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Leading by Example:

Blueprint for an energy-efficient City Hall

EXECUTIVE SUMMARY

Toronto's mayor, David Miller, has stated that Toronto will be the leading environmental city in North America. What better place to begin working towards this goal than at City Hall. A symbol of Toronto that is recognized around the world, City Hall can lead by example and be transformed into a state-of-the-art, energy-efficient facility. But the benefits of the improvements we have recommended go well beyond the symbolic. They provide real, measurable energy savings that will reduce City Hall's energy footprint and cut greenhouse gas emissions. Furthermore, these savings are sustainable, delivering lower energy consumption and reduced operational costs year after year. Across the country, Canadians are expressing a growing concern regarding the environment. A recent Decima Research survey revealed that the environment now trumps heath care as the top concern among Canadians[1] In the past, the citizens of Toronto have been highly supportive of civic environmental initiatives and the greening of City Hall is likely to be no different. People are looking for their governments to act and bringing energy efficiency to City Hall is an opportunity for the City of Toronto to demonstrate environmental leadership, economic foresight and social awareness.

[1] Source: Decima Research. 1,727 respondents were surveyed from December 22, 2006 to January 2, 2007. 19% said the environment was the issue of top concern while 13% rated concern with health care as the top issue.

> An opportunity to make a sustainable difference

Built in the 1960s when energy efficiency was not a concern, the City Hall facility presents a number of opportunities to reduce energy consumption. While several improvements to the buildings' energy consumption and infrastructure have been made in the past, exhaustive energy conservation and renewable energy systems reviews for the facility conducted in late 2006 and early 2007 have revealed the potential to save more than 5.6-million kWh of electricity and 18,759 kLbs of steam annually. This translates into approximately $1,074,127 in annual energy-related cost savings and will reduce greenhouse gas emissions by 13,541 tonnes each year. Implementation of the recommended improvements requires an investment of $8,968,397. With the projected energy savings, the payback on this investment is 8.3 years. During this 8.3-year period, the electricity saved will be enough to provide electricity to about 560 average homes in Toronto and we will eliminate the greenhouse gas effects of almost 22,428 cars.

> A realistic and practical approach

Energy use at the City Hall facility was thoroughly evaluated to identify realistic improvements and opportunities to incorporate renewable energy into the mix. Toronto Hydro Energy Services assessed current and emerging technologies to ensure City Hall can benefit from the most recent developments in energy-efficient technology. The end result is a comprehensive list of recommendations, which, for the most part, can be implemented with minimal disruption to City Hall operations and will comply with the building's requirements as a designated heritage site. These recommendations represent the best possible route to energy efficiency at City Hall.

The majority of recommended improvements is considered typical for buildings of City Hall's age and will serve as a model for increased efficiency in other buildings of similar size and age. While recommendations that incorporate renewable energy technology have a longer payback period than the more traditional energy improvements, they present a leadership opportunity for Toronto by showcasing the benefits of this technology employed in a high-profile, heritage facility.

> Summary of recommendations

Proposed improvements are outlined in the Discussion of Recommendations section of the report with complete details available in the Appendices.

DESCRIPTION	NET COST	ELECTRICITY saved		STEAM saved		PAYBACK	Maintenance	GHG
	$	kWh/yr	$/yr	kLbs/yr	$/yr	Yrs	$/year	Tonnes/yr
Micro-wind turbine	122,500	86,800	8,680	n/a	n/a	17	1,250	61
Photovoltaics – 120	290,000	25,260	2,526	n/a	n/a	>25	1,500	17
Green roof systems	1,350,000	198,000	19,800	35	1,030	>25	4,000	151
Window Photovoltaics-132	650,000	6,051	605	n/a	n/a	>25	1,500	5
Deep Lake Water Cooling	2,00,000	3,410,510	302,198	n/a	n/a	6.6	n/a	2,381
Chiller plant VFDs	188,000	113,686	11,369	n/a	n/a	16.5	1,500	79
VIP parking garage	1,800	1,870	187	23.1	678	2.1	9	8
Fountain pump control	3,000	27,994	3,079	n/a	n/a	<1	450	19
Window replacement	2,637,612	808,875	80,888	9,991	293,235	7.1	4,250	7,021
Window film	650,000	342,685	34,269	849	24,931	11	n/a	549
Steam system DHW	70,800	-326,860	-32,686	6,900	201,840	.5	1,000	2,226
Electric control valves	152,000	64,800	6,480	280	8,218	10.4	1,000	226
Council chamber lights	9,650	43,820	4,382	n/a	n/a	2.2	150	30
Daylight harvesting	45,750	78,810	8,669	n/a	n/a	5.3	600	55
Podium and office lights	670,475	350,551	35,054	n/a	n/a	19.1	1,250	245
Office programmable stats	78,660	164,160	16,416	n/a	n/a	4.8	2,000	114
Walkway program stats	1,200	25,000	2,500	n/a	n/a	1	500	17
Induction unit control valves	662,000	157,808	15,781	681	19,987	18.5	4,250	309
External lighting/LED	35,950	40,108	4,011	n/a	n/a	9	750	28
Induction unit upgrades*	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Building performance/LEED	20,000	n/a	n/a	n/a	n/a	n/a	12,000	n/a
TOTALS	**9,618,397**	**5,619,928**	**524,208**	**18,759**	**549,919**	**9.0**	**33,709**	**13,541**

> Outstanding issues

The Heritage Board will need to be consulted on any improvements that would alter the appearance of City Hall. Discussions with the Heritage Board in preparation of this report indicated that a key requirement for approval is the ability to restore the building to its original state, which in some cases may prove impractical and costly. These issues will need to be resolved before proceeding. Any issues or concerns relating to specific improvements are outlined in the Discussion of Recommendations section.

> Timing and resources

The majority of recommended improvements can be completed after hours and will take anywhere from a few days to a few months to complete, depending on the work involved and its impact on normal operations. Wherever possible and practical, city staff will implement the improvements and provide the ongoing maintenance. Otherwise, the recommendations can be implemented with conventional trades and specification protocols. Some of the improvements require specialized expertise – the micro wind-turbines and photovoltaics, for example, and will be managed accordingly. Once we have approval to proceed, the recommended improvements can be installed and will be delivering sustainable energy savings within the first year.

> Next Steps

Approval and acceptance of recommendations by city staff and City Council is required. Costs and pricing are based on current rates and the best estimates available at the time. These will need to be firmed up during concept refinement, specification and the tendering process for the various improvements.

Report presented to city staff ………………………March 23, 2007
Report presented to City Council ……………………………TBD
Resolution of outstanding issues……………………………..TBD
Engineering documents and performance specifications ……TBD
Project tendering begins……………………………………..TBD
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For future consideration
- External LED lighting
- Remote hybrid lighting
- Cogeneration for electricity and steam hot water

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INTRODUCTION

Since its construction in the 1960s, City Hall has become a symbol of Toronto around the world. The distinctive curved towers form part of the City of Toronto's official logo, reminding citizens of their government at work on websites, stationary, vehicles, blue boxes and household green bins. As the headquarters of municipal government, it houses Council chambers and the Mayor's office. More than 4,000 people come to work or meet here every day and the surrounding Nathan Phillips Square is home to civic celebrations and public events in Toronto. The building itself holds a special place in the hearts of Torontonians - symbolic of the time Toronto first took its place on the world stage with the selection of Viljo Revell's innovative design. Now we have the opportunity to renew the potency of City Hall as a symbol, this time as an example of the City of Toronto's leadership in renewable energy, energy efficiency and conservation.

The benefits of becoming a green facility

As is the case with most buildings of its vintage, the design and construction of City Hall was not overly concerned with energy management and costs, as energy was considered plentiful and inexpensive at the time. Over the years, building staff and facilities managers have made improvements at City Hall to reduce energy use and improve the indoor environment. Our evaluation outlines recommendations that enable City Hall to lead by example in both energy conservation and sustainable initiatives.

- **Net energy savings** – our recommendations will save up to $1,074,127 in energy costs per year (assuming current rates) through an estimated 5,619,928 kWh reduction in electricity use per year and 18,759 kLbs savings in steam requirements per year.
- **Less greenhouse gas** – Projected energy savings translate into a total elimination of 13,391 tonnes of harmful greenhouse gas emissions per year. This equals the greenhouse gas output of nearly 2,300 cars.
- **Elimination of waste** –with new technology and upgraded systems it is possible to correct the unnecessary use of energy caused by outdated and inefficient technology.
- **Reduced energy budget** – the cost of delivered energy is expected to rise between 5% and 10% annually. Without conservation, absolute energy expenditures at City Hall will consume a greater proportion of the facility's annual operating budget.

Not as easily measured as the previous benefits, but equally as important, is the leadership factor. As a high profile, public facility, City Hall can act as a model for other buildings, both new and old, throughout Toronto and in other municipalities, encouraging similar improvements by others. In addition, the environmental stewardship demonstrated by the City of Toronto by investing in energy saving measures will inspire residents to do the same. The ultimate benefit is a better environment for all.

Challenges

- As a designated Heritage Site, recommended improvements that would affect the appearance of City Hall must be approved by the Heritage Board. Preliminary discussions with the Board indicate that a key requirement of any modification is that the building must be able to be returned to its original state.
- City Hall is first and foremost a place to gather and work. Wherever possible, the implementation of the recommended improvements will take place with minimal disruption to staff and visitors.
- Anywhere from 2,500 to 4,200 staff can be in the building during operating hours. This fluctuating presence affects the cooling load, internal heat gains, indoor air quality, plug loads, light loads and domestic hot water loads. For this report, we have assumed 4,000 people per day throughput, which also accounts for public use of the facility. An average of 2,800 people per day is used when required for load definition.
- All buildings operate as a complete, integrated entity and City Hall is no different. Change in one area is likely to affect another so while many separate improvements are recommended; attention was also given to how the recommendations would interact for optimal building performance. As a result, certain recommendations are interdependent on others in order to obtain the projected results.
- The winner of the design competition to revitalize Nathan Phillips Square was announced on March 9, 2007. The winning proposal, submitted by Plant Architects Inc. & Shore Tilbe Irwin, includes features that address and incorporate issues of sustainability. Certain recommendations in this report, such as the green roof, photovoltaics, exterior lighting and fountain pump control, will need to be reassessed in keeping with the selected design.

Limitations of this report

- Deep Lake Water Cooling (DLWC) is under consideration for City Hall and for improvements such as the Chiller Plant Upgrade, we have assumed DLWC will be implemented in 2007/2008.
- Recommendations consider the impact their implementation would have on day-to-day operations. Some of the more inconvenient measures may be implemented with the less disruption whenever floors are refitted and should be considered as these opportunities arise.
- New technology to facilitate energy efficiency is being developed all of the time. In conducting our evaluation, we considered the most current commercially viable technology available today. As new technology emerges, certain recommendations may need to be revisited.
- The costing presented throughout the report is for budgetary and decision making purposes. Utility costs for steam and electricity represent the average costs for 2005. Formal project costs will be developed during the tendering stage.

City Hall at a glance

- Opened in 1965
- 52,215 m^2 of floor area
- West Tower – 20 floors, 18 above ground
- East tower – 26 floors, 24 above ground
- Operates for approximately 4,200 hours per year
- Between 2,500 to 4,200 staff on site daily
- Houses a daycare centre, library, fitness club and café.
- Energy infrastructure and systems typical of 1960s state-of-the-art building design when energy costs were low relative to other operating costs.
- Annual energy costs: $2,820,273 (62% electricity, 38% steam) in 2005

DISCUSSION OF RECOMMENDATION

For detailed information about each recommendation and product specification sheets, please see the Appendices.

Summary table of recommendations for renewable energy and conservation systems for City Hall

DESCRIPTION	NET COST	ELECTRICITY saved		STEAM saved		PAYBACK	Maintenance	GHG
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MICRO-WIND TURBINES FOR RENEWABLE ENERGY

The City of Toronto is committed to being a leader in the use of renewable energy technologies and City Hall presents a unique high-profile opportunity to take advantage of wind turbine technology on a small scale. We recommend installing three micro-wind turbines on each of the tower roofs, delivering a projected 86,800 kWh/yr of renewable energy and offsetting an estimated 61 tonnes of greenhouse gases per year. This is equivalent to 728 City Hall employees meeting the “one-tonne” challenge within 12 years.

> Recommended technology

The Cleanfield 3.5 kW Vertical-Axis Wind Turbine is designed to be installed on urban rooftops. With a 3-m by 3-m footprint and an installed weight of 250 kg, the micro-turbines have a height of 6 m and will be visible from ground level and surrounding office towers.

> Costs and payback

Turn-key cost for the recommended system is $122,000, which includes a $40,000 discount from Cleanfield Energy. The system comes with a 10-year warranty and the blades can be expected to need replacing in 15 to 20 years. By displacing 86,800 kWh/yr of electricity use, the system is estimated to save $8,680 per year, paying for itself in 14 years.

> Issues and challenges

• Wind quality

Wind in urban settings is typically “ dirty” – it can change direction quickly and be turbulent, as currents are influenced by surrounding buildings. Situated to the north and south of taller buildings, and taller than the buildings to the east and west, the City Hall towers are available to the dominant winds and previous wind monitoring reports indicate the site is well suited for an urban wind turbine installation.

• Heritage site requirements

As a designated heritage site, improvements to City Hall must be reversible in order to return the building to its original condition. Removal of the micro-wind turbines will meet this requirement and can be done.

Next steps

- Heritage Board must review the change to the look of the building.
- Structural analysis of the tower roofs is required.
- Municipal electrical utility must approve design and interconnection and net billing will have to be negotiated.
- Building and electrical, fire and insurance inspections will be required.
- Monitoring points will be added to the Building Automation System to receive and assess performance data from the turbine system.

HARNESSING SOLAR ENERGY WITH PHOTOVOLTAIC PANELS

Photovoltaic panels, a means of collecting and converting solar energy to electricity, were first installed on the podium at City Hall in a pilot project eight years ago. Greater use of photovoltaics at City Hall in a highly visible location will further demonstrate the City's commitment to renewable energy.

We recommend expanding the installation to a 120 panels on the podium, facing south, in front of the Council chamber. A 120-panel installation, at 190 watts-per-panel, will generate 25,260 kWh/year of clean, non-greenhouse gas producing electricity, saving 18 tonnes of greenhouse gas emissions per year. This represents the annual electricity required to light the Members Lounge and the handicapped washrooms in both towers.

In addition, we recommend introducing Building Integrated Photovoltaics (BIPV), a new technology that can be easily incorporated into building architecture such as windows, to replace 132 south-facing windows in the stairwells of the towers. At 75 watts-per-panel, this configuration is estimated to produce 6,951 kWh/year in renewable energy and reduce greenhouse gas emissions by 4.2 tonnes annually. This translates into the electricity required to light the base lights of the Council chamber for two months every year.

> Recommended technology

Solar panels are a proven fast-growing technology; many systems have been running for more than 25 years with very little maintenance. For installation around the podium, the latest high-efficiency Sanyo HIT Bifacial modules are the preferred choice and are expected to have a service life of more than 40 years. When mounted off the ground, these units are designed to capture backlight for increased output. In addition, these panels and the recommended Solgreen racking can work with a green roof system as they allow some light to pass through.

In the tower stairwells, custom-designed building integrated photovoltaics are recommended as the best performing option that will meet the Heritage Board requirements. Although this is new technology, its serviced life is expected to be similar to photovoltaic panels.

> Costs and payback

Photovoltaic systems are a long-term investment that demonstrate a commitment to renewable, clean energy. The installation of 120 panels around the podium is estimated to cost $290,000 with a payback period in excess of 25 years. The anticipated cost of replacing the windows in the tower stairwells with photovoltaic windows is $650,000, resulting in a payback period greater than 25 years. Benefits due to reduced cooling were not estimated.

> Issues and challenges

• Shading

City Hall experiences significant shading from the tall buildings located to the south, in particular during the winter months. However, a recent study by Sol Source Engineering[2] showed that the sunlight that is received is sufficient to generate energy. Using this information and a RETScreen Photovoltaic simulator, we have calculated and presented the performance potential of the recommended designs.

• Heritage issues

Any installed system would need to be removable in order to return the building to its original state. This requirement also implies that replaced windows would need to be stored, which is not feasible due to anticipated breakage upon removal and the cost of storage. Instead, custom-designed photovoltaic windows are recommended as they can be designed to retain the original look of the building.

> Nathan Phillips Square redesign

Inclusion of photovoltaic panels on the podium will need to be incorporated in the selected redesign of Nathan Phillips Square. The winning proposal includes a green roof concept, and the proposed solar array will impact this design feature.

Next steps

- Heritage Board must review the look of replacement windows.
- Coordination of recommendation with the Nathan Phillips Square design team.

[2] City of Toronto Solar Feasibility Study – Preliminary Sire Assessment Report, Sol Source Engineering, November 2006.

GREEN ROOF SYSTEM FOR THE PODIUM

The City of Toronto encourages green roof installations through an incentive program and a pilot green roof was installed on a section of the podium in 2001. We recommend extending the green roof on the podium area to cover about 43% of the area with plantings and pathways.

The environmental and energy conservation benefits of green roofs are well documented. They divert rain water from storm sewers, reduce heat island effects, collect particulates and some pollutants, reduce heat gain and localized carbon dioxide levels, decrease local sound levels, increase roof membrane life and improve the habitat for insects and birds.

> Recommended system

An intensive green roof, which has a growing medium greater than 15 cm in depth and is suitable for sedums, herbs, grasses and some shrubs, is recommended. The insulating properties of the proposed system would reduce electricity for cooling in the 2nd floor offices by 198,000 kWh/year and eliminate 35 kLbs/year in steam required for heating. It is anticipated the green roof will reduce greenhouse gases by about 151 tonnes per year – the equivalent of taking 38 cars off the road every year. The resulting savings equate to the electricity required for office lighting in 23 floors of the east tower.

In addition, the green roof will reduce storm water run-off and surge by 50% to 60%. Approximately 660 kg of airborne pollutants (particulates less than 2.5 microns in diameter) will be absorbed by the plants every year and noise levels in the surrounding area will be reduced by about 40 decibels. Furthermore, a green roof is anticipated to extend the lifespan of the existing roof system by two or three times.

To help keep maintenance costs down as well as involve community groups in the project on an ongoing basis, we recommend the City consider engaging volunteer group as grounds keepers.

> Costs and payback

Installation of the recommended intensive green roof is estimated at $1,188,000 to $1,350,000 with a payback period in excess of 25 years. Annual maintenance will be between $2,000 and $4,000.

Visible to all occupants of the tower offices and surrounding office towers,
the green roof will be a unique and inspiring application that will encourage the use of the podium as a promenade while improving the energy performance and environment. This would be a landmark addition to the City Hall and definitely position the building as a leader in environmental awareness and concern.

> Issues and challenges

• Structural support

The estimated weight of the green roof would be approximately 2,000 tonnes over 3,300 m^2 and it would have an annual water retention capacity of approximately 380 cubic metres. The current roof can structurally support emergency vehicles and is therefore capable of supporting the recommended green roof system.

• Nathan Phillips Square redesign

Inclusion of a green roof on the podium will need to be incorporated in the selected redesign of Nathan Phillips Square.

Next steps:

- Coordinate with the Nathan Phillips Square design team.
- Solicit volunteer and landscape organizations for planting ideas and maintenance.
- Verify legal aspects of opening up the podium deck. This may require altering the podium railing.

DEEP LAKE WATER COOLING

The City has before it a December 2006 proposal from EnWave to supply Deep Lake Water Cooling to City Hall. Cold provided by the deep lake water is pumped to a heat exchanger, which then collects the cold, or coolth, and pumps it to City Hall where heat exchangers in the basement transfer the coolth to the circulating chilled water eliminating the need for electric chillers. The savings accrue due to significantly reduced electrical use along with lowered water and chemical use normally required to make up losses.

> Costs and Paybacks

From the perspective of electricity saved alone, the City Hall will reduce its annual electrical consumption by 3,410,510 kWh, which is about $302,198/yr (using EnWave numbers). With the terms presented, the payback is on the order of 6.6 years without energy price escalation by turning off the chillers and 2,381 tonnes of greenhouse gases will be eliminated. This is equivalent to taking almost 450 cars off the highways coming into the core of Toronto each year.

MAXIMIZE SAVING OPPORUNTIES WITH ELECTRONIC CONTROLS

Building automation systems play an important role in the effective energy management of any facility as they ensure efficient regulation of building environments. City Hall recently upgraded its building automation system to a state-of-the-art, web-based, direct digital control system. The recommendations that follow will maximize savings opportunities without sacrificing comfort through the use of these new building controls and save approximately $85,949 in electricity and steam energy costs annually, reducing greenhouse gas emissions by 754 tonnes. That's the equivalent of the greenhouse gas produced by almost 108 average houses per year.

UPGRADE CONTROL VALVES TO ELECTRONIC ACTUATION AND CONTROL

The current configuration of controls on dampers and valves in the air-handling units is a mix of new direct digital controls and older pneumatic controls. All of the almost 300 control valves for the office induction units are pneumatic, old and difficult to set. We recommend that the remaining aging pneumatic controls on air handling units and induction unit valves be replaced with electronic ones and interfaced with the new control system eliminating the need for costly compressed air, improving control strategies, increasing comfort and bringing City Hall controls up to the current standard for HVAC systems in buildings today. Savings will result through reduced maintenance and improved control of heating and cooling, totaling approximately $50,386 per year. The cost to replace the valves is estimated at $814,000 and the payback period is 16 years.

> Replace thermostats in offices and walkways with programmable thermostats

Up until recently, all the thermostats installed in the tower offices and walkways between Council chambers and the offices have been one-setting models. They remain at the set temperature unless the occupant turns the unit down before leaving for the day or weekend. As a result, extra heat is provided by electric heaters, either in the ductwork for the offices or in the floor in the walkways. We recommend replacing these thermostats with programmable models that allow for weekday and weekend scheduling. In fact, wherever a thermostat is now used and cannot be interfaced easily with the new control system, a programmable model should be considered. With better control, night setback and other unoccupied time setback, a total of 189,160 kWh in electricity and $18,916 in costs will be saved each year. The greenhouse gas avoided will be the same as that removed by almost 20,000 trees each year. To replace 230 thermostats will cost $84,860 and the payback period is 4.5 years.

VIP GARAGE TEMPERATURE CONTROL

Heating load in the VIP parking garage can be reduced without the need to convert the existing "wet" sprinklers to a "dry" sprinkler system. Using line voltage programmable thermostats, the temperature can be set back from the current 68ºF to 48ºF at night, and trimmed back the set point to 50 °F during the day. This recommendation will cut steam use by 23.1 kLbs/year and lower electricity use by 1,870 kWh/year for a 12% reduction in energy use. At 50ºF, there is no concern that water from the wet sprinklers will freeze. The cost to install six thermostats is $1,800. With annual cost savings of $865 per year, the modification pays for itself in two years and avoids eight tonnes of greenhouse gases – about that equivalent of two VIP cars per year. Conversion to a dry sprinkler system, which would eliminate the need for heating in the VIP garage, was rejected at this time because the system would need to be uncoupled from the Records Centre, with which it is shared and would require recertification for legal and insurance reasons.

INSTALL VARIABLE SPEED DRIVES ON THE CHILLER WATER PUMPS

We recommend that the existing chilled water system be controlled by variable speed drives, which will allow for more effective control of the pumps that push cold water through the building for cooling purposes, slowing them down when demand is low. This will conserve significant amounts of electricity as the pumps are electrically driven and will result in greater and more consistent comfort in the building. Approximately 113,686 kWh/year in electricity, $15,782 in annual electricity costs and 80 tonnes/year of greenhouse gases will be saved through this improvement. At a cost of $188,000, the project payback period is 11.9 years. This energy is about what it takes now to light the Council chambers, Members Lounge and perimeter lights around the chamber each year (before improvements).

ENERGY EFFICIENT WINDOW REPLACEMENT

City Hall has more than 2,000 windows located on the two towers and around the Council chamber, representing more than 50% of the total exposed wall area. The thermal performance of the existing windows is varied and well below what is available through current technology.

We recommend wholesale window replacement with lower U-value* units because it will deliver the greatest amount of sustainable energy savings – 808,875 kWh/year in electricity and 9,991 kLbs/year in steam. This translates into $374,123 in annual cost savings and will eliminate 7,021 tonnes of greenhouse gases each year – similar to reducing automobile traffic by about 1,400 cars every year. Although window film has been used successfully in the past to improve thermal and glare performance of windows at City Hall, on its own, it does not deliver the same performance as window replacement, saving about 342,685 kWh/year in electricity and 849 kLbs/year in steam. However, window film reduces nuisance glare, is compatible with window replacement and would still reduce heating and cooling energy.
* U-value measures a window's ability to conduct heat. A low U-value indicates the window loses less heat than one with a higher U-value.

>Recommended technology

Low-emissivity-insulating glass is the preferred option as it is the most efficient, reducing heating and coaling loads by 60% to 75% and lowering U-values by as much as 73%. These higher insulation windows will allow about 40% relative humidity at outdoor temperatures around 15ºC before condensation begins, providing a more comfortable office environment. A self-cleaning version of these windows was rejected as not suitable because direct sunlight is required to activate the self-cleaning feature.

>Costs and payback

Several different products were evaluated, all with similar costs. Depending on crew size, it could take up to 12 months to complete the replacement without undue inconvenience to staff. The total cost to remove and dispose of existing windows and purchase and install new ones is $2,637,612 and based on the projected energy savings, the estimated payback period is 7.1 years.

> Issues and challenges

• Heritage Issues

The selection of the replacement windows must involve consultation with the Heritage Board. As a Heritage Site, any selected window design must preserve the original look of the buildings. Replacement of only some windows would create a "broken tooth" effect and is not acceptable. Because of breakage during removal and the cost of storage, it is not feasible to meet the requirement to return the building to its original state. Given the substantial energy savings available by replacing the windows, it seems unlikely that there would ever be a need to return the building to an energy inefficient state.

Next steps

- Clarify Heritage Board's position on window replacement and firm up requirements.
- Complete a full count of all windows eligible for replacement, possibly identifying additional savings.
- Select a low-emissivity insulating window for replacement.

TANKLESS DOMESTIC HOT WATER HEATERS AND CONDENSATE HEAT RECOVERY

Steam is supplied to City Hall by EnWave for heating and domestic hot water use throughout the year. We recommend switching from steam to electric, tankless units to provide domestic hot water on demand, eliminating the need for steam-to-hot water conversion in the summer months and reducing steam loads at other points in the year. This change would also assist in better management of steam use during the months where there is a transition from heating to cooling and vice versa. About 6,400 kLbs of steam would be replaced with another energy source –345,000 kWh of electricity. However, the net result is an annual cost saving of $155,154 in steam and a net greenhouse gas reduction of 2,000 tonnes.

We also reviewed capturing condensate heat that is normally sent back to EnWave to pre-heat incoming city water before it goes to the large domestic hot water tank. This collected energy would offset steam energy used to heat domestic hot water used on the ground floor, 2nd floor and restaurant, reducing the annual steam load by about 300 kLbs, saving $8,800/yr and offsetting 108 tonnes in greenhouse gases.

> Recommended technology

We recommend that electric instantaneous water heaters be installed on each floor sized to handle the three washrooms and a galley kitchen. We also recommend a heat exchanger be installed in Mechanical Room 101 to capture condensate water energy to pre-heat domestic water. In addition, aerators on hot water faucets must be installed on all faucets to keep the flow rate at 0.5 gallons per minute, which will further aid energy efficiency, heater capacity and water conservation.

Both electric and natural gas systems were evaluated. The benefit of lower annual operating costs for the natural gas units is outweighed by the cost of bringing natural gas into the facility, as there is none now, combined with higher upfront costs, the required exhaust and intake ducting and resulting Heritage Board issues.

> Costs and payback

Installation of the electric tankless units on each floor of the towers will cost $57,000. An estimated electrical bill is $33,000/year. Against an annual cost of $187,000 for steam means this concept will have a payback within a year. The tankless units will calcify as a result of heating hard water and will need to be inspected and cleaned annually at an estimated total cost of $1,000 per year.

The cost to install a tube in shell heat exchanger into the return condensate line and incoming city water line will be $12,800, resulting in about $14,000/yr savings giving a payback within 1.5 years. This will avoid a further 150 tonnes of greenhouse gases.

Next steps

- Determine floor hot water loads accurately and size instantaneous heaters to match current loads including potential for growth.
- Install aerators in any hot water faucets that have not already been retrofitted in City Hall.
- Verify access to condensate heat energy

DEMAND RESPOND CONTROL OF FOUNTAIN PUMP

During the summer season (June to September), the fountain in Nathan Phillips Square is operated around the clock. Turning the fountain off for extended periods would reduce electricity consumption but is not recommended because of standing water issues in the surrounding pool and concerns about people using the pool when the fountain is turned off. However, it is feasible to turn the fountain off during periods of high electricity demand and when it is raining. By regulating fountain operation through the existing building automation system, we can incorporate the fountain into the building's demand control sequence, turning the fountain off overnight from 22:30 to 6:00, Monday to Thursday, and from 2:00 to 6:00, Friday to Sunday, when electricity demand is high. These measures would save an estimated 27,994 kWh/year in electricity and 1 tonne of greenhouse gas emissions every year. At a cost of $6,220, the modification will pay for itself in 3.5 years.

ENERGY-EFFICIENT LIGHTING AND CONTROL

Advances in energy-efficient lighting and control technology present several opportunities for energy conservation throughout the City Hall complex. Collectively, the recommended initiatives will save an estimated 513,289 kWh/year in electricity and 32.3 tonnes in greenhouse gas emissions each year. Savings in electricity costs are expected to be $52,116 per year.

> Council chamber lights

City Hall's Council chamber is a high-profile location frequently used for media events and, as a result, requires specific qualities of light, presenting little opportunity to introduce low energy products such as compact fluorescent technology. The adjoining Members Lounge also has limited opportunity for improvements as the pot-lights, like the Council chamber, are mounted in an asbestos-covered ceiling. However, two improvements are feasible.

The first is to replace lights in the Members Lounge with lower wattage, compact fluorescent bulbs, taking advantage of the available ambient light in the Lounge. Similar improvements can be made with the up-lights at the base of the Council chamber.

The second initiative is to make better use of the existing computerized control system that allows for various dimming schemes and on/off controls. This can be achieved through better staff training and increased awareness of the energy savings potential of effective use of the controls.

Combined, these recommended improvements will reduce 43,820 kWh/year in electricity and 2 tonnes in greenhouse gas emissions each year. Cost savings are estimated at $4,382 annually resulting in a project payback period of 2.2 years.

CONTROL OF GROUND PODIUM AND OFFICE LIGHTS

Occupancy sensors and integrated controls are recommended to effectively manage lighting in the committee rooms, staff washrooms and workspaces. In addition, replacing older and inefficient incandescent light bulbs as required with newer compact fluorescent bulbs is also recommended. These two measures deliver combined electricity savings of 350,551 kWh/year in electricity, the equivalent of eliminating 245 tonnes of greenhouse gases. This equates to turning off the electricity for almost 35 homes each year.

