ABSTRACT: Institutional facilities share a unique characteristic because they form the fabric of their hosts from cradle to grave. In large urban centres, universities, hospitals, government buildings and many similar institutional facilities cannot simply be sold or abandoned in favour of new accommodations. Demolition followed by reconstruction is one possibility, however, often these buildings are historically designated or their replacement value cannot be afforded.

This paper examines the issues, alternatives and strategies for sustaining institutional facilities within the context of an established campus at the University of Toronto, Canada largest public university. The St. George campus of the University of Toronto is located on a 65-hectare site in the heart of the city and serves an academic community of some 8,000 faculty and staff, and more than 43,000 full and part-time students. Approximately 150 buildings comprise over 1 million square metres of occupied space, ranging in age from 145 years to the present, with a mean age in the range of 75 years. Decades of government under-funding to the educational sectors in the province of Ontario have resulted in the neglect of proper maintenance, repair and replacement of building fabrics and equipment. As a result, an overwhelming backlog of deferred maintenance continues to financially burden the academic community, both in terms of maintenance and operating budgets. Further, this stock of buildings, which exhibits high non-renewable energy consumption patterns, continues to impair national goals to achieve greenhouse gas reductions under the Kyoto Protocol.

Research undertaken to identify sustainable future scenarios for the management of institutional facilities focuses on prudent investments in energy conservation measures integrated within necessary expenditures aimed at addressing deferred maintenance. A life cycle cost approach is taken to determine the cost effectiveness of various energy conservation strategies that also contribute to the restoration and improved durability of fabrics and equipment. Results presented in this paper indicate that while it is not possible in the short term to improve the energy efficiency of existing institutional facilities to a level approaching that of new buildings, significant improvements can be realized in the medium to long term, such that their economic and environmental viability can be sustained without compromising present needs.

Conference Topic: 4 Energy and Urban Planning
Keywords: life cycle cost, deferred maintenance, durability, energy efficiency

INTRODUCTION

Most buildings nowadays, except for the very "green", are characterized by high energy consumption patterns, coming mainly from fossil fuels, and this has provoked severe environmental damage. The envelope components of buildings play a primary role in energy conservation, and therefore it is important to assess the performance of the building envelope and to propose corrective measures in existing buildings that lead to improving their energy efficiency and life cycle cost. Institutional buildings such as those found on many educational campuses exhibit common traits: high energy consumption patterns; low efficiency building technologies; high dependence on artificial climatization systems, severe economic burdens; and as importantly, questionable comfort conditions and quality of indoor environment. As a result, human intellectual productivity and health conditions may also be impaired in such buildings.

During the second half of the 20th century, the low cost of energy encouraged excessive consumption patterns in many academic buildings whose design and construction had departed from traditional and proven past precedents. Many of these "innovations" were highly susceptible to deterioration under cold climate conditions; unfortunately their inferior durability and potential future burdens were not foreseen. It was after the oil energy crisis of 1973 that the situation changed drastically and a decade after,
from the late 1980s, that scientific evidence correlated damage to the planet with the mounting economic burden on building owners and tenants associated with non-renewable energy consumption. This situation is now recognized as a global problem demanding urgent solutions. Furthermore, after approximately half a century of service for this cohort of “modern” buildings, under the so-called “International Style Architecture”, in addition to exhibiting high energy consumption patterns, mainly due to low efficiency envelopes and artificial climatization energy systems, there is also strong evidence of accelerating deterioration to the building fabric. The present situation finds that maintenance and energy costs are nearly equal burdens on institutional operating budgets. The promise of 20th century architecture has not been fulfilled and sustainable alternatives have not been well received, tending to produce aesthetic and formal solutions that are far from general acceptance.

