5. Summary and recommendations

This report is the first significant milestone in a bigger project undertaken by Ryerson University and funded by OCE-ETech through partnerships with the City of Toronto, Trow Associates and 401 Richmond. The objective of this report is to estimate the municipal level environmental benefits and costs of implementing green roofs in the City of Toronto.

A geographical information systems (GIS) based approach has been undertaken to identify buildings suitable for green roof application. Appropriate assumptions had to be made in the use of such data. It is expected that the methodology will continue to be refined and more refined data will become available to be used in the second part of this project.

Based on the work undertaken to date, Table 5.1 summarizes the economic benefits of green roofs in the City of Toronto. The benefits are based on greening 100% of the available flat roofs larger than 350 sq. m. on buildings. The identification of benefits, the process of quantification and the monetary valuation of the benefits have primarily been based on existing primary research available in the public domain.

Table 5.1
Summary of municipal level environmental benefits of green roof implementation in the City of Toronto (Assuming green roof coverage of approximately 5,000 hectares

Category of benefit	Initial cost saving	Annual cost saving
Stormwater		
Alternate best management practice cost avoidance	$79,000,000	
Pollutant control cost avoidance	$14,000,000	
Erosion control cost avoidance	$25,000,000	
Combined Sewer Overflow (CSO)		
Storage cost avoidance	$46,600,000	
Reduced beach closures		$750,000
Air Quality		
Impacts of reduction in CO, NO_2, O_3, PM_{10}, SO_2		$2,500,000
Building Energy		
Savings in annual energy use		$21,000,000
Cost avoidance due to peak demand reduction	$68,700,000	
Savings from CO_2 reduction		$563,000
Urban Heat Island		
Savings in annual energy use		$12,000,000
Cost avoidance due to peak demand reduction	$79,800,000	
Savings from CO_2 reduction		$322,000

5.1 Other benefits

Several benefits, particularly relating to the use of green roofs as an amenity space, could not be quantified, as too little research has been completed in this area. In some instances benefits have been documented, but apply to very specific types of greening options, which compete with other benefits. For instance, the benefits of green roofs as a medium for local food production are documented. However in a situation where such benefits have been quantified in terms of the amount of production per sq. m. of roof, the food is grown in a greenhouse on the roof. Greenhouses lend themselves well to plant growing on roofs but take away from other social and environmental benefits.

At the municipal level the greatest social and environmental benefits appear to be a result of the use of extensive green roof systems. Use of intensive roofs, with uneven green coverage, use of planters for greening, and use of greenhouses have their own individual benefits. These benefits are highly dependent on the actual design implementation or plan for greening. They are likely to have a very high value with respect to amenity space, aesthetics, direct health benefits and real estate values depending on the design. However, it is unclear as to whether such approaches and systems will provide a significant direct benefit at the municipal level.

There are several other social and environmental benefits of a green roof such as its impact on biodiversity, water quality and the quality of life. This can bring significant benefits, which would need additional research beyond the scope of this project to quantify.

5.2 Green roofs on sloped surfaces

It is inevitable that consideration may be given to green roofs on sloped surfaces such as those on wood frame houses. These types of buildings constitute a large portion of roof area in the City of Toronto and provide a tremendous opportunity for greening. We have, however, not found enough basis in the research to quantify the benefits of green roofs on such surfaces. There may also be some questions about the feasibility of constructing and maintaining such roofs. Until further research shows quantifiable benefits and feasible solutions for implementation, we are unable to recommend the use of green roofs on sloped surfaces.

5.3 Recommendation for types of green roofs

The major municipal level environmental benefits of green roofs identified in this study for Toronto are improvements in stormwater management, CSO control, air quality and reduction of energy use and its impact on carbon dioxide reduction. The characteristics of green roof technology that will impact the performance in the noted areas are as follows:

- depth and nature of growing and drainage medium;
- percent of roof greened; and
- plant coverage on greened area.

As each of these increases in quantity, the performance of the green roof will increase with respect to the environmental benefits. However the cost of green roof increases with the increase in the depth and area coverage. Also, for existing buildings structural load limitations impose a restriction on the nature of the green roof that can be implemented. Since the economic impacts of the benefits of green roof technology in this study have been calculated for existing buildings, structural load limitations are an important criterion and therefore will prevent green roofs with deeper growing medium.