We recommend installing an integrated lighting control and energy management system for controlling ground and 2nd floor office lighting at City Hall. The system uses a combination of occupancy sensors and scheduling that allows individual fixtures to be controlled for the tasks and light levels required. IR/motion sensors can be added to the light switches in staff washrooms and occasionally used rooms, ensuring lighting is only on when the room is in use. Some of the committee rooms use the same lighting control system as is used in the Council chamber. Staff training on this system and establishing a person to be responsible for committee room lighting for each meeting will ensure the control system is used to its maximum potential and savings incurred consistently.

The total cost for all recommended measures is $670,475 with 350,640 kWh/year of electricity saved and cost savings projected at $35,064. The payback period is 19.1 years. This recommendation avoids approximately 245 tonnes of greenhouse gases.

> Daylight harvesting

Both the east and west towers receive various degrees of direct and reflected light throughout the day that can be harvested to reduce the amount of electrical light supplied. The narrow nature of the footprint of each floor allows for significant and effective daylight harvesting. We recommend monitoring incident light levels through the existing building automation system with the addition of sensors placed in three defined zones. When incident lighting in a zone is sufficient, light fixtures in that zone can be automatically turned off and when incident lighting is insufficient, the lights can be turned on. Estimated electricity savings from daylight harvesting amount to 78,810 kWh/year, and a reduction of 5.3 tonnes in greenhouse gas emissions every year. At a cost of $45,750 and producing annual electricity cost savings of $8,669, this project pays for itself in 5.3 years.

EVALUATION AND ANALYSIS OF ENERGY PERFORMANCE

By acting on these recommendations, City Hall will be making a significant investment in energy conservation. Obtaining LEED (Leadership in Energy and Environmental Design) certification, which is an increasingly recognized standard of energy consciousness in North America, would be a testament to City Hall's commitment to energy efficiency. We recommend establishing and documenting building energy use indices, which measure energy performance per unit of floor space and are the basis for a LEED certification application. In addition, building energy use indices allow for monitoring energy improvements to ensure they are performing as expected and for comparison with other similar buildings. A cost of $20,000 is estimated to prepare a first-year evaluation of performance on the established building energy use indices and retention of a LEED certified auditor to determine if an application is feasible. In addition, a maintenance budget of $12,000 is recommended to complete an annual energy audit and report to ensure energy conservation measures are monitored and assessed.

Refurbish induction units

For a building constructed in the 1960s, induction units were the common air distribution method for heating and cooling. Inspection of under-window induction units at City Hall revealed that performance is hampered due to dirty filters, dislocated filters and obstruction by shelves and filing cabinets. In addition, the units are difficult to control, noisy and use more fan electricity than is necessary. Refurbishment of the under-window induction units is an option, improving air delivery and reducing energy used in cooling and heating by 60%. If all the tower units were refurbished, estimated savings of 157,808 kWh/year in electricity and 2,960 kLbs/year in steam will deliver $102,657 in cost savings annually and cut greenhouse gases by 718 tonnes per year.

> Recommended technology

Existing units would be refurbished with the Dadanco Starline refurbishment units. These more efficient units deliver more air per unit of primary air (4-6:1 versus 2:1 for the existing units) so the amount of air delivered can be lowered, allowing the main air handling units to operate consistently at reduced speeds. Because refurbishing these units would be a dramatic inconvenience to staff, we recommend that the existing induction units be cleaned, filters cleaned and fixed in place, obstructions removed and return air grilles and fan power monitored.

Then, when a floor is to be renovated, consideration should be given to refurbishing the induction units to gradually reap the benefits of improved air delivery, reduced fan energy and reduced noise.

> Costs and payback

The cost to refurbish all 1,089 induction units with Dadanco Starline units is $1,100,000. Given the estimated savings for electricity and steam once all units have been refurbished, the project will pay for itself within 15.7 years. While not estimated for this report, the cost to clean and re-fasten the filters can be carried out by City Hall staff or contracted out, and helps to ensure anticipate savings are maintained.

> Issues and challenges

• Controls

Recommended improvements to controls (see *Optimize building controls*) will enhance the energy efficiency of the induction units, ensuring more effective regulation of heating and cooling, particularly in the transition or "shoulder" seasons (April to June and September to November).

• Maintenance

Induction units must be kept clean and be unobstructed for optimum performance. An annual inspection and cleaning regime would need to be instituted and is estimated to take about four hours per floor.

Next steps

- Ensure all induction units are unobstructed. Move all filing cabinets, desks, etc., away from the units' bases and top surfaces.
- Ensure all return air grilles are unobstructed. These vertical grilles are located on either side of the main entrance doors to each floor office area.
- Institute an annual cleaning regimen for the filters at the base of each induction unit. Ensure each filter is fastened to the unit track.
- Monitor the control strategy for the supply fans and establish an actual delivered air volume against design volume.
- Evaluate benefits of refurbished induction units with actual delivered air volumes after a full year of refined controls strategies.

FOR FUTURE CONSIDERATIONS

Renewed interest in the environment is expected to accelerate the development of new technologies focused on energy efficiency and provide new opportunities for energy conservation. The options that are outlined below show great promise for the future. Although they are not recommended at this time, each merits further evaluation as the technology develops.

COGENERATIO FOR ELECTRICTY AND STEAM HOT WATER

One of the more exciting possibilities for the future is onsite generation of electricity and hot water using gas-fired turbine technology. City Hall could be capable of generating its own electricity and steam through the use of a Combined Heat and Power generator, reducing demand from the electricity grid. The technology evaluated is the Orenda OGT 2500 gas turbine provided by Magellan Aerospace Corp. Operating 25% of the time, the turbine would generate 25% of all electricity needs and 100% of steam needs. Any surplus electricity and surplus steam could be sold back to their respective grids – Toronto Hydro for electricity and EnWave for steam. With an installation cost of $4,100,000 and estimated net energy savings of $604,120 per year, the project would have a payback of 7 years. As the turbine would be installed in basement garage area, a complete engineering study and environmental assessment would be required before a recommendation is possible.

EXTERNAL LED LIGHTING

Low-wattage LED technology is currently used indoors for point of sale and signage applications but has not been fully developed for external lighting applications such as the lighting under the podium walkway and over the main entrance at the north edge of Nathan Phillips Square. However, manufacturers indicate that commercially viable products will be available in 12 to 18 months time. The City is currently monitoring a pilot project on the CNE grounds using LED street lighting and the evaluation of the CNE project and supplier reliability will help the City Hall determine the best technology for external LED lighting.

REMOTE HYBRID LIGHTING

Another emerging technology, remote hybrid lighting, provides outdoor lighting using a small, integrated windmill and a photovoltaic battery-charging unit. This lighting could be used in combination with LED technology as it becomes available to replace lights along the podium walkway and underneath the stairwells. This option should be re-evaluated in consideration of the selected Nathan Phillips Square design.

APPENDICES
The City Hall Facility

View of City Hall from south showing east and west towers and podium in front of Council chambers

City Hall from the north

City Hall is comprised of two towers, which are oriented north/south, with the Council Chamber in the middle. The windows in each tower face the interior of the facility. The facility includes a daycare, library, fitness club and, restaurant. that require energy unique to their operations. Nathan Phillips Square is located to the south of the main entrances and is bordered by Queen Street to the south, Bay Street to the east and the Osgoode Hall and Ontario Superior Court of Justice buildings to the west.
(See *Diagram of City Hall*)

> Hours of operation

Regular hours of operation are between 08:30 and 16:30 from Monday to Friday. The nature of the buildings' use means that practically the hours are between 07:30 and 19:30 during the week. The meeting rooms and Council chambers can operate until 23:00 on occasion and sections of the towers and main areas can be operating during weekends. Actual operating hours have been considered on the order of 4,200 hours per year.

> Heating and cooling environment

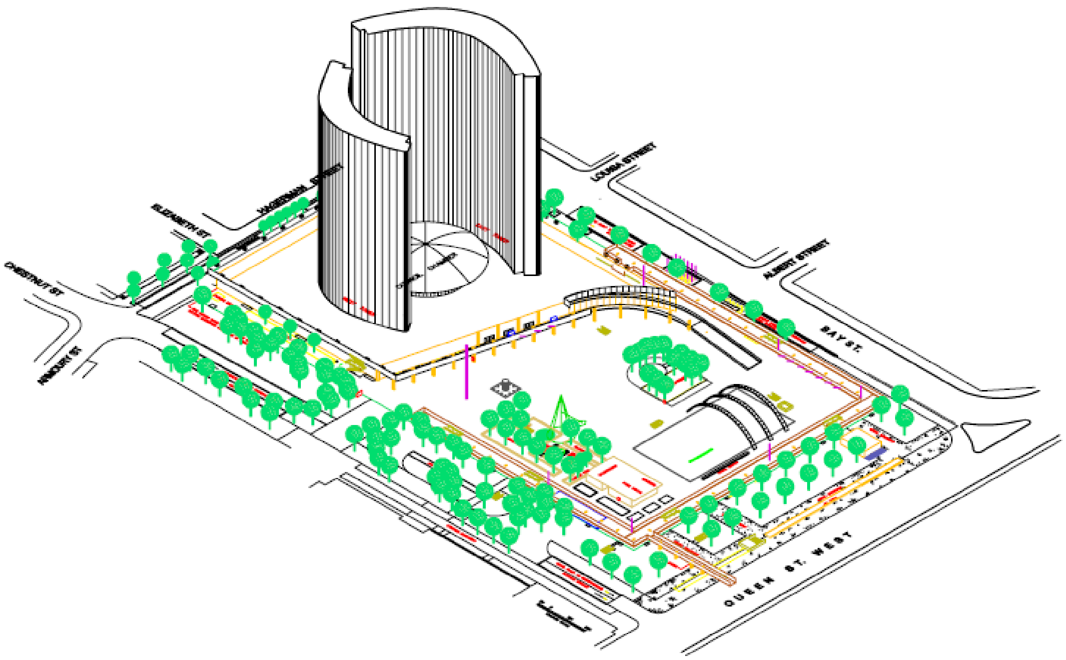
The facility is heated and cooled by a combination of systems typical at the time of its design. At that time energy costs were not a major criteria as electricity, steam, oil and gas were relatively inexpensive. Now the dominant system is a two-pipe system requiring a changeover from heating to cooling and vice-versa, as the seasons change. The change from heating to cooling is manual and is completed based on weather and operator experience each year. As a result, the building can experience uncomfortable periods when heating would be required in the morning and cooling required in the afternoons, which can be the case during the spring and fall months.

The envelope – walls, roof and windows, are not up to recent performance standards, resulting in competing comfort issues during the day. One side of the east tower will be warming up in the morning while the west facing windows are cool. Then the west-facing windows will let in afternoon sun and get hot with increased glare. When attempts were made to humidify the air, the thermal performance of the windows is so poor that moisture forms, which would run down and cause problems on the sills and walls.

Most of the air handling units have pre-heat and heating coils fed from the steam loop. There are 4 perimeter units and 4 core units in the East Tower and 2 perimeter units and 2 core units in the West Tower. The cooling coils are fed in a 3-way control configurations and controlled by the building automation system (BAS). Heat for the space and domestic hot water is provided by steam from EnWave. Cooling is through a trio of vapour compression chillers. The East Tower has Mechanical Rooms on the 13th and 26th floors; the West Tower has a Mechanical Room on the 11th floor.

The office towers are conditioned whether or not they are fully occupied or not, although this is being changed with the introduction of a new BAS. The City Hall has control over the air distribution system, though if any of the floors need cooling or heating the system operates as though it were a normal business day. Staffing numbers range between 2,500 and 4,200 people per day. The number of people affects cooling loads, internal heat gains, indoor air quality, plug loads, light loads and domestic hot water loads. For the purposes of this report, the higher range of staffing numbers have been used (i.e. 4,000 per day) to account for public use occupation of the facility.

CITY HALL DIAGRAM



Schematic of City Hall and Nathan Phillips Square from southwest

HISTORY OF ENERGY-EFFICIENT IMPROVEMENTS AT CITY HALL

Over the years the building staff and facilities managers have made many improvements to reduced the energy use and cost while improving the indoor environment. Some of these measures include:

• Beginning in the early 90's, new fluorescent lamps were installed throughout as the technology improved, saving energy without sacrificing light levels.

• Since the early '90's, there has been a committed effort to recycle.

• The windows were covered with state-of-the-art-solar reduction film in 1993 which has saved some +$48,000 since then while reducing glare for the staff.

• Beginning in 2001, whenever the opportunity arose, new and more efficient motors were installed on the numerous air handling units and exhaust fans. In some cases variable speed control is included, increasing savings.

• Since the late '80's, staff have been encouraged to turn lights off when leaving a room. Motion detectors turn lights on only when people are present in many offices and some washrooms.

• The Council Chamber lighting is now controlled by zones and can be dimmed according to use.

• Weather stripping on the ground floor and stairwell doors has been improved.

• A pilot photovoltaic system was installed on the podium in 1999.

• A pilot green roof project was installed on the podium deck in 2003.

• In 2004, water saving fixtures were retrofitted onto faucets saving water use and waste loads.

• Efforts to reduce steam use by improved heat exchange; temperature control and valve replacement began in 2006.

• The building temperature controls and automation systems have been upgraded as the technology, capability and functionality increased with the most recent improvement being completed in 2006/2007.

• This includes a comprehensive zoning and control of the office tower lights just is being completed and commissioned in 2006/07 as of this writing. This reduces the on time of the lights reducing energy and helping to reduce bird kill.

CURRENT UTILITY DATA FOR CITY HALL

For comparison purposes and benchmarking, we evaluated energy use over two periods: from January 1, 2005 to August 31, 2006 and the 2005 calendar year. Calculations in this report assume the cost of delivered electricity is $0.10/kWh; the cost for delivered gas (in comparison situations – there is no gas in the City Hall now) is $0.45/cu.m and the cost of steam is $29.35/kLb as defined by City Facilities staff.

Utility Data	January 2005 to August 2006 (608 days)			
Item	**Cost**	**Units**		**GJ**
Electricity (2 Meters)	$2,940,506	35,824,906	kWh	128,970
Steam	$1,079,818	44,836	kLbs	50,145
Total	$4,020,324			179,115

Summary of Utility Spend for 2005 to August 2006

Energy cost composition: 71% electricity, 27% steam

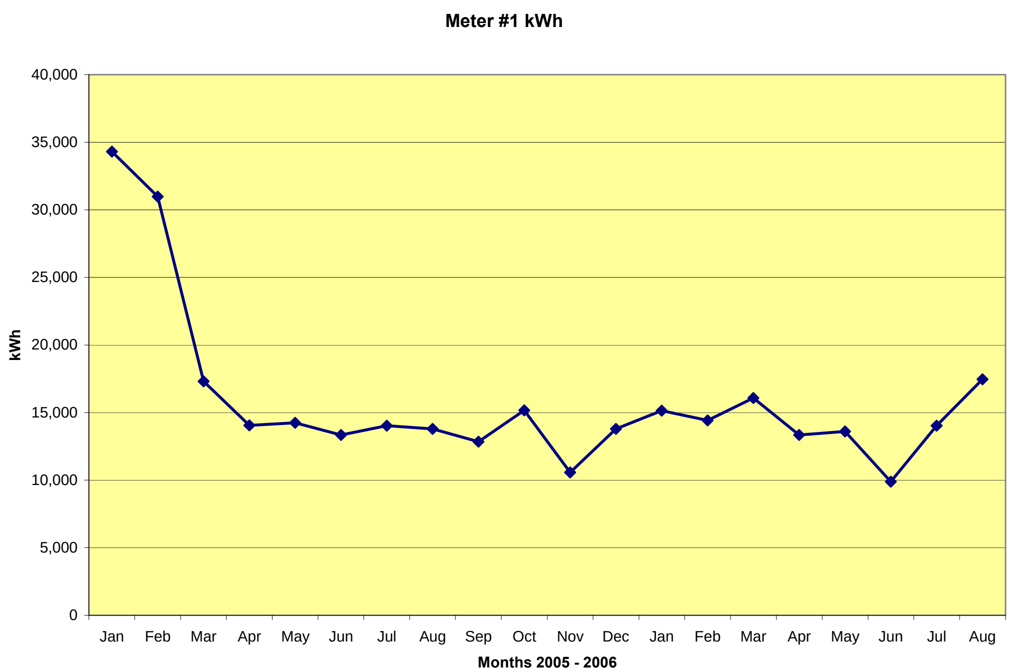
Average cost for electricity: $0.082/kWh ($22.80/GJ)

Average cost for steam: $30.73/klb ($21.53/GJ

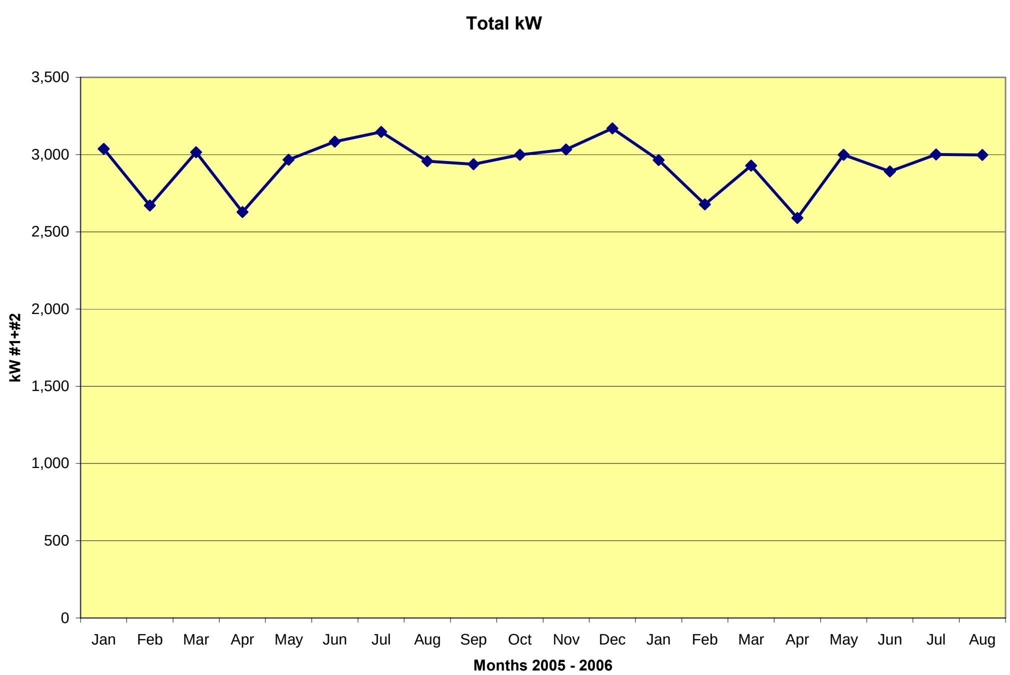
Utility Data	January 2005 to December 2005 (365 days)			
Item	**Cost**	**Units**		**GJ**
Electricity (2 Meters)	$1,740,455	21,745,983	kWh	78,286
Steam	$1,079,818	35,249	kLbs	39,423
Total	$2,820,273			117,709

Summary of Utilities for Base year Period January to December

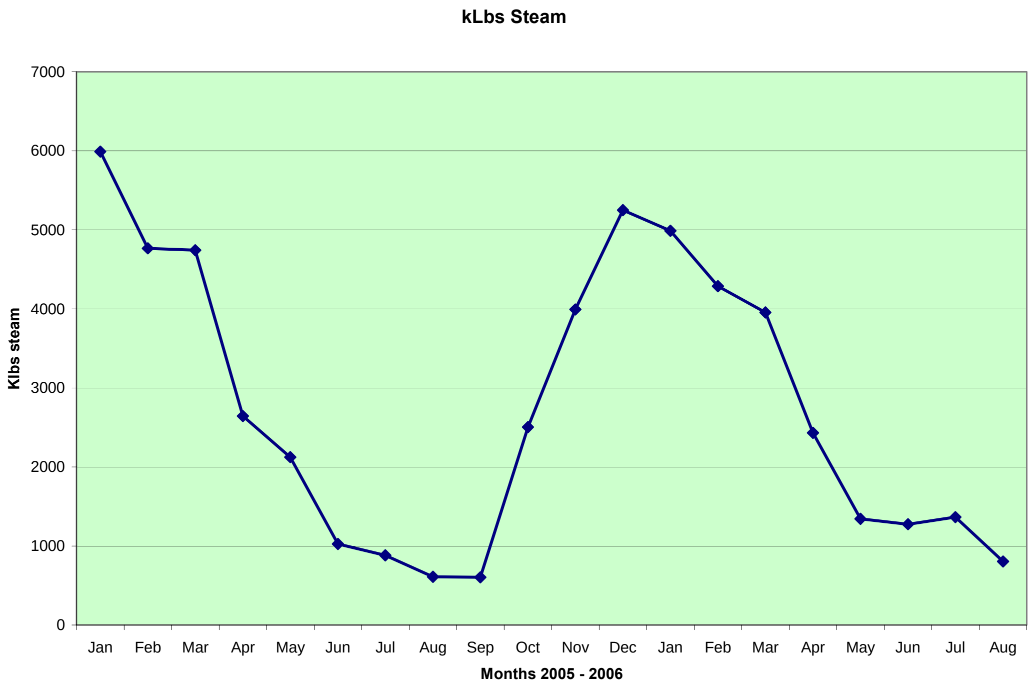
Energy cost composition: 62% electricity, 38% steam



Total kWh load for Main electricity meter for period January 2005 to August 2006



Total kWh load for Cafe Electricity meter for period January 2005 to August 2006



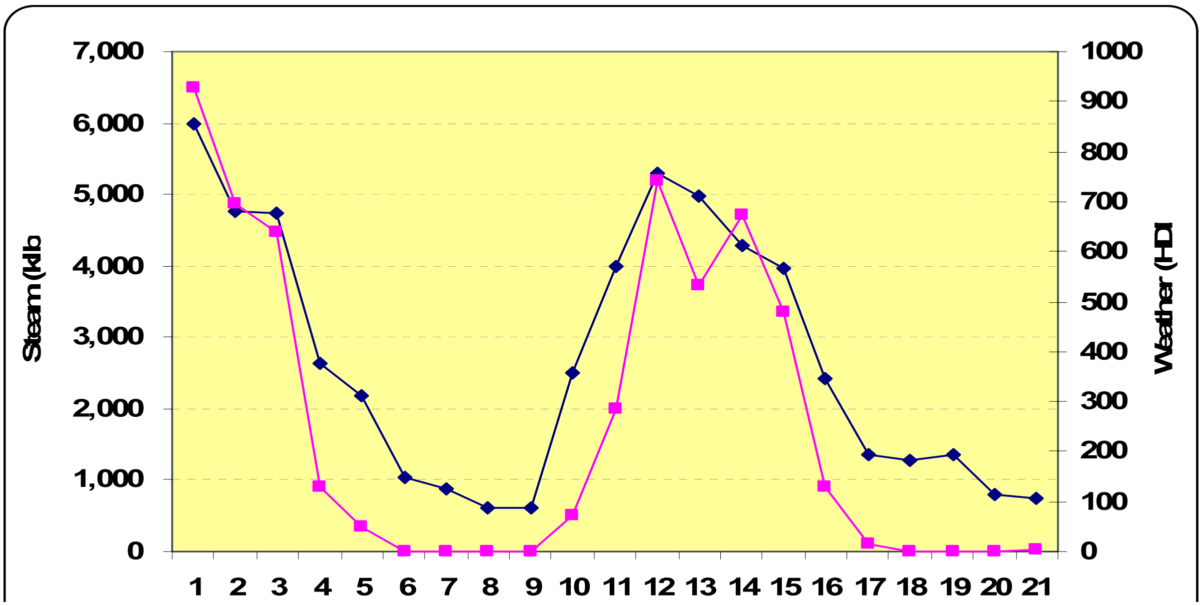
Total Steam Use for the Period from January 2005 and August 2006

> Comparison of cooling and heating loads – January 1, 2005 to August 31, 2006.

Heating and cooling degree-days indicate when energy is required to maintain comfortable conditions within the building. The base temperature is set to 10 °C, above which the system switches to cooling mode and below which the system changes to heating mode. Tower free-cooling (a means of providing cooling using the cooling tower only – no chillers) is initiated when the outside air temperature is consistently below about 6 °C. Note that in December of 2006, the building was still in cooling mode and would stay in this state until temperatures were consistently below 6 °C. As of the middle of December 2006, heating load in the 2005 was tracking higher than in 2006. The cooling season in 2006 was about 16% less than in 2005.

Month	2005 CDD-50	2006 CDD-50	Delta	2005 HDD-50	2006 HDD-50	Delta
	F°	**F°**		**F°**	**F°**	
Jan	0	0	0%	927	533	-74%
Feb	0	0	0%	696	672	-4%
Mar	0	1	100%	640	478	-34%
Apr	34	48	29%	131	128	-2%
May	169	275	39%	49	15	-227%
Jun	692	526	-32%	0	0	0%
Jul	785	759	-3%	0	0	0%
Aug	713	634	-12%	0	0	0%
Sep	488	319	-53%	0	3	100%
Oct	150	73	-105%	72	121	40%
Nov	25	2	-1150%	285	248	-15%
Dec	0	n/a	n/a	740	n/a	n/a
	3,056	**2,637**		**3,540**	**2,195**	

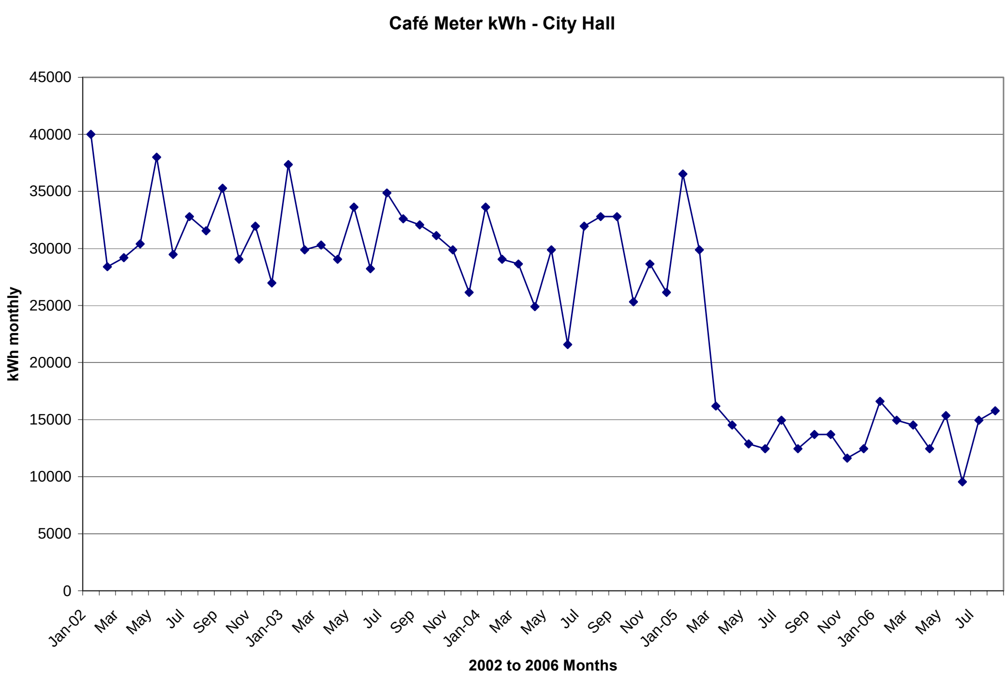
Cooling Degree Days (CDD) and Heating Degree Days (HDD) in Toronto, 2005

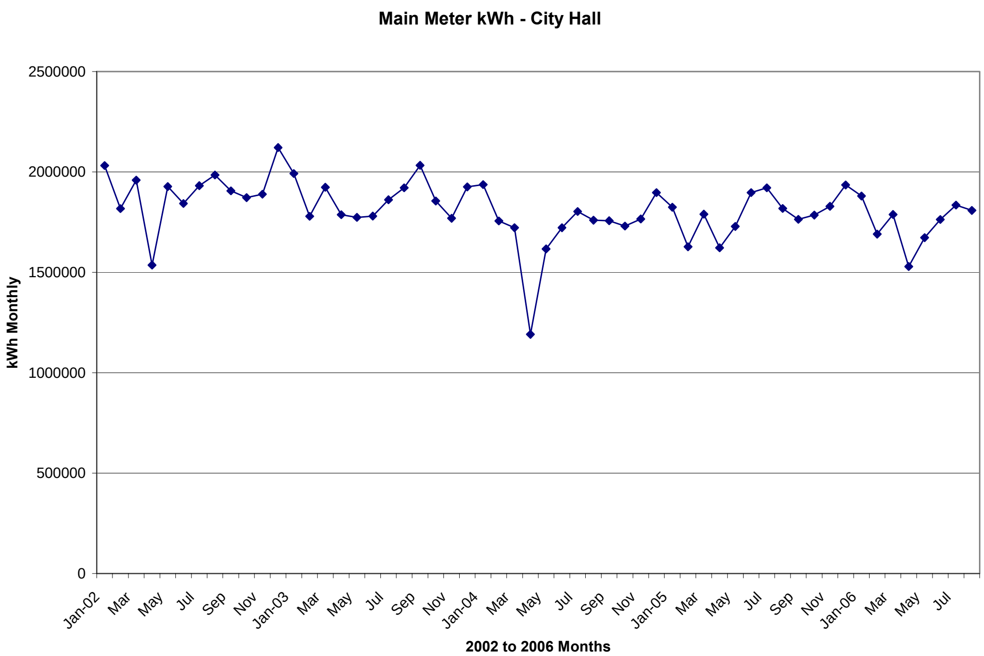


Steam use as it relates to heating degree days – January 1, 2005 to Sep 2006 (Months 1 – 21).
Note: Blue line is steam use.