The current situation is disturbing as universities are examples of public sector building owners from whom it would be reasonable to expect a commitment to the future well-being of the surrounding communities and a suitable relationship with the natural environment. In view of this reality, some NGO’s have proposed alternative solutions. One of the most promising approaches is that presented in the Talloires Declaration, established in 1990 by a number of university leaders, named as University Leaders for a Sustainable Future [1], who are committed to assisting colleges and universities in making sustainability an integral part of curriculum, research, operations and outreach. ULSF is also the secretariat for signatories of the Talloires Declaration of 1990, which has been signed by more than 300 university presidents and chancellors, around the world, representing 43 countries that are now signatories to the declaration. The mission of the ULSF is to make sustainability a major focus of teaching, research, operations and outreach at colleges and universities worldwide. ULSF pursues this mission through advocacy, education, research, assessment, membership support, and international partnerships to advance education for sustainability. As an example, Article 5 of the Talloires Declaration states that universities should:

“Set an example of environmental responsibility by establishing institutional ecology policies and practices of resource conservation, recycling, waste reduction and environmentally sound operations.”

The ULSF also states that: “Higher education is beginning to recognize the need to reflect the reality that humanity is affecting the environment in ways which are historically unprecedented and which are potentially devastating for both natural ecosystems and ourselves. Since colleges and universities are an integral part of the global economy and since they prepare most of the professionals who develop, manage and teach in society's public, private and non-governmental institutions, they are uniquely positioned to influence the direction we choose to take as a society. As major contributors to the values, health and well being of society, higher education has a fundamental responsibility to teach, train and do research for sustainability.

We believe that the success of higher education in the twenty-first century will be judged by our ability to put forward a bold agenda that makes sustainability and the environment a cornerstone of academic practice.”

Unfortunately, these points of view are not universally held and this presents a barrier to institutions, building owners, designers and constructors who wish to implement these principles.

2. SUSTAINABILITY AND BUILDING DESIGN

It is generally accepted that the term “sustainable development” means different things to different people, but the most frequently quoted definition is from the report Our Common Future (also known as the Brundtland Report) [2]:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Therefore, sustainable development focuses on improving the quality of life for all of the Earth's citizens without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely. It requires an understanding that inaction has consequences and that we must find innovative ways to change institutional structures and influence individual behaviour. It is about taking action, changing policy and practice at all levels, from the individual to the international. It is also true that sustainable development is not a new idea. Many cultures over the course of human history have recognized the need for harmony between the environment, society and economy. What is new is an articulation of these ideas in the context of a global industrial and information society and the understanding that the inhabitants and societies of the planet need to evolve into a more mature condition, harmoniously related to the natural environment.

During the last decade, there has been some relative progress on developing the concepts of sustainable development. In 1992 leaders at the Earth Summit in Rio de Janeiro, Brazil, built upon the framework of the Brundtland Report to create agreements and conventions on critical issues such as climate change, desertification and deforestation. They also drafted a broad action strategy - Agenda 21 - as the workplan for environment and development issues in the coming decades.

Throughout the rest of the 1990s, sustainability plans have been developed at national and international levels. However, other subsequent Earth Events, such as the Earth Summit +5, Kyoto 1997, Buenos Aires COP-4 1998, La Haya 2000, Rio + 10, and Johannesburg 2002, have not shown significant progress in neither major sustainable development objectives, nor on most global and local environmental concerns.
3. UNIVERSITY OF TORONTO CASE STUDY

This paper now turns to a case study of a major public institution that is grappling with the challenge of achieving performance and sustainability. It is worth noting that while the University of Toronto is not a signatory to the *Talloires Declaration*, it has voluntarily developed environmental policies that are strongly aligned with these sustainability principles.

The St. George campus of the University of Toronto is located on a 65-hectare site in the heart of the city and serves an academic community of some 8,000 faculty and staff, and more than 43,000 full and part-time students. Approximately 150 buildings comprise over 1 million square metres of occupied space, ranging in age from 145 years to the present, with a mean age in the range of 75 years. Decades of government under-funding to the educational sectors in the province of Ontario have resulted in the neglect of proper maintenance, repair and replacement of building fabrics and equipment [3]. As a result, an overwhelming backlog of deferred maintenance continues to financially burden the academic community, both in terms of maintenance and operating budgets. Further, this stock of buildings, which exhibits high non-renewable energy consumption patterns, continues to impair national goals to achieve greenhouse gas reductions under the Kyoto Protocol.

![Figure 1 – Arial photograph of the St. George Campus at the University of Toronto, 1999.](image)

The analysis and discussion which follows is based on part of a study supported by the Connaught Fund to examine the life cycle implications of various facilities management strategies. A first step in the study involved the collection of facilities data for the St. George Campus, as summarized in Table 1.

