Green Roofs: Infrastructure for the 21st Century

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Abstract

Rooftops are largely wasted spaces in our urban centres. They have been called 'the last urban frontier'! Green roof infrastructure is a proven technology that is becoming widespread in Europe where millions of square feet of rooftops are transforming the roofing industry and cities. This paper introduces green roof technology, describes some of the many drivers that will help to create this new, multi million dollar niche roofing market. It provides an overview of the latest green roof infrastructure development work and technical research in Canada and concludes by describing some of remaining steps required to turn roofs into a new force for cleaner air, water and cooler more healthy cities.

Introduction – Challenges & Opportunities

The residents of cities in North America are facing a considerable number of challenges as they enter the next century, and green roof infrastructure holds the promise of providing many of the required solutions. Air pollution in the form of fine particulates, nitrous oxides, sulphur dioxides and smog harms the health of humans and ecosystems and generally eroding our quality of life. Stormwater, which runs off roads, parking lots and roofs collects oil, grease, salt, pesticides and a host of other atmospheric pollutants has become the primary source of pollution in many of our lakes and local watercourses. Moreover, during rainstorms, many cities continue to discharge raw, diluted and untreated sewage directly into the environment because the same system is used to manage sanitary waste and storm water.

There are also new challenges. Climate change and variability promises to generate increasingly severe weather events. This threatens to increase the frequency and intensity of flooding and the number of summer heat waves. Warmer average temperatures in cities have become more common over the past decade and are increasing the negative impacts of the 'urban heat island effect' (the unnatural overheating of developed areas relative to the countryside). In Ontario for example, Environment Canada estimates that the number of days annually with temperatures above 30 degrees C will rise from 10 to 50 if atmospheric carbon dioxide levels double.

Dark roofing surfaces convert solar radiation into heat, acting like hotplates for the surrounding air. Rising summer temperatures increase the likelihood of smog formation, cause more particulate matter to circulate in the air and place increasing demands for energy to cool buildings (with resulting air quality impacts from fossil-fuel based generation). Rising city temperatures place the poor and elderly at risk and generally make cities unpleasant places to live and work.

Many local governments are strapped for financial resources at a time when aging populations and aging cities will make ever-increasing demands on the public purse. All levels of government need to invest strategically, through public-private partnerships for example, in order to gain the maximum amount of public benefit for every dollar spent on infrastructure. As cities promote redevelopment and increasing density in order to foster local and regional economies and take development pressure off the surrounding green spaces, residents will need to get far more benefit from buildings and roofs in particular. There will be increasing need for active and passive recreational spaces of all kinds, particularly in inner city areas that often lack such places.

These 21st urban challenges will help to drive new markets for green roof infrastructure, a technology that can exploit largely wasted rooftops. Green Roofs for Healthy Cities is a public and private sector consortium formed by the Cardinal Group Inc. in 1999. Its members share the goal of establishing a vibrant multi-million dollar market for green roof infrastructure in North America. Green Roofs for Healthy Cities members include: The City of Portland, Oregon; Soprema; GreenTech; Garland Canada, Elevated Landscape and Maintenance, Earth Pledge Foundation; Monica Kuhn Architects, Flynn Roofing and IRC Building Sciences Group Ltd.

Green Roof Infrastructure –History & Definition

Green roofs of one sort or another have been used for several millennia to cool buildings, improve their aesthetic and provide shelter from winter elements. Their use can be traced as far back as the hanging gardens of Babylon and the Roman Empire. The Romans used trees on top of buildings, such as the mausoleums of Augustus and Hadrian. In modern times, Le Corbusier and Frank Lloyd Wright made extensive use of green roofs in their buildings, such as Hollyhock House, Cheney House and Horseshoe Inn. In the early 1960's and 70's, a significant amount of technical research was conducted on the components of green roof technology in Europe. Research included studies on root repelling agents, waterproof membranes, drainage systems, light-weight growing media and plants. Green roof systems are not simply planter boxes, but are a component of the roofing system. Green roof infrastructure involves growing plants on a built structure, at, below or above grade. A typical system consists of the following:

- Typical roof structure and perhaps some insulation.