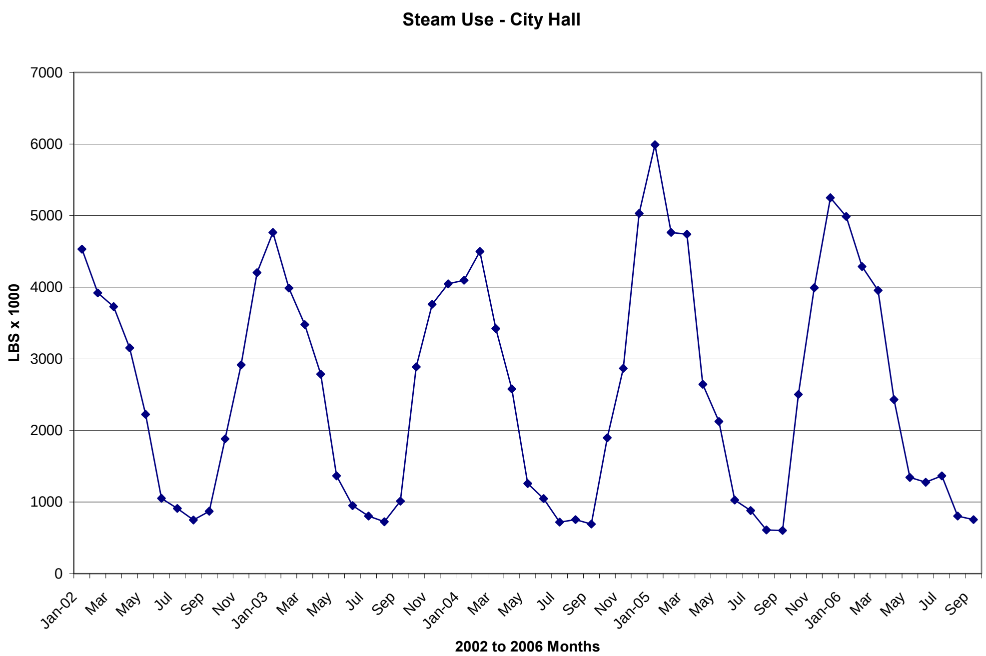
HISTORICAL UTILITY USE AT CITY HALL

The following tables indicate the pattern of utility use from January 2002 until August/September 2006. Though the Café electrical use seems to have decreased, it is not known if this is due to removal of some electrical equipment, reduced operating hours or other such measures that do not reflect actual energy per unit of measurement (i.e., kWh/meal). Nonetheless, it is an indication of a lower base level of electrical load as seen by the meter. The next charts show that the City Hall main electrical use is fairly constant over the time period, as is the steam use. In fact, the irregular pattern of the electrical profile indicates there are measures that can reduce the loads, which are not being implemented. This profile will change with the introduction of Deep Lake Water Cooling, which removes the summer chiller load. Notice that there are a number of peaks in the winter, which indicates weather-influenced load and could be due to electric heaters that are not well monitored.





Main Meter kWh - City Hall
kWh Monthly
2500000
2000000
1500000
1000000
500000
0
Jan-02 Mar May Jul Sep Nov Jan-03 Mar May Jul Sep Nov Jan-04 Mar May Jul Sep Nov Jan-05 Mar May Jul Sep Nov Jan-06 Mar May Jul
2002 to 2006 Months



Steam Use - City Hall
LBS x 1000
7000
6000
5000
4000
3000
2000
1000
0
Jan-02 Mar May Jul Sep Nov Jan-03 Mar May Jul Sep Nov Jan-04 Mar May Jul Sep Nov Jan-05 Mar May Jul Sep Nov Jan-06 Mar May Jul Sep
2002 to 2006 Months

SUN/SHADE IMPACT AT CITY HALL

The situation of City Hall within Nathan Phillips Square makes its energy needs susceptible to the effects of sun and shading. This has an influence on the use of Photovoltaics, Window film, Window replacement, Podium and office lighting and Daylight harvesting. The effect is most noticeable during the low sun months of winter. The shading tends to move along the Podium from the west side to east side through the day, but is not completely blocked at any one time. A more detailed evaluation of the actual shadow paths would be required to determine the energy contribution and availability for the green roof.

DEEP LAKE WATER COOLING INTIATIVE

Using Lake Ontario's lake bottom water as a source of cold energy was contemplated in the 80s an adopted in earnest in the 90s. EnWave has introduced this concept to a number of facilities in the downtown core. City Hall is now close to the distribution network and EnWave has prepared a proposal for putting Deep Lake Water Cooling to work at City Hall. For the purposes of this report, we have assumed the EnWave proposal is accepted and the benefits reported here are limited to the electrical energy avoided because operation of the chillers and cooling towers (see *Chiller Plant Upgrade*) would no longer be required.

> Summary of savings presented in the EnWave proposal

Cooling at the City Hall is typically provided from April 1st until November 30th each year – about 244 days/year (5,856 hrs/yr). The City Hall uses about 3,801,510 kWh/yr at a cost of $342,136 (2006) to provide cooling with the existing 2 x chillers in the basement. EnWave predicts the electrical energy for their system to provide the cooling with deep lake water will be on the order of ~ 400,000 kWh/yr or $40,000/yr (2008). From the perspective of electrical energy savings only, the City will avoid ~approximately 3,410,510 kWh/yr and 2,381 tonnes of greenhouse gases per year as a result of the chillers not operating. The City will also save on water and chemical costs, about $46,121/yr, normally associated with running chillers and cooling towers. Additional savings due to VFD control of the cooling plant pumps is outlined in *Chiller Plant Upgrade*.

This report presents the savings without consideration for any financing or energy terms proposed by EnWave. The proposal indicates cash flow going positive in five years of first cooling delivery.

OPPORTUNITIES FOR IMPROVEMENT
Renewable Energy

Rendering of the east and west towers with wind turbines

> Micro-wind turbines

Studies and efforts completed in the mid-'90s led to the installation of a large wind turbine on the CNE grounds. This is one of the first urban windmill systems in North America and has made such a concept acceptable to the point of it being a recognized part of the City's profile. We examined micro-wind turbine design for the roof of each tower at City Hall.

The wind regime in urban settings is typically "dirty" in that it can swing around quickly and be turbulent. The towers at the City Hall are situated north and south of taller buildings but are taller than the buildings directly to the east and west. The east tower is about 96 m at the roof level and the west tower is about 80 m to the roof level above grade. The towers are available to the dominant winds and represent good urban wind turbine installations.

The wind speed and direction data were taken from the original report prepared by Zephyr North in 1996 for the CNE windmill project. Data from the Ontario Place wind monitoring site is used to define the potential energy generation at the City Hall. The wind speeds at roof height were calculated using standard natural log ratios. The majority of the high energy density wind approaches from the compass points 180° to 360°.
Therefore the effect of the east tower on the west tower should be minimal.

The following table shows the potential for energy generation and greenhouse gas reduction using the Cleanfield's 3.5 kW modular vertical-axis Wind Turbine (VAWT) machine. They are vertical axis machines with 3 straight blades and produce nominal power of 3.54.0 kW at 12.53 m/s. They are designed to be mounted on rooftops. The RETScreen simulation tool was used to predict the performance and GHG reductions.

Performance potential for wind turbines on east and west towers

The columns in the table below indicate the performance potential during the months: May, June, July, August (Summer); March, April, September, October (Shoulder); November, December, January, February (Winter).

	East tower			West tower		
	Summer	**Shoulder**	**Winter**	**Summer**	**Shoulder**	**Winter**
# of Turbines	3	3	3	3	3	3
Height A/G, m	100	100	100	84	84	84
Avg speed at 10m, m/s	3.8	5	6.4	3.8	5	6.4
Avg speed at roof, m/s	8.5	11.2	14.3	8.1	10.7	13.7
Energy, MWh/yr	32	47	54	29	44	54
GHG avoided, tonnes/yr	22	33	38	20	31	38

Summary of roof-mounted wind turbines performance/year

Annual predictions for VAWT on east and west towers

If we assume each season contributes one third of the annual energy generation, we can predict the following annual energy contributions. The proposed VAWT system has the potential to produce about 86.8 MWh/year and displace 60.7 tonnes of GHG/year as indicated in the table below. As a result of the preliminary review and site visits, we believe that the proposed technology can be accommodated and will perform within 10% - 15% of predicted performance annually.

Season	East Energy, MWh	East GHG, Tonnes	West Energy, MWh	West GHG, Tonnes
Summer	10.7	7.3	9.7	6.7
Shoulder	15.7	11	14.7	10.3
Winter	18	12.7	18	12.7
TOTAL	**44.4**	**31**	**42.4**	**29.7**

Predicted energy performance based on seasons

> Siteing and Interconnection Issues

The towers have flat, reinforced concrete decks above what once was the Observation Deck on the east tower and the cooling towers on the west tower. There are three areas that are free of any obstructions located behind the window washing connections on each tower. Cleanfield VAWTs machines require a footprint of about 3 m x 3 m and weigh 2500 kg assembled. The total height is about 6 m. Installation would require hoisting the components up to the roof using, for example, a roofer's gantry. Although structural analysis is not a part of the feasibility study, it is highly likely that the loading can be accommodated. Before proceeding, a structural analysis will be required to review verify the effect of live and dead loads as a result of adding these turbines on to the roof decks.

Having three VAWT machines on each tower can deliver allows 3-phase power to the City Hall's grid through the 120/208-3ph-4 wire electrical service in each tower now. This service is located on each floor in electrical rooms at each end of the tower. The interconnection, as well as required controls and monitoring would be a part of the supplier's scope of work. We also recommend that the building automation system (BAS) receive performance data, such as, wind energy input, windmill output, to allow for more wide spread analysis and dissemination of the system's performance. A roof mounted anemometer with integral wind vane on each tower would have be minimal cost and would allow the conversion of the signals require engineering to convert the signals to a format be compatible with the DDC system. Alternately, the control system for the VAWTs provide system for the VAWTs provides a RS-232 connection, which could also be used to communicate with the existing BAS.

Without detailed evaluation of the structural and electrical criteria we cannot describe the complete interconnection process. The municipal electrical utility must approve of the design and interconnection. Net billing will have to be negotiated and approved. Local building and electrical inspectors must approve of the designs and fire and insurance providers need to be notified of the project and how it works and affects their concerns.

> Heritage issues

These machines can be removed at any time, meeting the main Heritage Site requirement of returning the building to its original form. Discussions with the Heritage Board staff indicate that they would want to see a sample of the "look" beforehand but they are cognizant of the need for lower energy use and GHG reductions and are willing to work with any proposed enhancements as long as the system(s) can be removed and the structure brought back to its original condition.

The micro-wind turbines se would be visible from the ground and surrounding office buildings. The blades can be painted any way the City likes. .

> Budgets and benefits

A budget turnkey cost for this system has been prepared and delivered by Cleanfield Energy. The installed cost is $162,500. A $40,000 discount/subsidy is proposed, which means the final cost to the City, before taxes, is $122,500. Installation cost is based on using union installers and includes a 10% contigenency. The supplier recognizes this would require a union shop for the installation and maintenance. Training would be by factory staff.

The RETScreen analysis for the six machines shows an annual output of 86 MWh/year at $0.1025/kWh (5% escalation/yr) which results in a simple payback of approximately in ~142 years. With one maintenance cycle and after 20 years of service, these machines will deliver approximately 1,720 MWh and displace 966 tonnes of GHG.

One way to present the benefits is to relate the energy generated to energy requirements within the City Hall. This way, people can associate the energy from wind to common, daily energy daily energy needs. For example the energy generated by the east tower system (, 44,400 kWh/year) can be equated to the amount of energy required for 228 x T328 fluorescent lamps for 14 hours/day over 365 days. Noting that the City Hall now uses predominantly fixtures with two 2 x T328 lamps per fixture throughout now, this energy offsets from the wind turbines equates to the energy used by lighting energy for 114 fixtures or about the quantity of fixtures in the elevator lobbies in all the floors of the east tower. The GHG reductions mean that 728 employees meet the one-tonne challenge within the payback term of 12 years.

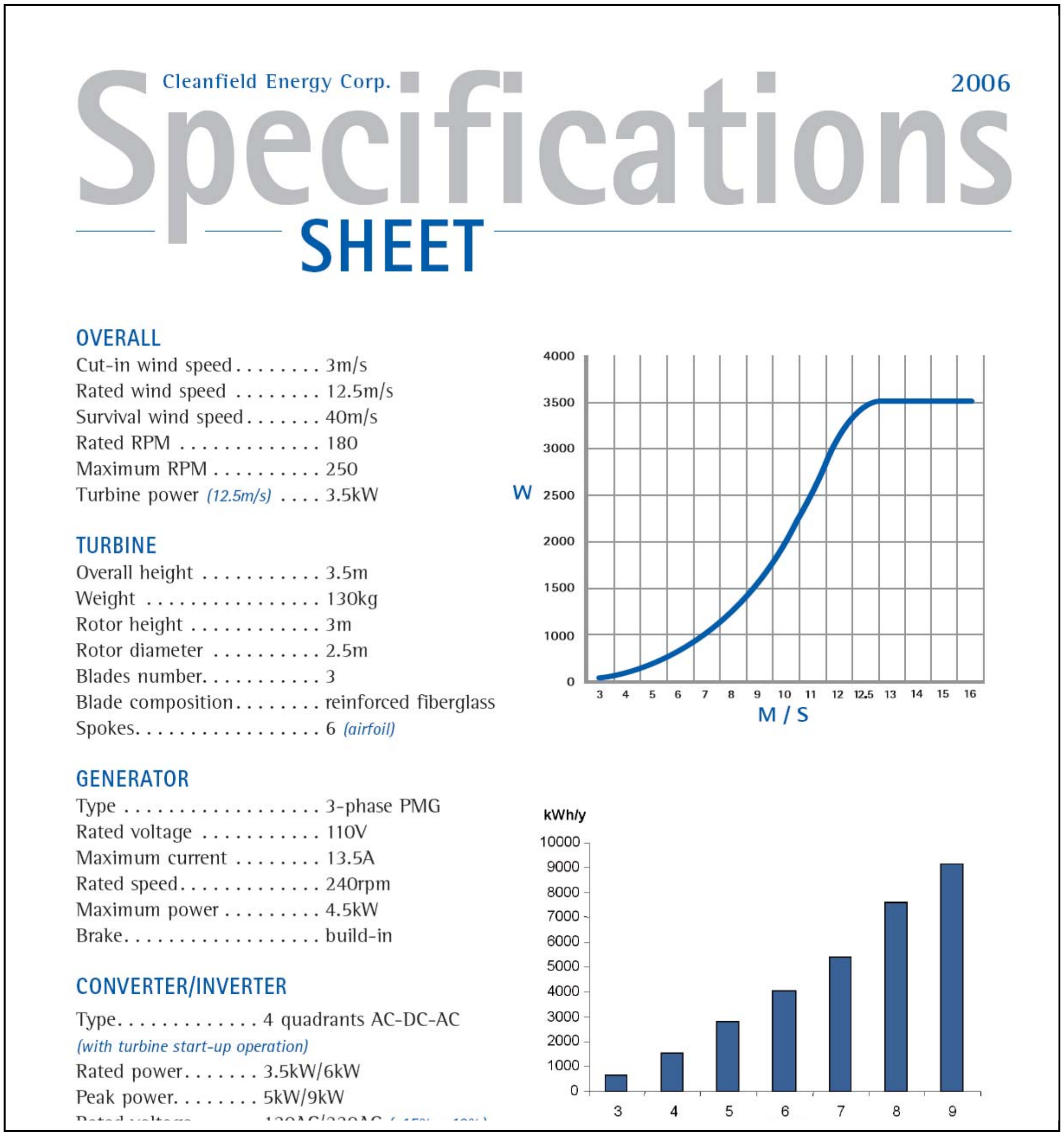
> Operation and maintenance

During the first year of operation, the turbines should be inspected monthly to ensure the mechanical, structural and electrical components are in good condition. There is a ten-year warranty on the electrical components and the blades. The blades may need to be replaced between 15 and 20 years. Costs presented assume maintenance for the blades at 15 years and drive train and generator repairs at 10 years.

The inverter technology allows for data transfer to the new DDC system that enables automatic analysis of each wind turbine.

These VAWTs would be a highly visible indication of the City Halls' commitment to renewable green energy. This also provides an opportunity to promote and monitor the concept of urban wind energy and is recommended.

> Product Specifications and data sheet



Cleanfield Energy Corp. 2006

Specifications SHEET

OVERALL

Cut-in wind speed 3m/s
Rated wind speed 12.5m/s
Survival wind speed 40m/s
Rated RPM 180
Maximum RPM 250
Turbine power *(12.5m/s)* 3.5kW

TURBINE

Overall height 3.5m
Weight 130kg
Rotor height 3m
Rotor diameter 2.5m
Blades number. 3
Blade composition . . . . reinforced fiberglass
Spokes. . . . . 6 *(airfoil)*

GENERATOR

Type . . . . 3-phase PMG
Rated voltage 110V
Maximum current 13.5A
Rated speed. 240rpm
Maximum power 4.5kW
Brake. . . . . build-in

CONVERTER/INVERTER

Type. . . . . 4 quadrants AC-DC-AC
(with turbine start-up operation)
Rated power. 3.5kW/6kW
Peak power. 5kW/9kW

Product specification data sheet for Cleanfield's 3.5 kW modular Vvertical-A axis Wind Turbine

PHOTOVOLTAICS

Photovoltaics (PV) are what most people think of when you mention solar power. This technology is the conversion of solar energy into electricity as opposed to using to solar energy to produce to hot water for use in pools or for domestic hot water. The City and Toronto Hydro have been active in putting PV onto buildings for over 20 years. Toronto City Hall has had two 2 banks of four PV panels installed at the podium level for approximately some eight years now. We have examined the opportunities to expand the use PV at the City Hall.

The podium level is a high profile location visible from the Nathan Phillips Square, City Hall offices and other points of view from the surrounding buildings. The proposed design is to install PV panels along the podium wall facing south for a run of about 54 m. A single row 950 mm wide collectors (including gaps) would put 60 panels totaling about 11.4 kW of power along the face of the podium parapet. The collectors should be mounted behind the parapet and elevated in order to avoid snow falling off to the entrance below.

A second simulation with 120 collectors is shown as well to illustrate the effect of a larger array. The second set of 60 would be installed behind the front row in two sections – 30 each, just in front of each tower base.

Siting and interconnection Issues

Shading at 1:30 PM on December 10, 2007

In any solar application the major issue is shading (see *Sun/Shade impact on City Hall*). In the case of the City Hall, there are some significant shading issues due to the tall buildings to the south. A recent study prepared by Sol Source presented some information that shows the insulation at two levels on the City Hall property; the podium and ground. From these solar path charts, we can determine when the sun is sufficient to generate energy. The sun is low in the sky during the winter and high in the summer. As a result, the podium level would be significantly shaded for four months of the year and the ground level shaded to some extent for six months of the year. However, shading is not complete across the podium – the shade moves as the sun does thereby exposing portions of the podium throughout the day.

During site visits on sunny days (mid-November to early December) we observed that the podium level was shaded partially, but never completely. At different times of the day, observations were noted; on a bright November 22nd at 10:00, the east section of the podium was shaded by about one third from the BMO tower to the south; at 12:00 the east section is clear but the centre section is shaded by the Sheridan Centre; at 13:45 the east one third is shaded again; and at 15:00 the podium is not shaded.

The RETScreen PV simulation tool was used to calculate the potential of the proposed system design. Locally available technologies were used as the performance basis to perform these runs analyses.

Before going ahead, electrical, insurance, fire and inspection requirements will need to be arranged and completed. Attention should be paid to ensuring fire truck access to the podium. There are suppliers/installers, some of whom are known to the City, which can take on this scale of work now.

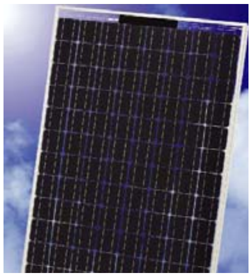
The following table illustrates the performance for the high efficiency Sanyo HIT Bifacial modules. These are designed to capture additional backlight, which increases the output when compared to conventional panels with front face collection only. These types of panels are best mounted off the ground to enhance ambient backlight. Because they let some light through, they would work with a green roof on the podium.

Model	Qty	Watts/panel	Nom kW	kWh/yr	$/yr*	GHG/yr	Cost	System area, m²	Payback
Sanyo-190	60	190	11.4	12,630	1,263	8 t	145,000	72.7	>25
Sanyo-190	120	190	23	25,260	2,526	18 t	290,000	145.5	>25

* The electricity rate is $0.10/kWh. If a standard offer contract is arranged the rate would be $0.42/kWh

Photovoltaic panel for podium application – 120 panels total

> Heritage issues



As with the wind energy system, the Heritage Board has requested that they be shown a sample of the technology. Ideally, this would include a photo-realistic presentation that illustrates the "look" at the proposed installation. Again, the system(s) have to be removable in order to bring the building back to its original condition. The racking would be fastened to the deck on the podium and therefore has to consider the integrity of the deck membrane.

> Redesign of Nathan Phillips Square

The Nathan Phillips Square redesign competition requires that sustainable initiatives be addressed. This is mentioned in the Design Competition Brief, pg 33 "Guiding Principles" and Section 6.6.1 – Sustainability. The Strategic Projects group at the City of Toronto was made aware of this feasibility work and encouraged to contact the authors to coordinate technology applications. The chosen design includes a green roof and discussions with green roof organizations indicate that the shading effect of solar arrays will have little impact on the performance of the proposed green roof.

> Budgets and benefits

The results of the simulations for this scale of project indicates between 11 MWh/year (60 panels) and 21 MWh (114 panels) with the collectors at 35° and taking shading into account an average solar availability of 60% of available from November to March. The 35° angle tends to provide more energy during the summer, increasing the annual generation as a result. This amount of electricity equals the energy needed to power between 25 and 50, 2-tube fluorescent fixtures for a year.

> Operation and maintenance

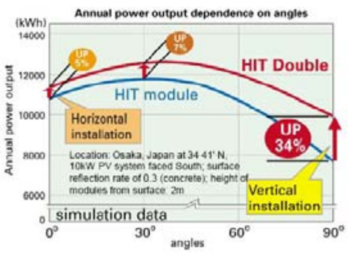
The photovoltaic panels require little to no maintenance and need only to be inspected for electrical and structural integrity each year. The electrical components inside the electrical rooms – the inverters, are scheduled for repair or replacement at 2015 years. Solar panels are a proven technology with systems running now for more than 25 years. The technology being proposed is expected to have a service life in excess of 40 years.

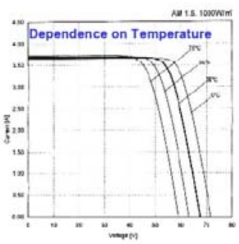
Information regarding the performance of the system should be gathered and reported at least annually and preferably seasonally. The inverter technology allows for data transfer to the new DDC system that enables fairly automatic data collection and presentation for review.

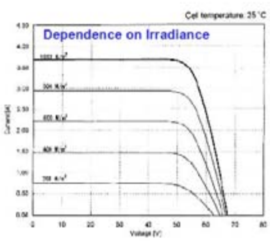
> **Product specification data sheet**

Models HIP-186DA1 & HIP-190DA1

SANYO







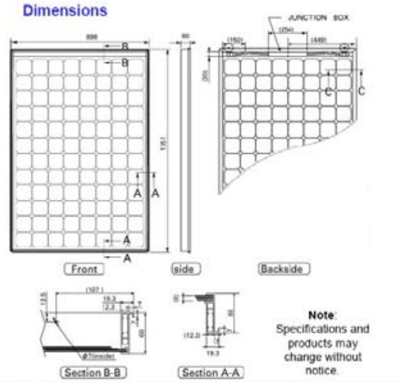
Special Note: These bifacial panel's "Rated Power" is measured at Standard Test Conditions (STC). **STC does not include the bifacial effect of the panels. Therefore, these panels may produce 110% (or more)** of their STC rating, depending on installation design, and your location's albedo—reflectance rate.

To maximize power output of the back side, elevate panels above a surface to maximize the amount of ambient light available beneath the panel. Surfaces with lighter colors will reflect more light, and help make more power. Support structures or rails should not directly cross the back face of the panels.

Application Possibilities

Architectural	BIPV	Ground Mounts
Awnings	Canopies	Siding
Bus Stop Shelters	Carports	Trellises
Balconies	Facades	Tracking Systems
Deck & Porch Coverings	Fences	Vertical Installations

Dimensions



Note: Specifications and products may change without notice.

Visit **www.sanyo.com** or contact an Authorized Representative for more information.

⚠ **CAUTION!** Read the operating instructions carefully before use of products.

Electrical Specifications

		186	190
Rated Power (Pmax)[1]	W	186	190
Maximum Power Voltage (Vpm)	V	54.8	55.3
Maximum Power Current (Ipm)	A	3.40	3.44
Open Circuit Voltage (Voc)	V	67.5	68.1
Short Circuit Current (Isc)	A	3.68	3.70
Minimum Power (Pmin)	W	176.7	180.5
Maximum System Voltage (Vsys)	V	600	600
Series Fuse Rating	A	15	15
Temperature Coefficient (Pmax)	%/ºC	-0.30	-0.30
Temperature Coefficient (Voc)	V/ºC	-0.168	-0.170
Temperature Coefficient (Isc)	mA/ºC	0.85	0.85
Electrical Tolerance	%	+10/-5	+10/-5
Back Side Output (reference)	W	130	133
Cell Efficiency	%	18.4	18.8
Module Efficiency	%	15.3	15.7
Power per Square Foot	W	14.2	14.6

Mechanical Specifications

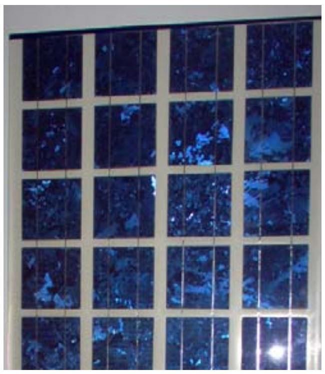
Internal Bypass Diodes	No.	4	4
Module Area	Ft^2	13.06	13.06
Weight	Lbs.	50.7	50.7
NOCT (ºC)	ºC	44.2	44.2
Dimensions LxWxH	53.2 x 35.35 x 2.36in		
Cable Length -Male/+Female	39.37in / 39.37in		
Cable Size / Connector Type	No.12 AWG / MC™		
Static Load Wind / Snow	50PSF / 39PSF		
Pallet Dimensions LxWxH	54.3 x 36 x 70.1in		
Full Pallet Quantity / Weight	20pcs / 1466.1 Lbs.		
Quantity per 20'/40'/53' Container	200 / 420 / 540pcs		

SOC and Safety Ratings

SOC Temperature	-4ºF to 104ºF[2]
SOC Relative Humidity	45% to 95%
Hail Safety Impact Velocity	1" hailstone at 52mph
Fire Safety Classification	**Class A**
Safety & Rating Certifications	UL 1703, cUL, CEC
Limited Warranties	2 Years / 20 Years

[1]STC: Cell Temp. 25ºC, AM 1.5, 1000 W/m^2.
[2]Lower and upper temperature range defined as: monthly average high, and monthly average low, of the location.

WINDOW PHOTOVOLTAICS



This technology, also called building integrated photovoltaics (BIPV), is relatively new on the photovoltaic market and gaining much attention as it can be easily incorporated into the architecture of existing and planned buildings. These panels can be "off the shelf" sizes or more commonly custom designs and manufacture. Monolithic PV glass can be made up of single sheets of low-iron glass (tempered, heat strengthened or annealed) with PV cells encapsulated within a back sheet of Tedlar or equal. Laminated PV glass is composed of two sheets of glass with the PV cells in between. Insulated PV glass has the PV laminate as the outer glazing, airspace typically 9.5 mm, then an inner lite of standard flat glass. The PV cells can be dark brown, black or blue. There is usually a maximum size of around 50" x 98" and up to 25 mm thick. All require a framing system to mount to the window frame. Several alternative BIPV systems were investigated.

One system uses crystalline cells, where the PV cells are opaque and typically 100 cm^2 to 235 cm^2, 5 to 6 square inches, they separated by a gap, approximately say 20 mm around, so that some light level, about 10%, is provided. A shading coefficient of about 80% results, which reduces the solar gain while at the same time producing electricity. A typical 0.60 m^2 unit produces about 50 W/m^2 and weighs about 27 kg at 17 mm thick total. Electrical connectors are at the back, inside surface.

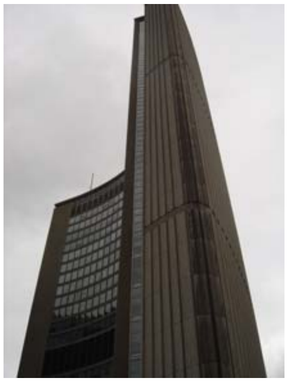
> **Window based integrated photovoltaic panels (BIPV)**

A second system uses thin film technology, which is semi-transparent across the complete pane providing a shading coefficient of 77%. A typical 0.60 m² unit produces about 40 W/m² and weighs about 27 kg at 17 mm thick total.

In the case of the east tower, solar gain during the afternoon from the western sun is significant and difficult to control with blinds or the HVAC system. The BIPV would provide significant shading effect wherever it is installed, though the view to the outside would be very limited.

> Siting and interconnection Issues

Window replacement has been considered before mainly because the glazing in place now is single pane, 6.35 mm (1/4") full frame glass which has a "U" value of 1.06. The two window areas being considered for BIPV are the main office windows on the top floor(s) of the east tower and the south-facing windows on the east and west towers that front the stairwell areas. The sun begins to shine on the east tower around 11:00 AM (to the north end) and goes away late in the afternoon all year round. The west tower does not block the top of the east tower before the sun actually sets behind the buildings to the west of the City Hall.



East tower "rib" showing vertical stairwell windows to be fitted with BIPV

The south-facing ribs for panes on each tower have right-angle panes at the stairwells. The windows are about 2.3m (92") w x 1m (40") t, 6 mm (¼") single glaze, annealed 2.3 m² (6 sq.ft. each). There are 75 south76 panes on the east tower and 57 south57 panes on the west tower (the 75 west-facing panes on the east tower and 57 east-facing panes on the west tower are not included as they are shaded for much of the day).

The office windows are 1.8m (48”) w x 2.4m (96”) t, annealed 6 mm (¼”)single pane 4.3 m² (8 sq.ft.) each. There are 30 per row on the east tower, which is the only one suitable as the west tower is shaded by the east tower in the morning and does not see much sun afterward. If office windows are not suitable for PIBV, another option to consider of interest is 30 BPIV windows for the top row of the east tower would be a good candidate as it fronts the unused observation deck. There would be little or no effect on the staff for installation.

Each floor has an electrical room at the south and north ends of each tower. The arrays would feed power into the closest room through a synchronized grid application inverter. The power would be combined and run to each electrical room from the end of the run. This would involve drilling through the concrete end walls then running surface conduit along the stairwell to the electrical room. In the case of the observation deck windows, the power would be run down to the electrical room through the stairwell in the surface mount conduit.

> Heritage issues

The building has to be able to be brought back to its original state. In theory, this means the removed windows must be stored. The cost of storage is not estimated in this report. It may not be feasible to retain every window removed, as there will inevitably be, i.e., breakages. The other issue is that if a surface-mounted solution were chosen, the plates would be fastened to the exterior ribbing of the window frames. These are “T” shaped ribs made of stainless steel. The Heritage Board would have to approve drilling into these ribs to fasten clips for the BIPV panes. The preferred method would be to replace the existing window with a custom BIPV unit. The cost of this was not evaluated at this time.

The Board would not approve a “”broken tooth” look, which means a complete row or column of windows must be completed. For this reason, we are specifying complete rows on the east tower and complete columns on the south faces of the east and west towers. From a cosmetic standpoint, the lowest impact would be installing BIPV on the south-facing windows in each tower.