<table>
<thead>
<tr>
<th>Facility Data for St. George Campus at University of Toronto.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Building Floor Areas</strong></td>
</tr>
<tr>
<td><strong>Annual Maintenance Cost</strong></td>
</tr>
<tr>
<td><strong>Annual Energy Cost</strong></td>
</tr>
<tr>
<td><strong>Replacement Value</strong></td>
</tr>
<tr>
<td><strong>Deferred Maintenance</strong></td>
</tr>
<tr>
<td><strong>Facilities Condition Index</strong></td>
</tr>
</tbody>
</table>

Energy costs as per 2002/03, all other data as of 12/31/2003. All currency is in Canadian dollars.

Using data provided by facilities management, a life cycle cost analysis was performed using an accepted North American methodology [5], and the parameters set out in Table 2. The critical parameters when using the modified uniform present worth measure are the study period, and the differential between the discount or interest rate, and the escalation rate for energy. Energy prices for the 2002/03 academic year were used in the analyses.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low</th>
<th>Current</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount Rate</td>
<td>3.0%</td>
<td>4.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Escalation Rate</td>
<td>2.0%</td>
<td>6.5%</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

25 and 75 year study periods considered in major study. Based on discount (interest) rate and energy price escalation rate projections, the current and high scenarios are considered more probable than the low scenario.

In order to grapple with the complexity of the campus facilities, a simplified approach to energy modelling was employed using the EE4 Screening Tool, developed by Natural Resources Canada [6]. The tool conveniently compares the performance of proposed or existing facilities against the requirements of the Model National Energy Code for Buildings [7]. The software yields annual energy consumption, energy costs and associated CO₂ emissions for the particular mix of non-renewable energy sources consumed by the facilities.

Estimates of potential energy savings were derived by embedding energy retrofit strategies within deferred maintenance work, and included:

1. Adding thermal insulation to roof replacements;
2. Upgrading glazing performance when fenestration systems are retrofit;
3. Incorporating air leakage control coupled to insulated cladding systems for deteriorated exterior wall assemblies;
4. Installing heat recovery on ventilation systems;
5. Replacing obsolete physical plant with energy efficient mechanical equipment; and
6. Implementing lighting system retrofits, by means of replacing old lighting fixtures with new generation, high efficiency luminaries, and converting from CRT to LCD computer monitors.

These strategies were complemented by potential energy savings associated with occupant behaviour modification, reinforced by an energy efficiency campus program. Historical data that has not been published by the University of Toronto Department of Facilities and Services indicated that following the 1970s oil crisis, behaviour modification yielded as much as a 20% reduction in energy consumption – a trend that reversed as the cost of energy decreased relative to the cost of living, but may also be attributable to increased demand for air-conditioning and computer terminals.

Table 3 provides a comparison between: the level of energy efficiency mandated under the 1997 Model National Energy Code for Buildings; the existing level of energy efficiency for the St. George Campus at the University of Toronto; and the feasible level of energy performance achievable with an appropriate blend of energy conservation measures embedded within deferred maintenance work. The potential annual savings are based on the difference between the existing and feasible scenarios.

<table>
<thead>
<tr>
<th>GJ</th>
<th>$CDN</th>
<th>$CO2 (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNECB</td>
<td>1,123,610</td>
<td>20,635,975</td>
</tr>
<tr>
<td>Existing</td>
<td>1,364,339</td>
<td>25,435,490</td>
</tr>
<tr>
<td>Feasible</td>
<td>1,137,131</td>
<td>20,884,294</td>
</tr>
<tr>
<td>Savings</td>
<td>247,808</td>
<td>$4,551,196</td>
</tr>
</tbody>
</table>

Table 3 – Annual energy consumption, costs and emissions indicating potential annual savings.

The analyses indicate that it is unlikely the campus can achieve the MNECB level of energy efficiency as a whole, but that there remains a significant potential for savings. Approximately $4.5 million in annual energy costs may be avoided through appropriate energy conservation initiatives, while achieving almost a 16,000 tonnes annual reduction in carbon dioxide emissions. The financial potential for greenhouse gas credits, which is very significant, has not been explored in this paper.