- A waterproof membrane with root repelling properties. This can be liquid applied or a specially designed sheet membrane. Modified bitumen roofing membranes are often used.

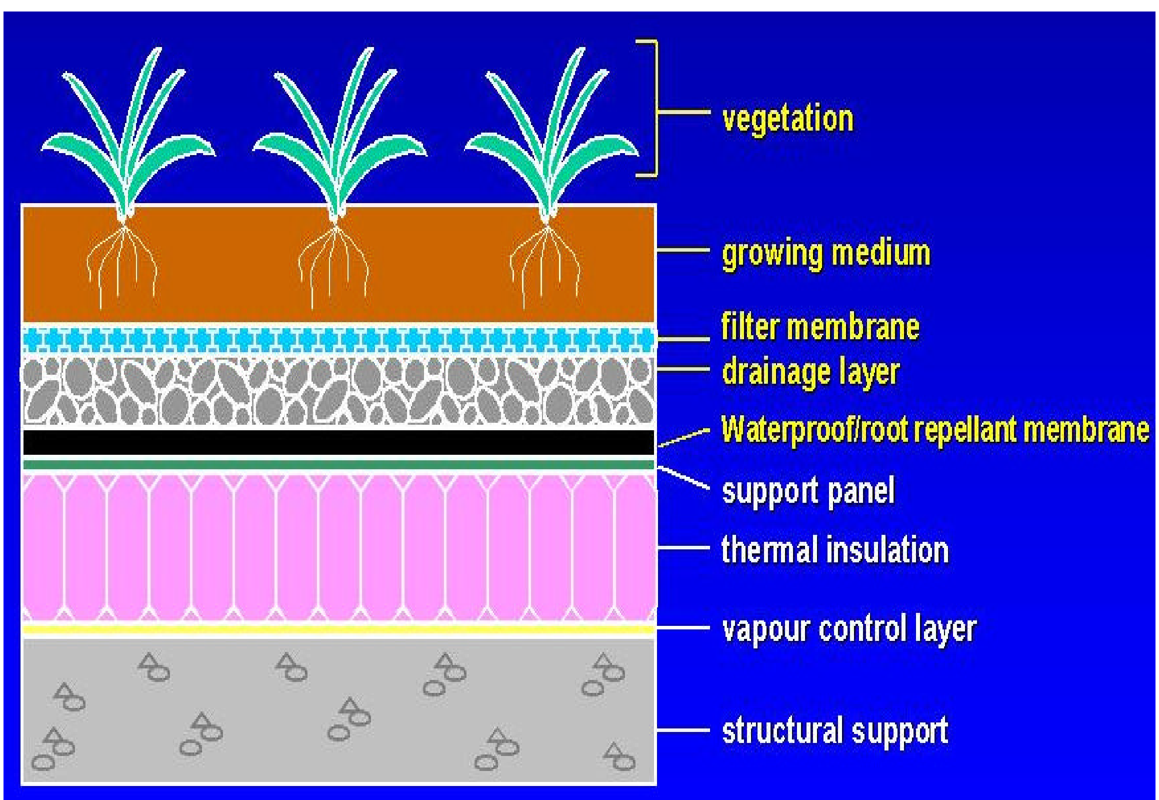
- A drainage layer, sometimes with built in reservoirs to retain water for the plants. The drainage layer allows excess water to runoff the roof. Can be made of gravel and chipping, lava and pumice stone, swelled burned slate or plastic/polystyrene webbing or chambers.

- A landscape or filter cloth to contain growing medium in order to prevent blockage in roof drains but to allow roots to anchor to the drainage layer.

- Engineered growing medium, which may or may not include soil. The engineered growing medium must be lightweight, absorbent, sufficiently porous to allow runoff and meet the nutrient and anchoring requirements of the plants. Materials that can be used in the preparation of the growing medium include mineral and organic soil components, soil mixture of humus; and mineral bulk material mixture with high or low proportion of organic matter.

