Planning Green Roofs in Toronto: Overcoming Obstacles to Private Investment

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Abstract

The objective of my research was to gain an understanding of the practical implications of using green roofs in the city of Toronto. The City is a leader in green roof use in North America and is actively encouraging green roofs through a strategy that combines incentives and standards. Currently, green roof literature does not contain the opinions and experiences of developers and building owners who are installing green roofs in Toronto. I focused on understanding the impact of Toronto's strategy on its development community, and determining whether the private interests involved have opportunities for gaining a competitive advantage.

In order to establish my research objective, I began with a literature review of various secondary research sources on green roofs. Following this, I interviewed representatives of four Toronto development firms regarding their perceptions and attitudes towards the use of green roofs in their projects. My primary research was structured as an exploratory study to get a general impression, rather than reach an absolute conclusion about Toronto development firms and green roofs.

The results of my research revealed that many of the benefits of green roofs attributed to building owners and developers (private benefits) that are identified in academic and industry literature are generally not recognized or considered by development firms. Firms committed to the concept of sustainability as a central component of their corporate philosophy have a stronger interest in some the features of green roofs. The urban agriculture potential, which is currently being explored by these firms, appears to be the best means to establish a competitive advantage with the use of green roofs.

My research suggests that there is a division of opinion between the authors of green roof literature and private developers as to which features of green roofs are actually beneficial. It also provides insight into the current strategies being used to incorporate green roofs into projects. This information is useful in understanding the implications of Toronto's green roof strategy and indicating the direction private interests may be pursuing with green roofs.

Figure 1: View from Mountain Equipment Co-op's green roof in Toronto. Green Ribbon 2013

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Foreword

My decision to focus on green roofs in Toronto reflects my interest in the influence of cities on the daily lives of its inhabitants and the evolving relationship between humans and our natural and built environments. When I first came across renderings of eco-cities, I imagined that these would be the cities of the future. My understanding and knowledge of cities, sustainability, and environmental planning have come a long way over the two years I spent completing my MES. Yet, as I considered options for my Major Research Paper, I could not help but be drawn back to the visually distinct characteristics and abundance of green systems in proposed eco-cities.

Figure 2: Rendering of Tianjin eco-city currently under construction in China. BBC 2012

The preparation of a major research paper on green roofs also draws on the primary components from my Plan of Study and my concentration on business and urban planning strategies for sustainability. Green roofs are a tangible example of a technology that is further integrating the features of the natural environment into our built environments.

I designed my Plan of Study to allow me to pursue my Planning Degree as well as a Diploma in Business and the Environment in FES. Therefore, it was essential to find a research topic that complimented this interdisciplinary focus. The research on Toronto's Green Roof By-law and Eco-Roof Incentive Program analyzes how municipal planning decisions regarding sustainable development impact the private development sector.

This research contributed to a better understanding of environmental planning in Toronto. It was also an opportunity to compare Toronto's green roof strategy with approaches adopted by other major North American cities also seeking to encourage the use of green roofs. Chicago, Washington and Philadelphia all want to accomplish similar goals as Toronto regarding green roofs, but the strategy of each municipality is influenced by characteristics of each city.

My focus on green roofs has also further immersed me into the conversation about sustainability and sustainable development. The visual characteristic of green roofs is highly distinct and seems to embody a tangible transition to greener, more sustainable buildings. However, green roof technology remains just one of many building elements contributing to more sustainable city development. Valuing their impact must be considered in this context and they are not an absolute solution. Instead, green roofs are a component of changing practices in urban form and land use planning that can lead to more sustainable cities.

Traditionally, in business, economic interests have conflicted with environmental concerns due to higher costs. However, sustainable business strategies advocate that new technologies and practices actually generate economic value with environmentally considered products and processes. For that reason, much of the literature around green roofs is focused on proving their financial viability compared to that of black roofs. By reviewing the literature and conducting research on the strategies currently employed by developers, I have come to better understand whether a business case can be made for private investment in green roofs.

Definitions

CBA - Life cycle cost-benefit analysis

CSO – Combined sewage overflow

GRHC – Green Roofs for Healthy Cities

LEED – Leadership in Energy and Environmental Design

NPV – Net present value

TGS – Toronto Green Development Standard

UHI – Urban Heat Island

UV – Ultraviolet

Section 1 – Introduction, research context & methodology

1.1 Introduction

The focus of my research is on the realities of green roof use by private development firms in the city of Toronto. I reviewed a range of literature that addresses green roofs in a broad context as well as specifically in Toronto. After establishing a foundational knowledge of green roofs, I explored how the literature compared to the opinions and practical experiences of private development firms in Toronto. I did so by learning about Toronto's green roof strategy and conducting interviews with various development firms operating in the city.

My research revealed that among development firms in Toronto, mandatory compliance for projects subject to the Green Roof By-law is not perceived as an obstacle. Rather, the use of green roofs and the financial costs associated with them are accepted as the reality of doing business in the city.

