Building Simulation 2005

Ninth International IBPSA Conference
Montréal, Canada
August 15-18, 2005

ASSESSING SUSTAINABILITY STRATEGIES FOR INSTITUTIONAL FACILITIES USING CBIP SCREENING TOOL

Ted Kesik
Associate Professor
Faculty of Architecture Landscape and Design
University of Toronto
230 College Street
Toronto ON M5T 1 R2
ted.kesik@utoronto.ca

ABSTRACT

Institutional facilities embody the physical infrastructure of the communities they house. Aging institutional buildings, especially those within extensive central campuses, cannot easily be disposed of or abandoned in favour of new facilities. Demolition followed by reconstruction is one alternative, however, this is highly disruptive and often these buildings are historically designated or their replacement value cannot be afforded.

This paper examines the application of the CBIP Screening Tool software to help assess the issues, alternatives and strategies for sustaining institutional facilities within the context of an established campus at the University of Toronto, Canada's 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 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 Accord.

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 a deferred maintenance deficit. The CBIP Screening Tool software developed by Natural Resources Canada was employed on a fleet averaged model and the results fed into a life cycle cost analysis to assess 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.

INTRODUCTION

Energy modeling is commonly employed to optimize the thermal efficiency of buildings at the design stage, to size HVAC systems and to assess thermal retrofit measures in existing buildings. This paper indicates an application that combines energy modeling with life cycle costing to address a deferred maintenance deficit on a large university campus.

In an ideal world, all of the relevant data would be available to facilities management personnel who could then apply various software that could explore a number of plausible scenarios for sustaining the physical infrastructure of an institution [Teicholz, 1995]. Further, this would be an on-going process whereby resources could be prudently invested for the greatest benefit, according to feedback on interventions.

Unfortunately, this has not been the case across Canada. In 2000, the Association of Universities and Colleges of Canada reported an accumulated deferred maintenance deficit of CAD$3.6 billion with $1.2 billion deemed urgent, "meaning that the conditions should be attended to in the very near future to avoid further deterioration and increased costs." [AUCC, 2000]

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 organizations 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. 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." [ULSF, 1990]

In general, the approach supporting these attitudes and practices is commonly referred to by the term "sustainable development" as defined below:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [WCED, 1987]

There are numerous barriers to implementing sustainability at Canadian colleges and universities through an "ideal" facilities management approach, chiefly the insufficient allocation of funding by government to sustain physical infrastructure. On a practical level, complex facilities are difficult and costly to model on an individual building basis. The time and effort needed to obtain the physical data are considerable, and the process of assessing among various plausible scenarios is cumbersome. The simplified adaptation of a well-correlated software, such as CBIP Screening Tool, makes it possible to identify feasible strategies that may then be suitably adapted to similar building typologies within a diverse campus environment.

ST. GEORGE CAMPUS 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, and reflected in the support of research such as that being presented in this paper.

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 [University of Toronto, 2002]. 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.

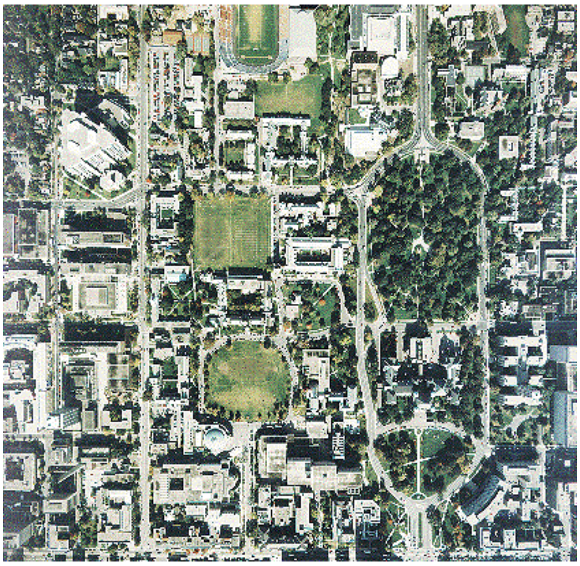

***Figure 1** – Arial photograph of the St. George Campus at the University of Toronto, 1999.*

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 rehabilitation strategies. A first step in the study involved the collection of facilities data for the St. George Campus, as summarized in Table 1.

