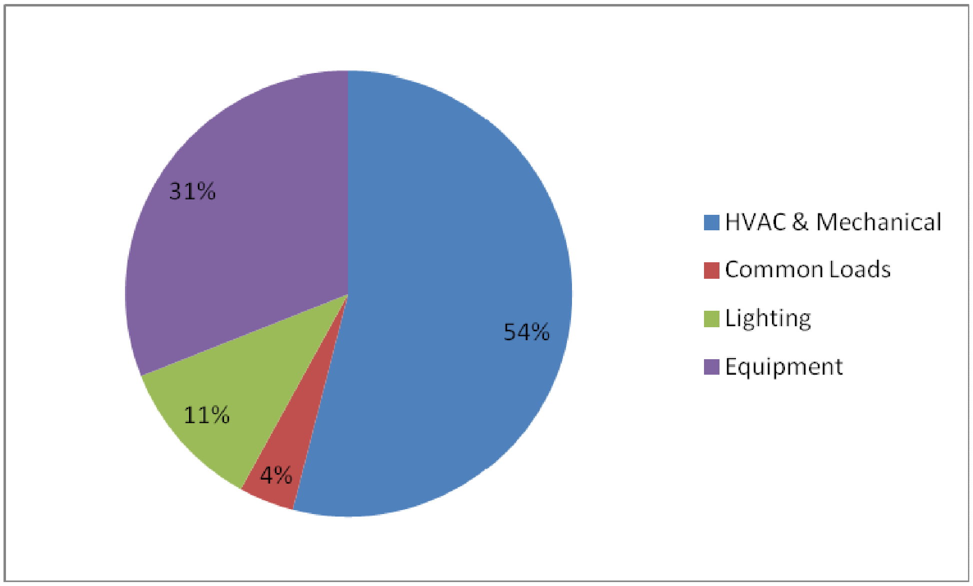

**Figure 26: Gilmour Hall Energy profile**

Recommendations from the plug load analysis include Energy Star equipment replacement, motion sensors, delamping vending machines, energy efficient settings for desktop computers and fan coil replacements. The total cost of implementing all recommendations is estimated to be $38,746 with an annual anticipated savings of $18,964 and an electrical savings of 189,644KWh.

## Hamilton Hall

Building analysis determined that Hamilton hall consumer 586,581 kWh of electricity annually, with a total area of 3,437m$^2$ for total electricity intensity of 171kWh/m$^2$.

Fig. 27 shows the energy profile of Hamilton Hall as percentage of total kWh.