Representatives of participating firms explained that the biggest challenge of building with green roofs is calculating and incorporating the private benefits highlighted in green roof literature. Firms are aware of the claimed beneficial features such as reduced energy use, increased property value and extended lifespan of the waterproof membrane. However, firms generally do not consider these features in their decision-making. Some participants were sceptical of how extensive the benefits of green roofs really are, while others noted that it would be difficult to convey the value of the benefits to customers, even if they could be calculated. Further complicating the problem is the absence of long standing examples of green roofs. As a result, alternate roofing options such as pavers and ballast roofs maintain an advantage over green roofs because they are simpler and their features (such as solar reflectivity) are more easily quantifiable.

Green roof use in Toronto is primarily driven by compliance. The Green Roof By-law has levelled the playing field for green roofs by requiring all subject buildings to incorporate a proportion of coverage. Urban agriculture is the primary use of green roofs that participating firms recognize and use to distinguish their product and gain a competitive advantage. However, firms that are actively implementing urban agriculture are going beyond conventionally designed intensive green roofs.

Aesthetics seem to be one of the more powerful benefits of green roofs, but emphasizing this feature does not appear to be a priority among participating firms. All participants expressed a preference for the aesthetics of green roofs compared to other roofing options. Yet, this feature is complicated by the various considerations and visions that contribute to the design of a building. I suspected that using green roofs could enhance the aesthetics of amenity spaces and improve the view from a building's suites to create a competitive advantage. Instead, participants explained that they believe that the priority of customers is on other suite and building feature such as appliances, finishing, and location. Thus, they give little importance to having visual exposure to green roofs. This attitude towards exposure to green roofs could become a desired priority for customers. However, the aesthetic feature of green roofs is currently an intangible feature with limited influence on designers and builders.

Discussions with participants revealed that a firm's individual perception and use of green roofs is informed by its corporate philosophy and intended customers. Firms which identified sustainability and green development as core components of the business had a greater interest in the potential opportunities of green roofs. Alternatively, one firm which is involved in larger projects primarily catering to investors did not recognize sustainability as a core feature. For this firm, green roofs are only used to fulfill the City's requirements.

1.2 Research Context

From 2011 to 2012, the square footage of green roofs in North America increased by 24 percent (Green Roofs for Healthy Cities 2013, 6). It is anticipated that as mandates and incentives become more prevalent, the global value of the green roof market will reach $7 billion dollars by 2017 (Peck 2013, 2). As of 2012, the City of Toronto was the leader among Canadian municipalities in green roof use with over 300,000 square feet of green roof coverage.

Trends of increasing green roof use and dramatic growth expectations in the green roof industry indicate that the acceptance and adoption of green roofs could become more common. Coupled with this growth is an increasing body of literature focused on understanding and measuring the performance of green roofs. However, a knowledge gap has been created by an absence in research on the practical implications of private green roof use. In Toronto, the experiences of the development community in relation to the City's green roof strategy are absent from Toronto based reports and studies due to their completion date and focus (Banting et al. 2005; Liu and Minor 2005; Carter and Fowler 2008; Loder 2011; Toronto Region and Conservation 2007).

Scholars, municipalities and industry advocates suggest that green roofs are a tangible approach to a variety of environmental challenges such as the urban heat island effect and combined sewer overflow (Banting et al. 2005, Green Roofs for Healthy Cities

2013). However, the features and performance of green roofs are influenced by numerous factors including design, climate, and public policy. Therefore, some characteristics are a function of all green roofs, while others are only realised under specific circumstances (Green Roofs for Healthy Cities 2013).

The features of green roofs are generally divided as they apply to developers and private building owners and to the broader public. This allows investors and decision makers to better understand costs and benefits associated with green roofs. Further, quantifying and monetizing the functions of green roofs facilitates comparison to conventional costs. However, not all the functions of green roofs can be simply quantified, leading to the recognition of 'hard' values and 'soft' values. Hard values such as stormwater management can be measured directly, while soft values such as increased biodiversity are more difficult to quantify (Tomalty et al. 2010).

Establishing the hard value for the features of green roofs allows them to be incorporated into a life cycle cost-benefit analysis (CBA). The CBA is an economic method that evaluates investment options over a set timeframe. Quantifying and including the features of green roofs in a CBA can demonstrate the potential economic viability of green roofs (Sprout et al. 2013). This method is commonly used to evaluate the performance of green roofs relative to alternatives such as black and white roofs in academic and industry literature.

Consideration of the long-term benefits is particularly important for green roofs as the primary criticism towards their use in literature is the significantly higher costs for installation and maintenance (Getter and Rowe 2006; Green Roofs for Healthy Cities 2013). A variety of factors influence the cost of green roofs, but generally a basic and simply designed green roof costs twice as much as a conventional black roof (Porsche and Kohler 2003, 461). Some studies indicate that the upfront expenses of green roofs can be offset over a roof's lifespan due to the associated benefits. However, the initial additional costs are the primary deterrent to private investment (Green Roofs for Healthy Cities 2013).