- The plants, which are determined largely by the type of green roof system and the loading capacity of the roof. The loading capacity determines the weight of the system with heavier systems accommodating a broader range of plants. Drought and heat tolerant plants that have shallow root systems and spread out are used on extensive green roofs that are typically large and inaccessible. Some systems may also include irrigation.

Figure 1: General Elements of a Green Roof System



Source: National Research Council, Institute for Research in Construction

There are also modular green roof systems, like the one developed by GreenTech wherein the drainage layers, growing media and plants can be built in and the modules lock into each other, like a giant gigsaw puzzle.

Green roof infrastructure is not an ‘off the shelf’ technology *per se*. Each new or existing building has unique opportunities and constraints that determine the type of system that is optimal for that structure and its location. There are two main types of green roof systems – Extensive and Intensive – and many hybrids that combine elements of both. Extensive systems typically involve thin (5-15 cm) lightweight growing medium, little or no irrigation, minimal maintenance and limited plant diversity. Their advantages include:

- Lightweight - a particularly important feature that facilitates retrofitting existing buildings that may have limited loading capacity. The weight increase of an extensive system generally ranges from 70-170 kg/m^2 saturated. *(Please Note: this information is general in nature and should not be used a basis for making design decisions about green roof installation. Please consult with an expert prior to developing a green roof)*.

- Can be used on large flat roofs or up to 30 degree slope (strapping is used to keep growing medium and plants in place).

- Low maintenance requirements (2-3 times per year to remove invasive plant species).

Extensive systems are the most cost effective, averaging between $4.00-$15.00 per square foot for the system and installation. Examples of extensive green roofs include the Mountain Equipment Co-operative 900 m^2 green roof installed in 1998 in downtown Toronto and the 2,400 m^2 green roof installed on the 7th floor of the Vancouver Public Library in 1995.

Intensive green roof systems are characterized by deeper growing medium (often soil based of 20-60 cm in depth), heavier, (290 – 960 kg/ m^2), often involving irrigation systems and additional maintenance requirements. Many intensive systems are accessible, and thereby provide building occupants or the general public new opportunities for recreation. Their advantages include:

- Greater diversity of plants and potential for improved aesthetics and landscape design.

- Better insulation for the building than extensive systems and improved stormwater retention.

- Can provide wildlife habitat, such as a butterfly garden and help preserve biodiversity.

- Often visually accessible, providing attractive views from neighbouring buildings year round.

- Allow for diverse utilization of roofing space, such as day care space, roofpark, urban agriculture etc.

The costs of intensive systems are hard to generalize given the uniqueness of each application. It is less costly to design green roofs into a new development than to retrofit an existing building. When green roofs provide new opportunities for useable space the benefits far outweigh the added capital investment. For example, the combined extensive/intensive green roof system installed by Ryerson University sits above a five story gymnasium complex below and provides much need recreational green space at the downtown Toronto campus.