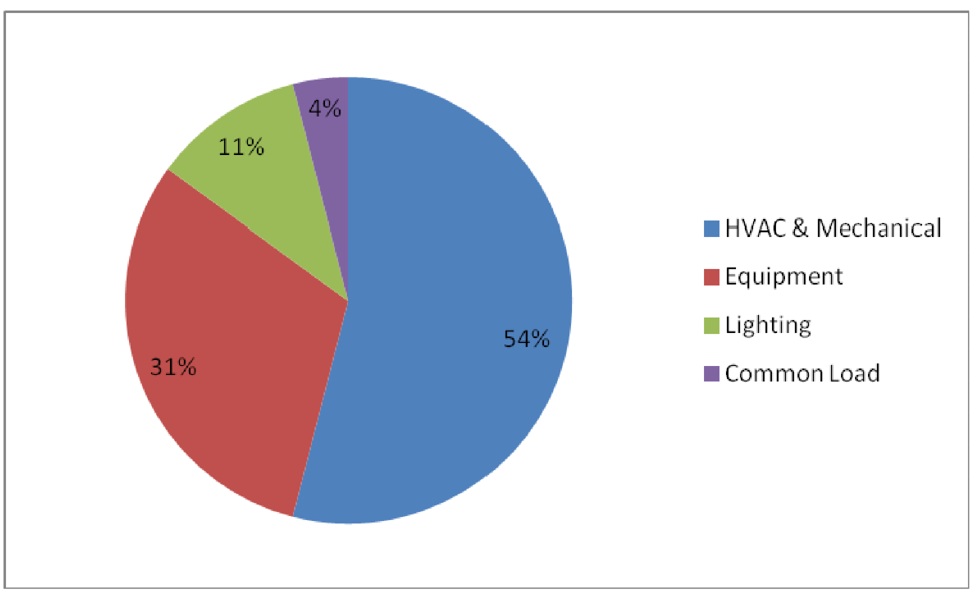

**Figure 27: Baseline Load profile for Hamilton Hall**

Recommendations from the plug load analysis include Energy Star equipment replacement, motion sensors, delamping vending machines, energy efficient settings for desktop computers and fan coil replacements. The total cost of implementing all recommendations is estimated to be $40,425.33 with an annual anticipated savings of $12,844 and an electrical savings of 128,844kWh.

## Chester New Hall

It was determined that Chester New Hall consumes 749,983kWh of electricity annually, with a total area of 6,935m$^2$ for a total electrical intensity of 108 kWh/ m$^2$.

The building energy profile as a percentage of total electricity usage is shown in Fig. 28:

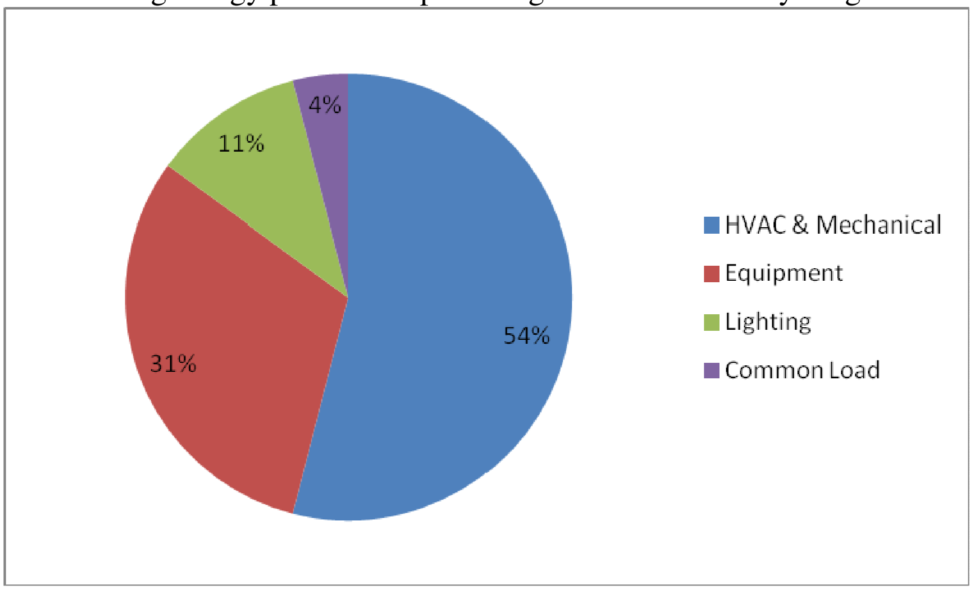


**Figure 28: Baseline Load profile, Chester New Hall**

Recommendations from the plug load analysis include Energy Star equipment replacement, motion sensors, delamping vending machines, energy efficient settings for desktop computers and fan coil replacements. The total cost of implementing all recommendations is estimated to be $72,311.44 with an annual anticipated savings of $21,975and an electrical savings of 219,745kWh

## Togo Salmon Hall

Toga Salmon Hall was determined to have an annual electricity consumption of 2,320,634kWh and an area of 11,362m$^2$ and therefore and electrical intensity of 204kWh/m$^2$.

