EXPANDING THE NORTH AMERICAN GREENROOFING INDUSTRY

The Value of and Paths to Widespread Adoption

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Introduction

The United Nations' Human Settlements Program UN-HABITAT estimates that nearly half of the earth's population is living in cities. By 2015, this number will grow to 60%.[1] Urbanization patterns have placed large areas of impervious surfaces (such as asphalt and concrete) on land, wetlands, and creeks. Our concrete jungles are causing water pollution and the urban heat island phenomenon, accelerating erosion and increasing flooding, deteriorating air quality, and annihilating wildlife habitats. Urban planning and the built environment is disconnecting people who live and work in cities from nature, and failing to provide them with quality spaces in which to work and live. This paper explains why the urban fabric is out of touch with both the human psyche and natural ecosystems.

Greenroofs can help mitigate the problems urbanization has created. Greenroofs (also known as eco-roofs) are living, vegetated alternatives to traditional impervious roofing surfaces. The technology is simple. A waterproofing membrane is installed on the roof deck, followed by a drainage layer and filter fabric. Next, a 2"-15" layer of engineered lightweight growth medium is brought in and planted with a wide variety of possible plant species (such as wild grasses, succulents, mosses, perennials, shrubs, and even trees). They can be either accessible or inaccessible to people. They can be installed on virtually any flat roof and on sloped roofs with up to 45° pitch, as a retrofit on an older building or as a planned design feature of a new building.

Extensive greenroofs have a thin layer of soil and are quite limited in the types of plants they can support. They are typically self-sustaining after the first year. They are also lightweight, and in many cases they are the only greenroof option due to roof deck load restrictions. They don't always offer the "rooftop park" atmosphere that comes with *intensive* greenroofs. Intensive greenroofs have a thicker layer of soil (6" or more), and they can support a much wider variety of shrubs and trees. Because of their weight, they may require structural enhancements. Intensive rooftops are more costly to install and they require more maintenance.

Greenroofs have the potential to make a profound and positive impact on urban environments if they become widespread. They benefit local ecologies by reducing stormwater runoff, improving air quality, and reestablishing biodiversity. They benefit human health and society, and they can be economically advantageous as well. Part One of this paper reports on these advantages and benefits.

Despite extensive research and empirical data indicating these benefits, greenroofs are relatively uncommon in North America. Barriers to widespread adoption include cost premiums, a lack of government financial support, a lack of public awareness, and a fragmented greenroofing industry. Part Two of this paper proposes solutions to these barriers, or "paths to widespread adoption."

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[1] *UN-HABITAT Program*

Part 1: The Profound Potential of Greenroofs to Improve Urban Environments

Benefits to Local Ecologies

Stormwater Reduction: Greenroofing as a Retention Strategy

Stormwater is rainfall which runs off the impervious landscape of the urban environment – buildings, streets, and parking lots - and into either manmade storm sewers or directly into natural drainage systems. Urban stormwater infrastructures are either independent systems or they are combined with sanitary sewer systems. Stormwater entering independent storm sewers does not usually receive any treatment before it enters streams, lakes and other surface waters[2].

Many cities have combined sewer systems, which combine sanitary sewage from human and industrial wastewaters with stormwater. This water *is* treated before it enters natural systems; however, combined sewer systems were built in the late 19th and early 20th centuries, and many have been outgrown by extensive urbanization. Overflows and bypasses frequently occur in systems with insufficient capacities. Every year in the Greater Vancouver Regional District, 50 combined sewer overflow pipes discharge 62 million cubic metres of untreated sewage and urban runoff[3].

Urbanization drastically alters the natural hydrology of an area. Under natural conditions, approximately 10% of the rainwater falling on an area runs into streams, rivers, or lakes. The rest infiltrates the soil, stocking groundwater reserves, or it is evaporated back into the atmosphere. As the amount of impervious coverage increases, the volume and rate of stormwater runoff increases (see figure 1). This accelerates erosion, alters streambed composition, and contributes to flooding. Excessive inflow of stormwater into sewers during major storm events in Surrey, BC causes sanitary sewer overflows. Untreated sewage and runoff water is released into overland ditches and agricultural lands. Sanitary sewer overflows can also enter the Nicomekl River, a fish-bearing waterway[4]. Not only do these untreated overflows overwhelm natural watercourses, flooding farmers' fields and reducing the productivity of limited and precious local agriculture, but they also pollute them. Watercourses draining urbanized areas commonly have poor water quality due to:

- sediment from construction sites
- fertilizers from suburban lawns
- oil, grease, and trace metals from automobiles and industry
- toxic and synthetic chemicals from pesticides, accidental spills, and illegal dumping

[2] *Stormwater Problems & Impacts: Why All The Fuss?*
[3] *Puget Sound-Georgia Basin Sewage Report*
[4] *Cloverdale Sanitary Sewer Overflow Storage Facility*