Several North American cities use standards and incentives as a means to encourage private investment in green roofs. Yet, Toronto is unique as it is the only major North American city that mandates the use of green roofs. For projects subject to the Green Roof By-law, developers receive no form of compensation for installing and maintaining a green roof. Developers in Toronto absorb all the additional costs of green roofs on projects that meet the By-law requirements (Claus and Rousseau 2012), unlike developers in Portland, Oregon, which incentivizes green roofs because of the public stormwater benefits, and Chicago, Illinois, which financially compensates developers for installing green roofs due to the reduction in the urban heat island effect (Carter and Fowler 2008),

Despite residential, office and retail buildings all varying in design, use and ownership, they are all subject to the same standards under Toronto's Green Roof By-law. A residential developer may be interested in green roofs to aesthetically enhance an amenity space while a retail developer may be focused on the stormwater management and energy saving features. The list below is how I suspect private green roofs may be perceived depending on the type of building based on the literature I reviewed.

Residential	Office	Retail
Developer Benefits • Higher Property Value • Inventory Turnover • Promote environmental values *Marketability to Buyers* • Energy cost savings • Aesthetic improvement (immediate/neighbouring buildings) • Enhance amenity space • Reflect environmental values • Urban agriculture	*Developer Benefits* • Higher Property Value • Inventory Turnover • Promote environmental values *Building Owner Benefits* • Increased membrane durability • Client retention • Improved health & well-being (tenants & neighbouring buildings) • Energy cost savings • Promote environmental value	*Developer Benefits* • Higher Property Value • Inventory Turnover • Promote environmental values *Building Owner Benefits* • Increased membrane durability • Energy cost savings • Aesthetic improvement • Enhanced amenity space • Reflect environmental values

Table 1: Suspected arrangement of recognized private green roof benefits base on building type

I compared the first hand experiences and opinions of several Toronto development firms with the latest literature on private green roof benefits such as Tomalty et al. 2010, US GSA 2011 and Berardi et al. 2014. Below is a comprehensive list of all the potential private benefits of green roofs that I assembled based on a range of literature prior to meeting with developers (Berardi et al. 2014; Carter and Keeler 2008; Doshie et al. 2005; Oberndorfer et al. 2007; Tomalty et al. 2010).

Aesthetic improvement
New amenity space & higher property value
Energy cost savings
Improved stormwater management (quality & quantity)
Integrated water management
Increased membrane durability
Fire Retardation
Solar panel system integration
Blockage of electromagnetic radiation
Overhead noise reduction
Marketability
Urban agriculture
Improved health & well-being
Tangible demonstration of environmental values

Table 2: Private benefits attributed to green roofs in literature

Toronto's green roof strategy makes it clear that this type of green infrastructure is part of the future development of the city. The responsibility of financing green roofs is relatively new for development firms. Therefore, I suspected firms would look to create a competitive advantage to maximize the financial return from using green roofs. If a firm could promote certain private benefits that are attributed to green roofs, I assumed it would be possible to gain an advantage over competitors. I anticipated that the additional costs of green roofs would be a challenge among developers, but that attaining certain private benefits could validate the use of green roofs.

I adopted a sustainable business perspective to examine whether the use of a green product (green roofs) could be advantageous for private interests (development firms and private building owners). I wanted to understand whether development firms in Toronto have adopted a minimalist compliance-based approach to green roofs or have identified opportunities to establish a competitive advantage.

The recognition of a competitive advantage requires clear and distinct characteristics of products, services and organizational processes. In Porter's (1980) work, a competitive advantage can be narrowed down to two generic types: low cost and differentiation. By efficiently using labour and capital, a firm can offer products and services at lower cost relative to the industry. Alternatively, a firm can also distinguish itself in the market by providing products and services that are unique and identifiable.

In Orsato's (2006) work on generic competitive environmental strategies, low cost and differentiation are both present in strategies that businesses can pursue. This framework is found in his journal article, *When does it pay to be green?*, which has been cited over 270 times in various works on sustainable business strategies and identifying value in green products and practices (Google scholar 2013). In Orsato's framework, the four strategies are separated in a quadrant, but the use of each strategy is not exclusive. This flexibility allowed me to consider whether a development firm was using any or all of the possible strategies available. Further, the framework also allowed me to consider the role green roofs have as a product as well as how their use fits within the operations and broader perception of a development firm.