> Budgets and benefits

The benefits of installing BIPVs are due to the reduction of solar gains – approximately 80%, while generating electricity. As this is a relatively new technology in North America, it is still expensive by photovoltaic standards. In this case, a major issue is the removal of the existing windowpanes and their storage, if required by the Heritage Board.

The most feasible option is for the south facing windows on each tower and is presented in the summary chart. An estimate of $1605/m²sq.ft was suggested (Mt. Pleasant Glass) to remove the existing windows. This does not include disposal.

A budget cost of between $1,290/m² and $1,6155/m² is typical for this technology at this time. This implies a cost of about $2,0001/m² to remove the existing panes and install the BIPV. For the office-sized windows window, 4.32 m² each, this is $8,880/window and for the south rib windows, the cost is about $4,810/window.

Model	Qty	Watts/panel	Nom kW	kWh/yr	$/yr*	GHG/yr	Cost	System Area, m²	Payback
Office (4.3m²)	30	100	2.25	1,613	161	1.1 t	$270,000	89.2	>25
Office	60	100	4.5	3,226	323	2.3 t	$540,000	178.4	>25
Office	90	100	6.75	4,840	484	3.4 t	$810,000	267.6	>25
South Stairwell (2.3m²)	132	75	10	6,051	605	4.2 t	$650,000	257.6	>25

* The electricity rate is $0.10/kWh. If a standard offer contract is arranged the rate would be $0.42/kWh

Fig A – 20 Table of BIPV potential for four different array sizes on east and west towers' stairwell ribs

The cost indicated in the chart above includes removal and replacement as well as interconnection to the electrical grid, disconnects and inverters. The final wiring to inverters would be determined during final engineering. For the south-facing window option, 6 x 1,000 W inverters are carried for the east tower and 5 x 1,000 inverters for the west tower. Each row of office BIPVs will require a 2.5 kW inverter.

> BIPV and window replacement

If the existing single-pane windows are to be replaced, a budget cost of $755/m²0/sq.ft for removal, tracking, standard double pane, and installation has been suggested leading to a cost of $3,400/office window and $1,900/south rib window. This does not include window film, which adds a further $150/m²4/sq.ft or $700 for the office window and $400 for the south window. Therefore the premium is $4,780/office window and $2,510/south window to use go with BIPV, as compared to standard issue, double-pane windows.

More about high efficiency windows is provided in *Window Replacement*.

> Operation and maintenance

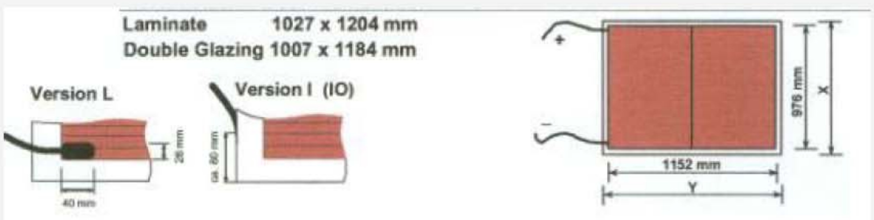
While relatively new, this technology is likely to require little maintenance. The BIPVs are vertically mounted and would be cleaned at the same time the main windows are cleaned. The electrical connections and inverters should be inspected annually. The inverter technology should be scheduled for repair or replacement at the 15-year mark. Although BIPV does not have the track record of conventional PV, it is expected to be on the same order and so can be expected to be reliable for 40 years.

The inverters will require bi-annual inspection and can be expected to perform for 20 years before consideration is given to replacement or repair.

> **Product specification data sheet**

CentennialSolar

BIPV THIN FILM MODULES



			Double Glazing	Double Glazing
Front Glass(white Glass)	6mm HSG	6mm HSG	6mm HSG	6mm HSG
Interlayer	1.1mm PVB	1.1mm PVB	1.1mm PVB	1.1mm PVB
Thin Film Solar Plate	Opaque	Transparent	Transparent	Transparent
Interlayer	1.1mm PVB	1.1mm PVB	/	/
Spacer	/	/	16mm	16mm
Back Glass	6mm HSG	6mm HSG	6mm HSG	8mm SGL
Cable Outlet	rear side	rear side	lateral	lateral
Cable Type/Diametr(+and-) Outer Diameter/Cable Length	Double isolated, black/2.5mm^2 5.2mm / 1m		Double isolated, black/2.5mm^2 5.2mm / 1m	
Connector(Male/Female)	Multi-Contact PV-KBT3/PV-KST3		Without Connector	
Dimension, Weight:**				
Dimension(X/Y)	1027 x 1204 mm		1007 x 1184 mm	
Total Glass Thickness	17mm	17mm	32mm	34mm
Total Weight	54kg	54kg	48kg	57kg
Physical Data:				
Heat Transmittance Ug-Value (DIN EN 673) (American)	~5W/m^{2}K ~0.88 Btu/hr ft^{2}F	~5W/m^{2}K ~0.88 Btu/hr ft^{2}F	~1.2W/m^{2}K ~0.21 Btu/hr ft^{2}F	~1.2W/m^{2}K ~0.21 Btu/hr ft^{2}F
Solar Heat Gain Coefficient(SHGC)	23%	27%	10%	10%
Light Transmission	1%	10%	10%	10%
Electrical Data:				
Initial Nominal Power P_{mpp}	71Wp	61Wp	61Wp	61Wp
Nominal Power P_{mpp}***	58Wp	50Wp	50Wp	50Wp
Current at Nominal Power I_{mpp}***	0.85A	0.74A	0.74A	0.74A
Short Circuit Current I_{sc}***	1.10A	0.98A	0.98A	0.98A
Voltage at Nominal Power U_{mpp}***	68V	68V	68V	68V
Open Circuit Voltage U_{oc}***	93V	93V	93V	93V
Maximum System Voltage	1000V	1000V	120V	120V

Product specification data sheet for BIPV panels for east and west towers' stairwell windows

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stabilized power data. This power bonus has to be considered when designing the system. All given electrical data are subject to a production tolerance of ±10%.

GREEN ROOFS

Green roofs harkens back to at least sod roof construction. Current technologies are compatible with typical roofing construction including sloped areas. The City of Toronto has already expressed interest in green roofs and has an incentive program to encourage installation of these systems. A small test plot has been installed on the eastern side of the podium and monitored with assistance from NRCan and Green Roofs for Healthy Cities. There is little, if any, maintenance of these test plots by City staff now. Currently, the podium area is not accessible to the public so the test plots are not providing any educational/awareness value.

Test plots of green roof concepts on the east side of the podium

The green roof concept is simple – cover the relatively unused roof areas of the City Hall podium buildings with a growing medium material that retains rain water, reduces heat island effects, collects particulates and some pollutants, reduces heat gain, reduces carbon dioxide levels locally, increases roof and membrane life and improves the habitat for insects and birds. There is a wealth of application-specific studies for cities (including Toronto) all over North America, including Winnipeg, Waterloo and Chicago, which have climates harsher or similar to Toronto. We reviewed the opportunity and value of putting an inextensive green roof on the podium area covering about 43% most of it with plantings and pathways.

There are many systems installed now and web site of Green Roofs for Healthy Cities lists the membership. As with most sustainable systems the upfront cost are high, but the life cycle cost analysis indicates positive returns financially and socially.

> Siting and interconnection issues

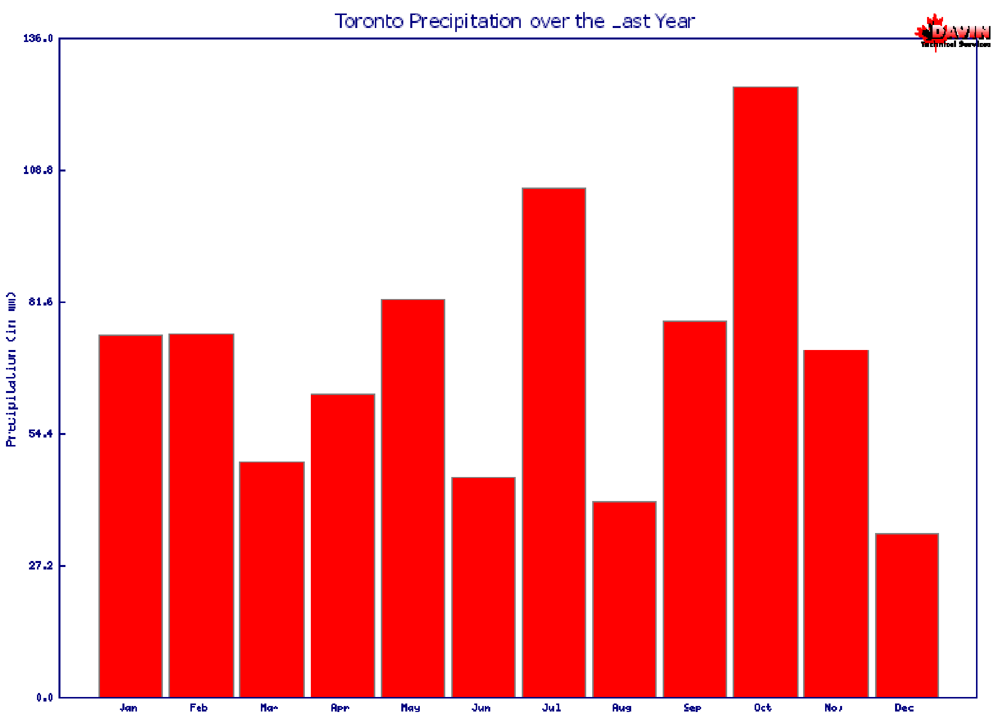
Green roof systems are best installed of roof systems that will not require new insulation or membranes for some time. If a green roof is to be installed the insulation and membrane must be investigated and signed off as viable for at least 10 – 15 more years. An important feature of green roofs is the fact that they extend the life of conventional roofing membranes.

There are seven test plots in place now, installed about six years ago. These represent a variety of green roof systems and planting concepts, such as butterfly and bird plots, permaculture, herbs, extensive, intensive. They are located on the podium at the east end of the deck. The original contractor, Flynn Canada Ltd. was brought in to review and advise on this concept.

Therefore, one of the first issues is to determine the state of the roof components for the suggested area. The area being considered is the Podium deck. It consists of a reinforced concrete deck covered with a membrane and rigid insulation then with interlocking stone. This area is easily reached by a ramp, although it is closed to the public now. The podium deck consists of a reinforced 200 mm concrete slab, membrane, 100 mm rigid insulation and 75 mm interlocking stones. It is built to withstand vehicle traffic (i.e., fire trucks) and therefore likely able to support a green roof system. However, a structural engineer should be retained to review the loads as apart of the design process. Consideration should be given to fire truck access if this area had been designed with this in mind.

Consideration for access, viewing and sun allows for approximately 3,300 m^2 of useable podium area. This represents about 43% of the podium area. The concept is to design and install 45 pods (8.5 m x 8.5 each) of intensive green roof design with walk ways between for maintenance and viewing. The podium areas considered are to the front of the Council Chambers, along the south area in front of the east and west towers, and slightly to the north along the east face of the east tower, and the west face of the west tower and along the north end of the towers. There are about 18 water collection and service points throughout this area...

Two generic types of green roof systems were considered and each has its own pros and cons – extensive (thin < 15 cm) and intensive (deeper >15 cm) specifications. The extensive design is the thinner format of the 2 options – the other; Extensive roof designs are low-to-no maintenance systems that are made up of shallow soil depths. The plant varieties typically include sedums, mosses and wild grasses. The soil dept h is usually 7 to 15 cm and the system weighs between 95 and 160 kg/m² and can retain 23-45 liters/m². Intensive green roofs have growing mediums is greater than 15 cm in depth and suitable for deeper rooting plants and is as a result heavier per square meter. The inextensive landscape system is suitable for sedum species, herbs, and some grasses and some shrubs/trees. They typically have a built –up height of + 40 between 9 and 14 cm and weigh between +50095 – 160 kg/m² and are capable of retaining between + 11523-45 liters/m².



Precipitation in Toronto, 2006 in millimetres

> Budgets and benefits

The intensive system is recommended. Key environmental and energy benefits are:

• Insulating qualities mean reduced heat and cooling loads. Heating savings average at 5% and cooling savings are 6% for the area below the green roof. These estimates vary depending on the roof design and depth. Environment Canada suggests up to 25% savings can be achieved in cooling energy. The area affected is the 2nd Floor offices. Average temperature reductions inside the 2nd Floor offices can be 3 – 4°C due to the green roof above. Average energy savings can be expected to be $0.3/m² for heating and $6/m² for cooling of the 2nd floor area. This equates to $1,000/year for heating and $19,800/year for cooling energy costs. The cooling and heating savings effect would be constrained to the offices below on the 2nd Floor.

• Reduce storm water run-off, which in turn, reduces the stress on urban sewer systems and decreases run-off related pollution. The roof will retain on average 50% - 60% of the annual rainfall and reduce peak flows by 2 – 4.5 hours. For 2006 this equals 50% of 1,370,000 Litres of water between April and September for a retention total of 685,000 Litres of rain water.

• Air quality improvement – lower rooftop temperatures mean less smog from the "urban heat island effect." The plants collect airborne pollutants. This roof is expected to remove 0.2 kg of particulates with diameters<2.5 microns ($PM_{2.5}$), which is considered an indicator of damaging pollution. This roof area would remove 660 kg of $PM_{2.5}$ per year.

• Noise pollution reduction – studies show noise levels surrounding a green roof area in a building can be reduced by as much as 40 decibels. Though subjective, the damping effect is noticeable.

• Extended life of the roof system due to moderated temperature swings that cause a roof system to expand and contract as well as protection from everyday wear and tear. Studies suggest the green roof can extend the life of a conventional roof by a factor of 2 – 3.

The roof is assumed as structurally sufficient to support the intensive green roof system. The predicted weight would be approximately 2,000 tonnes over the 3,300 m². The water retaining capability would be approximately 2,700 m³ over the total area in a year where 825 mm of precipitation falls (2006).

The budget costing presented by Flynn Roofing is between $360/m² and $410/m² for an intensive green roof system. The budget cost for the proposed 3,300 m² is $1,188,000 to $1,350,000. This includes the following work:

1. Remove existing interlocking stones in designated areas
2. Install 1 layer of hot fluid applied reinforced membrane over existing fluid applied membrane and embed a root barrier SBS membrane.
3. Supply and install a drainage layer.
4. Supply and install one layer of ship lapped 100mm Roofmate Insulation.
5. Supply and install air layer over Roofmate Insulation.
6. Supply and install Moisture Retention Mat/Reservoir Drainage Board and Filter fabric.
7. Supply and install 150mm Engineered Lightweight organic/inorganic mix rooftop soil mix compacted
8. Supply and install Seeded Native Meadow/Native Perennial plugs.
9. Includes new precast concrete curbs to enclose the pods.
10. Make good the existing interlocking pavers adjacent to the new green roof area.

The removed interlocking pavers would have to be disposed of and consideration given to selling them to a renovation materials recycler.

> Redesign of Nathan Phillips Square

The chosen design for Nathan Phillips Square includes a green roof on the podium and is compatible with what we are recommending. To elevate the profile of the green roof, it needs to be accessible to the public. The green roof would be visible from the tower office windows and many some of the surrounding offices including the – Sheraton and, BMO towers. In addition, we recommend that the podium deck be made accessible to the public again and that the running track is kept available, preferably going through the green roof area.

> **Maintenance**

An intensive green roof requires service and maintenance. A cost of between $2,000 and $4,000/year is assumed. Some maintenance costs could be avoided if City Hall can solicit the help of local landscape students and volunteer gardening groups.

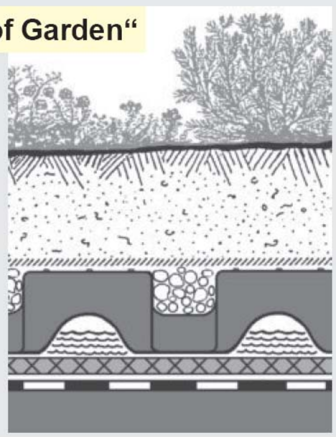
The green roof has to be weeded and mulched each year. Nothing needs to be done during the winter, as it will freeze up until spring thaw. Snow should not be piled up on the plots.

> **Product specification data sheet**

System build-up "Roof Garden" with Floradrain® FD 60

Benefits:

- Multifunctional Green Roof system build-up with high water retention capacity and roof dam irrigation. Suitable for lawn, shrubs and at a deeper substrate level, bushes, small trees etc. are also possible.
- Various combinations are possible, for example with walkways, patios, driveways or playgrounds.
- Floradrain® FD 60 can be filled with concrete as a sub-construction for driveways. The drainage layer and the waterproofing are not penetrated.



Lawn and shrubs; with deeper substrate levels, bushes and small trees

"Roof Garden" System Substrate or "Lawn" System Substrate

Filter Sheet SF

Zincolit filling

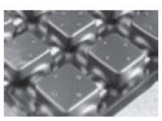
Floradrain® FD 60

Isolation Mat ISM 50
If no root barrier is installed:
Incorporate Root Barrier WSB 80-PO.

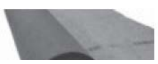
	Unit	Art.No.	Unit	Art.No.	Unit	Art.No.
Substrate "Roof Garden"	Big Bag	6161	bulk from factory	6162		
Substrate "Roof Garden" light	Big Bag	6164	bulk from factory	6165	silo lorry	6166
Substrate "Lawn"	Big Bag	6151	bulk from factory	6152	silo lorry	6153

	Art.No.	Dimensions	Unit	Pallet
Filter Sheet SF	2100	approx. 2.00 m x 100.00 m	200 m²- roll	4600 m²
	2102	approx. 1.00 m x 100.00 m	100 m²-roll	2500 m²
Cutting	2101	approx. 2.00 m x 10.00 m	20 m²	

	Unit	Art.No.	Unit	Art.No.	Unit	Art.No.
Zincolit	Big Bag	6031	bulk from factory	6032	silo lorry	6033



	Art.No.	Dimensions	Unit	Pallet
Floradrain® FD 60	3060	approx. 1.00 m x 2.00 m	2 m²-board	100 boards



	Art.No.	Dimensions	Unit
Isolation Mat ISM 50	2050	approx. 2.00 m x 25.00 m	50 m²- roll

Components for an intensive green roof system - Zinco

ENERGY EFFICIENT UPGRADES
Chiller plant upgrades

Serious consideration is being given to converting the primary cooling medium to deep lake water cooling (DLWC) in 2007. This would render the existing 23 x 500 Ton York vapour compression (R134-a) chillers and the older Trane chiller located in the basement Level as back-up or for peak load. The option presented is to control the existing chilled and condenser water pumps with new generation VFDs.

> Siting considerations

Variable speed control has been tried in the City Hall before (about seven years ago) but the sequences did not seem to be implemented properly and trouble sensing following the supply/return header pressure changes caused the trial to be terminated. These Magnetek GPD controllers are still in place and now by-passed. The state of these drives is not known at this time and due to the advances in VFD technology since their installation it is not reccoemended that they be reused may still be useable.

Even with chilled water coolth being provided by EnWave, a variable speed control strategy will conserve energy and improve the performance of the DLWC concept in that the most efficient temperature spread can be achieved and maintained.

All the pumps, supply, and return headers are located in the basement Level along with the chillers and tower free-cooling heat exchanger.

> Budgets and benefits

The costs to include the control points and savings due to variable speed control on the main chiller plant pumps are listed in the following table. Points associated with the deep lake water cooling are explained later in this report.

	Service	Flow	Head	Power	Saved	Saved	GHG	Cost	Payback
#	**Chilled water**	**USGPM**	**FT**	**HP**	**kWh/yr**	**$/yr**	**tonne**	**$**	**yrs**
14	Chilled water – east	2000	95	75	29,238	2,924	20.5	18,700	6.4
15	Spare - east or west*	3000	80	75	24,015	2,402	16.8	18,700	7.8
16	CHW sub-basement	1000	60	100	28,520	2,852	20	21,700	7.6
17	Chilled water – west	900	60	30	6,783	678	4.7	9,800	14.5
18	Condenser water #4	3000	80	75	22,485	2,249	15.7	18,700	8.3
19	Condenser water #5	2000	95	75	20,107	2,011	14.1	18,700	9.3
20	Condenser water #3*	2000	95	100	26,660	2,6,66	18.7	21,700	8.1
Controls								**60,000**	
TOTAL*					**157,808**	**15,782**	**111**	**188,000**	11.9

Values in red are estimated as the nameplates were missing.
Cooling system pump saving potential with VFD Control

* Note that the total cannot be used to calculate an annual savings as not all these pumps operate at the same time. Spare – east or west pumps can be configured to operate some or all the time; only two (2) condenser pumps operate at the same time with one being a back up or alternate. The cost is for the complete set of pumps and therefore the savings will be on the order of:

• kWh/year electricity saved = 113,686 kWh/yr
• GHG avoided/year = 8079.6 tonnes/yr
Total cost for set will still be the Total shown above.

The following table indicates the minimum point count to be considered for the EnWave Deep Lake Water Cooling system. These points will be added to the existing DDC system. The DLWC system analysis will require global points, such as outside air temperatures, representative space temperatures, time of day and over-ride requests, in order to establish the overall performance of the concept. All the additional points are located in the Mechanical Rooms with the chilled and condenser water systems.

> Additional control points to implement Deep Lake Water cooling strategy

System	AI	BI	AO	BO	Total
Chilled Water Pump East		2	1	1	4
Chilled Water Pump #E or W		2	1	1	4
Chilled Water Sub base pump		2	1	1	4
Chilled Water Pump West		2	1	1	4
Condenser Water Pump #1		2	1	1	4
Condenser Water Pump #2		2	1	1	4
Condenser Water Pump #3		2	1	1	4
Main CHWS Temp	1				1
Main CHWR Temp	1				1
CHWS Temp East	1				1
CHWS Temp West	1				1
CHWS Temp Sub Base	1				1
CHWR Temp East	1				1
CHWR Temp West	1				1
CHWR Temp Sub Base	1				1
Diff Press Sup & Ret W	1				1
Diff Press Sup & Ret E	1				1
Diff Press Sup & Ret Sub	1				1
Diff Press Sup & Ret	1				1
Flow Rate Main Sup & Ret	1				1
TOTAL	13	14	7	7	41

In this point list, the BI points represent status and alarm states, the BO points are start/stop and the AO are for speed control. Therefore, this strategy assumes the pumps are retrofitted with variable speed drives. The AI points are temperatures or a differential pressure to ensure the system has enough energy to provide cooling to the most remote (or largest pressure loss) system. The main supply and return flow is included to determine the actual energy delivered by the EnWave system to the building. The point count implies a further 3 x Invensys x VSC 1188 DDC controllers to be added to the network.

Some of these points may already be in place for use by the chiller controls, although the current DDC drawings do not show any connection to the stand-alone chiller control system. These points should be planned for in order to ensure monitoring and evaluation.

The cost to implement these controls and strategies is $60,058. These costs would be recovered through the VFD and efficient control strategies.

Given the reliability of the current VFD technologies and better understanding of the sequences involved, the control of the chiller plant with VFDs is recommended.

> Operation and maintenance

The sequences will have to be implemented and monitored. Variable speed controls extend the life of the motors and pumps, which has not been accounted for in this report. The regular maintenance schedule will still apply and not be unduly extended by the VFDs. The VFDs themselves will have a practical life and have to be repaired or replaced before their useful life cycle. With normal operation they are expected to perform satisfactorily for 15-20 years.

> **Product specification data sheet**

ACS550 Specifications

Input Connection	
Input Voltage (U_1)	208/220/230/240 VAG 3-phase +10% ... -15% 380/400/415/440/460/480 VAG 3-phase +10% ... -15%
Input Frequency	48 to 63 Hz
Line Imbalance	Max +/-3% of nominal phase to phase input voltage
Fundamental Power Factor (cosØ)	0.98 (at nominal load)
Connection	U_1,V_1,W_1
Output Connection	
Output Voltage	0 to U1, 3-phase symmetrical, U_2 at the field weakening point
Output Frequency	-500 to +500 Hz
Frequency Resolution	0.01 Hz
Continuous Current	1.0 * I_{2N} (normal use) 1.0 * I_{2hd} (heavy-duty use)
Short Term Overload Capacity	1.1 * I_{2N} (1 min/10 min) 1.5 * I_{2hd} (1 min/10 min)
Peak Overload Capacity	180% of 1_{2hd} for 2 seconds each minute
Base Motor Frequency Range	10 to 500 Hz
Switching Frequency	1, 4, or 8 kHz
Acceleration Time	0 to 1800 s
Deceleration Time	0 to 1800 s
Efficiency	98% at nominal power level
Short Circuit Withstand Rating	100,000 AIC

VIP GARAGE TEMPERATURE CONTROL

The VIP parking is a semi-circular, “C” shaped lot located below the main lobby around the central chambers tower. There are 73 parking spaces and it is now heated by six Trane steam unit heaters with the fans controlled by wall-mounted line voltage electric thermostats. The steam runs to the unit heaters all the time with the fan being switched on at the heater when the local thermostat calls for heat. The set point noted during site visits was ~approximately 68 °F. The concept for saving energy is to convert the current “wet” sprinkler system to a “dry” system thereby allowing for lower set points possibly below freezing on occasion.

Advance Fire Control staff was brought in to review the system and make suggestions for the requested conversion. This sprinkler system is a dual-feed – if water from one source is interrupted or the pressure drops, the system would flood from another source should the sprinklers go off. These sources are from two metered water mains in Rooms 55 and 101. The sprinkler supplies in the VIP garage enter at two points with 6” lines. One line supplies the SW and NE half of the garage and the other supplies the SE and NW half. These supply lines also feed to the adjacent hallway and the Records Centre.

Some areas have already been converted to a dry sprinkler system. Seven conversion points are now in place for the Taxi tunnel, which used to be fed with a glycol system, as it is unheated. The City therefore has experience with conversions so the issue is if it is appropriate for the VIP garage.

The second issue is that the VIP garage is below the main entrance lobby. Reducing the temperature in the garage will lower the lobby floor temperature and effectively shift the heating load to the lobby area. As this is a high traffic area, it will likely get noticed and commented on more frequently.

One concept considered is to valve off the main steam into the VIP garage and allow steam only when the temperatures fell below a certain set point. The problem with this strategy is that the Records Centre is also heated by the same steam line that feeds the VIP garage. If the benefits of turning off the steam into the VIP garage were sufficient, the Records Centre would have to have its own steam line routed before a new garage shut off valve to ensure it continues to get heat as required.

> Heritage issues

Changes being proposed do not directly affect the Heritage criteria and this kind of project has been completed before in the Taxi tunnel. The main issue is that the same sprinkler system that feeds the VIP garage also feeds the Records Centre and hallways from two entry points. It must be determined from legal, insurance and archival perspectives whether or not these outside areas can have a dry system. The factor is how long it takes to flood the dry areas when a head releases.

> **Budgets and benefits**

As the Records Centre under went renovations recently, this conversion is not recommended at this time. The recommended option is to replace the existing line voltage thermostats with line voltage programmable thermostats with set points below the current 68°F - 70°F to 50°F and even lower during unoccupied times. As these units are fed steam continuously with heat delivered when the fan comes on, the savings will be due to reduced steam use, some reduction in line losses along with some savings in fan energy. The set back of 18 F° (10 C°) would reduce the energy required for the area by about 12%.

Estimating current use at 3,800 hrs/season operation for the unit heaters and fans uses 10,150 kWh/season and 1,050 lbs of steam per season.

The cost to implement this is the time it takes the City Hall staff to reset each thermostat to the new set points point and is not expected to be more than an hours worth. To ensure the thermostats are not altered, protective covers should be installed at a cost of $1,800 for the six stations.

The new hours of use result in steam and electricity savings. The new hours of use will be on the order of 836 hours of operation leading to savings of 1,870 kWh/season of electricity and 23.1819 kLbs of steam. The total savings are then $187206 for electricity and $67825 for steam for an annual total saving of $865 and avoiding eight tonnes of greenhouse gases – about that generated by two cars/year231. The payback is then 5.2 years.

Area	Old use	New Use	Steam old	Steam Saved	$/yr	Elect old	Elect saved	$/yr	Payback
	Hrs/yr	Hrs/yr	kLbs/yr	kLbs/yr		kWh/yr	kWh/yr		Yrs
VIP Garage	3,800	2,964	1,050	23.1	678	10,150	1,870	187	2.1

> Potential for saving in VIP garage using programmable thermostats

A price to convert the wet system in the garage is presented for information, should the fill time be within the legal and Heritage criteria. The quotation from Advanced Fire Control includes the required valves, alarm and low-pressure switches, test points, interface with the alarm system and compressors (two units) for a total cost of $40,730. The savings potential does not warrant this change at this time.

> Operation and maintenance

Once the thermostats are programmed, the thermostats will not add to the maintenance schedule other than routine inspections of the heating system in the VIP garage and ensuring the ‘stats have not been changed. Covers can be added if they are found to be tampered with. One point to consider is that rust from road salt increases in heated garages. The reduced temperatures will be better for the cars as well.

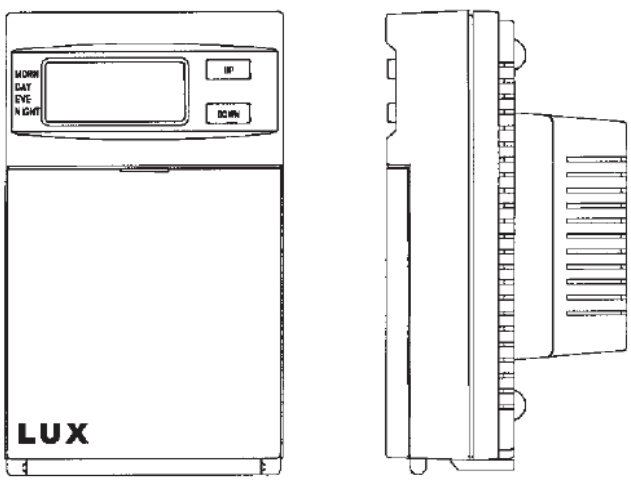
> **Product specification data sheet**

ELV1/PSPLV510

Programmable Line Voltage Thermostat

LUX PRODUCTS CORPORATION • Mt. Laurel, New Jersey 08054, USA 43331-04

WARNING: Use Energizer® or DURACELL® Alkaline Batteries Only.
Energizer® is a registered trademark of Eveready Battery Company, Inc.
DURACELL® is a registered trademark of The Gillette Company, Inc.



