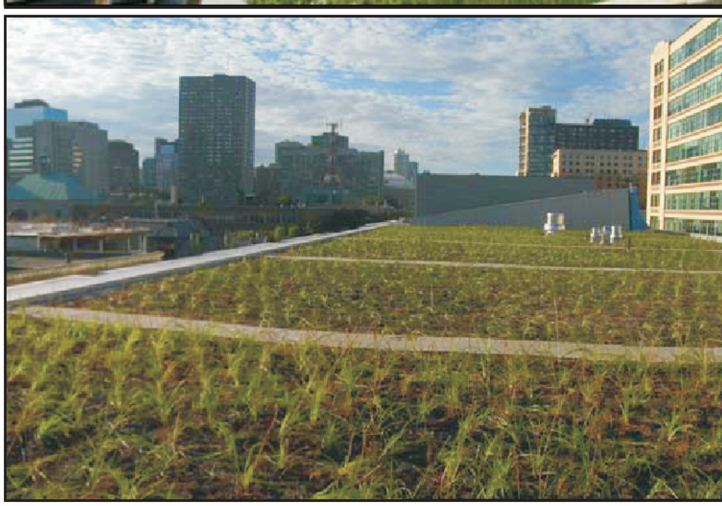
An Economic Analysis of Green Roofs:

Evaluating the costs and savings to building owners in Toronto and surrounding regions



Prepared by: Toronto and Region Conservation

July 2007

AN ECONOMIC ANALYSIS OF GREEN ROOFS:
Evaluating the costs and savings to building owners in Toronto and surrounding regions

A report prepared by:

Toronto and Region Conservation

under the

Sustainable Technologies Evaluation Program

In partnership with:

The Great Lakes Sustainability Fund
The Toronto and Region Remedial Action Plan
Orlando Corporation
The City of Mississauga
Fisheries and Oceans Canada
The City of Toronto

July 2007

NOTICE

PUBLICATION INFORMATION

Reports conducted under STEP are available at www.sustainabletechnologies.ca. For more information about the study, please contact:

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THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the real world data and analytical tools necessary to support broader implementation of innovative environmental technologies within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water and clean air technologies
- identify and address potential implementation barriers
- provide recommendations for guideline and policy development
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical structures; they may also include preventative measures, alternative urban site designs, and other innovate techniques that help promote more sustainable forms of living.

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ACKNOWLEDGEMENTS

This project was jointly funded by the following organizations:

- Government of Canada's Great Lakes Sustainability Fund
- Toronto and Region Remedial Action Plan
- City of Mississauga
- City of Toronto
- Orlando Corporation
- Fisheries and Oceans Canada

The following organizations and individuals have assisted in the completion of this report by providing information and/or expertise:

Professor Hitesh Doshi (Ryerson University)
Jamie Meil
Terry McGlade (Gardens in the Sky)
Bethanne Currie (Centre for Social Innovation)
Mike Buckley (Halsall and Associates)
Peter Kalinger (Canadian Roofing Contractors' Association)
Karen Liu (British Columbia Institute of Technology)
Bas Baskaran (Canadian National Research Council – Institute for Research in Construction)
Monica E. Kuhn (Monica E. Kuhn, Architect Inc.)

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EXECUTIVE SUMMARY

Background

The Greater Toronto Area (GTA) faces many of the environmental problems that are common in highly populated, urbanized municipalities, such as combined sewer overflows, air pollution, smog, and heat build-up. These problems stem largely from a lack of green space and abundance of impervious surfaces. Green roofs help to address these issues by replacing dark, impervious roofs with vegetated systems that retain stormwater runoff, enhance biodiversity, improve air quality, lower building energy use and create more attractive cityscapes.

Since 2005, the City of Toronto has been developing a green roof policy, which was approved by council in February 2006, and includes a commitment to greening new and existing roofs on municipal buildings where feasible and developing a pilot incentives program to assist with the capital costs of green roof construction. Various other municipalities in southern Ontario and across North America are considering or have already implemented such policies. Obtaining reliable local cost data is a key step in determining the nature and magnitude of government incentives that should be offered to encourage green roof industry development.