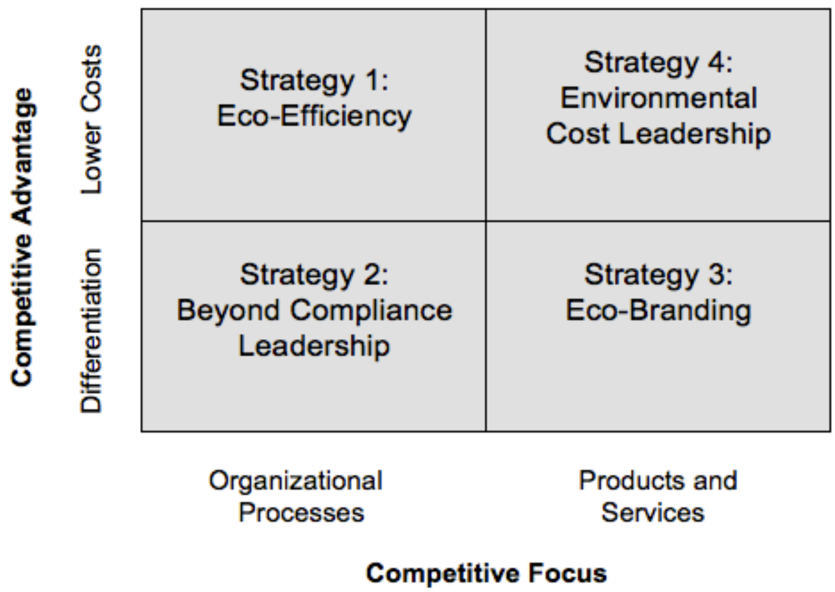

Figure 3: Generic Competitive Environmental Strategies. Orsato 2006

Below are the results of the assumptions I made based on my literature review compared with my research from select Toronto development firms.

Strategy 1:

The eco-efficiency strategy is focused on generating lower costs by orienting organizational practices towards innovative production models that draw on biological processes (Orstato 2006). I adapted this strategy to the use of green roofs by considering whether the construction and management of buildings with green roofs could generate operational efficiencies and financial savings for developers and private owners. I thought that the benefits from environmental processes such as reduced energy use and increased membrane longevity would contribute to making this strategy possible.

The firms that participated in my research indicated this was not a feasible strategy and is not something currently considered. Much of the green roof literature is focused on measuring and quantifying the features associated with green roofs to see whether they are more efficient financially when compared to alternatives. Among participants it appeared that green roofs are currently not thought of in this regard. This is likely due to the lack of tangible examples in North American cities as well as the long timeline necessary for green roofs to become cost competitive (participants A, B, C & D, personal communication).

Strategy 2:

The strategy of beyond compliance leadership seeks to highlight a firm's efforts of exceeding regulated standards with the intention of being recognized by customers and the general public (Orsato 2006). Currently in Toronto, there is no recognition or certification available that can be publicly promoted for firms that go beyond the requirements of the Green Roof By-law and Toronto Green Development Standard (TGS). Leadership in Energy and Environmental Design (LEED) certification exemplifies this strategy in the context of green buildings, but a green roof is only one of many features necessary for LEED accreditation. Two firms that participated in my research had used green roofs for this strategy in green buildings prior to the City's By-law. However, this is no longer the case among participants, because the inclusion of a green roof is a required practice for their projects (participants B & D, personal communication).

Strategy 3:

Businesses are responding to increasing consumer demand for sustainable practices and green products through eco-branding. Of the four potential strategies, this is considered the simplest to implement and pursue (Orsato 2006). In literature, green roofs are identified as tangible indicators of a builder's concern for the environment, which can resonate with customer values (Tobias and Vavaroutsos 2009). Participating firms that identified sustainability as an important component of the corporate philosophy also recognized this as a benefit of green roofs (participants B, C & D). One participant explained that many building features that provide environmental benefits such as reduced energy use or cleaner air are difficult to convey to customers. Alternatively, the visual characteristic of a green roof leads customers to assume that it is doing something positive for the environment regardless of whether they understand what the roofs actually contributes (participants B, personal communication).

The firms that are exploring the potential of urban agriculture to meet the Green Roof By-law requirements are pursuing further product differentiation. Beyond the positive visual association by customers, allowing residents to grow their own local, organic food enhances the environmental attributes of a site. This offers customers a unique amenity that can set a firm's product apart from competitors. This approach anticipates that customer will be able to able to clearly see the benefit of the urban agriculture and be willing to pay for the additional feature.

Strategy 4:

Environmental cost leadership identifies a business's ability to reduce a product's price based on efficiencies gained from utilizing environmental practices or inputs (Orsato 2006). If the attributed private benefits of green roofs could generate reduced costs compared with black or white roofs on projects, residential developers could pass the savings onto customers through lower prices on condominium suites. Yet none of the participants in this study used this strategy (participants A, B, C & D, personal communication).

All participants suggested that to his and her knowledge, the performance of green roofs did not generate savings compared to alternate roofing options. Instead, the inclusion of green roofs on projects meant that the higher installation costs of a green roof are passed onto customers in the purchasing price of a suite (participants A, B, C & D, personal communication).

1.3 Methods

My major research paper began with an individually directed study on green roof literature. After completing an extensive review of various types of literature on green roofs, I began to formulate my proposal. In the later stages of this time, I also began to formulate my primary research material in *ENVS 6183 Applied Research Methods: Qualitative*. Once my proposal was complete and my ethics had been approved, I began writing the initial sections of my paper as well as reaching out to find appropriate participants to interview for my primary research.