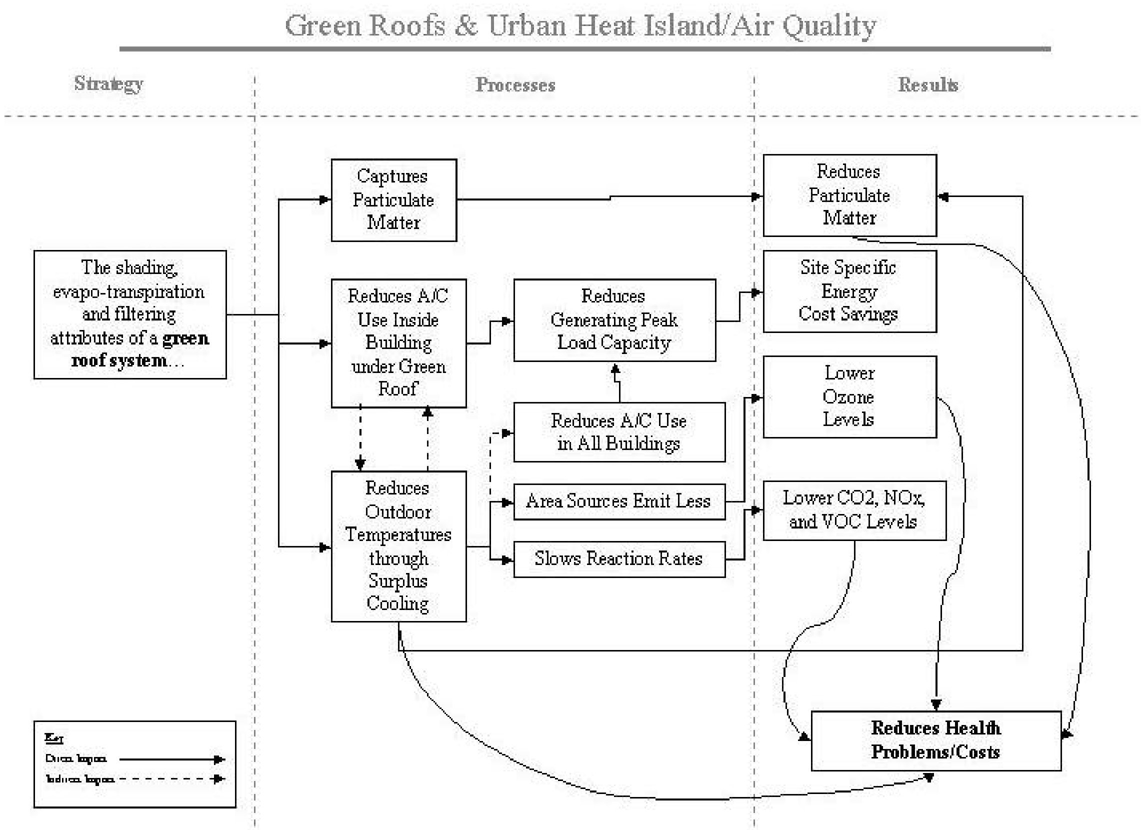
Addressing City Challenges

While green roofs are not a panacea, they do confer a wide range of public and private benefits. In European cities, public investments in green roof infrastructure are made largely to improve stormwater management and air quality. Stormwater runs off streets, roofs, lawns and parking lots collecting contaminants, sediment and heat and has become an important source of pollution for receiving streams, rivers and lakes. In many North American cities, the sanitary and storm sewers are still connected, so that when it rains, or during spring runoff, diluted sanitary sewage often flows directly into receiving water bodies, untreated. Studies conducted in Berlin show that green roofs absorb 75 per cent of the precipitation that falls on them. In general, summer retention rates vary between 70-100 per cent (depending on factors such as the depth of the growing medium, type of drainage layer and vegetation) and winter retention rates of 40-50 per cent. Most of the stormwater is taken up by the growing medium and the plants and returned to the atmosphere through the process of evapotranspiration. Water that does runoff of green roofs has more moderate temperatures and has less heavy metals and nutrients that are captured by the growing medium and plants. While more research on the ability of different green roof systems to cleanse stormwater needs to be conducted, existing research indicates green roofs can remove up to 95 per cent of the cadmium, lead, copper and 16 per cent of the zinc in rainwater.

Green roofs, if widely implemented, promise to generate significant improvements to the quality of stormwater runoff and to reduce the quantity, thereby reducing the potential for flood damage and associated infrastructure investments. A study conducted by Weston Designers for the City of Chicago on its new green roof suggests that 70% of the annual rainfall will be retained and used by plants for evapotranspiration. A study on the downtown area of Portland, Oregon found that roofs comprised about 30% of the total area. The study concluded that all the buildings had green roof systems they would capture 420 million gallons of stormwater annually and help the City address the National Pollutant Discharge Eliminations System municipal stormwater requirements. Combined sewer overflows would be also reduced by 15% in the northern quarter of the study area.