While significant progress has been made in the areas of green roof research and policy development in the GTA, building owners remain reluctant to build green roofs partly due to concerns that green roofs require higher capital and maintenance costs than conventional roofs, without the demonstration of offsetting benefits to the proponent. While there is general agreement that initial green roof costs are greater, what remains uncertain is the magnitude of this cost differential and the key life cycle factors that affect conventional and green roof costs.

Objectives

The primary aim of this study was to estimate the life cycle costs and savings associated with building and owning a green roof in the GTA. Costs related to structural modifications, materials and labour for installation, and long-term maintenance are discussed for both new and retrofit installations. The study focuses in particular on extensive installations which have been planted or seeded, and are above buildings that are heated during cold weather, but not necessarily air-conditioned. Cost variables included in the analyses were limited to those incurred by, or accruing to building owners or developers as these were the factors that were thought to most influence the decision to construct a green roof. An earlier study by the University of Ryerson (2005) addressed the economic value of the many public benefits offered by green roofs.

Approach

The life cycle costs of green roofs were estimated based on a variety of information sources, including literature, industry surveys, key informant interviews and supplier interviews. The literature review was the sole source of information on green roof energy savings and roof membrane longevity, and also provided important capital and life cycle cost information to supplement the interview and survey results. Cost data for local green roofs were collected through a survey distributed to individuals with knowledge of, or access to green roof cost data. Survey respondents consisted of green roof suppliers and installers, building managers or their representatives, and architects.

Telephone interviews were also conducted with representatives from several major Canadian companies that supply and/or install green roofs in order to obtain cost estimates of products currently on the market. All interviewees were asked to provide a per square foot cost range for their green roof systems, as well as a saturated weight. The weights helped to inform a discussion of the structural implications of building new and retrofit green roofs. Conventional roof cost and weight data were obtained from local literature (City of Toronto, 2005; Peck and Kuhn, 2002) and interviews with two representatives from development groups involved in construction of industrial buildings. Conventional roof costs obtained from these sources were also compared with estimates from green roof suppliers interviewed whose cost quotations included the underlying base roof (*i.e.* conventional roof).

Data obtained from industry surveying was entered into a spreadsheet database to facilitate price comparisons, identify trends, and determine averages. Information not available through surveying was estimated based on the literature review and key informant interviews. Data from surveys and other information sources were used as inputs to a life cycle costing tool developed by the Athena Sustainable Materials Institute. Cost analyses were conducted for a green and conventional roof on a model one-storey office building in Waterloo, Ontario. The data sources, assumptions and input values are clearly stated. The relative importance of individual inputs on life cycle costs was determined through alternative scenario analysis.

Costs

Installation and Labour

Figure 1 summarizes the installed capital cost of extensive green roof systems as obtained from two key literature sources (Peck and Kuhn, 2002 and GRHC, 2005), industry surveys, and supplier interviews. German averages from two other literature sources (Philippi, 2006; Beattie and Berghage, 2004) are also shown for comparison.

Lower German costs (shown in Figure 1) are a result of the well-developed green roof market in that country. There was significant cost overlap among the other sources of cost data. Capital costs for Canadian data sources range from a low of $6.00 to a high of $21.00 per square foot, not including the base roof. Key factors influencing green roof capital costs include the following:

- Size and complexity of the installation
- Building height (difficulty of transporting materials to roof on very tall buildings)
- Use of special features for enhancing aesthetics and safety of accessible green roofs (*e.g.* edging, walking paths, safety fencing)
- Local availability of materials

- Availability of labour-reducing technologies (*e.g.* growing media blower truck)
- Abundance of experienced local labour (*i.e.* installers, horticulturalists, architects)
- Market competition
- Availability of ready-made modular or complete systems (versus more expensive custom designed solutions)
- Need for structural modifications to increase load-bearing capacity on the roof