This data was subsequently fed into a life cycle cost model that explored varying degrees of energy efficiency measures. The following assumptions were employed:
1. The energy conservation measures would actually be phased in over several years; however to simplify the economic analyses, it was assumed these would all occur at a single point in time;
2. Offsetting this bias towards capital recovery, it was assumed that the slowing of serious deterioration by strategically addressing critical building conditions would save massive future expenditures roughly equal to the delayed savings that would be realized; and
3. Improving the conditions of existing facilities and management practices could yield a 5% reduction in repair/maintenance budgets, acknowledging that the captured energy savings would actually boost this budget to pay for deferred maintenance work.

Tables 4 and 5 indicate the potential savings associated with varying degrees of aggressiveness with respect to energy conservation. Table 4 indicates the current energy price escalation scenario, and Table 5 presents the results for a high energy price escalation scenario. A 25-year study period was selected to correspond with the useful service life of many of the retrofit strategies, accepting that projections beyond this time are highly speculative and unreliable.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>LCC $CDN</th>
<th>Savings $CDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>$4,143,874,664</td>
<td>$0</td>
</tr>
<tr>
<td>5% &amp; 5%</td>
<td>$4,065,943,924</td>
<td>$77,930,740</td>
</tr>
<tr>
<td>10% &amp; 5%</td>
<td>$4,022,008,546</td>
<td>$121,866,118</td>
</tr>
<tr>
<td>20% &amp; 5%</td>
<td>$3,934,137,789</td>
<td>$209,736,875</td>
</tr>
<tr>
<td>38% &amp; 5%</td>
<td>$3,776,909,829</td>
<td>$366,964,835</td>
</tr>
</tbody>
</table>

Note that the convention for % & % notation in scenario column indicates annual reduction in energy consumption and repair/maintenance, respectively.

Table 4 – Life cycle cost (present worth of facilities, energy, repair and maintenance) for a 25-year study period assuming the current energy price escalation scenario.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>LCC $CDN</th>
<th>Savings $CDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
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<td>$366,964,835</td>
</tr>
</tbody>
</table>

Table 5 – Life cycle cost (present worth of facilities, energy, repair and maintenance) for a 25-year study period assuming the high energy price escalation scenario.

5. OBSERVATIONS

The most important finding that stems from the analyses is that energy savings can substantially contribute to the affordability of deferred maintenance when this overdue work is integrated with appropriate energy conservation measures. The deferred maintenance reported at the end of 2003 ($375,278,044 CDN) can be feasibly addressed with an aggressive energy conservation strategy under the current energy price escalation rate scenario. In the case of the high energy price escalation scenario, energy savings can go beyond funding deferred maintenance and be directed toward other worthy sustainability initiatives. It remains to be seen which energy conservation scenario may be attained in practice at the University of Toronto, however, the economic burden of deferred maintenance may be considerably reduced through intelligent facilities management.
Other interesting observations related to the study include:

1. In general, there is a low level of academic focus on sustainable building design education and a lack of interdisciplinary initiatives aimed at the challenges of sustaining institutional infrastructure, both at the University of Toronto and most North American universities. There remains no formal linkage between the academic and the administrative (facilities management) cultures on campus, despite the fact that considerable expertise exists among faculty, researchers and graduate students. There is lack of institutional programs on energy efficiency in the vast majority of North American universities; which need to be implemented in a short and long term basis, and also, little attention has been paid to promote the use of renewable energies in buildings.

2. Facilities management remains relatively unsophisticated when compared to other fields of study in the university, and this has been identified by others [8]. Currently, the tracking systems for dealing with maintenance, repair and replacement are geared towards accounting structures rather than optimising life cycle costs and overall performance [9]. This may in part be attributable to the “blue collar” nature of facilities management and the view held by many academics that it is not a subject worthy of serious academic endeavour. The potentially severe impacts of deteriorating and inefficient physical infrastructure have not yet been experienced and this may also contribute to a lack of awareness of our dependence on buildings and services in the context of a prevailing cold climate.

3. Technology rather than behaviour modification continue to dominate the North American facilities management dogma. The heating of vestibules and storage areas, the air conditioning of hallways and excessive lighting levels in most building areas with no lighting control whatsoever are testimony to the standard thinking that governs mechanical and electrical system design. As long as building occupants are not educated on how to interact and control their building environment, buildings are left to control systems far inferior to human intelligence.