Based on this study we recommend the following as minimum considerations for the type of green roof system to be used to obtain the benefits listed in this study:

- Extensive green roofs with a continuous coverage of growing media over at least 75% of the roof footprint of the building.
- Green roofs to be installed over "flat roofs". Many of these roofs are nominally sloped by about 2%. Where roofs have zero slope, green roof systems will need to be designed to drain water away from the root.
- The green roof system should have a maximum runoff coefficient of 50%, based on annual average rainfall retention of 50% for Toronto conditions. There are many systems on the market with varying depths of growing medium that will meet these performance requirements.
- On existing buildings a structural analysis should be conducted to determine the thickness of growing media that can be accommodated. Where permitted by the structure of the existing buildings and on new buildings where there is flexibility at design stage with regard to the structural design, a green roof with a depth of at least 150 mm (6 inches) should be considered. This depth will permit greater flexibility in terms of the type and variety of vegetation that can be incorporated. It will ensure greater survival of plants.
- Green roofs with a growing medium thickness as low as 75 mm (3 inches) are available and can provide the benefits stated in this study. Such systems should be considered acceptable where structural loads on existing building do not permit green roofs of greater thickness. Manufacturers of such systems should be required to submit test data indicating the performance of these systems with respect to water runoff.
- This study is based on green roofs installed over air-conditioned spaces that are heated and cooled. Green roofs that are installed over unheated and unconditioned spaces, for example over underground parking garages, will not provide energy related benefits. In general green roofs where public and or vehicular access is possible from the grade level have been built without specific green roof incentives and policies. Although they will provide many of the benefits of green roofs, we are not recommending them to be included in the category of green roofs described in this study.

- Several of the systems described in Section 3 are available for green roofs in Toronto. It is recommended that green roofs systems be designed and installed according to manufacturers' recommendations.

5.4 Next steps

This study has enumerated the social and environmental benefits of green roofs on a city-wide basis. Not all benefits of green roofs can be quantified at this time. Given the quantifiable benefits and the potential benefits that cannot easily be quantified we believe that there is a case for public programs to promote green roofs. We recommend that the City of Toronto embark on consideration of such programs that will give further impetus to green roofs. The City of Toronto may wish to consult the users of such programs and determine the level of logistical, technical and financial support that may be appropriate to promote green roof construction in the city. Once determined the costs of such programs can be used to complete the cost benefit analysis of green roofs at the municipal level.

Although this study has made several advances in predicting benefits of green roofs and it has provided information for the City of Toronto to move further on programs and policies pertaining to green roofs, there are several areas that will require further work. Questions remain to be answered regarding the uncertainty of the benefits, impact of less than 100% green roof coverage, impact of building specific constraints, the quantification of costs leading to a complete cost benefit analysis, quantification of other social benefits and consideration of the effect of alternative technologies that may be able to perform one or more of the functions of a green roof. These questions are important and will need to be considered in further studies. Policy decisions regarding green roofs will need to consider the impact of these questions.

Uncertainty of benefits arises because of various factors. Some of the factors that contribute to the uncertainty in this study include the sources of building inventory data and the models used to predict benefits (stormwater, energy and air quality). Although not explicitly evident in the analysis, in this report we examine boundary conditions with respect to framing uncertainty of the information presented. However sensitivity analysis can better frame the predictions presented in this report.

In this report we examined 100% green roof coverage on available green roof area. This has provided a good starting point on the envelope of potential benefits. Knowing the impact of a range of green roof coverage would also be useful. The continuing part of this study will examine the possibility of developing models to predict such impacts.

Building specific constraints will dictate the feasibility of implementing green roofs and also impact the benefits that will accrue for any particular building. Many constraints will impact the costs and benefits related to green roofs such as: the structural load carrying capacity, the heating and cooling plants and distribution systems, and the building dimensions. Our research has indicated that the currently available green roof technology can cater to wide variations in building needs and overcome some of the obstacles such as structural loading.

Further studies may be considered to take into account building level constraints. Such studies can be helpful in predicting building level impacts and also in refining the municipal level impacts.

Another area that needs further development is the quantification of social and environmental benefits of green roofs beyond those that are available from current research. For that it may be necessary to draw on research done on similar benefits in other areas.

This report only examines green roof technology. Green roofs are unique because they can provide multiple benefits using one type of sustainable technology. While it is difficult to find any one technology that can provide the range of benefits of a green roof, there are technologies available that either singly or in combination can provide either some or all of the benefits of green roofs. Traditional models of comparing green roofs with other technologies are not suitable in this regard. Further work needs to be carried out to determine how decisions can be made in comparing green roof technologies to other technologies, either in combination or singly.

The intent of our continuing work remains to produce a model that will allow the benefits and costs to be analyzed. As this work continues we expect to develop models to predict costs that will enable a complete cost benefit analysis.