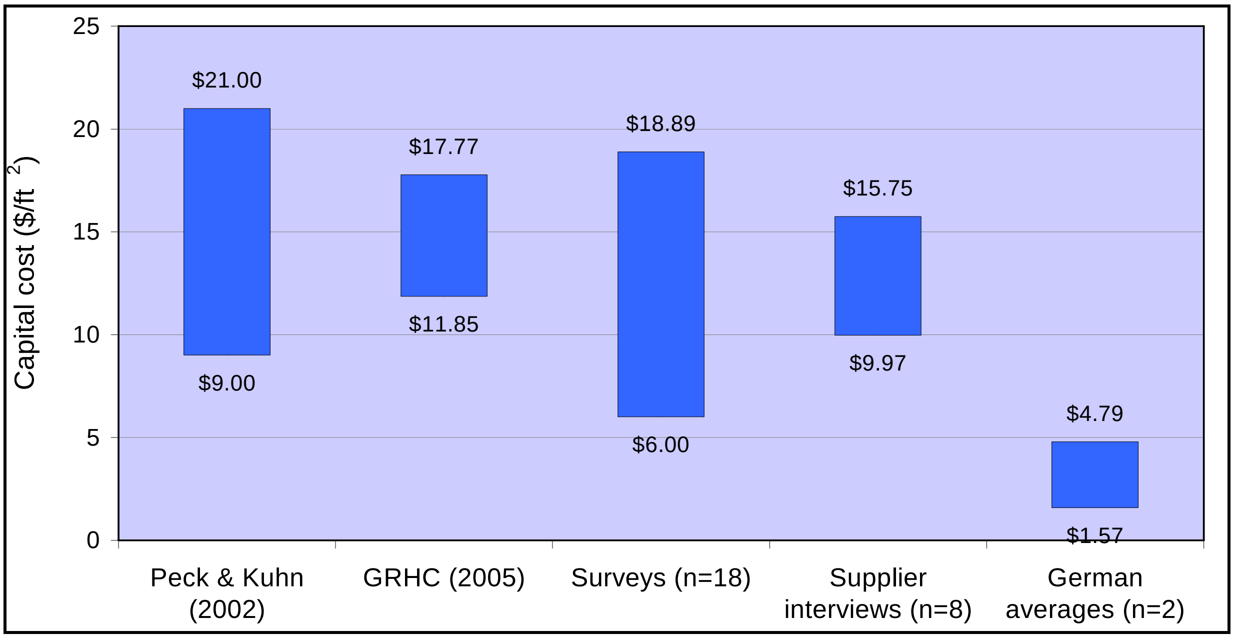

Figure 1: Summary of installed capital cost of extensive green roof systems from various sources

Among the 18 new and retrofit installations surveyed, only one respondent indicated that structural modification of the building design was required to accommodate the green roof. In this instance, the structural modification of the original building design increased the capital cost by 29%. The lack of structural modification costs listed for retrofit installations surveyed is likely due to the tendency for building owners to choose other non-green roof options if upon consultation with a structural engineer, it is determined that structural modifications are required.

Building Structural Modification

Depending on the version of the Ontario Building Code (OBC) in place at the time of building construction, many buildings may have been constructed with a load-bearing capacity as much as 18 lbs/ft^2 higher than what is required by the current version of the OBC (Peck and Kuhn, 2002). The removal of ballast or other surfacing aggregates – which can weigh between 10 and 12 lbs/ft^2 - may also allow for some additional weight to be accommodated (City of Portland, 2000; MAPC, 2005). Suppliers interviewed quoted green roof weights ranging from 8 to 50 lbs/ft^2, with several systems weighing less than 30 lbs/ft^2.

The additional cost associated with accommodating higher loads due to a green roof will vary widely based on building structure. In a tall building, the addition of weight associated with a green roof adds relatively little stress to the columns which are already capable of supporting significant weight. Conversely, one-storey industrial buildings occupying a larger ground area have more widely spaced column supports with lower load bearing capacities. The larger spans between columns mean that supporting additional weight on the roof is a greater challenge unless the structural roof framing is strong and rigid. Accommodating a green roof on these buildings would normally require structural support. Less expensive strategies to avoid or minimize building structural modifications are mainly targeted towards transferring weight or designing for heavy garden elements over load bearing members. While these strategies can help to minimize costs associated with a retrofit, a site-specific assessment by a structural engineer would still be required to determine whether they are viable options for a given building.