Literature Review

Throughout this paper, I have incorporated a variety of secondary sources including scholarly journals, published theses, books, municipal reports, policy documents, media materials and industry advocacy literature. Knowledge on green roofs is evolving as more research is completed and the technology advances. Therefore, I focused on material produced in the past 10 years with a preference given to the most recently published in order to incorporate the most accurate and relevant information.

Since the 1990s, interest in and use of green roofs in Toronto have contributed to the City's position as a leader in understanding and use of green roofs in North America. This has resulted in reports and case studies published with a focus on the role and performance of green roofs in Toronto. These proved to be particularly useful in my research to broadly establish the background and context of green roofs in the city.

Additionally, I used secondary research to understand the categorization of the benefits associated with green roofs and the issues associated their valuation. Secondary research also aided my understanding of Toronto's green roof strategy and provided a comparison of strategies and approaches in other North American and European cities.

Exploratory Study

I chose to conduct my primary research using an exploratory study due to the balance it provides in breadth and depth. As Dahnd (2013) describes, an exploratory study can hint at trends and common opinions of a group. While complete conclusions cannot be drawn from the sample, the objective is to get an impression rather than an absolute truth that can be statistically verified. By probing more deeply into the answers to my questions, I was able to seek out fuller and more comprehensive details. These questions targeted the information I identified as necessary to write about the experiences of a portion of the development industry with green roofs in Toronto.

Similar to a standard research survey, I established a set of 14 questions to ask during interviews to ensure that my questioning was consistent among all participants. However, similar to a purposive interview, I used probing questions to get a deeper understanding of each firm's unique approaches and opinions. With these questions, I wanted to identify both unique attributes of specific firms as well as commonalities that spoke to broader trends.

All interviews except one were conducted in person at the participant's office (the exception took place in a coffee shop). Interviews lasted between 30 to 40 minutes depending on length of answers and the amount of time participants were available. The interviews occurred in May and June 2014. Each interview was recorded for accuracy and transcribed afterwards. Firms that participated (in chronological order) are: TAS Design, Minto, Tridel and Great Gulf.

Questions

I thoroughly considered my objectives prior to crafting my list of questions by drawing on the context of my research and my research questions in my major research paper proposal. However, I also anticipated that the approach to my research and my questions would likely change as I better understood my research. With each interview I conducted, my understanding and knowledge of green roofs in Toronto grew. As a result, I revised my prepared questions for my primary research. The changes were slight, but necessary, and reflected the shift in my understanding of the practical realities of green roofs. These changes included characterizing green roofs as an accepted rather than additional cost, focusing on the relevancy of ownership structure and specifying the features of green roofs in relation to customer awareness and as a tangible method to demonstrate corporate sustainability.

Participants

At the outset of my research, my objective was to interview six different development firms involved in residential, commercial and retail projects. Ideally, I was looking to meet with a representative of each firm who could discuss how green roofs are incorporated into projects and the impacts they have on the design, functionality and marketability of a building. I had hoped to interview a representative from each division to gain a broad cast of opinions and approaches to green roofs for a total of 18 interviews. I initially prepared a list of various developments firms with planned, active or completed projects in the city of Toronto based on the firms' respective websites. From this list, I highlighted six firms in Toronto that met my criteria for being involved in all types of buildings (Appendix A).

The first step I took to connect with my targeted firms was reaching out to a previous employer who is involved in the development industry in Toronto. I was provided with contacts at Tridel and Great Gulf along with several contacts at landscape architecture firms. Landscape architecture firms retain experts on green roofs and act as consultants on development projects that include green roofs. I spoke with several landscape architects (Kay Laidlaw at Ferris + Associates, Jessica Hutcheon at Janet Rosenburg & Studio, Michelle Xuereb at Quadrangle, and Gus Maurano at the MBTW Group / Watchorn Architect Inc.), all of whom generously shared some of their knowledge of green roofs and experiences from working in Toronto. From this process I was provided contacts at TAS Design and Minto.

In addition to speaking with landscape architects, I also independently contacted a range of firms. This proved to be difficult without an introductory contact, and I ultimately was unsuccessful in connecting with participants through this approach.

Five participants spoke with me as representatives of their firms (Appendix B). The number of participating firms was less than I had anticipated, as was the diversity of their products. However, the interviews were ultimately dictated by the expiration of time for my research and writing. Each participant was tremendously helpful and very generous with his or her time. The biggest setback I encountered was learning that my initial participants could not suggest further potential contacts at other firms. Beyond their knowledge of each other, no one seemed to be in contact with the individuals who had an equivalent knowledge at other firms.