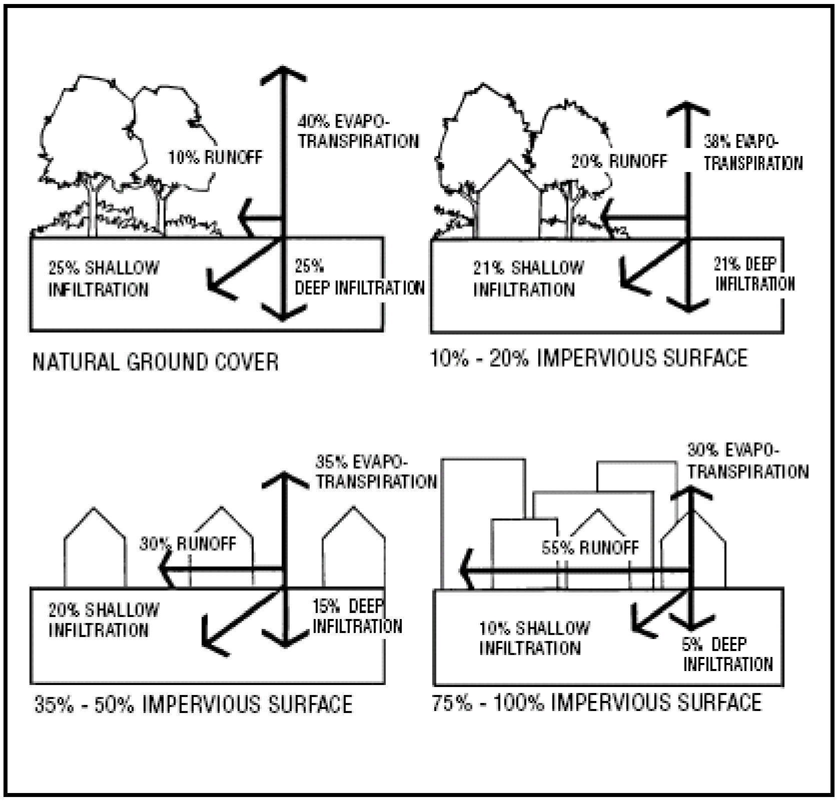

Figure 1: Changes in runoff flows resulting from paved surfaces

Over one thousand North American cities suffer from combined sewer overflows. In the rainy Pacific Northwest, the problem exists not just in the major centers of Vancouver, Seattle, and Portland, but in smaller towns as well. In the B.C. communities of Powell River, Sidney, and Ladysmith, more sewage bypasses the treatment plant than reaches it. In Washington State, Mount Vernon discharges 13% of its total inflow to western Washington's most important salmon river, the Skagit. In Renton, sewage overflows into the Green River, with anticipated overflow for 2005 of 85 million gallons per day during heavy rain events[5].

Insufficient capacities in combined stormwater systems are usually dealt with by expanding infrastructures to keep pace with rapid urbanization. In Portland, where pollution in the Williamette River violates *Clean Water Act* standards year after year, taxpayers will commit $1 billion in the 20-year Combined Sewer Overflow Program to upgrade its combined stormwater system.[6] In congested areas where "Best Management Practices" such as the use of bio-retention areas, wet and dry detention ponds, and constructed wetlands are not possible, stormwater management is typically dealt with using this kind of "widen the pipe" approach.

[5] *Puget Sound-Georgia Basin Sewage Report*
[6] Marriott

Greenroofs offer an alternative solution to stormwater management problems. Vegetation on greenroofs mimics natural absorption. Rainwater is retained in the foliage and root systems of plants, and in the greenroof system's drainage layer. Most of the rainwater remains on the roof, available to be evaporated back in to the atmosphere. Greenroofs take advantage of thousands of square feet available on rooftops that would not otherwise be available on the ground. Studies around the world have consistently shown that greenroofs significantly reduce the volume and pollutant loadings of runoff.

German research conducted in Hannover-Herrenhausen from 1985 to 1994 determined that 50 mm and 100 mm soils retained respectively 65% and 70% of the precipitation during summer months, and approximately 50% in winter months. The City of Portland conducted a 15-month monitoring study during 2002 and 2003 and found the water retention of an extensive greenroof to be 69% of the total rainfall. Research conducted at Michigan State University has shown that 66% of the precipitation was retained by an extensive greenroof.[7] In 2003, Public Works and Government Services Canada initiated a study to monitor the greenroof on the Vancouver Public Library and found that the overall reduction in runoff was 70%.[8]

Data on urban impervious coverage is limited, and is usually very specific to a given city. Roof coverage in single-family residential subdivisions varies greatly depending on density, ranging anywhere from 15% to 45% of total land area.[9] In commercial and industrial zones, total impervious surface coverage ranges from 69% to 96%.[10] Paved streets and parking lots account for 15-40% of this, and the remaining impervious surfaces are roofs. As of yet, there is no empirical model to predict the stormwater retention capability of an urban area with a defined proportion of greened roofs. However, an educated guess can be made using conservative assumptions based on the findings of the above mentioned research. For instance:

- in a downtown urban setting with 60% roof coverage;
- with 25% of rooftops greened;
- with greenroofs producing average stormwater runoff reductions of 65%;
- total stormwater reduction for the area would be 9.75%.