Roof Maintenance

Maintenance costs required for a green roof normally include services such as watering, weeding, pruning, application of organic fertilizer and occasional removal of invasive or undesirable plants and re-planting as needed. Drains and gutters must be inspected and cleared more frequently than on a roof without a garden, due to the build up of plant debris.

Maintenance costs are generally higher during the first two years of operation than in subsequent years as the garden is becoming established. Literature estimates of annual maintenance costs during the first two years ranged from \$0.25 to \$4.10/ft^2 (Peck and Kuhn, 2002). Survey respondents rarely cited maintenance as a cost because most installations surveyed were less than 2 years old and were, therefore, still covered under the installer's maintenance warranty. The oldest green roof installation surveyed cited an annual maintenance cost of \$0.50/ft^2, which is paid out to a green roof maintenance company and covers a minimum of 4 visits annually.

Informant interviewing indicated that an independent maintenance company would likely charge a minimum of \$250 per site visit and that 5 visits annually would be recommended to cover basic needs. In instances where the building manager already has a landscape maintenance contract in place, or employs an in-house landscaper, the maintenance work could likely be carried out by these staff for a lower added cost.

Savings

There are several benefits of green roofs that can translate into long-term savings to building owners and developers. Only quantifiable benefits relating to energy efficiency and roof longevity were included in the life cycle cost analysis. Other benefits relating to the public image of building green or tenant roof access are recognized but not explicitly included in the analysis as these will vary substantially from one building to the next, and are not easily defined in dollar value terms.

Energy Consumption

Estimates of the building energy savings provided by a green roof were obtained from several sources. Monitoring by the National Research Council (NRC) indicated a 75% reduction in energy demand for space conditioning in the spring and summer on a field roofing facility in Ottawa (Liu, 2002). Energy modelling conducted by the City of Waterloo (2004) for a 17,222 ft^2 extensive green roof on a one-storey office building indicated annual savings of $400 and $554 in heating and cooling energy costs, respectively. Martens and Bass (2006) reported significantly greater energy savings associated with roof greening for single story buildings than for 2 or 3 story buildings. During a July day in Toronto, a green roof with dimensions of 820 ft by 820 ft was found to bring about energy savings of 73%, 29%, and 18%, for 1, 2, and 3 story air conditioned buildings, respectively.

Membrane Longevity

Green roofs have the potential to increase the lifespan of the roofing membrane by providing protection from thermal stress caused by high temperatures and diurnal fluctuations (Liu and Baskaran, 2004). NRC monitoring conducted in 2002 and 2003 at the Eastview Community Centre in Toronto reported maximum conventional roof membrane temperatures above 60°C and a median daily temperature fluctuation of more than 45°C. By contrast, the membrane below the adjacent garden experienced a maximum temperature of only 40°C and temperature fluctuation of less than 15°C (Liu, 2006). A similar trend was noted during experiments at the NRC Ottawa Field Roofing Facility.

German literature indicates that, based on observation of installations in Germany, green roofs will at least double the lifespan of the roofing membrane to 40 or 50 years (Porsche and Kohler, 2003; Krupka, 2001). Porsche and Kohler (2003) also note that membranes beneath some older green roof installations in Berlin have even lasted 90 years without requiring replacement. Literature estimates of conventional roof longevity ranged from 10 to 30 years. A 15-year lifespan was most commonly cited in the literature reviewed (TMIG, 2006; Peck and Kuhn, 2002; Johnston and Newton, 2004; Porsche and Köhler, 2003).

Life Cycle Cost Analysis

Life cycle costs of a green roof and conventional roof alternative were calculated using a costing tool developed by the Athena Sustainable Materials Institute. Capital and long term cost (and savings) data used as inputs to the tool were based on the best information obtained from surveying, interviewing and review of other green roof studies.