I then pursued alternate methods to try to connect with other development firms. I was able to directly contact firms in a shorter amount of time, but it proved to be a fairly ineffective method of receiving a response. In hindsight, expanding my research to include my discussions with the landscape architects as formal interviews to be used in my research paper could have been very beneficial. Given their role as consultants for developers, they have an extensive understanding of the functions of green roofs and the conditions that exist when applying the Green Roof By-law to projects in practice.

Section 2 – Integrating green infrastructure & green roofs into cities

In this section, green infrastructure is defined and its role in contemporary cities is explored. Specific focus is on the use of green infrastructure to assist with essential city services while mitigating environmental problems that have stemmed from common development practices in urban centres. Green roof technology is highlighted as a form of green infrastructure that has a growing acceptance in North American cities, including Toronto. A detailed explanation of the characteristics and composition of green roofs is provided to add clarity to the challenges of measuring and valuing their contribution to sustainable urban development.

2.1 What is green Infrastructure?

The traditional definition of green infrastructure focused on the natural features that contribute to the health and quality of life of areas in and around cities. This included greenbelts, parkland, forests, floodways, rivers and wetlands (Foster et al. 2011). As the concept has evolved, there are now various interpretations of green infrastructure that range in focus and scale. This paper will adopt the definition set at the urban scale with attention given to technologies and practices that incorporate soils, vegetation and natural processes to improve the health of environments and provide similar environmental services as natural features (Benedict and McMahon 2006; Cirillo 2012)

Types of contemporary green infrastructure include urban forestry, hard and soft permeable surfaces, green walls and streets, and blue, white and green roofs. The application of "green" elements to traditionally "grey" infrastructure improves performance and extends the range of functions of the infrastructure (Austin 2014; Cirillo

2012; Foster et al. 2011). For cities with aging infrastructure and growing uncertainties about the performance of traditional forms of infrastructure, green infrastructure is becoming an acceptable alternative (Cirillo 2012; Mell 2009; Snodgrass and McIntyre 2010).

Current situation of cities

All around the world, patterns of development have left densely populated cities deficient in green space. Further, the replacement of natural features with built infrastructure has increasingly disconnected humans from nature (Jim 2012). In many cases, the social and ecological functions of natural landscapes are overlooked and undervalued in comparison to the economic returns of development (Mell 2009). As decisions in the construction industry are based primarily on financial considerations, sustainable development is often perceived as a premium (Halliday 2008). However, as landscapes become heavily urbanized, many valuable natural features and services such as water regulation, nutrient cycling and waste treatment are reduced or lost (Carter and Keeler 2007).

As the most complex human creations, contemporary cities are facing a wide spectrum of challenges (Brunner 2007). The development patterns of cities and their peripheries continue to have significant negative environmental repercussions and are key contributors to global warming (Bianchini and Hewage 2012; Merk et al. 2012). To address growing environmental challenges, the design and development of our built environments must reflect and incorporate characteristics found in natural ecosystems. Overcoming obstacles to the adoption of these principles can result in planned and developed cities that are financially viable and better equipped to address current and pending environmental challenges (Swayback 2007).

What can green infrastructure do?

Urban sustainability has become a prominent concern for cities as the loss and degradation of natural environments is increasingly more apparent (McDonald and Patterson 2007). For municipalities with planning and development policy focused on sustainability and resiliency, use of green infrastructure and the various services it can provide contributes to policy goals. In addition, use of green infrastructure can also help cities prepare for changing climates and extreme weather (Foster el al. 2011). The reshaping of natural landscapes into urban environments has generated vulnerabilities and therefore some believe that the adoption of a dramatically different design and development mindset that strives for a more balanced relationship with nature will contribute to the resolution of problems (Kellert 2008).

The conventional attitude of using urban green features primarily for aesthetic and decorative motivations remains prominent in many contemporary societies. If urban ecological principles are integrated and used to guide the configuration of greening, their features would be enhanced (Jim 2012). This is particularly pertinent for densely populated cities with limited green space where conservation practices and green infrastructure can enrich natural systems and prevent landscapes from overdevelopment (Cirillo 2012; Mell 2009).

Resilience is generally understood as the capacity of cities and communities to resist, cope with and recover from disasters and crises (Foster et al. 2011). Along with improving the quality and functioning of urban centres, green infrastructure helps cities prepare for changing climate conditions. Local climate and weather have substantial impacts on municipal services and economic activity in a densely populated city with concentrated infrastructure like Toronto (Toronto Environmental Office 2012). If implemented on a broad scale, green infrastructure would enhance the ecological resources of urban landscapes and develop areas more resistant to extreme variations in climate such as floods and heat waves (Mell 2009).

Cities can improve the quality of life while generating positive economic results by contributing to the mitigation of environmental damage and issues of social equity (Mell 2009). It is understood that the economic and physical health and welfare of individuals, communities and organizations are impacted by their surrounding environment (Halliday 2008). However, a significant hurdle with green infrastructure options available to municipalities is the challenge of calculating the costs and benefits of their implementation and deciding who will finance it (Foster et al. 2011; Mell 2009).