The air quality benefits of green roofs result from a variety of factors. Urban areas become unnaturally very hot in the summer – the urban heat island – creating vertical air movements that raise dust and dirt particles into the air. Vegetation on top of roofs can trap particulates. Based on studies of urban forestry, it is estimated that a 2,000 m^2 unmowed grass roof could remove as much as 4,000 kg of dirt from the air. Green roofs also help to reduce the urban heat island effect, which contributes to the formation of smog. The urban heat island effect also creates higher peak demand in buildings for electricity to power air conditioners: a demand often met by burning fossil fuels which contribute to air pollution. On a hot summer day, a typical insulated gravel roof can reach temperatures of up to 80 degrees C. Thus, roofs act as ‘hotplates’, heating up cities and moving particulates around. A green roof covered with thick vegetation will not heat up beyond 25 degrees C. In addition, there is no vertical air movement over heavily vegetated surfaces, so that green roofs, if sufficiently implemented, can bring down temperatures in cities, thereby helping young and old residents adapt to the more severe summer temperatures anticipated as a result of climate change and variability. Reducing summer temperatures also reduces the demand for electricity, and a 2-4 degree C drop in temperature could result in an estimated 10 per cent decrease in electricity demand for cooling – in all buildings.

A study of buildings in the City of Chicago was conducted in 1999 as part of the Cities’ “Urban Heat Island Initiative”. The analysis estimates that complete green roof coverage of the total area covered by rooftops (30% of 224 square miles) would result in savings of $100 million in avoided energy costs annually and would offset peak demand by 720 MW, the equivalent of several local-coal fired electrical generating stations. The study also includes estimates of measurable air quality improvements. It estimates a reduction of 0.4% for NO_x and 0.53% for SO_2 from greening all of the roofs in the City of Chicago. The nature of the benefits derived from reducing the urban heat island through green roof infrastructure are described in the diagram below.



Source: *Green Roof Infrastructure Monitor*, Spring 2001. Green Roofs for Healthy Cities

We are in the process of modeling the Urban Heat Island in the City of Toronto and will be measuring how green roofs can help to reduce the hot summer temperatures. This research is being done by Dr. Brad Bass (see earlier paper in these proceedings) of Environment Canada with colleagues at Simon Fraser University and will be released in September 2002.

The private or building owner benefits of green roofs vary depending on the application. Standard benefits include improved energy efficiency, particularly cooling in the summer – the extent of which is dependent on factors such as the size of the building, depth of growing medium, season, and type of plant cover. Using a MicroAxess simulation model for example, Environment Canada found that a typical one storey building with a grass green roof area of 500 m^2 and 10 cm of growing medium would result in a 25 per cent reduction in cooling energy needs in the summer.

The projected cooling cost savings for the green roof pilot project on City Hall in Chicago were estimated using a bin-method energy model developed by ASHRAE. The modeling showed that the cooling effective of the plants in the summer exceed the amount of heat entering the roofing system by 730%. This totally eliminates the cooling load on the roof and generates available total avoided cooling energy of 3,797 KWhr per 1000 feet of total roof area. This excess cooling is transferred to the surrounding micro-climate and could eliminate over $800 in cooling costs at buildings downwind from City Hall. Estimated cost savings for gas and electricity are in the order of $3,600 annually for City Hall.

Private benefits of green roofs also include:

- better sound insulation since the plants block higher frequencies and growing medium blocks lower frequencies;
- fire protection, particularly when the roof is wet;
- and a better life expectancy of the roofing system;
- smaller HVAC systems, for new construction; and,
- amenity space for the public or building occupants.

A green roof system is insulated from solar radiation and severe expansion and contraction from temperature extremes so it will last at least twice as long as a conventional roof. Based on experience in Germany, green roofs will prolong the service life of conventional roofs by 20 years. The German organization, Zentralverband Gartenbau has estimated that the lifetime cost, (based on a 36 year service life), of an extensive green roof is 15% lower than a comparable bituminous roof with a gravel ballast.

It is very important that we make maximum use of the ‘last urban frontier’ our waste roof spaces in cities. Underutilized roof space in cities also challenges designers and developers to maximize unique roof applications as the need for useable space in cities grows. Demonstrated green roof applications include:

- Amenity spaces or ‘roofparks’ for public or building occupants;
- Gardens on hospital roofs which lead to improved rates of recovery for hospital patients;
- Improved productivity for office workers who view or have access to green roof gardens;
- Replacing the need for cooling towers;
- Grey water reuse and recycling;
- Private gardens for condominium owners;
- High quality food production;
- Community gardens for co-operative housing and senior citizens residents; and, believe it or not,
- A putting green.