For Use On:
- Heating Only 120/240 Vac Single Pole Applications
- Baseboard, Ceiling Cable and other Radiant Heat

Not For Use On:
- Double Pole Applications
- Heating/Cooling or Cooling Only
- Low Voltage (24Vac) Systems

Electrical Rating

Batteries
- Two Energizer® or DURACELL® "AA" alkaline batteries (not included)

Programming
- Preprogrammed - 4 Periods per day
- 5 / 2 Programming
- Weekdays/Weekends can be different
- °F / °C Changeable

Line-voltage thermostat to control the unit heaters in the VIP Garage

FOUNTAIN PUMP CONTROL

The fountain and pool is the centrepiece of the current Nathan Phillips Square. Thousands of tourists and Torontonians use or pass by this feature every week. It is a refreshing vista in the summer with the fountain-feature running and a crowd pleaser as a skating rink in the winter. The pool is filled in June each year and drained in September in preparation for the skating rink. In the summer season the fountain is left on 24/7 and accounts for about 2,040 hours of operation. The concept being reviewed is to turn off the fountain pump, especially when there is a high demand for electricity for instance during hot summer evenings.

The fountain pump is located in the sub-basement, below the grade of the pool, and, and operates for most of the summer season once the pool has been filled. This is a 50 HP (37.3 kW) pump pushing about 1,200 USGPM of water. A concern voiced by the operating staff is that if the pump is turned off, some people will use the pool as a bath. Apparently, when the fountain is on this is not as much of a problem. The pump should not be turned off such that biological growth is encouraged either. People are aware of standing water issues and a large body of water, such as the pool, would be noticed if it were to be, or appear to be, standing for any length of time.

> **Options for consideration**

Options include manually turning the pump off during certain time periods of the day, a time clock, or interfacing with the building automation system. Manual control is often neglected and should be implemented only as an over-ride strategy. A time clock is independent of actual energy concerns and may be a problem if it is not changed during special events. Adding this pump to the point list of the new DDC system will give the most flexibility and energy savings. One strategy would be to turn the pump off when the outside air temperature is still above 33 °C by 14:00 and turn it back on at 16:30 when people are leaving work. It could then be turned off again 23:00 and brought back on at 06:00. In addition, the pump could be turned off manually at the DDC host when it is raining.

> Heritage issues

Although this concept was not brought up directly with the Heritage Board, no changes are being planned to the fountain itself, so it is not felt that control strategies will pose a problem. The proposed sequences might want to be disabled during special events.

Budgets and benefits

The savings are based on reducing the operating hours of the fountain pump during the summer season. The recommended strategy is to add the pump to the building automation system. The sequences could be as follows:

1 .Demand response such that the pump is part of one of the levels of demand control for the building.

This pump should be in an early stage as it is really not critical to comfort.

2. The pump should be turned off when it is raining. An on/off cycle could be decided to make sure there is enough cycle through the filters to ensure the pool does not get stale.

3. The pump could be turned off at 2230 from Monday to Thursday until 0600. From Friday until Sunday, it could be turned off at 0200 and on again at 0600 each weekend morning.

System	kW	Old hrs/yr	Old kWh/yr	New hrs/yr	New kWh/yr	Saved kWh
Fountain pump	37.5	2,040	76,500	1,294	48,506	27,994

> Potential for saving with fountain pump control

The costs involve an interposing relay to interface with the pumps' starter. This is a 416 V motor. The relay would then be connected as a digital output point to the new DDC system. The DDC control drawings do not show a logic controller near the fountain pump. An additional unit, i.e., VLC-550, would be required and connected to the one of the UNC trunks.

The cost to provide this will be $6,220. The result is a payback within 3.5 years and is recommended.

> Operation and maintenance

The concept is to reduce the operating time of the pump, which should reduce the maintenance required to a small degree as well as extend the life of the pump and motor. The DDC controller and interposing relay may need to be replaced after 12 -15 years. The cost to do this is approximately $1,500 (2007).

WINDOW FILM

Available for around for more than twenty years, window film continues to be installed on many windows to reduce solar heat gain, save air conditioning costs, glare reduction, furniture degradation, heat loss and improve overall comfort. Window film is likely to become an integral part of any energy saving program or initiative (i.e. Go Green, LEED-EB, etc.) due to the low cost of upgrading the performance of existing glazing without window replacement. However, for this report, window film is recommended only if window replacement, which is preferred and yields greater energy savings, is not pursued.

City Hall has experience with window film. In the early 90s, the tower office windows were covered with an early 3M film (aluminum, medium density, medium-performing polyester) and it has now aged to the point where the film is cracked in a patina-like fashion and should be replaced in order to maintain the efficacy of the concept. The film is laminated to the inside of the glass.

Solar heat gain reduction and some glare reduction resulted when the Scotchtint P-34 film was installed in 1992 on approximately the 9,240 m^2 of glazing in 1992 on the two towers, Council chambers, stairwells, ground floor and 2^{nd} floor offices. This film was chosen based in part because it had a minimal impact on the appearance of the facility, as was required by the Heritage Board. At the time energy savings due to reduced cooling and heating were estimated at $48,000/year (1992This film e technology application can be assumed to have avoided more than $5,600,000 in energy costs since it was applied.

Window film technology has evolved from a performance and environmental point of view since 1992then. The original suppliers and installers, 3Mm and Convenience Group Inc., were brought in to review the options and prepare suggestions suitable for a building of this heritage that would minimize disruption to City Hall staff. Both companies are familiar with the site, and scope and constraints. We also considered the possibility of the work must being completed by unionized workers and completed with little or no interference to the City Hall staff.
The following table outlines the film systems available and their respective benefits. Each has a different look from the outside and inside – from shiny to no impact.

3M Film P/N	Technology Base	Manufacturer Warranty	Aesthetics (Outside View)	Impact of Viewing Out	Visible Light Transmit.	Solar Heat Reduction	Heat Loss Reduction	Glare Reduction	Total Solar Energy Rejected (TSER)	Solar Heat Gain Coeff.*
Single Pane 6mm Clear					88%	3%	0%	2%	18%	0.802
P18ARL	Metal (older)	10 Years incl labour	Reflective silver	Blue rendering limited night viewing	19%	72%	10%	78%	77%	0.23
NV15	Carbon (newer)	12 Years incl labour	Less reflective earth tone	Natural allows night viewing	15%	69%	2%	83%	75%	0.25
Prestige 70 (Winter)	Nano no metals	15 Years incl labour	No change	No impact -	69%	38%	7%	23%	50%	0.50
(Summer)	(latest)				69%	50%	7%	23%	59%	0.41

* Solar Heat Gain Coefficient is used by most energy software programs to calculate energy savings - opposite of TSER -– a lower value is better.

The windows being considered for window film are the main office windows in each tower from the 2nd floor up and the south rib-facing windows. Some of the glazing on the main and 2nd floor and Council Chambers are double pane now and did not show the same level of degradation as the tower office or south rib windows. The combination of sun control window film affects the thermal performance of the window. The existing glazing is 6mm (¼") annealed clear glass. It is mounted into the stainless steel frame with a gasket system similar to those found in automobile windows screens.

The "U" value for a single pane is 1.06. Adding the film will reduce this to 0.951.04 for the P-18ARL, 1.04 for the NV-15 technologies, and 0.99 for the PR-70 system.

Not considered for window film at this time are the ground floor windows, which include the main lobby, restaurant and library. See *Window Replacement* for these areas.

> Siting considerations

Film is placed onto the inside surface of the windows after the old film has been removed. Mechanical removal (scrapping) is the best method for removing the old film, ensuring no chemicals are required. The film requires detergents to remove the film which may be mildly obnoxious to the staff. Consideration should be given to non-polluting chemical solutions for the removal of the film. The replacement film must be installed by trained personnel and once installed will take up to about 30 days to completely dry. The top floors will benefit the most from the application as they are subjected to the most solar energy (west in the morning; east in the late afternoon).

There are 213 floors of office windows (30 windows per floor) in the east tower and 18 floors of office windows (22 windows per floor) in the west tower. The east tower has 2 floors of mechanical Rooms without windows and the west tower has one floor of mechanical room without windows. The top floor of the east tower encloses the observation deck.

The tower office windows have draw down blinds for each pane. These are drawn during the day to reduce the bright sun during the day – both direct and reflected (from the opposite tower and the Council chamber roof). These blinds are often drawn even when bright sun does not seem to be an issue, possibly for privacy and this will impact any daylight harvesting options.

The following table indicates the areas considered for the new film. All glazing is 6mm, single pane.

	East tower				**West tower**			
Unit	**Size**	**Area**	**Qty**	**Total**	**Size**	**Area**	**Qty**	**Total**
	Tall x Wide	m2		m2	Tall x Wide	m2		m2
Main Towers	2.4x1.8	4.32	690	2,981	2.4x1.8	4.32	396	1,710.7
South Ribs	1x2.3	2.3	150	345	1x2.3	2.3	114	262.2
TOTAL				**3,325**				**1,972.9**

Note that the proposed total area is less than the original film area (9,240 m^2 vs. 5,298m^2), the difference being that the Council chambers, ground floor, north ribs, and 2ndSecond and 3rd floor offices are not included in this analysis. These windows are shaded for most of the time by neighbouring buildings or over-hangs on the City Hall and t, i.e., Podium. This window film is not showing the same amounts of degradation either and so was not considered at this time.

The area that accounts for the ground level windows for the north, west, south and east faces is ~approximately 1,570 m². The north rib windows accounts for about 607 m². The remaining 1,765 m² is accounted for with the ground floor, Council chambers, 2nd and 3rd Floors as well as service landings around the Council chambers.

> Budgets and benefits

The main function of window film is used to reduce heat gain and glare. Newer film technologies also take into account the angle of the sun and reduce both heating and cooling loads. Window film can also provide privacy and security functions. As a large proportion of the exterior surface of the City Hall is glazed, efforts to reduce losses while improving staff comfort bring about important benefits.

The costs to implement this option involve removing the existing film and then installing the new chosen window film. Typically, a project of this nature requires removal of existing film after office hours and film application during regular hours. This was the method used for the original 1992 application of then P-34 film. There is sufficient space in front of the windows over the induction units and window bases to allow professional installers access during office hours. Film removal and re-installation takes approximately 45 minutes per tower office window or about 24 hours per floor for the east tower and 18 hours per floor for the west tower. Removal and installation has little effect on the office staff during normal office hours.

This work would require the staff be relocated when work is being completed in their area (1 day) or not be present or the contractors must work after-hours when the staff has left for the day. The following Table indicates the budget costs for the re-filming of the office and south windows. These costs include removal of the existing film and installation of new film during after-hours by union certified installers.

The savings due to cooling are reported in kWh. When the City changes to Deep Lake Water Cooling the savings will be measured in reduced Ton-hours of delivered EnWave chilled water. The savings calculations take into account the mutual shading from each tower and the actual orinetaion of the tower windows The Towers do not face exactly south. For instance the east towers' glazing faces southwest to northwest and the west tower glazing faces southeast to northeast.

The east tower is taller and so it shades the lower portion of the west tower in the early morning except for the summer mid-morning period. Therefore the savings estimates per square meter will be less for the west tower. The west-facing glazing of the east tower receives more solar energy as it is taller and faces the strong setting sun. The overall cooling energy savings for both towers can be expected to yield up to 100 kWh/m² per year. Average yields of between 60 and 80 kWh/m²/yr were used to account for shading effects and the orientation of the Towers.

The heating savings are based on the improved U value for the new films. In the case for the NV-15 style mid-level film, about 5% savings of the steam energy costs can be estimated for a reduction is use of approximately ~0.333 kLbs/HDD of steam avoided each season.

The following table outlines the costs and savings for the three film systems presented for replacement. These values are based on window film installed onto the existing 6 mm, annealed glazing.

Tower	Window Film	Area m² Main	Area m² South	U value W/C.m²	SHGC	$/m²	Total, $ Offices Installation	Total, $ South Ribs Installation	Total $
East	6 mm single	2,981	345	1.06	0.80	n/a	n/a	n/a	n/a
	P-18ARL	2,981	345	0.95	0.23	90	270,000	32,000	302,000
	NV-15	2,981	345	1.04	0.25	110	330,000	38,000	368,000
	PR-50-Winter	2,981	345	0.99	0.5	125	358,000	42,000	400,000
	PR-50-Summer	2,981	345	0.99	0.41	Incl in winter	Incl in winter	Incl in winter	Incl in winter
West	6 mm single	1,710.7	262.2	1.06	0.80	n/a	n/a	n/a	n/a
	P-18ARL	1,710.7	262.2	0.95	0.23	90	155,000	24,000	179,000
	NV-15	1,710.7	262.2	1.04	0.25	110	188,100	32,000	220,000
	PR-50-Winter	1,710.7	262.2	0.99	0.5	125	214,500	35,500	250,000
	PR-50-Summer	1,710.7	262.2	0.99	0.41	Incl in winter	Incl in winter	Incl in winter	Incl in winter

The table below illustrates the saving potential for replacing the window film with the PR-50 nano-technology. As it is a non-carbon based technology, we considered it a better choice to enhance a low carbon footprint. Note that these savings are considered against glazing without any film. At this time, we cannot be sure of the effectiveness of the existing film/glazing combination.

Note that the cooling savings recorded below are for cooling effect and do not take COP into account. With deep lake water as the cooling medium, this represents the actual cooling load reduction as seen by the DLWC system. Likewise, the steam saved is at an efficiency of 100% at the heat exchangers and is all delivered to the space.

The total cost is $655,000 to remove the existing film and replace new onto the windows of both towers from floors 3 and up, and the south rib glazing. Annual savings of $59,269,300 results in a payback of 117.9 years.

Tower	Total	Cost	Cooling	Saved	Heating	Saved	Total	Payback
East	3,326	400,000	225,700	22,570	574	16,860	39,430	10.1
West	1,973	250,000	116,985	11,699	275	8,071	19,770	12.6
TOTAL	5,299	650,000	342,685	34,269	849	24,931	59,200	11.0

The application of window film is complementary with replacing the window recommended in the next section. The window film system has the added benefit of reducing annoying glare currently dealt with by window shades pulled down by the staff when required. Energy savings would also be improved as the effect of the film is to improve any glazings' thermal performance.

* Total equivalent energy avoided assuming 100% at the steam exchangers and cooling without COP accounted for.

Based on the mid-level film (NV-15) total cost of $801,828 a simple payback of 8.9 years is possible by removing the existing film and replacing it with the newer technology.

> Heritage issues

Any new film will affect the look of the glass. The Heritage staff asked that samples of the film be presented for review, their main concern being that the film does not alter the look of the windows dramatically. They do not want what they called a "broken tooth" look for anything done to the windows. As this concept has been used before, it is not anticipated as being a problem from a heritage point of view. If there were a concern, the PR-70 film technology would be recommended, as it does not show once installed. The window film system used in the report is a less reflective, earthy tone look from inside and outside. All office windows for the east and west towers should be replaced at the same time.

> Operation and maintenance

There is no maintenance required for the film itself. The film requires a curing period of up to about 30 days during which time the film should be inspected for faulty installation and repaired. The manufacturer's labour and material warranty, depending on the technology used, is between 10 and 152 years. The window film system used in this report has a full-parts and labour manufacturer's 12-year warranty.

> **Product specification data sheet**

Glass Type (All 1/4")	Single Pane Clear	Single Pane Tinted	Double Pane Clear	Double Pane Tinted
Visible Light Transmitted	50%	30%	44%	27%
Total Solar Energy Rejected	56%	60%	47%	60%
— On Angle	63%	66%	53%	64%
Infrared Rejected	97%	97%	97%	97%
Visible Light Reflected Int.	8%	7%	10%	9%
Visible Light Reflected Ext.	9%	6%	16%	9%
UV Rejected	99.9%	99.9%	99.9%	99.9%
Glare Reduction	43%	44%	44%	43%
Shading Coefficient	0.51	0.46	0.61	0.46
Emissivity	0.78	0.78	0.78	0.78
U Value	0.99	0.99	0.47	0.47
Luminous Efficacy	0.98	0.65	0.72	0.59

High-efficiency window film specifications – Prestige 50 model

WINDOW REPLACEMENT

The majority of the windows at the City Hall are single glaze, 6 mm, annealed units fixed in place with a gasket. These are the original panes. Some of the windows on the ground floor and 2nd floor are double-glazed units. Some are wire mesh glazing (Georgian) found in the stairwell areas. A large proportion, about 50%, of the exterior surface of the City Hall is glazed. This is therefore a major heating and cooling load. Single glazing typically has an insulation value of R 1.06.

Newer and more efficient glazing has U-values as low as 0.28 – a 73% improvement when compared to single glazing, which leads directly to reduced heating and cooling loads. Technologies reviewed include low-e insulating glass and low-e self-cleaning glass.

View showing the majority of the windows to be replaced – offices of the east and west towers, all floors.

> Siting considerations

The process is removal, disposal and replacement, while maintaining administrative functions. It is possible to replace the windows with higher insulating value panes of the same thickness and using the same gasketing system.

One consideration in analyzing the windows' performance is that the building suffers from a lack of humidification, as appropriate levels cause condensation problems on the predominantly poor insulating, single glazing throughout. For example, previous attempts were made to humidify the Council chambers but the condensation on the sloped chamber windows became too much of a problem and the humidification was turned off. During site visits, the relative humidity was noted at between 25% and 30% (at air handler unit return air sensors, December 2006), which is not comfortable for most people. Indoor air quality sufficient for office environments requires relative humidity in a range between 40% and 50%.

The following table presents the areas of glazing that could be replaced with more efficient units. Note that some of the units are double pane now and coated with the window film installed in 1993. These could stay in place and the film be replaced. The main benefit of the window film on double glazed units is a reduction of glare as the insulating value of double panes exceeds that of window film. Because of the significant use of computer monitors in offices today, glare is a very important consideration. This table does not represent all the windows as time and resources did not allow for a comprehensive evaluation (i.e., doors are not included here). The intention is to show the effect on the thermal performance of City Hall when a significant proportion of the glazing is retrofitted with higher R-value units.

Glazing	Size	Quantity	Area	U-value*	SHGC	Location
	m		sq.m.	W/C.m²		
6 mm, annealed	2.4 x 1.8	978	4,225	1.04	0.80	Tower offices
Double pane	2.4 x 1.8	82	354			Ground and 2nd south face
6 mm, annealed	4.9 x 2	40	196	1.04	0.80	Podium level
Double pane	2.3 x 1	11	25.3			Library ground south
6 mm, annealed	2.4 x 2.3	44	243	1.04	0.80	Chamber sloped
6 mm, annealed	2.4 x 1.5	44	158	1.04	0.80	Chamber sloped
6 mm, annealed	2.4 x 1.8	80	346	1.04	0.80	East face ground and 2nd
6 mm, annealed	2.4 x 1.8	96	415	1.04	0.80	North face ground
6 mm, annealed	2.4 x 1.8	80	346	1.04	0.80	West face ground
6 mm, annealed	1 x 2.3	270	621	1.04	0.80	South ribs, east and west
6 mm, annealed	1 x 2.3	270	621	1.04	0.80	North ribs, east and west

* The U-values include window film effects.

> Budgets and benefits

The costs to replace the existing windows include delivery, removal, placing the new windows and re-gasketing. Disposal could not be budgeted, as storage may be an issue due to heritage criteria. All work must not disrupt administrative activity. This means after hours work, completed with site clean-up before the start of the next business day. Some areas can be retrofitted without staff disruption, such as the stairwell panels and non-staffed areas. A commercial glazing contractor (Mt. Pleasant Glass) was brought in to review this and suggested one week per floor for removal and replacement with an after-hours schedule. Weekends were assumed to be available during normal hours. This implies almost one year of effort to replace all windows with a minimal crew size.

Commercial window technology for solar management is available that will reduce the thermal losses (winter) or gains (summer) significantly. Units that incorporate low-e (emissivity) concepts are particularly efficient at reducing heating and cooling loads. Because of the higher insulation properties, the outside air temperature point at which condensation occurs on the inside surface is lowered, thereby allowing higher relative humidity levels before the water in the air condenses on the windows.

The self-cleaning system, Activ™, by Pilkington was reviewed. As it requires direct sunlight to activate, this technology was not recommended. The glazing on the City Hall “sees” direct sunshine sporadically on the lower office floors, which means this concept, will not work consistently across the whole façade. Heritage criteria would not allow for the inconsistent look of using this system with other solar management glass.

The following table illustrates two available insulating solar management glass products supplied by Pilkington Glass and AFG Glass as supplied by Triple Seal that have been considered for this report. All product performance is based on double 6mm panes with a 12 mm gap. Total thickness is 25 mm and will require new mounting channels.

Product	Transmittance	Reflectance	U-value-summer		U-Value-winter		SHGC	SC	Cost
	%	%	Air	Argon	Air	Argon			$/sq.m.
Single pane, with film			1.04	n/a	1.04	n/a	0.8		
Pilkington									
Optifloat - clear	73	17	0.33	0.28	0.33	0.29	0.66	0.76	56
Optifloat - grey	56	27	0.3	0.25	0.31	0.26	0.51	0.59	60
Advantage - clear	51	22	0.32	0.25	0.28	0.26	0.6	0.69	72
Advantage low -e- clear	73	16	0.33	0.28	0.33	0.29	0.61	0.71	75
AFG									
Comfort - Ti-AC-clear	58	23	0.27	0.21	0.29	0.24	0.44	0.51	56
Comfort - Ti-AC-Grey	30	18	0.27	0.22	0.29	0.24	0.33	0.38	60
Comfort - Ti-AC-40	68	11	0.28	0.22	0.29	0.24	0.47	0.55	72

The table below provides the costs to supply the glazing. Both the AFG and Pilkington are about the same cost per square meter so the two models are shown to illustrate the range. There is also a $0.40/unit energy surcharge, which totals an additional $760 for all replacements. These supply costs include tempering charges for the inside lite. The installation costs include removal (not disposal), aluminum track and installation of the new windows.

Glazing	Size	Quantity	Area	Glass Systems Cost		Install	Location
	m		sq.m.	Opticlear	Advanclear	$	
				56$/m2	72$/m2		
6 mm, annealed	2.4 x 1.8	978	4,225	236,600	304,200	1,267,500	Tower offices
Double pane	2.4 x 1.8	82	354				Ground and 2nd south face
6 mm, annealed	4.9 x 2	40	196	10,976	14,112	58,800	Podium level
Double pane	2.3 x 1	11	25.3				Library ground south
6 mm, annealed	2.4 x 2.3	44	243	13,608	17,496	72,900	Chamber sloped
6 mm, annealed	2.4 x 1.5	44	158	8,848	11,376	47,400	Chamber sloped
6 mm, annealed	2.4 x 1.8	80	346	19,376	24,912	103,800	East face ground and 2nd
6 mm, annealed	2.4 x 1.8	96	415	23,240	29,880	124,500	North face ground
6 mm, annealed	2.4 x 1.8	80	346	19,376	24,912	103,800	West face ground
6 mm, annealed	1 x 2.3	270	621	34,776	44,712	186,300	South ribs, east and west
6 mm, annealed	1 x 2.3	270	621	34,776	44,712	186,300	North ribs, east and west
TOTAL		**1995**	**7,550**	**401,576**	**516,312**	**2,151,300**	

The main benefits of replacing the single glazing windows will be improved thermal resistance – U value. This will reduce both heating and cooling loads by factors on the order of 60% to 75%. These higher insulation windows will also allow humidity levels to increase as the inside surface of the windows will be warmer during cold weather thereby lowering the incidence of condensation substantially. The improved R-value windows will allow about 40% relative humidity at outdoor temperatures of around -15°C before condensation begins.

Predicted energy savings are due to the reduction of heating and cooling loads. These savings are summarized in below.

Load	Existing	Improved	Saved	Saved	Cost	Payback
				$	$	yrs
Heating, kLbs	26,825	16,834	9,991	293,235		
Cooling, kWh	2,311,075	1,502,200	808,875	80,888		
Total				**374,123**	**2,151,300**	**5.2**

Note that these costs and savings do not include any window film required for glare reduction.

> Heritage issues

Any changes to the windows must be consistent. The Heritage Board will not approve a mixed replacement plan that is apparent to viewers. Therefore, the tower windows should all be changed, as they are very visible. The 2nd floor and ground floor windows around the City Hall might be allowed to be different as they are not contiguous with the tower façade.

As with any changes to the façade, the Heritage Board must be kept in the dialog. It is suggested that any changes to the windows be presented to the Board during the evaluation phase. The Heritage Board is cognizant of the need for energy savings and will work with any efforts to reduce the energy footprint while extending the life of the facility.

A significant point mentioned by the Heritage Board staff is that the original glazing might have to be stored (see also *Window Photovoltaics*). This will put a large strain and expense on the glazing contractors. The existing glass is not tempered so breakage will happen. This request must be clarified before any further design and bidding occurs and may not be feasible.

It is suggested that the existing glazing be cut into pieces to be small enough for removal by the elevators and offered up for sale as recycled windows to the public. This would be in keeping with efforts to reduce the embedded energy content in the façade, ensure public awareness and offset the cost of the retrofit slightly. Recycling construction materials enhances the opportunities for LEED certification.

> Operation and maintenance

Self-cleaning windows were reviewed but not considered in detail for this facility. Though the thermal performance is worthy, the value of having the self-cleaning feature where windows will not “see” direct sunshine means the windows would have to be cleaned using conventional techniques and then with extra care.

The cost to clean the windows was not determined during this report time frame. If conventional double pane or low-e windows are used, the current cleaning techniques can be used. Maintenance costs will be as they are now.

> Product specification data sheet

Monolithic Performance Data[1, 10]

Product	Nominal Glass Thickness		Visible Light[2]			Solar Energy[2]			U-Factor[5]			Solar Heat Gain Coefficient[7]	Shading Coefficient[8]
	in.	mm	Transmittance[3] %	Reflectance[4] % Outside	Reflectance[4] % Inside	Transmittance[3] %	Reflectance[4] %	UV Transmittance[2] %	U.S. Summer	U.S. Winter	European[6]		
Pilkington **Energy Advantage**™ Low-E Glass (#2 Surface)[9]													
Energy Advantage Low-E	3/32	2.5	83	11	11	71	11	60	0.50	0.65	3.7	0.74	0.85
	1/8	3	82	11	12	69	11	57	0.50	0.65	3.7	0.72	0.83
	5/32	4	82	10	11	68	10	55	0.49	0.65	3.7	0.71	0.82
	3/16	5	83	11	12	68	10	53	0.49	0.65	3.7	0.71	0.82
	1/4	6	82	10	11	66	10	49	0.49	0.64	3.6	0.70	0.81
	5/16	8	81	10	11	62	9	45	0.49	0.64	3.6	0.67	0.77
	3/8	10	80	10	11	59	9	42	0.49	0.63	3.6	0.64	0.75
Pilkington **Eclipse Advantage**™ Reflective Low-E Glass (#2 Surface)													
Eclipse Advantage Clear	1/4	6	67	25	28	58	19	30	0.53	0.67	3.8	0.62	0.72
Eclipse Advantage Grey	1/4	6	32	10	27	29	8	10	0.53	0.67	3.8	0.41	0.48
Eclipse Advantage Bronze	1/4	6	38	11	27	35	10	11	0.53	0.67	3.8	0.45	0.53
Eclipse Advantage Blue-Green	1/4	6	56	19	27	35	11	16	0.53	0.67	3.8	0.45	0.53
Eclipse Advantage EverGreen	1/4	6	48	15	27	23	8	7	0.53	0.67	3.8	0.36	0.43
Eclipse Advantage Arctic Blue	1/4	6	39	12	27	23	8	10	0.53	0.67	3.8	0.36	0.42
Eclipse Advantage Gold	1/4	6	41	32	41	47	20	7	0.62	0.75	4.2	0.53	0.62
Pilkington **Solar-E**™ Solar Control Low-E Glass (#2 Surface)[9]													
Solar-E Solar Control Low-E	1/8	3	60	8	9	46	8	48	0.50	0.65	3.7	0.54	0.63
	5/32	4	60	8	9	44	8	46	0.50	0.65	3.7	0.53	0.62
	3/16	5	60	7	9	48	7	44	0.50	0.65	3.7	0.53	0.61
	1/4	6	60	8	9	46	7	44	0.50	0.65	3.7	0.52	0.61
	5/16	8	59	8	9	42	7	41	0.50	0.64	3.7	0.51	0.59

Data sheet for high insulation, low e window technology suitable for the tower offices

STEAM SYSTEM

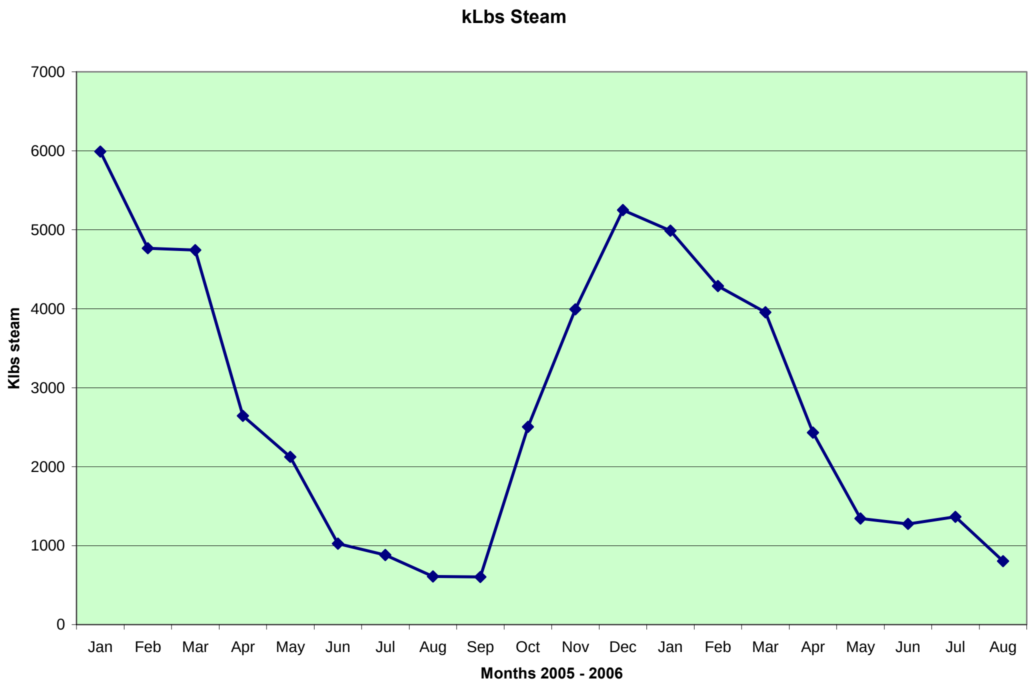
Steam is provided by contract to the City Hall by EnWave and supplies energy for the domestic hot water (DHW) and space heating. In some cases, such as DHW, the energy is transferred to the load through tube and shell or, more recently, through plate and frame configurations. Air to be conditioned in the air-handling units is heated or pre-heated directly by steam through coils in the AHUs. Options are considered here to reduce the steam consumption in the summer season by converting the existing steam heated DHW to either instantaneous, tankless heaters or steam fed plate and frame systems (also a tankless solution). A recommendation to recover condensate heat to pre-heat City water before it is heated by steam in the Mechanical Room 101 is also described.