2.2 What are green roofs?

Green roofs are defined as form of green infrastructure that mimics natural processes using plants and growing medium that can contribute to healthier urban environments (Foster et al. 2011). Also known as livings roofs, vegetated roofs or eco-roofs, green roofs use a layer of vegetation to partially or completely cover a roof's surface. While conventional roofing practices use materials such as tar and asphalt to cover a black roof, green roofs are visually distinct and are intended to improve the roof's aesthetics and functionality (Snodgrass and McIntyre 2010).

Green roofs technology is manufactured to replicate forms and scientific processes found in nature by mimicking natural ecosystems and the services they provide. Similar to other forms of green infrastructure such as bioswales and sewage treatment wetlands, green roof technology can be categorized as biomimicry or bioengineering. The various components that compose a green roof are designed to operate similarly to vegetation on the earth's surface. By functioning as an ecosystem, green roofs provide ecosystem services to areas transformed through urbanization (Oberndorfer et al. 2007). Practitioners and academics highlight the integration of natural elements into buildings as a sustainable approach that increases urban green space and addresses environmental challenges in urbanized areas (Berardie et al. 2014).

2.3 Altering the rooftop to reduce a building's environmental impact

When buildings replace natural landscapes, the movement of water, matter and energy are disrupted in the local ecosystem. This contributes to environmental challenges in urban areas that include increased temperatures, flooding and reduced biodiversity (Oberndorfer et al. 2007). In addition to altering the landscape, the construction and maintenance of buildings demands significant amounts of resources. Estimates identify that 40 percent of global energy is consumed by constructing and maintaining buildings along with contributing 33 percent of greenhouse gas emissions worldwide (Berardi et al. 2014, 412). In response to these realities, awareness of green building practices is increasing amongst real estate and design professionals and the construction industry (Tobias and Vavaroutsos 2009).

Green roofs contribute to improving the environmental attributes of buildings along with other accepted practices such as energy efficient systems, renewable energy sources and eco-technologies (Berardi et al. 2014; Carter and Fowler 2008). In urbanized areas rooftop coverage makes up as much as 32 percent of the surface area, resulting in a substantial area to affect (Frazer 2005) (Oberndorfer et al. 2007, 824). By changing the composition of building rooftops, certain characteristics of structures are altered helping to mitigate environmental problems and improve efficiencies (Oberndorfer et al. 2007).

Figure 4: Before and after comparison of 45,000 square foot roof converted to green roof in Philadelphia. PECO 2009

2.4 Composition of green roofs

Green roofs are designed to function similarly to ground level vegetation, except rooftop conditions are a much harsher environment making it difficult for plants to thrive. Exposure to high wind speeds and intense light, moisture stress, severe drought and more extreme temperatures damages and destroy rooftop vegetation (Dvorak and Volder 2010; Oberndorfer et al. 2007). Further, the variability of a rooftop's slope exacerbates these challenges as water runs more quickly and increases drought stress (Austin 2014). This variability in building characteristics and conditions influences the features of a green roof as well as design elements such as the type of plants, growing medium and other components used.

Underneath a green roof's top layer of vegetation are the components that sustain its organic matter and waterproof the roof. Amongst types of green roofs, there is a range in design and use, however many of the components required are similar (Getter and Rowe 2006). Along with a waterproofing membrane that protects the roof from water damage there is a drainage system, filter cloth, a root repellent system, a lightweight growing substrate and vegetation. To install green roofs, practitioners use either individual parts or prefabricated modular systems that include all of the components installed (Green Roofs for Healthy Cities 2013a).

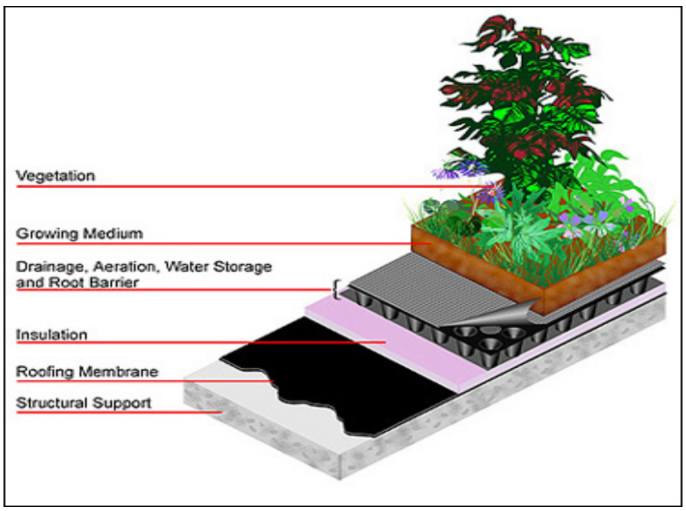

Figure 5: Layers of a typical green roof. City of Toronto 2014

Similar to vegetation that grows on the earth's surface, plants on green roofs require a substance in which to settle. While soil is a natural growing medium, the clay and organic particles contained within it become heavy when saturated. Due to weight capacity considerations of structures, green roofs use manufactured, lightweight growing mediums known as substrates (Bianachini and Hewage 2012). There are several varieties of growing mediums, however ideal characteristics of a substrate are: an adequate capacity to retain water and nutrients; permeability; lightweight; and resilience to decomposition (Getter and Rowe 2006).