Specifications of the building used in the life cycle analysis were the same as the reference building used in a green roof feasibility study conducted by the City of Waterloo (2004), which included a full energy savings calculation and translated the energy savings into a dollar amount. The reference building is a new, one-story 17,222 ft^2 office building, using electricity for cooling (at a rate of $0.12/kWh) and natural gas for heating (at a rate of $0.010/$ft^3$). It was assumed that structural modifications would not be required. For the base scenarios, the conventional and green roof life spans were assumed to be 15 and

30 years respectively, and the LCC was run for a 30 year investment period. The discount rate of 6.5% was used.

Life cycle costs of six alternative scenarios were also calculated to illustrate the cost impact associated with changes in assumptions. Figure 2 presents the results of the LCC analysis. The base case and alternative scenarios are presented as the ratio of green to conventional roof LCCs and as the percentage change from the base case. To simplify, results were calculated based on the green and conventional roof cost minimums only. Scenario results are summarized in the following sections.

Extended Green Roof Membrane Scenario

Increasing the life of the green roof membrane from 30 to 45 years reduced the green-to-conventional roof LCC ratio from 1.56 in the base case to 1.37 (a 12% decrease). The impact was less significant than anticipated because the costs for conventional roof replacements that occur at 15 and 30 years are much lower than the initial installation cost when converted to present value dollars.

Non-air Conditioned Building Scenario

Eliminating the summer cooling energy savings from green roofs increased the LCC ratio by 2% relative to the base case. This scenario did not consider capital cost savings associated with downsized HVAC system requirements in a green roofed building because these data were not available. The cost impact of this scenario would have been greater had this consideration been incorporated.

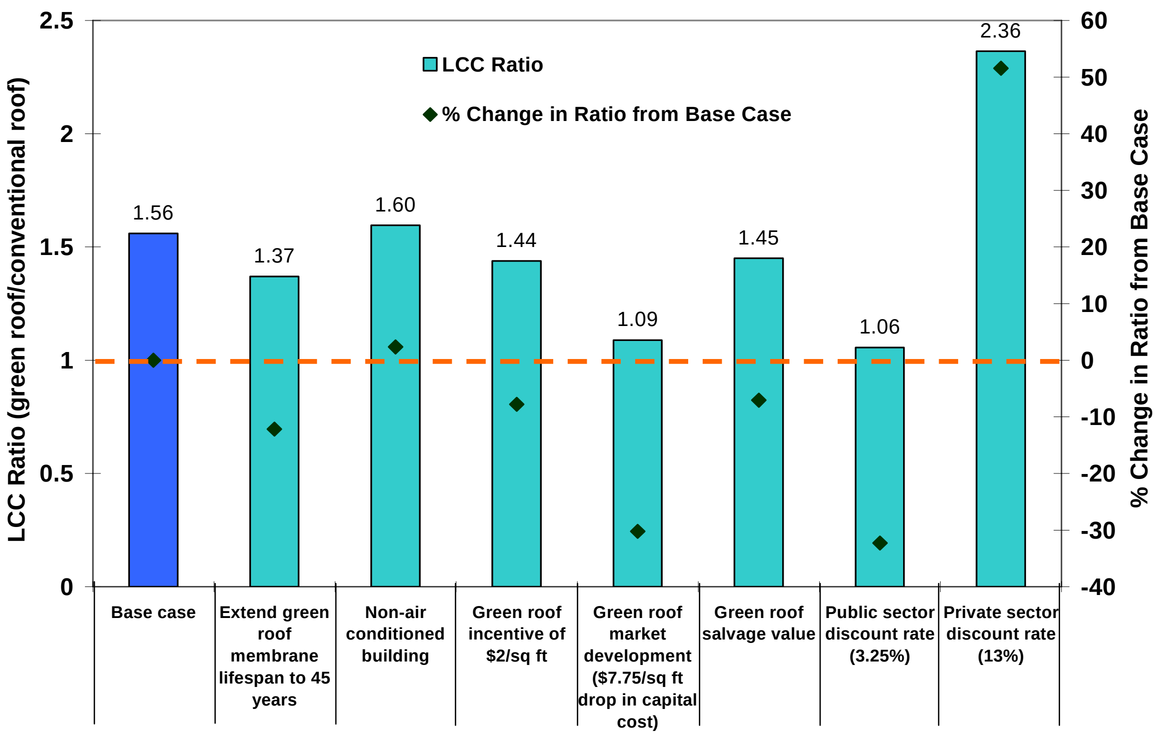

Figure 2: Ratio of green roof to conventional roof LCC for all scenarios (based on minimums)