A conversion from tube-in-tank DHW has been completed by Spirax Sarco EasiHeat using an Alfa Laval plate type heat exchanger fed by steam. This removed a 2 ft dia. X 4' long DHW storage tank and tube bundle. This concept is being developed by Spirax Sarco, Concord, and H.H. Angus, Toronto, for the remaining DHW tanks. The following table and graph indicate the annual steam consumption profile for 2005.

End Date	Total, $	Days	Stat days	HDD-50	kLbs	$/kLb	kLbs/day	kLbs/HDD50
Jan	164,559	31	1	927	5,990	27.5	193.2	6.46
Feb	131,535	28		696	4,766	27.6	170.2	6.85
Mar	130,872	31		640	4,742	27.6	153.0	7.41
Apr	73,676	30	2	131	2,645	27.9	91.2	20.19
May	29,384	31	1	49	2,194	13.4	68.5	43.37
Jun	29,239	30		0	1,027	28.5	34.2	0.00
Jul	25,178	31	1	0	883	28.5	30.4	0.00
Aug	17,503	31	1	0	612	28.6	19.7	0.00
Sep	17,265	30	1	0	603	28.6	20.1	0.00
Oct	73,270	31		72	2,504	29.3	80.8	34.78
Nov	172,574	30		285	3,992	43.2	133.1	14.01
Dec	214,763	31	2	740	5,291	40.6	181.0	7.09
	$1,079,818	**365**	**9**	**3,540**	**35,249**	**29.3**		

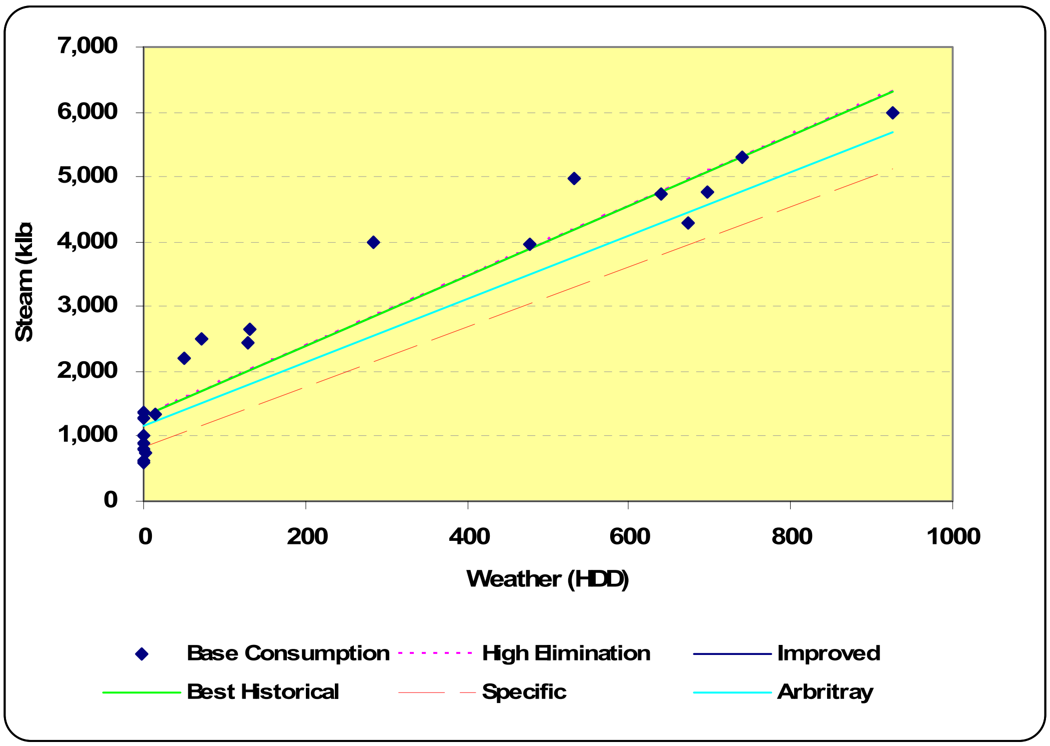
Steam consumption indices – 2005

Steam consumption between January 2005 and August 2006



This graph, from January 1, 2005 to August 31, 2006, indicates a typical profile for a building with DHW and space heating provided by the same energy source – valleys in the summer and peaks in the winter. The options being reviewed are to reduce the summer steam load. The "shoulder months" indicate the effect of confused controls typical when there is a mix of heating and cooling with a 2-pipe system configuration. The sudden increase in kLbs/HDD in the spring and fall illustrates this condition. The building will likely start off cold in the morning and heat up as the day progresses and poses a difficult control situation where a quick change-over will result in sudden increases in steam use to heat the building mass.

The following graph illustrates a monitoring and targeting tool that presents the steam energy use as a function of heating degree-days. The “best historical” line represents the actual operating conditions. The slope is 5.42 kLbs/HDD and the intercept is 1,303 kLbs, which is the level of steam use with no HDD load. The intention of this graph is to show the range of operating conditions with possible reduction scenarios brought on by close attention to operation of the heating plant.



> Opportunity for steam savings based on typical applications and weather

The “specific” line shows how the steam use would appear with a 15% reduction in the slope to 4.607 kLbs/HDD and reduction by 35% of the intercept to 941 kLbs/day. This line was forced in order to get the intercept closer to the actual value of between 600 and 1,300 kLbs/day. The “arbitrary” line relates to a 10% reduction for the slope and intercept, 4.878 kLbs/HDD and 1,172 kLbs/day respectively. This potential is based on monitoring and targeting experience with typical energy consumption. The savings would be achieved through making sure the controls respond to the outside temperature conditions, ensure the steam valves are completely off during the cooling season and the heating coils are kept clean.

An example would be to tailor the controls to delay the heating system during the shoulder months. A morning start-up sequence followed by a cycled open/close strategy to allow any building mass effects to manifest in the space and return air temperatures would save steam energy use when outdoor air temperatures increase during the shoulder months and thereby reduce the effective kLbs/HDD.

The following table summarizes the summer steam consumption for 2005 and 2006 with conversions to equivalent units for kWh and cubic meters of gas.

Month	kLbs	$ Steam	kWh	$ Elect	cu.m equiv	$ gas
Jul-05	883	25,871.90	274,320.05	30,175.21	26,504.35	13,252.18
Aug-05	612	17,931.60	190,128.96	20,914.19	18,369.95	9,184.97
Sep-05	603	17,667.90	187,332.94	20,606.62	18,099.80	9,049.90
Jul-06	1367	40,043.26	424,579.09	46,703.70	41,022.13	20,511.07
Aug-06	804	23,559.10	249,797.45	27,477.72	24,135.02	12,067.51
Sep-06	755	22,131.90	234,664.80	25,813.13	22,672.93	11,336.46

Comparison of steam with electricity and natural gas during the summer

Assumptions:
Electricity rate is $0.10/kWh
Steam rate is $29.35/kLb
Gas rate is $0.4505/m³
Based on this information we have assumed a space-heating load of 27,825 kLbs per year and 7,424 kLbs per year for DHW.

Using service water design criteria from ASHRAE Fundamentals:

- Between 1.4 L/person/day and 7.3 L/person/day of DHW.
- Occupancy based on one person/18.6 m² of office floor space. City Hall is 52,191 m²; about 2,800 full time people.
- Assumed 4,000 people/day at 5 L/day at 55 °C. This accounts for the public occupancy.
- Restaurant uses between 5.5 L/meal to 9.1 L/meal.
- Assumed around 350 meals/day.
- Daycare uses 3.0 L/student/day.
- Floor level galley kitchens use about 40 L/day

With these assumptions we arrive at the following DHW loads for the months July, August and September where there are no HDD. The following values are for a single average month:

- 4,000 people x 5 L/day = 20,000 L/day at 55 °C = 95,430 kWh = 311 kLbs steam
- 350 meals x 9 L/meal/day = 3,185 L/day at 55°C = 15,200 kWh = 50 kLbs steam
- About 50 kids x 5 L/day = 250 L/day at 55°C = 1,190 kWh = 4 kLbs steam
- 43 galley kitchens x 40 L/day = 1,720 L/day at 55°C = 8,250 kWh = 28 kLbs steam

These amounts give a summer month steam use of 393 kLbs of steam for DHW. If we consider the value of 61903 kLbs as the best scenario DHW use per month year-round, this implies the heat exchangers are operating at about 625%, which is not unreasonable. The galley kitchens are being retrofitted with small under counter electric tanks (John Wood, 12 USgal, 3 kW). This will reduce the steam load slightly (about 43 kLbs/yr); though add to the electric consumption by around 13,000 kWh/yr (about $1,500/yr, 2006).

> Siting considerations

Natural gas and electric instantaneous, tankless water heaters were reviewed. The natural gas models will require natural gas lines and supply and exhaust air breeching to the outside walls. Currently there is no gas available in the City Hall for this service and would have to be brought in to each unit. Both the breeching and running gas lines could be problematic and therefore not as appropriate for this application.

An alternate is to use electric instantaneous heaters. In this case, the steam energy use is reduced but now electricity is required. The systems considered are 240 V, single-phase heaters that can be wall mounted and interfaced with each floors hot water supply system. The recirculation of the hot water will still be in place, though we recommend this be turned off during the evenings to reduce unnecessary electricity use.

The current flow rate for design purposes is 1 gpm at the hot water faucets. If there are aerators now, or being considered, the flow rate would be 0.5 gpm. This rate of flow is the manufacturers design rate. It is strongly suggested therefore that aerators be implemented throughout the office towers for this recommendation to be effectively implemented. Aerators have been previously considered and are recommended before any tankless option is considered as it impacts the system size and performance.

All the condensate from the 8 air handling units in the basement and 6 tanks on the tower mechanical rooms returns to the main condensate tank in Room 101. The hot condensate is then pumped to a return line back to EnWave. The water in the main tank is typically about 150 °F (66 °C). The domestic hot water tank is in the same room and supplied by city water at about 48 °F (8.8 °C) on average throughout the year. A level switch in the condensate tank determines when the pump goes on. The level is determined by the heating loads – as space heat and domestic hot water loads increase so does the amount of condensate.

Main condensate line.

Tank and pumps in Mechanical Room #101

> Budgets and benefits

The concept presented is to replace the DHW steam heat tube-bundle/tank system with tankless, instantaneous units. Natural gas would require natural gas be brought in to the building for this purpose alone. It will also mean breeching for exhaust and combustion air for the new units. Using electrical units will require electrical energy but no breeching. Therefore the electrical option is recommended.

Based on the DHW loads defined above and fixture counts from an earlier water audit the DHW load can be met with the following configuration. There are five hot water fixtures per floor in the two towers in the washrooms. The Galley kitchens were not considered here as they are being retrofitted with new under-counter electric tanks now.

The costs listed in the table below include 12 m40 ft of breeching for each of the gas-fired units and basic interconnection to the existing DHW lines. In the case of the gas units, there will also be plumbing between floors, as there is a single unit for about every 6 floors. We could not estimate the gas line costs at this time and they are extra. Estimates also assume the breeching can be run directly out the building from each location.

The cost for the electric option includes some electrical work, 240 V, single phase, 40 A breakers. Each floor will have an electric unit so the plumbing is not as difficult as for the gas option. In both options only the office towers are considered. The restaurant, daycare and fitness club have not been included.

Tower	System	Output Per system	Quantity	Total Output	System Cost	Energy Req'd	Energy Cost
		kW		kW	$	kWhe/yr	$/yr
East	**Takagi**						
	MT-I	7 to 68	5	35 to 340	32,300		
	TM-RE-20	n/a	2	n/a	2,900		
	TM-RE-10	n/a	2	n/a	1,500		
	TOTAL				36,700	247,300	11,950
	Stiebel Eltron Tempra - 15	15	22	330	33,000		
	TOTAL				33,000	234,300	25,773
West	**Takagi**						
	MT-I	7 to 68	3	21 to 204	19,400		
	TM-RE-20	n/a	1	n/a	1,550		
	TM-RE-10	n/a	1	n/a	750		
	TOTAL				21,700	97,700	4,720
	Stiebel Eltron Tempra - 15	15	16	240	24,000		
	TOTAL				24,000	92,560	10,182

Performance Indices of natural gas and electric tankless heaters for DHW

As the above table indicates, the initial cost for the gas option will be more than for the electric option, but the operating costs for the gas option will be less annually. It is not known whether or not all the steam use for DHW ca be offset so 6,400 of a possible 7,400 kLbs was considered as displaced for this report.

For the purposes of this report, the electric option is what is presented in the *Summary Tables*.

The condensate heat recovery option requires a plate-type heat exchanger inserted between the condensate pumps and the return to EnWave. The city water that feeds the domestic hot water tank would be connected to the heat exchanger before it goes on to the tank. If there is a domestic cold water supplied as there is a hot condensate flow, the incoming cold water will be pre-heated to about 90 °F (32 °F) and then heated by steam to the 145 °F (63 °F) domestic hot water setpoint. The system saves money by reducing the steam required to heat the water up from 32 °C instead of 8.8 °C.

Mechanical Room DHW storage tank beside condensate return lines and tank for pre-heating.

> Operation and maintenance

These units heat up water on demand through a large temperature rise, i.e., 28 C to 36 C, and will calcify if not cleaned. These are easier to clean than the existing tube-in-tank, plate and frame or conventional tank designs. Calcification is dependent on the hardness of the water being heated as well as the temperature to which it is heated (calcification increases with increasing temperature). The new tankless units should be inspected annually and cleaned if required.

Cleaning of the DHW components is a necessary maintenance aspect of these systems and would require between two and three days per year for City staff to inspect and clean.

The electric units proposed come with a manufacturers 3-year parts warranty.

UPGRADE CONTROL VALVES TO ELECTRONIC ACTUATION

Until recently, all control actuation was provided by compressed air and pneumatic controls. Conversions over the last 15 years have resulted in a mix of DDC controls with pneumatic actuation of the dampers and control valves. Pneumatics has a reputation for robust, fast, strong closing power. However, they also begin to leak, actuators' membranes weaken and the knowledge to repair and maintain them is fading. These systems also require air compressors, typically with redundancy, which are expensive to run and maintain. Compressed air is in fact one of the most expensive energy sources in a facility.

In keeping with the concept to replace the induction unit control valves, consideration is given to replacing the aging pneumatic valves on the air-handling units. Some three-way cooling water control valves on the air-handling units are being replaced now, though with pneumatic actuation. The DDC system now controls the pneumatic valves through an electronic to pneumatic converter, which allows the comprehensive strategies in the DDC sequences to be employed at the existing pneumatic actuators.

> Siting considerations

The valves being considered here control cooling and heating in the air-handling units. Most of the AHU's are located in the basement level. The valves consist of two-way units for steam (heating coil) control and three-way for chilled water (cooling coil). The valves range in size; 2', 2-1/2", and 3" line size. Each AHU has a cooling coil and a heating coil. There are 38 AHU's to be considered. This results in 38 x two-way heating valves and 38 x three-way cooling valves for retrofit. The sequences of operation now implemented with the new DDC system will still apply. Replacing these valves with electric actuators will still not remove the pneumatic system. If total electric controls are required, all pneumatic controls will have to be replaced (i.e., the induction control valves, stand-alone temperature sensing, dampers, DHW heat exchanger valves).

It is recommended that a complete pneumatic survey be completed if conversion to a completely electric control strategy is desired. Any control strategies considered from now on should be with electric actuation and connected to the new DDC system. Heating valves will be open/close and require digital outputs only. The cooling valves are three-way and should be modulating and require an analogue output for each. This results in 38 x DO for the heating valves and 38 x AO for the cooling valves.

> Budgets and benefits

Electronic control and electric actuation is the standard method for controlling HVAC systems in buildings today and will continue to be so henceforth. Pneumatics is a fading technology in commercial applications with decreasing operation and maintenance knowledge as well as restricted sequences of operation. It is still the best as far as closing power, but DDC systems can accommodate the delays of electric actuation with anticipatory control logic. For the City Hall to stay current and provide state of the art sequences and strategies, as well as monitoring and reporting facilities, only electronic systems should be considered from this point forward.

The savings will be as a result of reduced maintenance and improved control as the existing valves are old enough to be suspect as far as closing and modulation goes. If an average of $2,000 per valve is assumed for the 76 valves including removal, replacement, DDC controllers and commissioning, the complete replacement could be done for about $152,000. Tighter control of both heating and cooling along with better monitoring should present a 10% saving resulting in a 10 – 11 year payback.

It is recommended that Direct Energy Business Services be asked to prepare a quote to supply these valves and introduce them to the existing control system.

> Operation and maintenance

The retrofit would be accomplished by a combination of City mechanical staff and sub-trades that will remove and replace the valves. Operation will become a part of the DDC sequences of operation, as is the case now. Some commissioning will tune the system to account for the slower actuation and finer control. Maintenance will be lowered, as the new valves will not require significant over sight for the first 7 – 10 years. Actuators will likely need to be repaired or replace after 10 -12 years.

> Product specification

Typical electronic valve for three – way control up to 3 " line size.

> Council chamber lighting

The Council chamber a dominant feature of the City Hall and houses the elected officials of Toronto for council meetings and other events deemed appropriate for this chamber. It consists of two areas – the Council chamber proper and the Members Lounge, which is at a level above the chamber seating. In each area there are ceiling-hung hanging pot-lights, which can be controlled by a remote system within the Chamber. . The perimeter around the chamber is up-lit by fluorescent lamps above a parapet up-lighting the ceiling at the top of the windows.

The concept is to review lighting technologies that can reduce the energy levels without sacrificing the quality of light required for meetings and television broadcast equipment. The light must have an appropriate colour rendering index (CRI) as well as colour temperature, know in units of °K (the higher the number, the closer to real daylight energy levels and the better for broadcast purposes).

Another set of lights noted during site visits is the floodlights that cover the chamber base. There are 60 x 150 W, 240 V, 30° floods which are on for most of the day as they are an architectural on the main entrance level feature. Though not directly related to the Council chamber, they are mentioned and included here for the savings potential.

>Siting considerations

The Council chamber, Members Lounge and perimeter up-lights are controlled by a Crestron stand-alone system. The in-house A-V Department is fully aware of this system and its scope. This system allows for multiple zones and three levels of dimming control of the Members Lounge, chamber lights and on/off control of perimeter up-lights. There are three touch-screen control points – on the Council floor, at the balcony level A-V booth and the main A-V offices. An over-ride timer turns off all the lights at 2300 hr each day, unless controlled otherwise from one of the three control points. There is sufficient control in place to maintain very efficient on/off/dimmer schedules for the Council chamber. However, the control system is not used to its fullest potential from an energy conservation perspective.

Council chamber lights

Members Lounge lights

Broadcast quality lighting is required about three times per month. This still defines the quality of light, as broadcast specific lighting systems are not realistic (i.e., how to spot a particular councillor or speaker anywhere in the chambers from a choice of four camera locations). Changing the existing pot-lights poses a problem in that they are high and surrounded by asbestos. Changing the fixtures is not recommended.

Council chamber perimeter lighting

> Options

The Council chamber area has 56 x 250 W, 120 V, 4200 °K, 3600 lumen, 30 ° flood lamps. The Members Lounge has 16 of the same lamps. The perimeter lamps are 4 ft x T38 fluorescents, although the count could not be determined during the site visits but is estimated for the purposes of this report. A significant issue is the fact that the lighting must be compatible with television broadcasting. This implies a minimum light level (lumens) as well as high colour-rendering index (CRI).

The existing pot fixtures used in the Council chamber and Members Lounge appear to be mounted to asbestos covered ceiling. It would be difficult and expensive to change these fixtures so this option was not considered.

The following table illustrates the savings if the Members Lounge is changed to CF-30 twist models. The Members Lounge also has ambient exterior light sources so the lamp wattage should be reduced. The Members Lounge fluorescents can be replaced with the newer FT32/25 lamps as the old ones fail. The ballasts should also be changed to the newer high efficiency models.

Area	Lamp Type	Qty	Old Watts	Hours	Old energy	New lamp	New Watts	New energy	Saved	Saved	Cost
					kWh/yr			kWh/yr	kWh/yr	$/yr	$
Council Chamber**	Q250 PAR 38	56	250	4400	61,600	Same	250	56,000	5,600	560	2,250
Members Lounge**	Q250 PAR 38	16	250	4400	17,600	Par 38 150	150	9,500	8,100	810	2,250
Chamber Base	Q250 PAR 38	60	250	5200	78,000	Par 38 150	150	46,800	31,200	3,120	2,250
Chamber Perimeter*	T8-32	90	64	4400	25,344	FT-32/25	54	21,384	3,960	396	2,900
TOTAL					**182,544**			**140,344**	**43,820**	**4,382**	**9,650**

* The lamps could not be counted during the site visit. The count is estimated from "light" patterns.
** The costs for the Council chamber and Members Lounge includes for training on the Crestron System
Potential for saving with control and lamp changes in Council chamber areas

> Budgets and benefits

Some of these lights can be changed by City Hall staff as part of regular replacement schedules or gang-replaced to jump start the savings (i.e., the up-lights, the chamber base lights). At this time no reasonable replacement for the Council chambers is proposed due to the lumens required and unavailability of reduced wattage with sufficient CRI and temperature replacements at this time. The Members Lounge can be replaced now using the proposed CF-30 lamps by City Hall staff. Any changes should be confirmed as appropriate with dimming options using the in-place Crestron control system.

The savings pointed out for the Council chambers reflect controlling the lights with the existing controls to reflect the actual operating hours. During site visits the lights were on in the Council chambers when there was no current or planned activity for one (1) hour increments. The new electricity consumption kWh/year value is an attempt to show the value of turning the lights off for some of the year as a result of dedicated control based on occupancy. The new value is 4,400 hrs/year as compared to an estimated 5,200 hrs/year. This will require a training building operators to program the system to reflect the actual operating hours of the area at least weekly with the possibility of over-ride requests. The cost is therefore to have the A-V Department train City Hall staff to program the system regularly and ensure the protocol is followed and add an over-ride option that local staff can operate from the main lighting control panel. The cost has been assumed at $4,57,800/year based on 602 hrs/week/year at $75/hr. This leads to a payback of about 4 years.

Again, the most effective way to ensure savings is to train staff to operate the existing control system. Each chamber meeting should have a person responsible for the lighting. The currently installed control system is dimmable and controllable. Savings projected here as “hours reduced per year” can be accomplished by using the existing lighting control system.

In order to save energy in the chambers and Members Lounge, training of meeting coordinators should be implemented. This system is not connected to the main building automation system so an education program is the only way to ensure consistent savings. This strategy must be driven from meeting management.

It is estimated that changing the Members Lounge will take City Hall staff about 8 hours to change the existing incandescent lamps to the proposed CFL. The total cost would be on the order of $1,000. This gives a payback of about 1 year.

The Council Chamber base lamps can also be changed out by City Hall staff .If they were all to be changed at once the cost would be $1,800 for the lamps and about $1,200 for staff time. The total of $3,000 would be recovered within 1 year.

The Chamber Perimeter lamps can be replaced by the City staff using the newer FT-32/25 lamps. The current ballasts could not be seen or determined during the site visits. The savings presented here are based on replacing the lamps only and would cost $3,350. The payback would then be approximately ~7 years.

> Operation and maintenance

Maintenance will be the replacement of the lamps on a schedule determined by the degradation of the lamps' output or failure. The PAR series lamps have a typical life of 3,000 hours, which implies replacement once per year. Any reduction in use will extend the time between replacement and the maintenance cost cycle time.

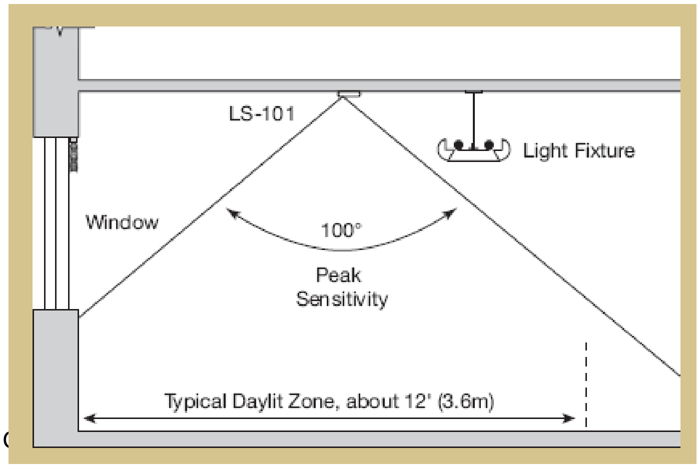
The existing control system could be used to better effect through training of staff who are consistently present during meetings held in the chambers. The control screens are located on the chamber floor, as well as the upper floor control booth. This is a touch-screen system that controls the zones in the chamber. The A-V department also has control but cannot always be responsible for the changing light requirements.

This effort should be directed from senior staff of these meetings to ensure a person is assigned responsibility for the lighting controls. A note to that effect is advised at the desk of the meeting attendant to remind them to control the lights.

TOWER OFFICE DAYLIGHT HARVESTING

The east and west towers receive various degrees of direct and reflected light throughout the day. This causes discomfort for the employees who have to resort to complete shading to reduce glare. However, the perimeter office space is also supplied with an indirect lighting system using up-lit fluorescents that bounce off the white ceiling. This is a good source of "skylight" type illumination but in this case is over powered by the incoming solar light on sunny days.

A new Square D lighting control system has been installed in both towers and tied into the new BAS that controls and monitors the complete facility. This provides for scheduled light on/off cycles including timed over-rides.



> Siting considerations

This considers controlling zones on each floor based on incident light levels. The lights to be controlled are the fluorescent up-lights at the perimeter spaces. During site visits we were told that these lamps are replaced with F32T8 lamps when required and so they were assumed as all F32T8 for this analysis. The fixtures were retrofitted with reflectors in 1993 or so. The ballast technology was not determined. The ceiling is all exposed. Asbestos may be an issue but was not determined during these site visits.

> Budgets and benefits

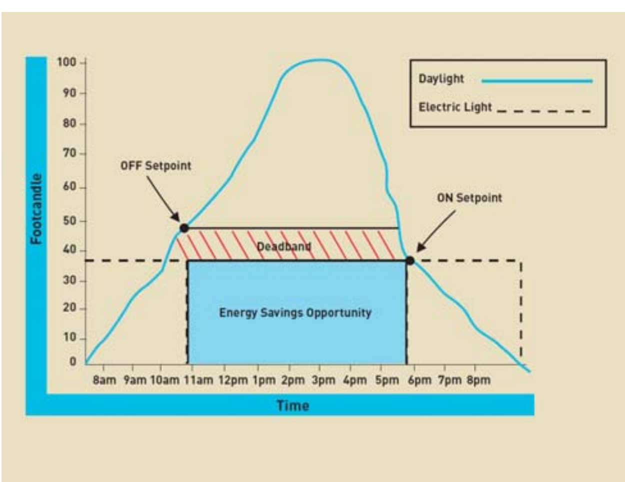
The level of lighting provided by the up-lights during a sunny day barely registers. With zoning the up-lights can be turned off when sufficient light levels are present and would not, or rarely, be noticed by the staff. As with any energy management program, the staff should be informed of the concept and trained about the proposed change.

The following table describes the potential of daylight harvesting in the east and west towers. By reducing the hours of operation the rated life of the lamps and ballasts will be extended. It can be expected that the replacement cycle will be extended by about 35% as a result of daylight harvesting.

Tower	Up-lights	Old hrs/yr	kWh/yr	New hrs/yr	kWh/yr	Saved	Saved	Cost
	kW		Old		New	kWh/yr	$/yr	$
East	82	4,000	328,000	2,600	213,200	114,800	11,480	69,000
West	43	4,000	172,000	2,600	111,800	60,200	6,020	50,000
Totals			500,000		325,000	175,000	17,500	119,000

Potential for saving by using Daylight Harvesting Control Strategy

> Product specification data sheet



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Daylighting Controls Matrix

	LS-101	LS-301	LCO-203	LCD-203
ON/OFF switching	X		X	
Dimming Control		X		X
Single Zone	X	X		
Up to Three Zones			X	X
Open Loop	X		X	X
Closed Loop	X	X		
Adjustable Deadband	25, 50, 75, 100%		10-80% per channel	
Adjustable Setpoint(s)	ON Setpoint 1-850 fc OFF Setpoint 1.25 - 1275 fc	20-60fc	5-60fc for each channel	5-60fc for each channel
Adjustable Time Delay	3, 10, 20, and 30 minutes		ON, 5-60 seconds per channel	programmable dimming, 5-60 sec. per channel, fade rates
			OFF, 3-60 minutes per channel	optional cutoff delay from 0-20 minutes
LED Status Indicator	X	on remotes		
LCD Status Display	X		displays photocell readings	displays photocell readings
Manual Control Option	X	remote adjusts target levels	wall switch	wall switch
Programming				
Menu Driven Programming	X		X	X
Remote Programming		X		
Use with these products				
Power Pack	Watt Stopper power pack	Watt Stopper power pack	BT-203	BT-203
Photocell	included in controller	included in controller	LS-290C	LS-290C
Handheld Remotes		LSR-301-S and LSR-301-P		
System options				
Wall Switch	low voltage wall switch	low voltage wall switch	LS-4C	LS-4C
Enclosures			LS-8E and LS-12E	LS-8E and LS-12E

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Daylighting

Sample of Daylight Harvesting Technology

PODIUM AREA OFFICE AND COMMON AREA LIGHTING

Podium area Dimming Control of office and common area lighting

There is a mix of fluorescent (compact and linear), high intensity discharge and incandescent lamps throughout the facility. Controls strategies, as well as recent lamp and ballast technologies, are considered in this section. There is a Square D lighting control system being completed and commissioned now that controls the light circuits from floor 4 to the top of each tower. This system is interconnected with the new DDC automation system and will be programmed for occupancy with timed over-rides. The suggestion is to install occupancy sensors in some rooms and refit burned or old lamps with newer and higher efficiency lamps.

Committee Rooms #1 and #2 have a Crestron Lighting Control system (similar to the Council chambers) that allows remote control of the lights. Each of these rooms has a tabletop touch screen near the front of the meeting room and an A-V booth screen. They are used now though not consistently. Control is usually assumed by the meeting attendant.

Committee Rooms #3 and #4 have hard-wired switches only and as a result tend to be left on more regularly.

The office areas on the 2nd floor of the central, east and west towers are lit predominantly with F32T8 fluorescent lamps with some CFL 13W lamps. There are some incandescent, 50 W, in a few areas. Task lighting is also used but not accounted for here. Access to all the office areas was not possible during the site visits due to on-going meetings or security issues, but hours of operation are about 2,346 hours/year, if the lights are turned off at the end off the business day. With some overtime, we have assumed 2,800 hrs/yr for the 2nd floor office area lighting. Some areas, rooms 101 – 110 operate for 4,432 hours/year.