Using this simple calculation, if 75% of the rooftops were greened, the total stormwater reduction would be nearly 30%. More empirical evidence and thorough calculation is required to establish a more sophisticated model of greenroofs' potential stormwater retention performance. However, common sense implies that even a modest amount of greenroof coverage would translate into significant stormwater reductions.

Climate: The Urban Heat Island and Greenroofs' Cooling Potential

Standard building materials (such as concrete, asphalt, cement, and tar) absorb light and store heat. On hot summer days, the surface temperature of urban rooftops climbs 50°F to 70°F hotter than the ambient air temperature; this happens to be where the in-vents for air

[7] Moran, Hunt, Jennings
[8] Johnston, McCreary, Nelms
[9] Gadd and Kennedy; Mattraw, Hardee, Miller
[10] Bowles

conditioners are, forcing them to work much harder to cool the building below. All of the surfaces in the city get hotter, creating what is known as the urban heat island. Summer temperatures in cities increase by 2°F to 10°F when compared to the surrounding countryside. The urban heat island increases energy demand for air conditioning purposes, increasing power plant activity and emissions of sulfur dioxide, carbon monoxide, nitrous oxides, suspended particulates, and carbon dioxide.[11]

Green roofs counteract this problem with the natural process of *evapotranspiration*: the cooling effect plants have when they give up their moisture to evaporation. Recent studies by the National Research Council of Canada have shown that if just 6% of Toronto's rooftops were greened, the city would reduce summertime temperatures by 2°C, and reduce its green house gas emissions by 2.18 megatonnes per year.[12] Greenroofs' capacity to counter the urban heat island means that significant energy savings can be accomplished by reducing metropolitan ambient air temperatures. Dr. Brad Bass, an Environment Canada researcher working to adapt cities to the coming heat waves of the pending era of global warming, estimates that even as modest an effort as 6% greenroof coverage can reduce the demand for electric-powered summer cooling needs in by 5 to 10%.[13]

A 1999 study done for the city of Chicago estimated that the greening of all of the city's roofs would save $100 million energy each year - the equivalent energy consumption of several coal-fired generating stations or one small nuclear power plant.[14] A study by the City of Portland's Bureau of Environmental Sciences modeled greenroof development potential for the downtown eastside district. The study found that with 100% greenroof coverage, 60-90% of the area's heat island problem could be eliminated.[15]

Air Quality: Rejuvenating Greenroofs

Deteriorating urban air quality goes hand-in-hand with the urban heat island. Heat, sunlight, and pollution interact to form smog, a harmful "photochemical stew" of ground level ozone which is known to aggravate respiratory problems. The warming of ambient air through the urban island heat effect facilitates and accelerates smog formation. A NASA study conducted in Atlanta found that the 10°F increase from that city's urban heat island doubles ozone production. By virtue of their ability to reduce summertime ambient air temperatures, greenroofs can combat deteriorating urban air quality.[16]

In addition, the plant foliage on greenroofs rejuvenates the air, producing oxygen and absorbing carbon dioxide and other airborne toxins. The plants filter the air by capturing the particles that make up smog, and with the plants perched high atop greenroofs, they are in an optimum position to trap airborne particles. One square meter of grass roof can remove approximately 0.2 kg of airborne particles from the air every year.[17]

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[11] Gorsevski, Taha, Quattrochi, Luvall, pg. 1
[12] Empey
[13] Roberts
[14] Elston
[15] Marriott
[16] Johnson
[17] Minke and Witter

Biodiversity: Conservation in the Urban Environment

Greenroofs are implicitly good for wildlife, although they should not be considered substitutes for natural wildlife reserves. They can serve as valuable island habitats in a series of stepping-stones composing green corridors and facilitating wildlife movement. Also, greenroofs provide microhabitats for valuable insects, birds, bees, and butterflies - enhancing biological diversity even in highly populated urban centres. Greenroofs can be specifically designed to mimic endangered ecosystems such as the prairie grasslands of the Midwest US, the rocky alvars of Manitoulin Island, and the Great Lakes Region in Ontario. If they are sufficiently designed, greenroofs can serve as habitat compensation for rare and endangered species. An investigation of an extensive greenroof on the Rhypark building in Basel, Switzerland revealed 70 beetle and 40 spider species. 13 of the beetle and 7 of the spider species were classified endangered.[18] Spiders are a good indicator of the invertebrate communities residing on greenroofs due to their position on the food chain.