It is important to note that the Facilities Condition Index (FCI) is the ratio of deferred maintenance to replacement value, almost 3 times the recommended level for institutional buildings [Fagan and Kirkwood, 1997]. This indicates decades of fiscal neglect for public universities by government, coupled with an aging building stock that requires extensive repair and maintenance to provide acceptable performance.

Table 1 *– Facilities data for St. George Campus at University of Toronto.*

Total Building Floor Areas	1,076,492 m2
Annual Maintenance Cost	$19,680,921
Annual Energy Cost	$25,435,491
Replacement Value	$2,585,259,869
Deferred Maintenance	$375,278,044
Facilities Condition Index	14.5%
Energy costs as per 2002/03, all other data as of 12/31/2003. Currency in Canadian dollars ($CAD) unless noted otherwise.	

Figure 2 *– A typical example of deferred maintenance on the St. George Campus where rehabilitation has the potential to improve durability and thermal performance.*

In order to grapple with the complexity of the relationship between deferred maintenance and energy efficiency improvements for campus facilities, a simplified approach to energy modeling was employed using the CBIP Screening Tool, developed by Natural Resources Canada [Beausoleil-Morrison et al., 2001]. The tool conveniently compares the performance of proposed or existing facilities against the requirements of the Model National Energy Code for Buildings [NRC, 1997]. It is used within the context of a commercial building incentives program to assess the eligibility of new commercial buildings for federal funding to support energy efficient design and construction. The software yields annual energy consumption, energy costs and associated CO_2 emissions for the particular mix of non-renewable energy sources consumed by the facilities.

The application of CBIP Screening Tool software followed the process depicted in Figure 2. After gathering the existing data for the St. George Campus, a simplified facilities model was developed. The reasons for simplifying the existing data are as follows:

1. The campus buildings employ a number of different space conditioning and domestic water heating fuel types and technologies.
2. Part of the campus district heating and electricty is delivered through a co-generation plant.
3. Cooling in the buildings is provided by a central chilling plant serving some of the facilities, and separate cooling equipment serving other parts of the campus. In many instances, older offices are cooled with window-mounted air-conditioners.
4. The type and condition of building envelopes varies considerably with many buildings having no thermal insulation and single glazed windows, versus more modern counterparts that are thermally efficient.

The simplified facilities model resides on a spreadsheet as a single equivalent building that is intended to exhibit the same characteristics as the aggregated campus data in terms of energy consumption.

The CBIP Screening Tool is used to determine the equivalent building envelope thermal characteristics for walls, windows and roofs, and the thermal efficiencies of space conditioning and domestic water heating equiipment. This process is performed iteratively until a good fit is achieved between the simplified facilities model and the CBIP single building model.

After a reasonable model has been developed, it is possible to apply various retrofit strategies and energy management practices to the CBIP model. For example, carrying out deferred maintenance on roofing for a portion of the entire campus translates into a corresponding increase in the thermal resistance of the CBIP building model's roof. The same technique may be applied to other components and systems and the net energy savings with each of the measures, and then logical combinations of the measures, may be determined.

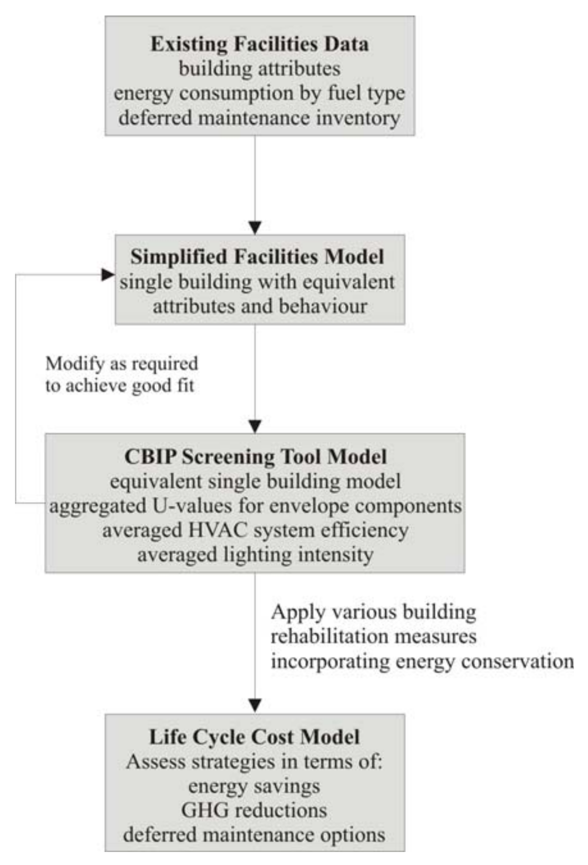

***Figure 2** – Facilities energy modeling process employing CBIP Screening Tool.*

Using data provided by facilities management personnel, a life cycle cost analysis was performed using an accepted North American methodology [ASTM, 1994], 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. Only the 25-year study period results are presented in this paper as many of the contemplated measures may only provide this length of service.