The Committee Rooms #1, #2 and #3 have FT08-32 fluorescent lamps configured mostly as two tubes per fixture. Committee Room #4 has three tubes per fixture. Committee Room #1 also has some compact fluorescent lamps. These are all controlled manually The lights and were almost all on during site visits, though no meetings were planned. There are schedules outside the doors that indicated the rooms could be vacant for hours at as time. Assuming the rooms are lit for 10 hours

per day over 317 days/year on average. The sensors that sense motion and infra-red (dual technology) should have to be installed on each lighting circuit for Committee Rooms #3 and #4 and turn lights on only when the room is occupied. The sensor would be a Sensor Switch or equal.

Occupancy sensors considered are those supplied by Sensor Switch and Watt Stopper. The following table indicates the energy and cost savings by reducing the on time of the fixtures. The cost figure for Committee Rooms #1 and #2 represent training time to provide education and manuals to the meeting attendants on the operation of the Crestron Control system. The costs for the other Committee rooms represent supply and installation of dual technology sensors. They can be supplied and installed for $250 each giving a total cost of $4,500 for all four rooms. The payback would be on the order of $3,427/yr for a simple payback less than return in <22 years.

Area	Lamp Type	Qty	Watts	Old hrs/yr	Old	New hrs/yr	New	Saved	Saved	Cost
					kWh/yr		kWh/yr	kWh/yr	$/yr	$
Committee Rm #1	FT08-32	72	65	3170	14,836	2,346	10,979	3,856	386	1,000
Committee Rm #1	CFL-17	26	50	3170	4,121	2,346	3,050	1,071	107	incl
Committee Rm #2	FT08-32	62	65	3170	12,775	2,346	9,454	3,321	332	1,000
Committee Rm #3	FT08-32	69	65	3170	14,217	2,346	10,522	3,696	370	1,000
Committee Rm #4	FT08-32	72	65	3170	14,836	2,346	10,979	3,856	386	1,000
TOTAL					**60,785**		**44,985**	**15,800**	**1,580**	**4,000**

Potential for saving in committee rooms by optimized control strategies

The following table illustrates the savings potential by installing occupancy sensors in the office tower floor washrooms. During the site visits, some handicapped washrooms have sensors already. Each floor has three washrooms – one male, one female and one handicapped. Each washroom has one switch so the cost to add an IR/motion Sensor Switch is $350250 per unit. There are 165 switches to retrofit for a total installed cost of $57,741,250. Note that we did not include the public washrooms as there is more likelihood of them being turned off and on at short cycles which harm the ballasts and lamps.

Area	Lamp Type	Qty	Watts	Old hrs/yr	Old	New hrs/yr	New	Saved	Saved	Cost
		Fixtures			kWh/yr		kWh/yr	kWh/yr	$/yr	$
Floor washrooms	FT08-32	110	65	4400	31,460	2,800	20,020	11,440	1,144	34,800
Floor washrooms	CFL-13	220	42	4400	40,656	2,800	25,872	14,784	1,478	Incl
Floor washrooms	FT08-17	110	50	4400	24,200	2,800	15,400	8,800	880	34,800
Handicapped	CFL-13	38	42	4400	7,022	2,800	45,276	25,872	2,587	12,100
TOTAL					**103,338**		**106,568**	**60,896**	**6,089**	**81,700**

Note that Watts indicated above and in all lighting charts include the ballasts.

Potential for savings with lower wattage lamps in washrooms – office floors

Ground floor and 2nd floor office lighting

The office areas in the central, east and west towers use predominantly F32T8 fluorescent lamps with electronic ballasts now. As they are T8's mostly, further savings could be had by replacing burned out or old lamps with the newer F25/32T8 lamps available. A study of the lighting in the central building, east and west towers was completed by Toronto Hydro Energy Services in 2004

The ceiling in these offices is predominantly a grille-like system as a 20 cm dropped ceiling. Some of the offices have a drywall finish, but this is not the norm. The system proposed is an integrated lighting control and energy management system that addresses individual fixtures through staff computer based software. A combination of occupancy sensors and scheduling allows each area to be controlled for the tasks and light levels required.
This type of system is in use now at the Metro Hall, which can be referred to for experience and function.

> Budgets and benefits

Note that there is a combination of fluorescent, compact fluorescent, PAR and incandescent lamps in these offices. Any opportunity to convert the incandescent lamps to compact fluorescent should be encouraged. These incandescent lamps represent almost 14 kW of energy, which account for about 60,275 kWh/year or $6,030/year. If these 271 lamps could be replaced with 13W CFLs, a further saving of 10 kW would be achieved at an annual energy saving of 17,275 kWh/yr or $1,728/yr. This would likely lead to a < two-year payback.
Access to all the Office areas was not possible during the site visits due to on-going meetings or security issues, but hours of operation are about 2,346 hours/year, if the lights are turned off at the end off the business day. With some over time we have assumed 2,800 hrs/yr for the 2nd floor office area lighting.
The following table indicates the lighting in the central building area. We have assumed the system will reduce the overall energy required by 40% annually.

Potential for saving by Improving 2nd floor office lighting

Area	Lamp Type	Fixtures	Old hrs/yr	kW	Old	New	Saved	Saved	Cost
		Count			kWh/yr	kWh/yr	kWh/yr	$/yr	$
Room 101	F32T8	99	4,432	5.2	23,046	13,828	9,219	922	22,275
Room 101	CFL-13	4	4,432	0.1	222	133	89	9	225
Room 102	F32T8	105	4,432	6.3	27,922	16,753	11,169	1,117	23,625
Room 102	CFL-13	34	4,432	0.4	1,950	1,170	780	78	1,500
Room 103	F32T8	178	4,432	10.8	47,866	28,719	19,146	1,915	40,050
Room 104	CFL-13	8	4,432	0.1	443	266	177	18	450
Room 104	F32T8	88	4,432	5.7	25,262	15,157	10,105	1,010	19,800
Room 105	75 W PAR	40	4,432	3.0	13,296	7,978	5,318	532	
Room 105	F32T8	224	4,432	14.6	64,707	38,824	25,883	2,588	50,400
Room 106	F32T8	121	4,432	7.9	35,013	21,008	14,005	1,401	27,225
Room 106	CFL-13	97	4,432	1.3	5,762	3,457	2,305	230	4,500
Room 107	F32T8	137	4,432	8.9	39,445	23,667	15,778	1,578	30,825
Room 108	F32T8	150	4,432	4.9	21,717	13,030	8,687	869	33,750
Room 108	CFL-13	5	4,432	0.1	288	173	115	12	225
Room 109	F32T8	66	4,432	4.3	19,058	11,435	7,623	762	14,850
Room 109	50 W incan	48	4,432	2.4	10,637	6,382	4,255	425	
Room 109	CFL-13	8	4,432	0.1	443	266	177	18	225
Room 110	F32T8	114	2,346	7.4	17,360	10,416	6,944	694	25,650
Room 110	CFL-13	32	2,346	0.4	985	591	394	39	1,500
Room 201	F32T8	85	2,346	5.5	12,903	7,742	5,161	516	19,125
Room 201	CFL-13	60	2,346	0.8	1,830	1,098	732	73	3,000
Room 202	F32T8	63	2,346	4.0	9,384	5,630	3,754	375	14,175
Room 202	CFL-13	90	2,346	1.2	2,745	1,647	1,098	110	4,500
Room 203	F32T8	62	2,346	1.6	3,754	2,252	1,501	150	13,950
Room 203	CFL-13	124	2,346	1.6	3,754	2,252	1,501	150	5,500
Room 204	F32T8	88	2,346	5.7	13,372	8,023	5,349	535	19,800
Room 204	CFL-13	76	2,346	1.0	2,346	1,408	938	94	3,300
Room 205	F32T8	76	2,346	4.9	11,495	6,897	4,598	460	17,100
Room 205	CFL-13	118	2,346	1.5	3,519	2,111	1,408	141	5,000
Room 206	F32T8	91	2,346	4.9	11,495	6,897	4,598	460	20,475
Room 206	CFL-13	140	2,346	1.8	4,223	2,534	1,689	169	6,000
Room 207	F32T8	96	2,346	13.1	30,733	18,440	12,293	1,229	21,600
Room 208	F32T8	19	4,432	1.2	5,318	3,191	2,127	213	4,275
Room 209	F32T8	182	4,432	11.5	50,968	30,581	20,387	2,039	40,950
Room 209	CFL-13	69	4,432	1.0	4,432	2,659	1,773	177	3,000
Room 209	50 W incan	50	4,432	2.5	11,080	6,648	4,432	443	
Room 210	F32T8	74	4,432	4.7	20,830	12,498	8,332	833	16,650
Room 210	CFL-13	28	2,346	0.4	938	563	375	38	1,500
Room 210	50 W incan	52	4,432	2.6	11,523	6,914	4,609	461	
Room 211	F32T8	217	4,432	14.7	65,150	39,090	26,060	2,606	48,825
Room 211	CFL-13	20	4,432	0.3	1,330	798	532	53	1,500
Room 211	50 W incan	64	4,432	3.2	14,182	8,509	5,673	567	
Room 212	F32T8	75	4,432	4.1	18,171	10,903	7,268	727	16,875
Room 212	CFL-13	12	4,432	0.2	886	532	355	35	600
Room 212	50 W incan	57	4,432	2.9	12,853	7,712	5,141	514	
TOTAL				**180.7**	**684,637**	**410,782**	**273,855**	**27,385**	**584,775**

> Operation and maintenance

Once the sensors are in place there is little maintenance required. Any lamp replacement can occur according to regular scheduled changes.

Where the automated control system is in place – Meeting Rooms #1 and #2, meeting attendants should be trained on the operation of the system and instructed to turn off the lights when the meeting is finished. If the room is planned to be used right away, the lights should be left on and the incoming person responsible for the lights will take over the control. If the rooms are going to be unused for more than 15 minutes the lights should be turned off.

This project has not been included as a measure since the staff replaces old and burned out lamps with the latest high efficiency models. We do recommend that staff be trained on the use of the existing lighting control systems where they are in place for the Committee Rooms. This is a recommendation for the Council Chamber lighting as well and should be carried throughout the City Hall wherever the control system is used.

TOWER OFFICE AND WALKWAY PROGRAMMABLE THERMOSTATS

> Office line-voltage thermostats

Along the outside walls of each tower are separate offices that have an electric booster heater in the spaces' supply air duct. The heaters would have been required because these offices back onto an exterior wall that presents a large heat loss area. Each office has a line voltage thermostat to control these heaters. The thermostat can be set by the occupants and have a range of set points. There are about 228 of these in the two towers, controlling about 200 kW of electric heat.

> Council chamber to tower walkways radiant floors

Also mentioned here as it pertains to electric heating is the fact that the walkways between the Council chambers and east or/and west towers (enclosed) are heated with an electric radiant floor. These two walkways were noticeably hot (uncomfortably so) to the touch on a cold winter day. The thermostat is a conventional wall-mounted, line-voltage unit but is not suitable for radiant heat control as it measures ambient air temperature. Information about these heaters was not readily accessible – likely on the order of 10 kW each walkway. If these are on all the time at the set points noted – 25 °C, about 120,000 kWh and cost of about $12,000/yr would be being used for areas that do not require this level of comfort.

> Sitting considerations

The Office thermostats are accessible and mounted on the back wall in each office. There is an air proving switch to make sure the heater does not turn on without air flow.

> Typical office thermostat (left unit) for an electric duct heater

We recommend that the line-voltage thermostats be replaced with line-voltage programmable thermostats and set up for night setback temperatures to prevent the heaters from coming on when the office is empty at night and weekends. These thermostats have an over-ride function to allow the heaters to come on during over-time or weekend/holiday work, if required.

The walkway thermostats are mounted on a column near the exit/entrance doors to the walkways. These walkways are glass enclosed and will have a large heat loss for the volume. These systems should be looked at in more detail to find out the system size and why the floor must be heated (perhaps under-floor plumbing). The thermostats should be replaced with programmable radiant floor compatible thermostats and set at a reasonable temperature for comfort when people are traversing the walkways. These can also be programmed to heat the slab when electricity rates and demand is low after 23:00.

> Budgets and benefits

We anticipate an average of 720 hours/year that the office heaters would be off, resulting in about 164,160 kWh/yr saved. In combination with other recommendations, such as new windows and refined control on each floor, this saving value would increase.

The predicted cost to replace the thermostats and program them is $78,660. The project would pay for itself in about 4.8 years and further reduce the greenhouse gas load by almost 114 tonnes/year. This would be comparable to turning the electricity off in 16 houses every year.

The walkway radiant energy is about $12,000/year. With an estimated installed cost of $1,200 for the two programmable radiant thermostats, the payback would occur within the first year, based on a 25% reduction of energy used.

> Product specification and data sheet

ELV1/PSPLV510
Programmable Line Voltage Thermostat

LUX PRODUCTS CORPORATION • Mt. Laurel, New Jersey 08054, USA 43331-04

WARNING: Use Energizer® or DURACELL® Alkaline Batteries Only.
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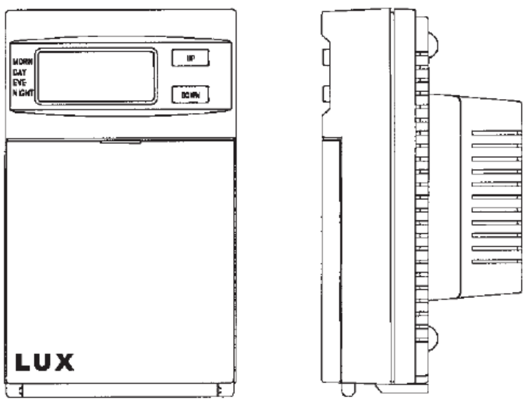


For Use On:
- Heating Only 120/240 Vac Single Pole Applications
- Baseboard, Ceiling Cable and other Radiant Heat

Not For Use On:
- Double Pole Applications
- Heating/Cooling or Cooling Only
- Low Voltage (24Vac) Systems

Electrical Rating
16A at 120/240 Vac
1900W at 120Vac
(Non-Inductive)
3800W at 240 Vac
(Non-Inductive)

Temperature Differential
- ±1°F Factory Preset; Adjustable

Batteries
- Two Energizer® or DURACELL® "AA" alkaline batteries (not included)

Programming
- Preprogrammed - 4 Periods per day
- 5 / 2 Programming
- Weekdays/Weekends can be different
- °F / °C Changeable
- Temporary Temperature Override
- Vacation Hold

Dimensions
- 4.7" T x 2.7" W x 2.4" D
- 1.4" D from wall surface

Wall Plate
- 4.8" W x 5.0" H Wallplate Included

Line voltage programmable thermostat for office heat control

Radiant heating programmable thermostat for walkway control. Cooling mode turns the heaters off as well.

DDC CONTROL OF FLOOR INDUCTION CONTROL SYSTEMS

The City Hall has recently upgraded the main building automation system (BAS) with a BACnet based, open protocol direct digital controls package (DDC) by Direct Energy Building Services . This is a state of the art system that encourages operator and management monitoring and interaction. Some of the suggestions mentioned in this report are cross-referenced to this section. See Refurbished Induction Units for more details about the induction unit system.

The specific option here is to replace the floor level pneumatic controllers used to manage the induction unit control valves with DDC compatible valves. The impetus for replacing the pneumatic controls and valves is the age and poor control. The existing over-ride and scheduled night set back/up control strategy implemented by the DDC system will still apply and be implemented by electronic actuation and temperature sensing.

There are 30 induction units and 8 x Johnson T-275 (3/41 inch) pneumatic control valves per floor in the east tower for a total of 690 induction units and 184 control valves. The west tower has 22 Induction units and 6 x control valves per floor for a total of 396 induction units and 108 control valves. The total control valve count is 292 for the two towers. A combination pneumatic supply air bulb (per control valve) and pneumatic space stat (two per floor) control the valve. Each valve can be manually set for maximum and minimum positions. The building operators are often asked to adjust these valves for comfort requests.

There are 67 induction units at the perimeter on the ground floor between the Security Office and Parking Permit Offices. The valves are not visible at the floor level.

Window induction units during renovations in the west tower

Close-up of induction unit control valve and manual control dial

Typical induction unit pneumatic control valve, 6 – 8 per floor

> **Sitting considerations**

The majority of the work will occur in the offices of the east and west towers. All work on the induction units will have to take place during off-hours to allow administrative activity daily. The floor being worked on will not have perimeter heating or cooling during the repair/retrofit. The water supply to each floors' induction system can be manually shut off at a main valve on the supply line. Based on site visits, there will need to be coordination with the staff to ensure the induction units are not blocked by filing cabinets, shelves etc. by anything.

The existing valving allows for a discharge air temperature control and night setback schedule. This is a conventional pneumatic sequence and can be emulated with higher precision using DDC/electronic actuation.

Many of the valves examined during site visits were showing scale and likely leaking at the stems and seats. This means basically no control and is manifested in calls to maintenance staff to adjust the valves.

Each floor controller will then have to be connected to the DDC network and programmed.

> Budgets and benefits

The options are to replace the existing control valves and temperature control with new electric valves and control them through the new DDC system. The space temperature would be controlled by new space sensors also connected to the new DDC system. There would be one2 space sensors per floor and one return air sensor.

The existing pneumatic valves will need to be cut out and new electric valves installed. All valves will have to be wired back to the DDC network controller per floor. The replacement valves will be three wire-floating types that get their power from the DDC controller. The replacement valves will fit into the line when the existing valve is removed. A space sensor will be installed close to the return air grille and also wired to the DDC controller.

There are two strategies available to control these valves. One has all the valves controlled in parallel, such that each "bay" (a collection of induction units controlled off a single valve) is controlled as a single zone on the floor. Then individual valves could not be controlled independently.

A second version is to define certain zones and use LON-based controllers on the valve heads so that they can be controlled separately from the remaining floor valves. One suggestion is to control the north-2-zones and south-2-zones with LON-based valves and leave the middle zones as parallel control. This concept allows for differing loads during the day. It assumes the north zone is cooler in the winter and summer seasons and the south zones are hotter during the summer and winter seasons.

The cost to remove existing valves and install the new control valves and one zone space sensor on the floors is $2,200,650 per valve for a total cost of $615,000 for 292 valves. Note that this cost does not include the removal of asbestos, which was mentioned as likely in some of the lines, but could not be determined during the site visits. If we assume there are 16 control valves for the ground floor perimeter, a cost of about $35,040,800 to retrofit them results. Approximately $12,000 would be required for engineering and programming. The total cost to retrofit the valves throughout would be $662,088,800.

The cost to install the LON version adds $250 per valve. Assuming four LON valves per floor in both towers adds $40,000 to the cost mentioned above. For the purposes of this report, the option without LON controllers is recommended. The LON controller option will increase comfort levels more than encourage significant energy savings. However, maintenance calls would be reduced saving on staff costs. The preferred system is to use a combination of parallel control in the central zone with LON controllers at the north and south zones.

The following table outlines the additional point count to control each control valve for the induction units along with a representative space temperature (i.e., close to the return air grilles) on all the office floors of each tower. With the current DDC system components, a single Invensys VLC-1188 controller (11 x UI, 8 x BO, 8 x AO) would be required for each floor if there are no other points available on the network. The cost to implement these points is included in the pricing described below. Most points now reside on systems in the Mechanical Rooms so only floors close to these areas will be candidates for existing controllers.

Tower	AI	AO	BI	BO	Total
East	25	184	0	0	209
West	18	108	0	0	126
Total	43	292	0	0	335

Additional control points required to control recommended induction control valves

The savings are due to reduced hot/chilled water use at the floor level during the evening/unoccupied periods, lower maintenance costs and reduced time re-setting the control valves manually. Currently, the BAS controls the induction primary air units for the towers to scheduled times with over-ride capability during summer and winter modes. The night set back strategy (unoccupied mode) is to let the space temperatures sit between 15.6 °C and 16.6 °C by controlling the air handling units' heating control valve. The space temperatures are sensed by return air and single space thermistors per air-handling system.

The strategy would be to use the induction units as a convective heating (no forced air) source until the space temperature cannot be maintained. The space sensor will then enable the air-handling units to provide air to induce conditioned air into the spaces during unoccupied times and shut down the induction unit control valves during unoccupied times and let the main air handling unit maintain the night back/up temperatures. If the space temperature drops below the allowable alarm set points the control valves can be opened prior to the main air handling system moves into recovery mode.

Combined with variable speed control on the induction pumps, the strategy will lead to lower pump energy costs as well. The ABB VFD series variable speed controllers were used to determine the performance, costs and savings.

These pumps operate during heating and cooling seasons all year – 8,766 hrs/yr. The following chart indicates a possible operation schedule for variable speed drive control of each of the induction pumps.

Annual Running Time		
% of Time	Hours/yr	% of Flow
5	435	100
10	870	90
15	1,305	80
20	1,740	70
20	1,740	60
15	1,305	50
10	870	40
5	435	30
0	0	20

Possible operating schedule using variable speed drives on induction pumps

The following chart illustrates the potential of variable speed drives on the induction pumps. As a result of the reduced operation time, due to night setback and unoccupied time reductions, the following energy savings are predicted.

	Service	Flow	Head	Power	Saved	Saved	GHG	Cost	Payback
Zone	**Induction**	**USGPM**	**FT**	**HP**	**kWh/yr**	**$/yr**	**kg**	**$**	**yrs**
0	Council Chamber	300	30	5	2,422	266	220	4,790	18
9	2nd floor west	60	100	5	1,934	213	193.6	4,790	22.5
8	1st floor west	60	100	5	1,934	213	193.6	4,790	22.5
7	2nd floor north	60	100	5	1,934	213	193.6	4,790	22.5
6	1st floor north	80	150	5	3,418	376	342	4,790	12.7
5	2nd floor east	75	100	5	2,417	266	242	4,790	18
4	1st floor east	60	100	5	1,934	213	193.6	4,790	22.5
3	2nd floor south	75	100	5	2,417	266	242	4,790	18
2	1st floor south	60	100	5	1,934	213	193.6	4,790	22.5
1	Podium entrance	120	10	7.5	3,867	425	386.8	5,010	11.8
11	Podium induction	275	15	2	822	90	82.4	4,470	49.7
12	Induction Units East	950	60	20	12,952	1,425	1,295.2	5,700	4
13	Induction Units West	500	50	10	5,680	630	2,726.8	5,100	9
14	Stairwell Induction W	75	20	0.75	350	35	166	4,200	120
15	Stair well Induction East	100	25	1.5	1,396	154	139.6	4,470	29
	TOTAL				45,411	4,998	6,811	72,060	

Induction pump schedule with potential VFD implemented savings and paybacks

Zone pumps #1 - #9 have pressure differential control of a 1.5 " 2-way, electric, valve between the supply and return headers for each pump now. Zones #1 - #8 are controlled by the new DDC system, such that during occupied times the pump runs and the pressure-control valve modulates to maintain a differential pressure set points point.

The payback values other than the main perimeter induction pumps, #12 and #13, and the fact that the zone pumps are controlled now by differential pressure makes speed control an option only for the two main induction pumps. The control strategy for these pumps is currently continuous operation.

> Operation and maintenance

The variable speed systems available are reliable and require little on-going maintenance. These units will be interfaced with the existing DDC system and will be available for monitoring and control from the host station. A suggested maintenance cycle is 10 to 12 years at which time they may have to be replaced or serviced. This is considered normal for electronic and controls equipment.

> Product specification

Typical electronic control valve for induction unit control

REFURBISH INDUCTION UNITS

Induction units were a very common air distribution and heating/cooling method for buildings built in the 60s. Conditioned primary air is delivered to an air chamber and vented to the space through nozzles, which then entrains secondary, space air through a filter and over a heating/cooling coil. Banks of units receive conditioned water through a pneumatically controlled two-way valve in the supply line. A combination pneumatic supply air bulb (per control valve) and pneumatic space stat control the valve. Each valve can be manually set for maximum and minimum positions. The building operators are asked often to adjust these valves based on occupancy complaints.

Typical entrainment ratios for these early designs is somewhere around 2:1 (two units of air entrained for every unit delivered). The induction units are located under the windows around the perimeter of the East and West towers and on the main, entrance and 1st and 2nd floors. The air is returned to the main air-handling units through return air grilles located on either side of the floor lobby doors. The concept is to review induction unit refurbishing kits that improve the entrainment ratio, reduce noise and fan energy.

> Siting considerations

The units investigated during the site visits found them with dirty filters, dislocated filters, and a number of the units blocked by shelves or filing cabinets. These obstructions will hamper the effectiveness of the units and make it difficult to control or save energy.

The induction unit pumps supply both chilled and heated water to the units depending on the season and thus run continuously. Change over is manual based on the weather. For example, in early December the system was still in cooling mode as the weather in the near future was going to be warm. It is difficult to change over on short notice so the operators prefer to make the changeover when they know it will be for the rest of the particular season.

The conditioned water for heating or cooling is sent to tube bundle converters in the mechanical rooms and pumped to the induction units. Source energy water is on the shell side; service water in the tube side. The specifications for the induction unit converters are 2,000 MBH each – two in the east tower and one in the west tower. The stairwell converters are 700 MBH in each tower.

• 30 induction units per floor in the east tower with 8 x Johnson T-275 pneumatic control valves. This then give a total of 690 induction units and 184 control valves.
• The west tower has 22 induction units per floor and six control valves. There are 396 induction units and 108 control valves.

There are four AHUs for the perimeter induction units. All but AHU #13 have ABB speed controls on the fans. The specifications for the induction AHUs are as follows. Actual conditions are based on spot readings during a site visit.

AHU #	Service	Rated	Rated	Actual	Actual	kW	Δ Press	Δ Power
		CFM	" W.C.	CFM	" W.C.		" W.C. / %	kW / %
13	North	5,800	8.5	n/a	n/a	11.2	0/ 0%	0
14	East	9,000	8.5	3,370	3.9	15	-4.6 / 54%	-10 / 65%
15	South	10,500	7	5,648	3.7	15	-3.3 / 47%	-9 / 60%
16	West	9,000	8.5	13,672	4.4	11.2	+4.1 / 48%	+6 / 50%

Induction air handling unit specified and operating parameters

Based on the rated and actual airflows the induction units are not delivering 100 cfm per unit as specified in the original drawings. Nor are they operating at estimated pressures for the assumed induction units. The VFDs are now saving a significant amount of energy for AHUs #14 and #15 (unsure for #13). The controls for AHU #16 show an increase in delivered air and therefore power.

These AHUs are under control of the new DDC system for start/stop/status along with typical damper control and supply air/return air sequences. The system is not interfaced with the variable speed drive, which operates as a stand-alone system when in place.

> Budgets and benefits

The choice is to retrofit the existing nozzles with a refurbishment kit or to replace the complete Induction unit. The technology considered is by Dadanco , which supply a range of induction unit refurbishment kits as well as replacement units that include their proprietary and efficient nozzle design. The nameplates for the units were not found during any of the site visits either on the floors or on units that had been taken out and stored in the basement.

Top view of exposed induction unit nozzles

It is believed they are York NCV based on the dimensions and era of construction. These units are designed to deliver air at 100 cfm each based on original drawings. In discussions with the Dadanco representative, the most effective measure is to replace the existing units with more efficient units. If the units are replaced the amount of air delivered can be lowered as the new designs entrain more air per unit of primary air (4-6:1 as compared to 2:1 for the existing units). This will allow the main air-handling units to operate consistently at reduced speeds thereby saving electrical energy. Combined with proper controls the savings will also include those due to reduced steam and cooling energy.

FOR FUTURE CONSIDERATION
External LED Lighting

Dadanco specifications indicate the existing induction units would require a static pressure of approx. 600 Pa (2.25 “W.C.) in order to deliver 100 cfm/induction unit. The AHUs’ design pressure will drop by about 50%, from 4 “ to 2” W.C. by refurbishing the induction units. This would result in a power reduction on the order of 60% consistently. It is from the lowered pressure regime that the VFD would then operate.

A determining factor is whether or not the spaces are receiving sufficient air now. An advantage of upgrading the units is that more air can be delivered at lower noise levels and reduced power. Increasing the delivered air by 30% at the same temperature difference across the coils means an increase in delivered cooling/heating energy by the same amount. The induction unit refurbishment payback would be achieved through energy reductions at the heating and cooling systems by about 30%. This can be accomplished with reduced chiller pump and induction pump speeds and reduced temperature differences.

The cost to replace the existing 1,089 induction units with Dadanco Starline units is $1,100,000. The work would be completed after office hours using unionized staff.

The estimated additional savings in steam heat through reduced loads is 2,963,000 kLbs/year which equates to $87,000/yr in savings.

> Operating and maintenance

The induction unit filters have to be cleaned now and must be kept clean for optimum performance. The filters looked at during the site visits were dirty or dislodged. If the units are replaced, the filters will be cleaned at the same time. If this option is not considered the City should begin a cleaning program and inspect the filters annually. To clean the filters would take about 8 hours per floor. The cost of this was not determined at the time of this report.

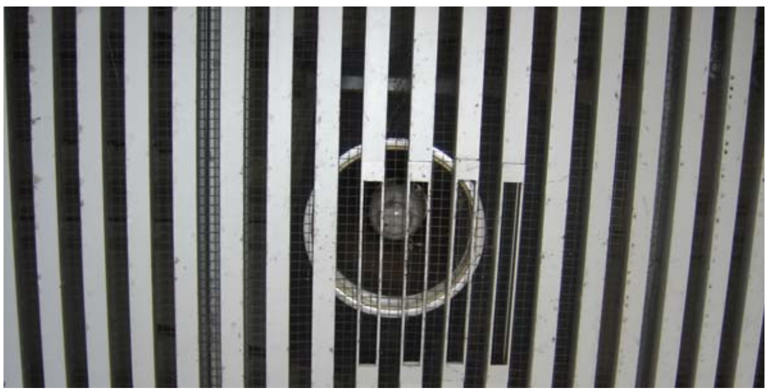
The current state of the valves is such that they are in need of cleaning and due for replacement in any case. Then new valves will be easier to look after and comfort levels should increase with increased control. This will reduce the nuisance call time for the maintenance staff.

> Product specification data sheet

Dadanco Induction Unit Refurbishment Technology to fit into existing housing

FOR FUTURE CONSIDERATION
External LED Lighting

External lighting now consists of high intensity discharge, metal halide lamps with the required ballasts and fixtures. These are predominantly under the podium walkway, which runs along the east, south and west borders of Nathan Phillips Square, as well as over top of the main entrance area at the north edge of the square before the entrance to City Hall. There are quite few of these, 291 x 175 W, 240 V units. The concept is to review lower energy lamps, including the possibility to use very low wattage LED technology.



Typical under-walkway exterior light

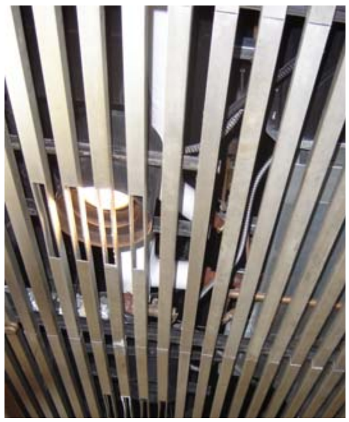
Currently LED technology is specified for outdoor use in point of sale and signage applications. The light levels – lumens – do not yet provide for general outdoor lighting applications. LED lighting is also not readily available for 240 V source. However, the major lamp manufacturers recognize the value and impending market and are preparing models for general lighting to be released in the next 12 – 18 months. Reliability and performance will take time to establish.