Brownfield sites are areas that have at one time been developed and then left to the processes of nature. They are common in the UK, where recent demand to develop them has brought attention to their amazing diversity. Many species that have lost their natural habitats to intensive agriculture have made homes on brownfield land, and now these refuges will soon be lost to development. A recent survey of 10 greenroofs in London found 59 spider species, accounting for 26% of the area's resident spider faunas.[19]

There is an abundance of case studies providing insights on designing greenroofs to optimize their habitability. Other greenroof initiatives focusing on biodiversity include the Black Redstart Project in London, which acts as a driver to ensure that green roofs are used in new developments in London where such developments threaten the endangered bird species; and the Toronto City Hall Demonstration Project, which features a native plant and butterfly plot.

Positive Impacts to Human Health

Greenroofs are an important aspect of the emerging architectural philosophy of "biophilic" design. Biophilia describes the deep bonds between humans and nature. Biophilic buildings go beyond popular "low environmental impact" trends in the construction industry, and aim to "produce a valued and cherished experience based on contact with natural systems rooted in the innate human affinity for the nonhuman environment as an essential source of mental well-being and health" (Kellert, 2004). The ultimate goal of biophilic design is to ensure long-term retention of buildings. Even if it uses recycled materials and minimizes energy consumption, a cutting-edge green building will not last long if it fails to tie humans to the natural environment. Structures which meet this test have been proven to reduce stress, improve health, foster creativity, and improve productivity.

[18] Brenneisen
[19] Gedge and Kadas

Accessible greenroofs are an obvious tool for achieving true biophilia in urban design. They are beautiful amenities which provide urban inhabitants with access to sunlight and fresh air. The tranquil, relaxing atmospheres of greenroofs offer refuge from the stress and congestion of city life. Even inaccessible greenroofs are beneficial to human health: the mere view of greenroofs from neighbouring offices and apartments is a sanctuary for the eyes amongst the grey sprawl of the city.

Biophilia is a phenomenon founded on biological premises and substantiated by data from social science and health research. It addresses a wide range of issues in human functioning, including psychological, physical, and social well-being; and cognitive functioning, which is linked to various measures of performance.

Well-Being

Dr. Robert Ulrich cites over 12 scientific studies demonstrating that the simple sight of ordinary nature is effective in diminishing anger and relieving stress to the extent of measurable improvement. One study conducted by Roger Ulrich involved the recovery process of surgery patients. Half of the patients' rooms looked over a small grove of trees. The other half of the patients looked onto a brick wall. Patients in the rooms with the natural views stayed in the hospital for fewer days, used fewer pain killers, and had a more positive recovery process overall than the matched group of patients who had a view of the wall.[20] Greenroofs are becoming more and more common in hospitals: the burn unit at the Vancouver General Hospital has a rooftop garden to create a therapeutic environment for the unit's patients. The staff's goal was to provide the benefits of greenery to their patients, and they have all reported "great satisfaction and enjoyment of the roof top garden."[21]

A study performed by Rachel Kaplan found that workers who could view nature scenes from their windows felt less frustrated and more patient, and reported higher overall life satisfaction and better health than workers who could not view the outdoors. Other research has shown that residents of high-density developments are less susceptible to illness if they have a balcony or terrace garden.[22] In another study, residents of public housing projects in Chicago derived a significant positive impact on social behavior from having access to green spaces. They were found to spend more time talking to one another, developed stronger ties with neighbors, and reported feeling a stronger sense of community than residents in public housing projects lacking outdoor green spaces.[23] Of course, most city blocks are completely built-out, and cannot accommodate new parks. Roofs are an unutilized space which can be planted with greenery to reconnect urban residents and workers to nature.

Cognitive Functioning

The calming influence of natural surroundings enables sustained focus in highly distractible children. Children living in low-income urban housing who moved to

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[20] Heerwagen
[21] Davis, pg. 31
[22] Peck, pg. 32
[23] Heerwagen

locations with more access to natural outdoor vegetation improved their scores on standardized tests for Attention Deficit Disorder. This calming effect benefits adults as well; NASA research indicates the distant views draw out a cognitive tranquility, which is crucial for sustained work performance in stressful atmospheres.

Researchers at the University of Michigan have consistently found that contact with nature increases concentration abilities for tasks demanding high mental effort. In a study by Virginia Lohr, subjects working at computers in a windowless room with plants felt more attentive, worked more efficiently, and had lower blood pressure than subjects working in the same room without any plants.[24]

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[24] Ibid.