***Table 2** – Life cycle costing parameters used in the St. George Campus study.*

Scenario	Low	Current	High
Discount Rate	3.0%	4.0%	6.0%
Escalation Rate	2.0%	6.5%	10.0%
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.			

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

1. Adding thermal insulation to roof membrane 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 (MNECB); 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, and represent approximately a 17.9% reduction in energy consumption.

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

	GJ	**$CAD**	**CO_2 (kg)**
MNECB	1,123,610	20,635,975	72,084,641
Existing	1,384,939	25,435,490	88,850,085
Feasible	1,137,131	$20,884,294	72,952,058
Savings	247,808	$4,551,196	15,898,028

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. It is important to note that the impact of user behaviour and reductions in maintenance costs were not considered in this initial round of analysis.

In the subsequent round of analysis, user behaviour and a reduction in annual maintenance costs were examined using 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 additional 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.

In both Tables 4 and 5, the final row assumes an annual 38% energy consumption reduction (consisting of an 18% reduction due to feasible rehabilitation measures, and an additional 20% reduction due to conserving user behaviour consistent with past observations), and a 5% reduction in annual maintenance costs.

***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.*

Scenario	**LCC $CAD**	**Savings**
Current	$4,143,874,664	$0
5% & 5%	$4,065,943,924	$77,930,740
10% & 5%	$4,022,008,546	$121,866,118
20% & 5%	$3,934,137,789	$209,736,875
38% & 5%	$3,776,909,829	$366,964,835
Note that the convention for % & % notation in scenario column indicates annual reduction in energy consumption and repair/maintenance, respectively.		

***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.*

Scenario	**LCC $CAD**	**Savings**
Current	$4,476,673,869	$0
5% & 5%	$4,382,103,169	$94,570,700
10% & 5%	$4,328,786,602	$147,887,267
20% & 5%	$4,222,153,469	$254,520,400
38% & 5%	$4,031,353,814	$445,320,055

The preceding analyses have not considered the value of emissions trading potential associated with making the St. George Campus more energy efficient. Under the umbrella of the Kyoto Protocol, emissions trading is an important part of the solution necessary to control greenhouse gas emissions. New greenhouse gas markets are emerging in countries, regions and corporate alliances around the world. It is highly foreseeable that the University of Toronto can sell its certified emission reduction (CER) at a fair market price that is estimated between USD$4.50 to USD$5.50 per tCO2eq (tonne of equivalent CO2) [CO2e, 2004]. More recent sources project a price range of CAD$2.00 to CAD$10.00 [cleanerandgreener.org, 2005]. It should be noted these credits are traded on an annual basis.

Table 6 below indicates the present worth of the greenhouse gas emission credits associated with the feasible energy conservation scenario presented in Table 3 (i.e., 72,952,058 kg reduction). Assuming the escalation rate for greenhouse gas credits will most likely correspond to the current or high economic scenarios, the present worth of the greenhouse gas (GHG) credits ranges approximately between CAD$2.7 and CAD$3.3 million. It is not unreasonab le to assume this could fund hard costs associated with implementing a more sophisticated facilities management software infrastructure.

***Table 6** – Present worth of greenhouse gas credits for a 25-year study period assuming three emission escalation scenarios.*

Economic Scenario	**GHG Credits Present Worth**
Low i=3%, e=2%	$1,754,873
Current i=4%, e=6.5%	$2,746,107
High i=6%, e=10%	$3,332,463
Above analysis assumes CO_2 valuation of CAD$5 per metric tonne.	

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 [Hitchcock et al., 1998]. 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 [Pullen, 2000]. 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 lends optimism to achieving important environmental targets under the Kyoto Protocol while enhancing the sustainability of vital cultural institutions such as universities.