The building energy profile as a percentage of total KWh is shown in Fig. 29below:

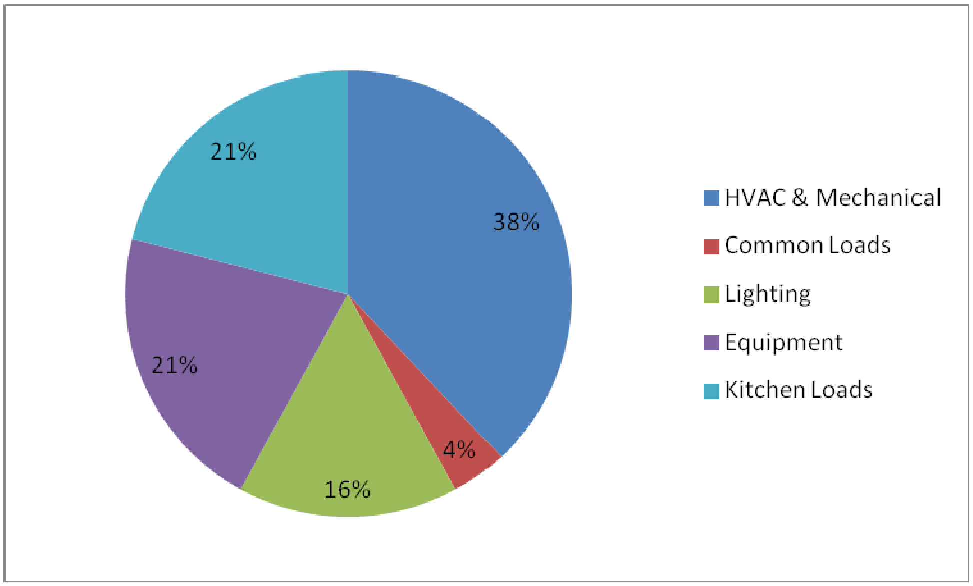


**Figure 29: Baseline Energy Profile for Togo Salmon Hall**

Recommendations from the plug load analysis include Energy Star equipment replacement, motion sensors, delamping vending machines, energy efficient settings for desktop computers and fan coil replacements. The total cost of implementing all recommendations is estimated to be $64,061.00 with an annual anticipated savings of $20,749.06 and an electrical savings of 207,496kWh

Upon surveying feasible replacement and equipment upgrades, the total savings and energy reduction for the four buildings surveyed are compiled in Table 28:

| Cost Savings | Capital Cost | Annual Savings | Payback Period |
|---|---|---|---|
| | $215, 543 | $74, 543 | 3.1 years |
| Energy Savings | Electricity Savings | Gas savings | Water savings |
| | 749 ,759 kWh | 0 | 0 |

**Table 28: Plug load Analysis- Energy & Cost savings from selective implementation**

Note: Similar analysis of other campus buildings may reveal similar potential for energy savings.

### *8.1.14 Miscellaneous Control Systems*

1. Gilmour Hall (1st floor and east wing) and Biology Greenhouse Controls retro fit
   This project involved upgrading the mechanical system to a digital control system from a pneumatic control system.

| Project | Capital cost | Annual savings | Payback period |
|---|---|---|---|
| **University Hall controls upgrade** | $300, 000 | $25, 375 | 11.82 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 87, 500 $m^3$ | 35, 000kWh | 0 $m^3$ |

**Table 29: University Hall controls upgrade**

2. All building mechanical fan belt upgrade
   This project involves installing slip reducing fan belts on all campus buildings ventilation and exhaust systems.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Building mechanical fan belt upgrade** | $125,000 | $53,000 | <2.3 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 0 $m^3$ | 530,000kWh | 0 $m^3$ |

**Table 30: Building mechanical fan belt upgrade costs and savings**

3. All building heating systems set-backs after hours
   This initiative involves utilizing the outdoor air reset system to cut back all campus building ventilation and heating systems operation during low occupancy periods on campus (nights and weekends).