Part 2: Barriers & Paths to Widespread Adoption

The primary barrier to widespread greenroof adoption is cost. This can be partly addressed by educating property owners on the life cycle savings which can result from many greenroof applications. The cost barrier will be fully removed when government financial support of greenroofs is achieved. Policy makers must be convinced of the potential benefits to society, the environment, and the economy before they will invest public finances in the greenroof concept. This will require an expansion of the knowledge base on all aspects of greenroof performance in each climatic region. The results of this research must be made available in a structured framework to effectively convey the significance of greenroofs to policy makers and the general public. The general public must be made aware of greenroof benefits, because ultimately they will drive the greenroof revolution. Finally, entrepreneurial energy is required to pull the industry out of its current fragmented state. These entrepreneurs will act as local experts in greenroof contracting will make it easier for curious early adopters to have greenroofs built.

The Greenroof Investment: Outlay Costs & Life Cycle Benefits

Greenroofs require a larger capital outlay than traditional roof surfaces. Each site will have a different cost premium for a greenroof, but the premium will always exist. This is because the waterproof membranes used in greenroofing are usually of higher quality, and because more materials and labour are required to install the greenroof system. In some cases, structural upgrading may also be required. Extensive greenroofs cost 50-80% less than intensive greenroofs. If the concept is included early in the design of a new project, a greenroof can be installed at very little extra cost. Due to these variables, the cost premium may range anywhere from 1.25 to 3 times the cost of a traditional roof, or a final price of approximately $6 to $15 CAD per square foot.[25]

From a life cycle perspective, however, greenroofs are competitive with conventional roofs. The economic advantages provided by greenroofs over the long term include a significantly extended roof life, energy savings, and in many jurisdictions, storm water savings. In many applications, greenroofs can also attract increased building revenues.

Extended Life of Roof Membrane

Greenroofs protect the underlying roof structure from harmful temperature extremes. Exposed membranes on traditional roofs absorb solar radiation during the day as the surface temperature rises, and the energy is re-radiated at night as the surface temperature drops. These variations create thermal stresses in the membrane and reduce its service life.

The National Research Council of Canada (NRC) constructed an experimental Field Roof Facility on its Ottawa campus. The reference roof's exposed membrane was recorded to reach over 70°C in the summer. Under the greenroof, the membrane stayed between 25°C and 30°C. The median temperature variation of the reference roof each day was 45°C, while

[25] Peck, pg. 35

the greenroof's daily variation was only 6°C.[26] On clear winter nights traditional exposed surfaces such as asphalt and bitumen can cool down as far as 20°C below that of the surrounding air. In winter, common erosion and fractures from frost and ice can be eradicated by greenroofs.

Typical service lives of traditional, exposed roofing systems range from 10 to 20 years. The protective benefits of greenroofs *at least double and often triple the service life of roofs*, and that translates into long-term ongoing savings from reduced roof maintenance and replacement.[27] The greenroofs at Rockefeller Center were constructed in the 1930's, and they still have their original waterproofing membranes.[28] Researchers in Germany expect many greenroofs systems now 35 years old to reach their 50th birthday before requiring significant repair. A roof membrane installed under a planting on a department store in London in 1938 was found to be in exceptional condition 50 years later.[29]

Energy Savings

The NRC's Field Roof research found that the greenroof reduced heat flow through the roof by 75%.[30] The thermal insulation offered by greenroofs can significantly reduce energy costs for both cooling and heating. Environment Canada found that an average one-story building with a grass roof and 10 cm of growing medium would result in a 25% to 30% reduction in summer cooling bills.[31] Reductions in winter heating costs do exist in temperate climates where it is not cold enough to freeze greenroof soil and vegetation. Structures taller than three stories benefit less from energy savings because their roof comprises a smaller proportion of the building envelope. For example, the Environment Canada study projected that a three-story building can expect a 10% reduction. Therefore, low-rise buildings like factories, warehouses, and single-family residences stand to gain the most in terms of energy savings.

The Gap Headquarters in San Bruno California features an award-winning undulating greenroof with 6 inches of insulation and 6 inches of growth medium. The building was completed in 1997, and The Gap expects to have saved enough money by 2005 from lowered energy costs to have paid for the greenroofs and all the other environmentally friendly features of the building.[32]

Financial Savings from Storm Water Retention

Recent amendments to the U.S. *Clean Water Act*, called the "National Pollution Discharge System" and "Total Maximum Daily Load" regulations, have pressured over 300[33] mid- to large-sized American communities to adopt more comprehensive strategies to manage stormwater. These fee structures are commonly referred to as "stormwater

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[26] Liu and Baskaran
[27] *Economic Advantages of Greenroofs*
[28] Velazquez
[29] Peck, pg. 30
[30] Liu and Baskaran
[31] *Private Benefits of Greenroofs*
[32] Velazquez.
[33] *City of Edmonton's New Land Drainage Utility: FAQs for Non-residential Customers*, pg. 4

infrastructure levies," "stormwater utility fees," or "impervious surface fees." These new fee structures are modelled after those used in Germany since 1984. Fees are assessed according to the impervious surface area on a property that drains into a sewer system. In Germany, the original intent of the system was to improve the fairness of stormwater billing; however, the change from a flat rate system there has "significantly influenced the way property owners think about impermeable surfaces"[34] As a result of Germany's impervious surface fees, greenroofs typically receive a 50-100% discount, and can pay for themselves based on reduced stormwater bills savings alone over the span of 10-15 years.[35]

In Canada, "Land Drainage Utilities" have recently been established in Edmonton, Calgary, Strathcona County, Regina, Saskatoon, and Winnipeg. As users become familiar with these fee systems, they will begin to look for ways to reduce their land drainage expenses. As their German counterparts have already discovered, greenroofs are a cost-effective way to accomplish this.