The following table compares possible LED technology with conventional light sources. The values for LED represent commercially viable products, which are not yet available.

Area	Lamp Type	Qty	Old Watts	Hours	Old energy kWh/yr	New lamp	New Watts	New energy kWh/yr	Saved kWh/yr
Exterior under walk	MP-175 CB-U	291	175	3,285	167,288	MP-150	150	143,390	23,898
TOTAL					**167,288**			**143,390**	**23,898**

Potential for saving by reducing lamp wattage under the podium and walkway

An area considered as external for this report is the lamps/fixtures in the entrance lobbies. There are three lobbies, each with eight fixtures using 150 W PAR, 240 V metal halides, for a total of 24 lamps. The options are limited with the existing technology due to the 240 V supply voltage. As these lamps are on for much of the year, consideration should be given to changing the fixtures to compact fluorescent lamps and compatible ballasts. A fixture company would have to retrofit the existing lamp chambers.



Area	Lamp Type	Qty	Old Watts	Hours	Old energy kWh/yr	New lamp	New Watts	New energy kWh/yr	Saved kWh/yr
Entrance Lobbies	MP-150 PAR	21	150	8,300	26,145	FT36 DL	57	9,935	16,210
TOTAL					**26,145**			**9,935**	**16,210**

Note: This will require a new ballast and fixture retrofit to apply. New watts include the ballast watts.

Potential for saving by changing entrance lamps to CFL technology

> Budgets and benefits

In both locations – under the walkway and the lobbies, there are grilles covering the fixtures that would have to be removed before the lamps or fixtures can be replaced or altered. This is not an easy task, which might explain why some lamps are not being replaced when they burn out. The lamps under the podium, over the Main Entrance doors are located high up and would require a scissor platform to change.

The cost to replace the existing lamps under the ramp and podium would be $27,325 and take about three weeks for two workers, including the use of a scissor lift.

The cost to replace the Entrance Lobby lamps with CFL would have to include new fixtures and ballasts, as they are 240 V systems now and the CFL systems are not available here at that voltage here yet. This would add considerably to the cost. However, the conversion to allow 120 V lamps would make the choice of lamps broader and offer consistent savings over the long term.

The cost to retrofit the Entrance Lights will be $8,625.

REMOTE HYBRID LIGHTING

A novel light standard is presented for information and future consideration. This system, called the Remote Hybrid System by Panasonic, has a small vertical axis wind turbine as well as a photovoltaic panel to power a 20 - 40 W fluorescent light. These are typically used along walkways for security purposes. The concept would work well at the top of the stairs along the walkway that surrounds Nathan Phillips Square. For example, eight standards could be installed at stairwells and midpoints for security purposes.

The standards are either 5.84 m (FY-17) or 6.04 m tall (FY-34). They do not require any electrical grid connections as they have a battery/UPS. The wind turbine for both models generates 30 W at 2.5 m/s to 250 W at 15 m/s. The FY-17 has 168 W of PV and generates a peak of 0.418 kW. The FY-34 has 336 W of PV and generates a peak of 0.586 kW. Each will operate the light for between seven and 14 hours per day. A LED retrofit kit is expected to be announced in 2007 that will extend the operating times due to lower power needs. They also have an optional WiFi video camera for security purposes.

> Heritage issues

These are stand-alone systems that do not require any wiring. The foundation for each standard has to be fixed to the existing deck. As with the other systems, this has to be removable and the deck brought back to its original condition at any time. Nathan Phillips Square has been designated as a heritage site so the Heritage Board should see the standards before the design goes too far.

The other related issue is the Nathan Phillips Square revitalization project. These might impact the design selected and need to be brought to the attention of the winning design team to see if they can be incorporated.

> Budgets and benefits

This concept is meant to be considered along with the External Lighting section, as a future possibility. Costs and savings have not been included in the Summary Tables. It is described separately so as not to confuse the scope for the External Lighting review. It is included here to introduce the technology for external lighting applications without the need for wiring and represents a sustainable system that provides exterior light where there is none now.

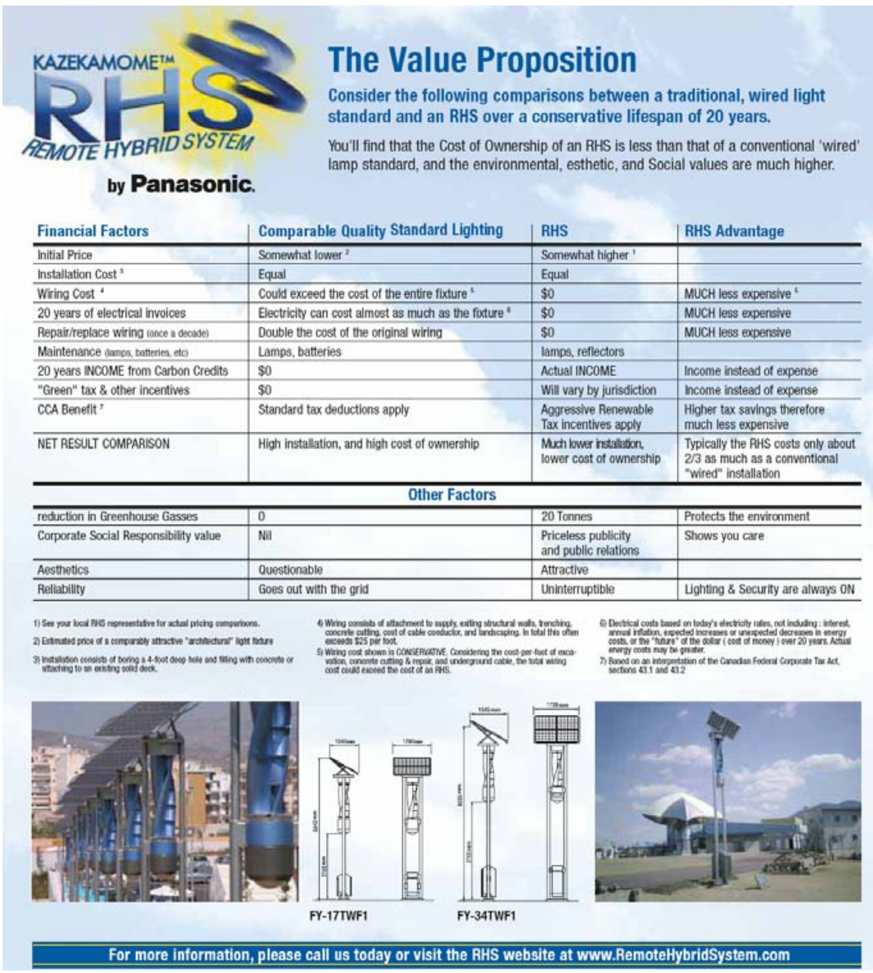
The cost of a single standard is $18,3000 with an estimated installation cost of $800 for a total installed cost of $21,100 per light. The suggested system would include nine lamps at City Hall, along the walkway, at the stairs and in between to provide security light. The total cost would be about $172,000.

When compared to a typical architectural wired light at about $26,000 installed, each with about $50/yr in electricity, over 20 years, the RHS has a $6,000 advantage per light. This represents 10,000 kWh in electricity savings over the 20-year period.

> Operating and maintenance

The N estimated cost for the upkeep of the battery and lamps is given in the literature at as about $2,300/year.

> **Product specification data sheet**



KAZEKAMOME™ RHS REMOTE HYBRID SYSTEM by Panasonic.

The Value Proposition

Consider the following comparisons between a traditional, wired light standard and an RHS over a conservative lifespan of 20 years.

You'll find that the Cost of Ownership of an RHS is less than that of a conventional 'wired' lamp standard, and the environmental, esthetic, and Social values are much higher.

Financial Factors	Comparable Quality Standard Lighting	RHS	RHS Advantage
Initial Price	Somewhat lower [2]	Somewhat higher [1]	
Installation Cost [3]	Equal	Equal	
Wiring Cost [4]	Could exceed the cost of the entire fixture [5]	$0	MUCH less expensive [5]
20 years of electrical invoices	Electricity can cost almost as much as the fixture [6]	$0	MUCH less expensive
Repair/replace wiring (once a decade)	Double the cost of the original wiring	$0	MUCH less expensive
Maintenance (lamps, batteries, etc)	Lamps, batteries	lamps, reflectors	
20 years INCOME from Carbon Credits	$0	Actual INCOME	Income instead of expense
"Green" tax & other incentives	$0	Will vary by jurisdiction	Income instead of expense
CCA Benefit [7]	Standard tax deductions apply	Aggressive Renewable Tax incentives apply	Higher tax savings therefore much less expensive
NET RESULT COMPARISON	High installation, and high cost of ownership	Much lower installation, lower cost of ownership	Typically the RHS costs only about 2/3 as much as a conventional "wired" installation
Other Factors			
reduction in Greenhouse Gasses	0	20 Tonnes	Protects the environment
Corporate Social Responsibility value	Nil	Priceless publicity and public relations	Shows you care
Aesthetics	Questionable	Attractive	
Reliability	Goes out with the grid	Uninterruptible	Lighting & Security are always ON

1) See your local RHS representative for actual pricing comparisons.

2) Estimated price of a comparably attractive "architectural" light fixture

3) Installation consists of boring a 4-foot deep hole and filling with concrete or attaching to an existing solid deck.

4) Wiring consists of attachment to supply, exiting structural walls, trenching, concrete cutting, cost of cable conductor, and landscaping. In total this often exceeds $25 per foot.

5) Wiring cost shown is CONSERVATIVE. Considering the cost-per-foot of excavation, concrete cutting & repair, and underground cable, the total wiring cost could exceed the cost of an RHS.

6) Electrical costs based on today's electricity rates, not including : interest, annual inflation, expected increases or unexpected decreases in energy costs, or the "future" of the dollar (cost of money) over 20 years. Actual energy costs may be greater.

7) Based on an interpretation of the Canadian Federal Corporate Tax Act, sections 43.1 and 43.2

FY-17TWF1 FY-34TWF1

For more information, please call us today or visit the RHS website at www.RemoteHybridSystem.com

Data sheet for remote hybrid system using micro-wind and photovoltaics for lighting options on the podium and walkway

COGENERATION FOR ELECTRICITY AND STEAM HOT WATER

City Hall requires electricity and heat to meet its operational needs in providing services. The result is conditioned air and hot water. Currently electricity and heat are supplied by outside providers. An option to consider is onsite generation of electricity and hot water using gas-fired turbine technology – Combined Heat and Power (CHP). This is a base load concept that will reduce the amount of grid energy and provide steam energy, however it will add a natural gas bill. The decision is then based on the cost effectiveness of energy provided by gas through the CHP turbine as compared to off-site electricity and steam supply. The main benefit is a reduction of grid power and steam loads. This is a distributed energy concept and makes the City Hall a potential generator. The wind energy and photovoltaics fit into this category as well, except they are based on a renewable source of fuel. The intent of alternate sources is to reduce the energy supplied from the grid and generate the facility's power needs on-site.

> Siting considerations

The technology presented here is designed and manufactured by Magellan Aerospace Corp ., Mississauga, Ontario. The turbine reviewed is the Orenda OGT 2500 gas turbine powered electrical generation package. This turbine is capable of operating with bio-fuel. The performance summary is:

- 2.55 MW of power at the generator terminals at 15°C.
- 26.1% efficiency at 15°C based on the power output at the generator terminals
- 13.8 MJ/kWh heat rate
- 35.6 GJ/hr fuel consumption
- 54,000 kg at 460°C exhaust flow
- Designed to include a heat recovery steam generator (HRSG) rated for 4.926 MW
- Capable of producing 7,400 kg/hr (16.3 kLbs/hr) of steam at 1,034 kPa (150 psig)
- 75.5% net system thermodynamic efficiency
- Condensate temperature at 93°C
- NOx < 75 ppm
- CO < 25 ppm
- Availability of generator running > 98%

The concept involves placing a turbine in the lower basement garage area. The complete generator, not including the waste heat steam boiler, is 10m L x 3m W x 3m H and weighs 39 tonnes. A significant engineering study would have to be completed to ensure noise and exhaust gases are not a problem. An environmental assessment would likely have to be completed.

> Budgets and benefits

An urban-based CHP is a novel application that is becoming more common in North America. The result is to take electricity off the grid during peak months, possibly with a surplus, while generating steam for DHW, again with a possible surplus. Ideally, the surplus energy would be sold back to the respective grids – Toronto Hydro and EnWave. For example, if the system ran for about 2,200 hours/year (25%) it would generate almost 25% of the total electrical needs and all of the current steam needs. The time frame presented is from about the middle of June until the middle of September running at 24/7, which represents the peak period and best time to offset electricity.

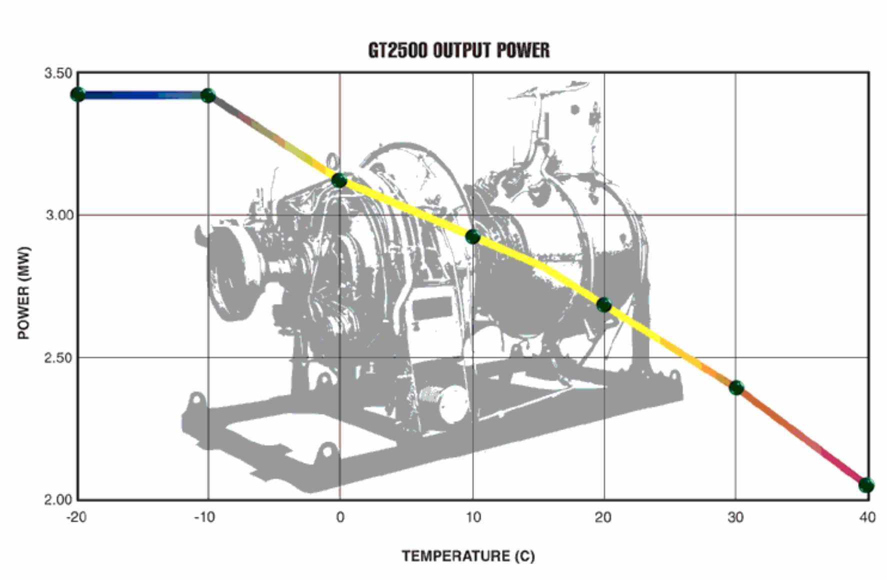
System	Size	Operation	Electrical	Electrical	Value Elect	Steam	Steam	Value Steam	Natural Gas	Cost gas
		Hrs/yr	MW	kWh/yr	$/yr	MW	kLbs	$/yr	cu.m./yr	$/yr
OGT 2500	2.5 MW	2,200	2.55	5,610,000	561,000	4.9	35,200	1,033,120	2,200,000	990,000

Natural gas would have to be brought into the basement area to the turbine. The budget installed cost for the OGT 2500 as a CHP plant is $4,100,000. If the energy generated can be sold or used to offset future purchases a net energy cost benefit of $604,120 results. It is possible that this system will support a 7-year simple payback.

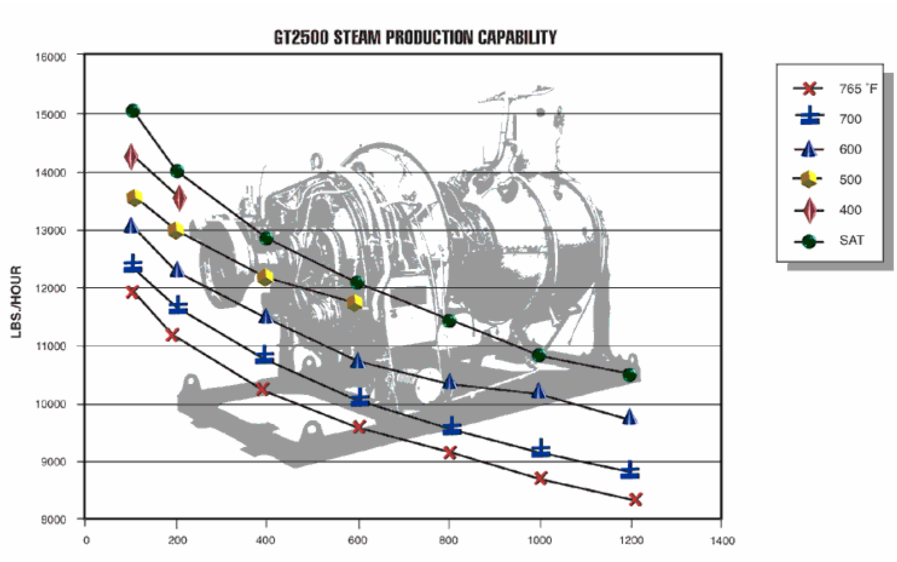
> Maintenance

This is a technically involved piece of equipment that will require training for City Hall operators to ensure smooth operation. The manufacturer will provide training and assist with the first two maintenance service reviews. Subsequent maintenance requirements will be handled by City staff. Service is based on hours of operation and typically is required every 4,000 hours. Based on a 2,200-hour operation, a major maintenance review will be required every other year. An ongoing inspection will be required as would be the case with any energy plant such as a large boiler would.

> Product specification data sheet



Power output curve for the 2500 Combined Heat and Power system



Steam output curve for the 2500 Combined Heat and Power system

BUILDING USES INDICES

A common method of comparing a buildings' energy footprint is to calculate performance indices based on accepted units of energy and operation parameters, and then compare these against buildings of similar operation. City Hall is unique compared to typical office towers, as it is a public and administrative building; it has to be "open" for more than regular office hours and yet operate as a typical office tower. As a result, staff and citizens need to be able to use the facility in an occupied mode of operation for more than conventional office tower use. It is therefore imperative to provide the required energy in the most efficient manner possible.

The objective of this report is to reveal how the effect of the proposed energy conservation measures and renewable energy systems will permanently and consistently reduce the energy required to provide the services required as long as the building is used. This will be reflected in the building use indices.

The following tables illustrate the building energy use indices for the City Hall against other City properties for 2005.

Facility	Floor Area	Electricity Use	Electricity Demand	Load Factor	Average Power Factor	Heating Energy
	m2	kWh/m2	W/m2			ekWh/m2
City Hall	52,191	416.70	60.32	0.78	1.03	209.82
NYCC	33,398	279.57	47.22	0.68	1.01	335.56
SCC	30,003	252.88	41.56	0.69	1.00	54.89
EYCC	8,364	208.01	53.32	0.45	1.01	150.39
Metro Hall	66,383	231.59	54.25	0.49	0.99	101.74
703 Don Mills	12,361	633.80	86.40	0.84	0.98	174.20
Average	33,783	312.84	54.70	0.65	1.00	167.42

Building energy use indices for similar properties in Toronto

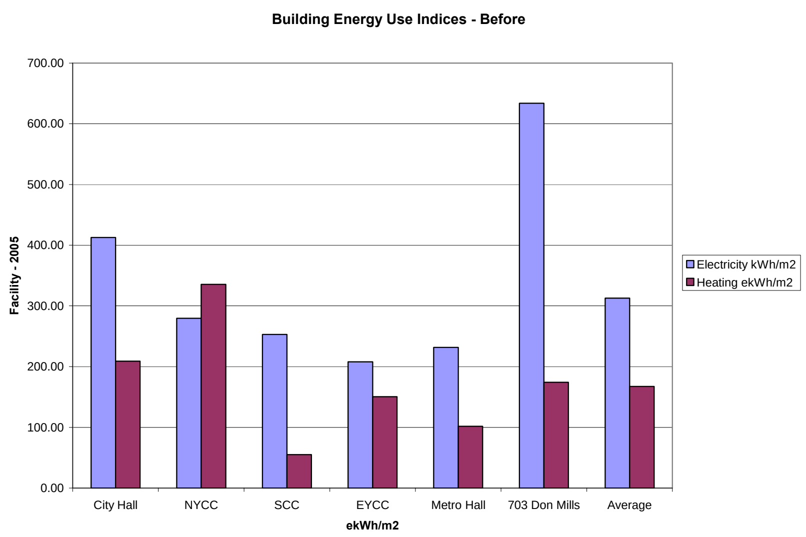
When we implement the measures recommended and reviewed in this report, the following energy indices result. The measures selected to present these indices are:

Facility	Floor Area	Electricity Use	Electricity Demand	Load Factor	Average Power Factor	Heating Energy
	m2	kWh/m2	W/m2			ekWh/m2
City Hall	52,191	309.0	39.98	0.78	1.03	101.1
NYCC	33,398	279.57	47.22	0.68	1.01	335.56
SCC	30,003	252.88	41.56	0.69	1.00	54.89
EYCC	8,364	208.01	53.32	0.45	1.01	150.39
Metro Hall	66,383	231.59	54.25	0.49	0.99	101.74
703 Don Mills	12,361	633.80	86.40	0.84	0.98	174.20
Average	33,783	312.84	54.70	0.65	1.00	167.42

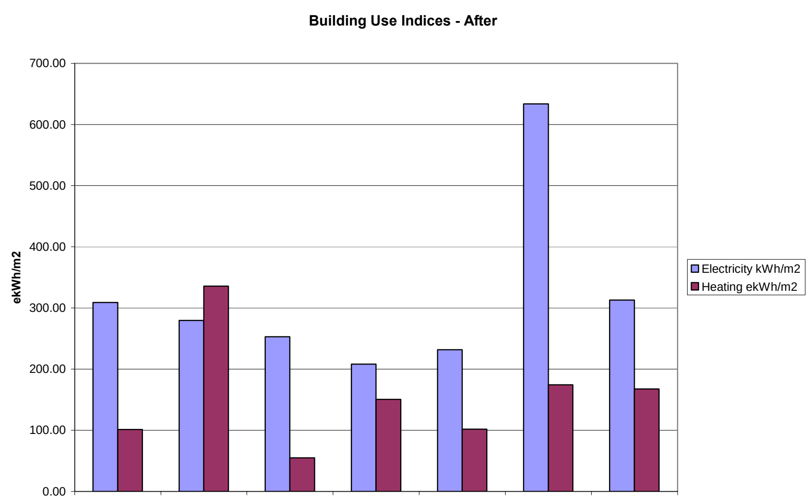
Building energy use indices for City Hall after the recommended measures are in place

This indicates a potential for about a 26% reduction in electrical use and a 48% reduction in steam heat use per year. This puts the City Hall in the same energy index as the much newer Metro Hall. The cost to achieve these predicted savings is $8,968,397 resulting in annual cost savings of about $1,074,127. This investment would be cash positive in about 8.3 years assuming no energy escalation.

The cost of $20,000 to develop Building Energy Use Indices for City Hall represents a first-year evaluation and report of the measures taken. It also includes an estimate to retain a LEED certified auditor to prepare a report on the potential to submit for LEED certification. This opportunity appears feasible, and application should be prepared and submitted. (See LEED Certification).



This chart illustrates the energy use per square meter of floor area for some representative City buildings in 2005. The units are based on equivalent kWh of energy, so steam is converted to its equal in electricity.



This chart shows how the building energy use indices would look for the City Hall if it were to implement the recommendations described in the report. Notice how the City Hall compares with the much newer Metro Hall with respect to heating. It would also be very close to the average for electricity use.

LEED CERTIFICATION

City Hall is embarking on some significant energy savings and sustainable initiatives that could enable an application for LEED certification. This would provide a testament to the commitment to reducing the energy footprint of City Hall and help lead the way for others to attempt the necessary programs in Toronto.

LEED (Leadership in Energy and Environmental Design) is dedicated to promoting and accelerating the design and construction of high performance buildings. The Canada Green Building Council holds the licence for LEED in Canada. Both new and existing buildings can qualify.

>Siting considerations

The efforts to reduce the energy footprint of City Hall may be appropriate for LEED certification. The concepts considered in this report enable point accumulation that may allow certification under the LEED criteria. The renovation of Nathan Phillips Square would also qualify for points depending on the systems and designs incorporated.

> Budgets and benefits

Certification begets credibility and the LEED program is an increasingly recognized standard of energy consciousness in North America. By considering and striving for LEED certification, City Hall would be committing to ongoing energy and environmental consideration for the life of the facility. It also ensures recognition as an energy and environmentally aware facility.

As this is an existing building, the first option is to be “certified” within the criteria of the LEED program. Each energy conservation action or renewable energy system provides points. When the total is 26 points or more, certification is possible. There are four divisions that allot points and one division for design concepts. These are:

- Onsite development
- water and energy efficiency
- material selection
- Indoor air quality
- innovation of design

For example, the green roof would be eligible for between three and six points; the lighting would be eligible for about three points. Lighting controls, depending on the options, allow for two - three more points. Controls, monitoring and evaluation also add to the point count.

Once the conservation and renewable energy projects have been decided upon, LEED certification potential should be evaluated. The cost is to retain an accredited LEED surveyor and begin the process of certification. The final point count will depend on the projects implemented and the commitment to ongoing monitoring and analysis.

INCENTIVES AVAILABLE

The only source of funding for this project is from Enbridge, which will provide incentives for any gas savings on the project at a rate of between \$0.05 per m3 and \$0.10 per m3 of natural gas saved. To qualify for the higher rate it is necessary to complete three or more gas-saving measures in a building. Some of the eligible measures include control upgrades, boilers and envelope sealing. Lighting and other measures that specifically save electricity only are not eligible.

The renewable energy projects are subject to CRA Class 43.1 tax advantages only if the City arranges to lease equipment and have the leasing company gather the credits an and pass them on to the City as beneficial lease terms.

The Renewable Energy Deployment Initiative (REDI) is not available as of this writing. This program is still up for review and may be brought back later. The wind turbine and photovoltaic projects would be eligible.

The City of Toronto has an incentive of \$10/m^2 of approved green roof area for the installation of green roof systems. The maximum is \$20,000 per installation.

SUMMARY TABLE OF RECOMMENDATIONS

Micro-wind turbine	122,500	86,800	8,680	n/a	n/a	17	1,250
Photovoltaics - 60	145,000	12,630	1,263	n/a	n/a	>25	1,250
Photovoltaics – 120*	290,000	25,260	2,526	n/a	n/a	>25	1,500
Window photovoltaics-30	270,000	1,613	161	n/a	n/a	>25	1,250
Window photovoltaics-132*	650,000	6,051	605	n/a	n/a	>25	1,500
Green roofs	1,350,000	198,000	19,800	35	1,030	>25	4,000
Window film	650,000	342,685	34,269	849	24,931	11	n/a
Window replacement**	2,637,612	808,875	80,888	9,991	293,235	7.1	4,250
Induction unit upgrades	944,800	55,000	5,500	960	28,176	>25	4,250
Induction unit control valves	662,000	157,808	15,781	681	19,987		
Electric control valves	152,000	64,800	6,480	280	8,218	10.4	1,000
Chiller plant VFDs	188,000	113,686	11,369	n/a	n/a	16.5	1,500
Fountain pump control	3,000	27,994	3,079	n/a	n/a	<1	450
Council chamber lights	9,650	43,820	4,382	n/a	n/a	2.2	150
VIP parking garage	1,800	1,870	187	23.1	678	2.1	9
Podium and office lights	670,475	350,551	35,054	n/a	n/a	19.1	1,250
Office programmable stats	78,660	164,160	16,416	n/a	n/a	4.8	
Walkway program stats	1,200	25,000	2,500	n/a	n/a	1	
Daylight harvesting	45,750	78,810	8,669	n/a	n/a	5.3	600
Steam system + DHW	70,800	-326,860	-32,686	6,900	201,840	.5	1,000
CHP***	4,250,000	5,610,000	561,000	35,200	43,120 net	7	4,000
Deep Lake Water Cooling	2,000,000	3,410,510	302,198	n/a	n/a	6.6	
External lighting/LED	35,950	40,108	4,011	n/a	n/a	9	750
Remote hybrid lights****	172,000	n/a	n/a	n/a	n/a	n/a	2,300
Building performance	20,000						12,000

•*One of each of the PV options has been selected.
•**Window replacement is compatible with window film. The film reduces glare.
•***CHP energy is generated so does not reflect saving. Any energy generated would offset that bought from Toronto Hydro and EnWave. Natural gas would have to be installed and purchased. The cost of natural gas is not shown here but is assumed at $990,000/yr for 2,200 hrs/yr use.
•**** Remote hybrid lights are mentioned for information and consideration along the Podium walk. Their use may depend on the new Nathan Phillips Square design.
Table of all systems, potential savings, costs and benefits reviewed

> Summary table of recommendations for renewable energy and conservation systems for City Hall

DESCRIPTION	NET COST	ELECTRICITY saved		STEAM saved		PAYBACK	Maintenance	GHG
	$	kWh/yr	$/yr	kLbs/yr	$/yr	Yrs	$/year	Tonne/yr
Micro-wind turbine	122,500	86,800	8,680	n/a	n/a	17	1,250	61
Photovoltaics – 120	290,000	25,260	2,526	n/a	n/a	>25	1,500	17
Green roof systems	1,350,000	198,000	19,800	35	1,030	>25	4,000	151
Window Photovoltaics-132	650,000	6,051	605	n/a	n/a	>25	1,500	5
Deep Lake Water Cooling	1,350,000	3,410,510	302,198	n/a	n/a	6	n/a	2,381
Chiller plant VFDs	188,000	113,686	11,369	n/a	n/a	16.5	1,500	79
VIP parking garage	1,800	1,870	187	23.1	678	2.1	9	8
Fountain pump control	3,000	27,994	3,079	n/a	n/a	<1	450	19
Window replacement	2,637,612	808,875	80,888	9,991	293,235	7.1	4,250	7,021
Window film	650,000	342,685	34,269	849	24,931	11	n/a	549
Steam system + DHW	70,800	-326,860	-32,686	6,900	201,840	.5	1,000	2,226
Electric control valves	152,000	64,800	6,480	280	8,218	10.4	1,000	226
Council chamber lights	9,650	43,820	4,382	n/a	n/a	2.2	150	30
Daylight harvesting	45,750	78,810	8,669	n/a	n/a	5.3	600	55
Podium and office lights	670,475	350,551	35,054	n/a	n/a	19.1	1,250	245
Office programmable stats	78,660	164,160	16,416	n/a	n/a	4.8	2,000	114
Walkway program stats	1,200	25,000	2,500	n/a	n/a	1	500	17
Induction unit control valves	662,000	157,808	15,781	681	19,987	18.5	4,250	309
External lighting/LED	35,950	40,108	4,011	n/a	n/a	9	750	28
Induction unit upgrades*	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Building performance/LEED	20,000	n/a	n/a	n/a	n/a	n/a	12,000	n/a
TOTALS	**8,968,397**	**5,619,928**	**524,208**	**18,759**	**549,919**	**8.3**	**33,709**	**13,541**