Municipal Incentive Program Scenario

The installed cost of the green roof was subsidized by $2/ft^2. The subsidy reduced the LCC ratio from 1.56 in the base case to 1.44 (a decrease of 8%), making the investment a more attractive option to building owners.

Green Roof Market Development Scenario

Reducing the installed cost of the green roof (including the cost of the underlying base roof) from a minimum of $23.75/ft^2 to 16.00/ft^2 substantially narrowed the cost gap between the green and conventional roof LCC, bringing the ratio down to 1.09. Relative to the other scenarios, market development yielded the second lowest cost differential between green and conventional roofs.

Green Roof Salvage Value Scenario

This scenario involved assigning a salvage value to green roof materials once the roof membrane needed replacing (30 years). Accounting for salvage value of the green roof caused the LCC ratio to fall to 1.45 from 1.56 in the base case.

Public vs. Private Discount Rate Scenario

LCCs were calculated based on discount rates of 3.25% and 13%, representing public and private sector rates respectively. The LCC ratio fell to 1.05 when the public sector rate was applied, and increased to 2.36 with use of the private sector rate. These results indicate that green roofs will tend to be more affordable for investors such as those in the public sector, who tend to look for lower risk investments with more modest rates of return.

Results obtained for the base and alternative scenarios demonstrate that the differential between conventional and green roof LCC is most affected by factors that impact capital or replacement costs. These factors include: (i) roof membrane longevity, (ii) market transformation, and (iii) discount rates. Variations in annual costs and savings associated with maintenance and energy use reduction did not have a strong impact on the LCC.

Of course, these LCC calculations only apply to buildings with the same specifications as the reference building described earlier. Changes in these specifications could have a significant impact on the LCC. The cost estimates provided in this study do not replace the need for a site specific cost assessment, as circumstances vary widely. Those considering a green roof must carefully consider the various conditions that apply in their particular case. It is hoped that this study provides information and data that help facilitate this process.

Recommendations

Market Development

- GTA municipalities wishing to aggressively support green roof infrastructure should provide an incentive to reduce the capital cost of green roof projects, as green roofs are currently cost-prohibitive for many building designs and uses.
- A direct financial incentive of $4 - $7 per square foot is needed in order to decrease capital costs enough to make green roofs an attractive option, and thus spur market growth.
- Offering an incentive of more than $8/ft^2 could potentially stunt market growth, as it may lead suppliers to keep costs high rather than striving to develop solutions that reduce prices charged to potential clients.
- The use of other creative policies and incentives may help to stimulate market growth without some of the pitfalls of a direct financial incentive. Examples include reduced size of end-of-pipe facilities or expedited application approvals for owners proposing a green roof.

Further Research

- Further research is needed to investigate the effectiveness of innovative strategies (*e.g.* weight transferring structures, creative green roof design) aimed at minimizing the need for large investments in structural modifications on new and retrofit commercial or industrial roofs.
- While it will be several years before data on the longevity of local green roofs will be available, laboratory simulations of the conditions experienced by a membrane beneath a green roof could be an effective way of quantifying expected life spans in the GTA.
- There is evidence that less quantifiable benefits of green roofs associated with the amenity and public relations value of green roofs can translate into substantial cost savings to building owners. These benefits should be further investigated and their value estimated in economic terms to provide a more comprehensive life cycle cost for green roofs to building owners than was provided in this study.
- Results from this study and other research specifically addressing the public values of green roofs (e.g. Ryerson University, 2005) should be combined and re-examined to determine the extent to which the cost of green roofs borne by owners is offset by their overall societal value.