   The cost and energy savings from this project are shown below:

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Building heating cut back** | In house labour | $100,000 | <1 year |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 360,000$m^3$ | 0 kWh | 0 $m^3$ |

**Table 31: project energy savings**

4. All building domestic hot water shutdown after hours
   The project involves shutting down all building domestic hot water after hours and during weekends to reduce energy usage and costs.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Building domestic hot water shutdown** | $30,000 | $30,000 | 1 year |
| | Gas Savings | Electricity savings | Water savings |
| | 108,000$m^3$ | 30,000 kWh | **0** $m^3$ |

**Table 32: Building Domestic hot water costs and savings**

5. Central plant/Chilled water plant operational modifications

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Central/Chilled water plant** | $20,000 | $8,006 | 2.5 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |

| | | | |
|---|---|---|---|
| **operational modifications** | 72,000$m^3$ | 0kWh | **336** $m^3$ |

**Table 33: Central/Chilled water plant operational modifications costs and savings**

6. Strobic fan systems upgrade

This project involves upgrading building strobic fans (in JHE, NRB and ABB buildings) to be more energy efficient.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Strobic fan systems upgrade** | $20,000 | $8,006 | 2.5 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 72,000$m^3$ | 0kWh | **336** $m^3$ |

**Table 34: Strobic fans systems upgrade costs and savings**

### *8.1.15 Water savings*

**City Water Savings**

This project will involve converting city water cooling on process units to a chilled water supply. This project is anticipated to cost $250,000 up front, with a projected savings of $144,000, and an annual water savings of 60,000m$^3$.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **City Water Savings** | $250,000 | $144,000 | 1.7 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 0 | 0 | 60,000m$^3$ |

**Table 35: Chilled Water cost and energy savings**

**Life Sciences Building Fish tanks**

This project involves controlling the water supply to fish tanks, and is anticipated to cost $75,000 in capital costs, with an annual savings of $300,000 and a water savings of 125,000 m$^3$.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Life Sciences Building Fish tanks** | $75,000 | $300,000 | <1 year |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 0 | 0 | 125,000 m$^3$ |

**Table 36: Life Sciences Building fish tank water control- cost and energy savings**

***8.1.16 Union Gas Contract***

This project involves changing McMaster University from an M5 class customer to a T1 class customer. While the project does not have any associated energy savings, it is anticipated that it will save the university $70,000 annually with no initial investment.

Under the M5 customer contract McMaster University is obligated to inform Union Gas of its anticipated gas usage for the year (Nov 1- Oct 31 of the following year). Using this prediction Union gas calculates a Daily committed Quantity (DCQ) which is the anticipated gas usage per day. During the “balancing period” Union Gas reviews consumption and if the University’s prediction is incorrect, and the estimate was too low, McMaster University is obligated to purchase the difference at a different (usually higher) rate, and thus it is often better to overestimate consumption than underestimate it. Conversely, if the University overestimates its usage, it is forced to sell the surplus, usually at a lower rate.

Under the T1 customer contract, the University is responsible for its own daily balancing, and purchasing its own gas storage from Union Gas. Transportation fees are ultimately lower, since the University performs much of the work on behalf of Union Gas. Currently, the McMaster University Hospital, due to its cogeneration plant requirements is engaged in this contract and it could be expanded to include the rest of the campus also. It is anticipated that the reduced transportation costs will result in a savings of $70,000

### *8.1.17 Chiller replacement*

This initiative will involve replacing the 40-year-old Chillers 5 and 6 with ammonia chillers in order to reduce the power usage of the chillers by up to 30%. This project will commence in the 2015-16 fiscal year and the costs and savings are shown in Table 38.

| Project | Capital cost | Annual Savings | Payback period |
|---|---|---|---|
| **Chiller 5 and 6 replacement** | $2,000,000 | $225,000 | 8.9 years |
| | **Gas Savings** | **Electricity savings** | **Water savings** |
| | 0 | 2,250,000kWh | 0 |

**Table 37: Chiller 5 and 6 replacement costs and energy savings**

***8.1.18 Energy Manager***

Through their SaveONenergy program, the Ontario Power Authority offers funds for institutions to hire energy mangers to reduce the organizations' consumption.

The OPA describes the role of the energy manager as follows:

"...to help you take complete control of your energy, by monitoring your performance, by leading awareness programs, by finding small but powerful ways to save, or by spearheading large upgrade projects."

The OPA will fund up to 80% of an Energy Manager's salary as well as 80% of reasonable implemented projects if the facility has the potential to save up to 0.3MW × Load Factor× 8760 hours/year, or a maximum savings of 2628MWh per year.