Challenges for A Green Roof Industry

Despite the fact that green roof infrastructure is a proven and widely utilized technology in Europe, there are a number of important technical, financial and information challenges facing the establishment of a new green roofing industry in North America. Public investment and/or regulation of green roofs in Europe have created the economic basis for a new green roof industry.

Over 10 per cent of all the flat roofs in Germany have a green roof system in place, the result of direct investment or regulations from over 75 municipal governments. Thirteen German cities allow reductions in stormwater fees of up to 80% for building owners with green roofs. Over a 36 year period this measure alone can compensate building owners for as much as 50% of the added capital costs of the green roof. Twenty-nine cities invest directly in green roofs with the amounts varying from $0.51 to $6.20 per square foot.

Examples of similar public investment by North American cities are virtually non-existent. One reason for this is that most of the public benefits described above are at a city-wide scale, and have not been adequately quantified or valued in different urban contexts in North America. Without understanding the nature of the public benefits of green roof infrastructure it is difficult for policy makers and political leaders to justify new investments in this technology.

From a private sector perspective the standard private sector benefits like energy efficiency are often insufficient or too ill-defined to generate a sufficient enough return on investment to justify the added capital expense.

Increasing awareness of green roof infrastructure benefits, addressing site level technical benefits and preparing a strong case for public financial incentives for private sector investment in green roofs are all interrelated challenges that are key to unlocking the full potential of this technology.

Canadian Market Development Activities

There are a number of initiatives underway to address technical, financial and information challenges to building a new green roof industry. In order to expand awareness, Green Roofs for Healthy Cities has established a web site with detailed technical information and now publishes a quarterly journal on green roof developments in North America and Internationally. The *Green Roof Infrastructure Monitor* is available in electronic format free of charge. To subscribe, please send an e-mail to **speck@cardinalgroup.ca.**

Green Roofs for Healthy Cities is also working in partnership with the National Research Council's Institute for Research in Construction, the City of Toronto, Environment Canada and the Toronto Atmospheric Fund to raise awareness and research the technical benefits of green roofs at two building sites. The objectives of this $1 million, three-year project are to overcome technical, financial and information barriers to the widespread adoption of green roof infrastructure in the marketplace by:

- Generating reliable technical data on green roof performance in areas such as energy efficiency, stormwater retention, the extension of roof membrane life span and plant survival in the Toronto climatic context.

- Conducting research on city-wide cooling benefits of green roofs in the summer and the potential spin off greenhouse gas, smog reduction and energy efficiency gains by reducing cooling energy needs in all buildings.

- Evaluating the costs and benefits of future public-private investments in green roofs.

- Increasing the awareness of the benefits of green roof technology by giving professionals the opportunity to visit a working demonstration site with multiple applications.

Major Project Elements

The project combines proposed technical research at the site and city-wide level with technology demonstration. There are two demonstration sites: the publicly accessible Toronto City Hall Podium Roof and the gymnasium steel deck roof at the Eastview Neighbourhood Community Centre.

Funding from the Federal Government's *Technology for Early Action Measures* program has allowed the National Research Council's Institute for Research in Construction to install monitors at Eastview and City Hall to measure temperatures and moisture levels over the next three years. Soprema's *Sopranature* and Garland's *GreenShield*™ are the green roof systems utilized on both sites, which are now fully implemented. Detailed stormwater quality and quantity research at the Eastview site is planned, with anticipated funding secured by mid-September 2002.

The City Hall demonstration site on the podium roof is approximately 7,000 square feet in size. The City Hall re-roofing and green roof installation investment was $260,000. Eight green roof demonstration plots of 3,200 square feet now feature different green roof applications. The site was design as a living 'green roof trade show' area which is highly public visible and accessible. The eight plots at City Hall consist of:

- Black oak savannah, a native prairie ecosystem that is now extremely endangered in North America. These plants are drawn from the local High Park gene pool;
- Two extensive plots featuring a variety of sedum and alpine perennials, typical of industrial and commercial applications;
- Two semi-intensive plots featuring a variety of flowering plants, shrubs and small trees;
- Native butterfly and bird habitat; and
- Two urban agricultural plots featuring perennials and annuals.