Greenroof Life Cycle Analysis: A Case Study from Multnomah County, OR

In 2003, Dr. Allen Lee from *Quantec LLC* was recruited by Multnomah County in Oregon to perform an exhaustive life cycle cost analysis of a greenroof proposed for its headquarters office building. Dr. Lee has over 20 years of energy-efficiency and buildings analysis experience, including several benefit-cost and life cycle cost analyses of a wide range of building types and technologies. The analysis used standard life cycle cost economic methods, discounted the stream of future costs at an appropriate rate over a 60-year period, and included sensitivity analyses to address issues of uncertainty in key inputs.

The analysis considered the installation cost of the greenroof and the replacement cost, energy, and stormwater savings derived from the greenroof. It also considered operations and maintenance costs associated with the greenroof. The final result was a negative net present value (NPV) of -$17,300, or 7% of the traditional roof's capital cost. This number is certainly much easier to swallow than the 200-300% cost premiums frequently cited for greenroof installation. Furthermore, Dr. Lee acknowledged that his assumptions for the lifetime and maintenance costs of the greenroof were conservative. For instance, a 52-year lifespan for the membrane would not be unrealistic, and it would produce a positive NPV of $62,000 as compared to the conventional roof. Also, it was recognized that the energy savings would be much greater in a hotter region with a heavier cooling load.

[34] Keeley, pg. 178
[35] Ibid.

Increased Revenues

The life cycle analysis does not account for the very real potential for greenroofs to increase property values and attract higher lease and rental rates from commercial and residential tenants alike. Building users perceive value in accessible greenroofs. Residential tenants in the urban setting typically suffer from a lack of natural surroundings. Balconies may offer a hint of fresh air, but they do not substitute for a yard the way greenroofs do. Greenroofs are tremendously appealing to condominium and apartment dwellers, not only for the tranquility of their natural atmospheres but also for their provision of relaxing places for neighbours to meet and interact in these often impersonal and detached neighbourhoods. Many corporations now think of their facilities as not just a place to house their workforce, but as an important way to achieve strategic goals.[36] Companies operating out of greenroofed buildings reap the rewards when their employees can enjoy rooftop space - previously wasted, the space is now utilized by greenroofs, which can become soothing break- or lunch-time retreats for workers. At the Broadway Technology Centre in Vancouver, the main driver for greenroof implementation was:

> "…providing amenity and recreational areas for employees. Creating creative, social space took precedence in the project. It is believed that the landscaping is one of the reasons behind the building's high lease rates and leasability."[37]

For organization- or operator-owned buildings, the intangible benefits of greenroofs can translate indirectly into financial gain. Greenroofs contribute to an organization's competitive advantage through positive public relations, goodwill, recognition, and free advertising and market exposure. They are a common element in achieving the highest levels of LEED certification – a marketable distinction. Greenroofs provide a superior workspace for employees, as indicated in the earlier discussion of the known benefits to well-being and cognitive performance that come from natural contact. They have also been used successfully as urban agriculture sites by both restaurants and residents. On many sites, it is possible for a greenroof could pay for itself from the increased revenues derived from these valuable benefits alone.

Greenroofs are an innovative technology in North America, still in the "early adopter" stage. As they are accepted in the construction industry and become more popular and widespread, their costs will decrease. Furthermore, it is very likely that policy makers at various levels of the Canadian and American governments will become convinced of greenroofs' potentially profound benefits to the environment, and hence to the public good. Because greenroofs are a legitimate alternative improvement to stormwater infrastructure, a verified remedy for the urban heat island and deteriorating urban air quality, and a known beneficiary to the health of a city's population, it is unfair to expect private building owners and developers to bear the entire financial burden of greenroofs. Governments must recognize these values to society and provide financial incentives to property owners who invest in greenroofs. Without government incentives, the greenroof

[36] Heerwagen
[37] Davis, pg. 44

industry will continue to serve the high-end market exclusively and the technology will not be able to break into the mainstream, which is of course necessary to realize their environmental advantages. Government support will remove the primary barrier to widespread adoption by making them an affordable, win-win roofing transaction for ordinary people.