THE FUTURE OF ENERGY ESTIMATING TOOLS IN BUILDING RESOURCE MANAGEMENT

Applications such as the CBIP Screening Tool are invaluable aids in developing appropriate strategies for managing buildings and facilities. Acknowledging the limitations of the CBIP Screening Tool and its specific purpose within a commercial building incentives program, it rapidly generates reliable estimates of energy savings and greenhouse gas reductions. In a post-Kyoto world this is an extremely important consideration for facilities managers and policy makers.

Energy estimating tools are preferable to more sophisticated energy simulation software in many instances because they are quick and easy to use, and are often at least as accurate as the initial data afforded the facilities manager. More accurate and detailed analysis may be pursued after feasible strategies have been identified using "fuzzier" estimating tools. Indeed, the future of energy estimating tools likely lies in the appropriate incorporation of fuzzy logic and expert rule sets to provide useful insights to decision makers.

The next logical development would be the stringing together of such "insight" tools to deal with life cycle costing exercises and the prioritization of facilities maintenance and rehabilitation activities. This is in keeping with the view that while the most important determinents of building life cycle performance are determined at the design stage, the actual realization of these potentials occurs after construction when the building stock may be managed as a social infrastructure resource.

CONCLUSIONS

This paper represents a fragment of a larger study which is soon to be completed. 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 pubic 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.
8. The development of reliable and easy to use estimating tools that provide initial insights to decisions makers is especially important in the field of facilities management. A suite of related applications that informs strategic policy development is essential to sustainable building resource management.

Optimising the performance and sustainability of institutional facilities are seldom achieved goals in practice. In cold climates like Canada, buildings and services are essential to shelter and support 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 [Hartkopf and Loftness, 1999].

ACKNOWLEDGEMENT

The author wishes to acknowledge the collegial assistance of the Department of Facilities and Services, University of Toronto, and the financial support of the Connaught Fund, University of Toronto and the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

American Society of Testing and Materials 1994. *Standard ASTM E 917-93, Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*, ASTM Standards on Building Economics, Third Edition.

AUCC 2000. *University Infrastructure*. Association of Universities and Colleges Canada. http://www.aucc.ca/publications/reports/2000/election/infrastructure_e.html

Beausoleil-Morrison, Ian, Rob Calla, Maria Mottillo, Julia Purdy, Paul Wyndham-Wheeler, Phylroy Lopez, Francois Dubrous, Mike Lubun 2001. *Using Building Simulation to Support an Energy Efficient Incentive Programme*. Seventh International IBPSA Conference, Rio de Janeiro, Brazil, August 13-15, 2001.

Cleanerandgreener.org 2005. *Emission Trading: Examples of Transactions* http://www.cleanerandgreener.org/environment/transactions.htm

Fagan, Marc M., and Dennis Kirkwood 1997. *Facility Condition Assessments: More than Just Making a List.* American Society for Healthcare Engineering, 34th Annual Conference & Technical Exhibition, July 15, 1997.

Hitchcock, Robert J., Mary Ann Piette, Stephen E. Selkowitz 1998. *Performance Metrics and Life-Cycle Information Management for Building Performance Assurance*. Proceedings of the ACEEE '98 Summer Study on Energy Efficiency in Buildings.

NRC 1997. *Model National Energy Code of Canada for Buildings 1997.* National Research Council, Ottawa, Canada.

Pullen, Stephen 2000. *Energy Assessment of Institutional Buildings.* Proceedings of ANZAScA 2000. 34th Annual Conference of the Australia & New Zealand Architectural Science Association. December 1-3, 2000. The University of Adelaide, Adelaide, Australia.

Teicholz, Eric 1995. *Computer-aided facilities management and facility conditions assessment software*. Facilities, Volume 13, Number 6, May 1995, pp. 16–19.

University of Toronto, December 2002. *Crumbling Foundations: Report on St. George Campus Facilities*. Department of Facilities and Services.

USLF 1990. *Talloires Declaration of 1990*. Composed in 1990 at an international conference by the University Leaders for a Sustainable Future in Talloires, France.

Volker Hartkopf, and Vivian Loftness 1999. *Global Relevance of Total Building Performance.* Automation in Construction 8, pp. 377-393, 1999.

WCED 1987. *Our Common Future.* World Commission on Environment and Development (WCED). Oxford University Press.