The Eastview re-roofing and green roof investment was $274,000 and the green roof portion of the building is 5,000 square feet, on a steel deck. The green roof component was included in the City's existing budget for the entire re-roofing of the 25,000 square foot building with no additional cost. The Eastview site features an extensive green roof. The City of Toronto, in partnership with Green Roofs for Healthy Cities and the Toronto Region Conservation Authority is planning to conduct stormwater quantity and quality research on this site and monitor energy savings.

Environment Canada is modeling of the urban heat island in Toronto to determine how green roofs can reduce excessively hot summer temperatures in urban areas. Urban heat island technical information will be made available in September of 2002.

Green Roofs for Healthy Cities is also working to co-ordinate or support green roof research efforts in Ottawa, Portland, New York, Winnipeg, Vancouver and Chicago to develop a common resource of technical information and protocol for conducting further site and city-wide research and cost benefit analysis. On June 13, 2000 Green Roofs for Health Cities co-hosted a North American workshop that brought experts together to begin developing an approach to conducting a comprehensive cost-benefit analysis of the city-wide benefits of significant public green roof investment. The proceedings will be designed to help policy makers develop appropriate incentives for implementing green roof infrastructure in partnership with the private sector in a manner that addresses the key challenges facing specific cities and maximizes the return on public infrastructure investment.

It is very important in each of these cities to bring together a range of different stakeholders to prepare a plan to evaluate the range of benefits that green roofs can bring to the inhabitants of a particular city. Due to the different climates and build out of cities, the benefits of green roofs will vary from location to location. Establishing a sound technical basis for green roof performance at the building level, and at the subwatershed and urban heat island scale, will continue to be a critical step in convincing the public and policy makers that this technology is worthy of direct and indirect public investment. Only then will we be able to fully exploit the benefits of green roof infrastructure.

CONCLUSION

Green roofs are proven technology that can exploit our underutilized roof spaces – the final urban frontier. The many challenges facing North American cities at the start of the 21st Century, such as the negative impacts of the urban heat island effect, will undoubtedly help to drive the market for green roofs once technical and cost-benefit evaluations are complete.

Green roofs provide new solutions that not only deliver tangible private and public economic benefits but also make our cities healthier, more beautiful and enjoyable places to live and work.

References

Beckman, S., Jones, S., Liburdy, K. and Peters, C. "Greening Our Cities: An Analysis of Benefits and Barriers Associated With Green Roofs" Portland State University Planning Workshop. 1997.

Green Roof Infrastructure Monitor. Spring 2001. Green Roofs for Healthy Cities. www.greenroofs.ca

IPCC, 1998. *The Regional Impacts of Climate Change – An Assessment of Vulnerability*. R.T. Watson, M.C. Zinyowera and R.H. Moss (eds.). Prepared at the request of the United Nations

Framework Convention on Climate Change, Cambridge University Press: New York.

Johnston, J. and Newton, J. “Building Green: A Guide to Using Plants on Roofs, Walls and Pavements” London Ecology Unit. 1997.

Miller, C. “Vegetative Roof Covers: A New Method for Controlling Runoff in Urbanized Areas”, Proceedings from the 1998 Pennsylvania Stormwater Management Symposium, Villanova University.

Peck, S., Callaghan, C., Bass, B., and Kuhn, M. “Green Backs from Green Roofs: Forging a New Industry in Canada”. Prepared for Canada Mortgage and Housing Corporation. 1999. (This report is available on-line in a pdf format at www.greenroofs.ca)

Roy F. Weston Inc., Conservation Design Forum, Inc.; William McDonough + Patners; Halverson & Kaye Structural Engineers, PC; J.T. Katrakis and Associates; and Atelier Dreiseitl. “Urban Heat Island Initiative Pilot Project: Final Report”. Prepared for the City of Chicago, Department of Environment, Department of General Services and Department of Planning and Development. 2000.