Government Support: Making Greenroofs Affordable for Everyone

North American policy makers have thus far failed to recognize the public benefits of greenroofs partly due to a lack of understanding about those benefits and partly due to a pervading short-term mindset which pressures public finances into bottom line decision making. But greenroofing is about quality, longevity, and innovation; a greenroof "revolution" will be a lengthy process. Environmental benefits will not be immediately apparent. Policy makers will require an abundance of empirical evidence and local success stories to persuade them that the greenroof is a crucial element of urban sustainability, and an important step towards restorative environmental design. Potential government support includes grants and subsidies for implementation, green roof procurement policies for publicly owned buildings, and legislation and building codes with environmental performance standards encouraging the use of greenroofs.

Germany is known as a progressive society from many angles, and greenroofing is no exception. Over 80 municipal governments there are now providing direct incentives and/or using regulations in support of green roof implementation, where more than 1 in every 10 flat-roofed buildings has a green roof. 21 German cities have added roof greening requirements to their Local Development Plans. In Berlin, roof greening measures are eligible for the equivalent of up to $85 CAD per square metre in compensation, or roughly 34% of installation costs. A further 20% of maintenance costs are compensated. In Munich, up to 50% of the capital cost is repaid via direct subsidy.

There are indications that North American policy makers are already beginning to recognize the value of greenroofs. On Sept. 26, 2003, Quebec's Energy Board approved the first greenroof incentive in Canada: an $11 CDN per square metre incentive for green roof implementation, or approximately 4% compensation. This is a first small step in the right direction. Early efforts to introduce greenroofing policies in Germany date back nearly 30 years. In Canada, similar efforts have only been undertaken in the past 5 years.

The Natural Resources Canada and its Office of Energy Efficiency has a Commercial Building Incentive Program (CBIP) which awards financial incentives equal to twice the annual energy savings for building owners whose design meets CBIP requirements. To qualify for the incentive, a building must be at least 25 percent more energy-efficient than if it were constructed to meet the requirements of the Model National Energy Code for Buildings (MNECB). Most low-rise buildings with greenroofs will meet this requirement.

Government support will arise out of knowledge. The body of research on greenroof performance and social, environmental, and economic benefits is growing. It must continue to grow, and findings must be organized and made more easily accessible. Greenroof benefits are specific to climatic regions, so studies must be carried out in each of these regions to produce qualified and relevant models of the effects of widespread greenroofing. An extensive and localized knowledge base such as this will facilitate government cooperation, and it will also help to overcome the next barrier: lack of public awareness.

Public Awareness: The Key to Market Demand

Despite numerous demonstration projects across the continent, greenroofs are still an unfamiliar concept to the critical mass. This lack of public awareness must be dealt with. An ambitious but not unrealistic goal would be to make the greenroof concept a "household name" by 2010.

To reach this lofty goal, there must be a strategy to communicate the benefits of greenroofs to the public. In the early stages of greenroof industry development, community workshops in residential neighbourhoods might be a good technique to get greenroof experts face-to-face with environmentally conscientious citizens. These workshops would be educational and experiential, allowing people to gain a deep understanding of greenroofs. They could generate enough interest to get contracts for pioneer projects, which would attract attention and generate more interest.

As curiosity grows, individuals must have easy access to a comprehensive greenroof information source. The logical media for this is the internet. This online "greenroof encyclopedia" must be frequently updated by experts and it must have no ties to any commercial interests. It will be organized according to climatic regions. Its objective will be to educate and to enable grassroots, participatory greenroof development. There are several greenroofing websites already in existence, but most are slaves to advertising sponsors, disorganized, and confusing. Redundancy needs to be eliminated and more sophisticated information needs to be made available.

Another important element in fostering public awareness is youth education. High school, college, and university students represent a "green" generation, and they possess the energy and enthusiasm required to keep the greenroof revolution rolling through the coming decades. Students at Manhattan's School of the Future are currently designing experiments for a demonstration greenroof and helping to develop a research-based greenroof curriculum guide for replication in other New York high schools. The guide will be disseminated on www.greeninggotham.org in fall 2004. This is precisely the kind of initiative required to give students knowledge and hands-on experience with urban environmental issues.

The final stage in achieving mainstream public awareness is the use of traditional advertising media. This should not occur until some degree of government support for greenroofs is in place, and the greenroof industry has been mobilized (and ideally standardized and regulated). This is because greenroofs must be affordable, available, and reliable before a campaign is launched to set off a major demand for greenroofs. Once these elements are in place, however, a very effective campaign could be launched. The greenroof product would lend itself very well to inspiring imagery for print ads, and exciting animation and cinematography for TV and film.

Bibliography

Bowles, Glen. *Impervious Surface – an Environmental Indicator.* The Land Use Tracker. Vol. 2, Issue 1. 2002. http://www.uwsp.edu/cnr/landcenter/tracker/Summer2002/envirindic.html.