4. Students remain the most enthusiastic supporters of sustainability initiatives and have far fewer preconceptions about what is feasible.

5. The approach presented in this work can also lead to important environmental benefits for countries like Canada, and in particular for cities like Toronto. Canada is committed to reduce its CO₂ emissions by 30% from 1990 levels, and the costs to implement the Kyoto Protocol are about CDN$ 20 billion per year. According to Canadian government estimates, the Kyoto Protocol will cost Canada from 2-6% of its GDP per year, beginning in 2008. Other predictions by 2012 are as follows: Kyoto would increase gas taxes by 30%; 30,000 jobs will be lost in the Great Toronto Area; the auto industry will contract by 13%, among other negative consequences that clearly indicate that there will be a huge and adverse economic impact on Toronto.

4. THE ROLE OF SUSTAINABILITY FOR EDUCATIONAL INSTITUTIONS

It is uncontroversial to state that for educational institutions "sustainability" should imply that the critical activities are (at a minimum) ecologically sound, socially just and economically viable, and that they will continue to be so for future generations. A truly sustainable educational institution, school, college or university should emphasize these concepts in its curriculum, as well as in its teaching and research activities, preparing students to contribute as working citizens to an environmentally sound and socially just global society. The institution would function as a sustainable community, embodying responsible consumption of energy, water, food, and natural resources, treating its diverse members with respect, and supporting these values in the surrounding community aimed at promoting an effective and positive "cascade multiple effect" in the society.

It is important to mention that In December 2002, the United Nations General Assembly adopted a resolution declaring a "Decade of Education for Sustainable Development" (DESD) to begin on January 1, 2005. The UN Educational, Scientific, and Cultural Organization (UNESCO) are serving as the lead agencies of this Decade, and nations are being encouraged to establish their own decade-oriented initiatives. Some NGO's (mainly: The Global Higher Education for Sustainability Partnership (GHESP), which includes ULSF, the International Association of Universities (IAU), COPERNICUS-CAMPUS, and UNESCO), are already concentrating resources on the DESD at both national and international levels aimed at promoting education for sustainability and also to assist higher educational representatives in reorienting their education, research, community outreach, and campus operations toward sustainability, that contribute to generate a new evolved global culture on our precious blue planet.

CONCLUSIONS

This paper represents a fragment of a larger study which is to be completed later this year. Based on the research conducted to date, the following conclusions are submitted for consideration:

1. Institutional buildings have the potential to become significantly more energy efficient and thereby reduce greenhouse gas emissions.

2. A significant improvement in energy efficiency can also be achieved through appropriately modified user behaviour and facilities management practices and programs.
3. Energy conservation measures may be intelligently integrated with deferred maintenance programs so that energy savings pay for maintenance, repair and replacement of building fabrics and equipment.

4. In many cases, it is not possible to improve all buildings to achieve current performance standards. It is unlikely that historical buildings will be retrofit to achieve high levels of energy efficiency – the only hope is renewable energy sources to power these buildings.

5. Universities and other public institutions can take a leadership role with respect to the new facilities they construct to set an example for the local communities. The University of Toronto has commissioned leading international architects for some of its recent facilities, however, there remains a bias towards first costs rather than life cycle costs.

6. Public sector organizations need to develop sound business and technical plans aimed at improving the performance and sustainability of their facilities. A lack of sophistication in facilities management relative to other disciplines at universities severely impairs intelligent decision making.

7. Most of the world’s modern buildings are prematurely aging and in need of unacceptable levels of maintenance and repair. While this may be acceptable in the private sector, public institutions must work together to develop effective design/construction standards and facilities management procedures for sustainable physical infrastructure serving the public good.

Optimising the performance and sustainability of institutional facilities remains an elusive goal in many parts of the world. In the context of a cold climate, buildings and services are essential to shelter and promote a knowledge-based economy. Libraries, laboratories, lecture halls and offices are not luxuries that can be virtually replaced. Public institutions continue to represent cultural resources that are vital to a sustainable future, and hence deserve intelligent consideration and wise investment [10].

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