Brenneisen, Stephan. *From Biodiversity Strategies to Agricultural Productivity.* University of Applied Sciences Wädenswil, Switzerland. Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Carey, Patrick. Residential *Green Roof Policy, Strategies and Tactics.* Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

City of Edmonton's New Land Drainage Utility: FAQs for Non-residential Customers. http://www.gov.edmonton.ab.ca/

Cloverdale Sanitary Sewer Overflow Storage Facility: Greater Vancouver Regional District. http://www.sustainability.ca/

Davis, Kim. Green *Roof Inventory: Preface Report Greater Vancouver Regional District*. 2002. http://www.betterbuildings.ca/content/articlefiles/41-Green_Roof_Inventory.pdf

Economic Advantages of Greenroofs. greenroofs.com. 2003. http://www.greenroofs.com/economic.htm

Elston, Suzanne. *Green rooftop technology saves energy, cools air.* The Environmental News Network. 2000. http://www.enn.com/news/enn-stories/2000/12/12302000/rooftops_40979.asp

Empey, Allison. *Green Roofs, An Icon For Our Urban Future*. City Farmer, Canada's Office of Urban Agriculture. http://www.cityfarmer.org/roofFuture.html

Gadd and Kennedy. *Preliminary Examination of the Nature of Urban Roof Runoff in New Zealand.* 2001. http://www.kma.co.nz/

Gedge, Dusty and Kadas, Gyongyver. Bugs, Bees, and Spiders: Green Roof Design for Rare Invertebrates. www.Livingroofs.org /Royal Holloway University of London. Greening Rooftops for Sustainable Communities Conference Proceedings. 2004

Gorsevski, Taha, Quattrochi, Luvall. *Air Pollution Prevention Through Urban Heat Island Mitigation: An Update on the Urban Heat Island Pilot Project.* http://wwwghcc.msfc.nasa.gov/uhipp/epa_doc.pdf

Green Roof Initiative Activities. Earth Pledge Foundation. 2004. http://www.earthpledge.org/GRIA.html

Heerwagen, Judith, and Hase, Betty. *Building Biophilia: Connecting People to Nature in Building Design.* Environmental Design & Construction Magazine. 2001. http://www.edcmag.com/

Johnson, Kirk. *Climate Scientists Zoom In on Changes.* 2003.http://www.sustainability.ca/

Johnston, McCreary, Nelms. Vancouver Public Library Green Roof Monitoring Project. Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Keeley, Melissa. Green *Roof Incentives: Tried and True Techniques from Europe.* Technical University of Berlin. Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Lee, Allen. *Life Cycle Cost Analysis – Green Roofs from an Investment Perspective.* Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Liu, Karen, and Basran, Bas. Thermal *Performance of Green Roofs through Field Evaluation.* National Research Council, Institute for Research in Construction. Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Marriott, Dean. *Portland's Combined Sewer Overflow (CSO) Program.* http://www.cleanrivers-pdx.org/what_we_do/cso_program.htm

Mattraw, Hardee, Miller. *Urban Stormwater Runoff Data for a Residential Area, Pompano Beach, Florida.* http://sflwww.er.usgs.gov/publications/ofr/78-324/

Moran, Hunt, Jennings. *A North Carolina Field Study to Evaluate Greenroof Runoff Quantity, Runoff Quality, and Plant Growth.* Greening Rooftops for Sustainable Communities Conference Proceedings. 2004.

Minke, G and Witter, G. *Hauser mit Gruenem Pelz, Ein Handuch zur Hausegruenung.* Verlag Dieter Fricke GmbH, Frankfurt, 1982.

Peck, Callaghan, Kuhn, and Bass. Greenbacks from Green Roofs: Forging a New Industry in Canada. Prepared for the Canada Mortgage and Housing Corporation. 1999. http://www.greenroofs.ca/grhcc/Greenbacks.pdf

Puget Sound-Georgia Basin Sewage Report. 1997. http://www.pugetsound.org/sewage/report/default.html

Private Benefits of Greenroofs. Greenroofs for Healthy Cities. 2002. http://peck.ca/grhcc/

Roberts, Wayne. *Green Roofs.* City Farmer, Canada's Office of Urban Agriculture. http://www.cityfarmer.org/greenroofTO.html#roof

Stormwater Problems & Impacts: Why All The Fuss? Land-of-Sky Regional Council, Asheville, NC. http://h2o.enr.state.nc.us/su/PDF_Files/Land_of_Sky_factsheets/FactSheet_1.pdf

Velazquez, Linda. *Economic Benefits of Greenroofs: Invest in the Future of our Environment & Construct Healthy Buildings to Reap Biological and Financial Rewards.* http://www.greenroofs.com/pdfs/past- atlanta_botanical_garden_economic_brochure.pdf

UN-HABITAT Program. United Nations website. http://www.unchs.org/about/challenge.asp