2.5 Classification

There are a range of factors of that influence the variability in green roofs, but a key physical differentiator between types of green roofs is the depth of growing medium (Oberndorfer et al. 2007). A green roof's design, function and cost are all directly impacted by the depth of the growing medium. As a result, three general categories are used to distinguish green roofs: extensive, semi-intensive and intensive. While the classes generally do not adhere to strict technical definitions, they are commonly recognized in academic journals and industry literature.

Aside from growing medium depth, the chart below demonstrates that general characteristics rather than exact parameters are used to differentiate each green roof type.

General Characteristics of Extensive and Intensive Green Roofs			
Characteristics	**Extensive**	**Semi-Intensive**	**Intensive**
Growing medium depth	6" or less	25% of the green roof area above or below 6"	More than 6"
Accessibility	Often inaccessible	May be partially accessible	Usually accessible
Plant Diversity	Low	Greater	Greatest
Cost	Low	Varies	High
Maintenance	Minimal	Varies	Varies, but generally high

Table 3: General Characteristics of Extensive and Intensive Green Roofs. Green Roofs for Healthy Cities 2013a.

Extensive

Extensive green roofs have the shallowest level of growing medium of the three categories with a maximum substrate depth of 6 inches (15 cm). As a result, these roofs have a reduced profile along with being lighter and simpler in design compared to other green roofs variations (Snodgras and McIntyre 2010). This contributes to extensive roofs generally being easier to design, construct, finance and maintain, making them the most commonly used form of green roofs (Henry and Frascaria-Lacoste 2012). The Green Roof for Healthy Cities 2012 North American industry survey demonstrates this as the installation of intensive green roofs far outweighed any other type of green roof as seen in the graph below.

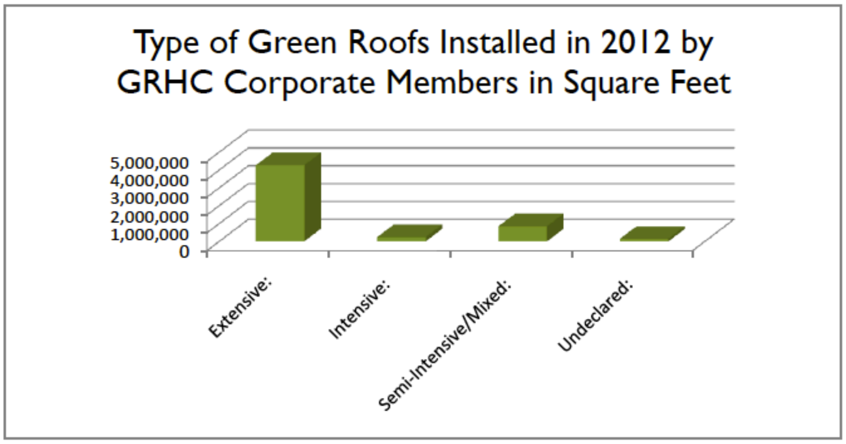

Figure 6: Type of Green Roof Installed in 2012 by GRHC Corporate Members in square feet. Green Roofs for Healthy Cities 2013, 7.

Philippi's (2006) work on Germany's well-established green roof market further emphasizes this trend where over 80 percent of green roofs in the country are extensive (Snodgrass and McIntyre 2010, 22). This prominence is further accentuated by the fact that roughly 13.5 million sq.m of additional green roof coverage is added annually (Orbendorfer et al. 2007, 825).

The shallow growing medium depth of extensive green roofs has advantages as well as limitations. A prominent drawback is that there are only a select number of plants that can succeed on extensive green roofs. Among these plants, important shared qualities are characteristics and strategies that contribute to stress tolerance. This includes "low mat-forming or compact growth", "evergreen foliage or tough twiggy growth", "succulent leaves" and "water storage capacity" (Orbendorfer et al. 2007, 826). The plant varieties primarily used include mosses, herbs grasses and sedum (Mullen 2013). Sedum is a specific type of drought tolerant succulent, but as Snodgrass and McIntyre (2010) note, sedum has come to be used by some to reference any vegetation used for extensive green roofs.

- Inaccessible
- 20,175 sq.ft
- 66 percent of total roof area covered
- Vegetation: alpine grasses

Figure 7: Extensive green roof on the Computer Science Building at York University. City of Toronto 2014

Semi-intensive

Semi-Intensive green roofs are a blend between extensive and intensive green roofs that combine various depths of growing medium. With 25 percent of the green roof area either above or below 6 inches, these green roofs can have a wider diversity in vegetation and a richer ecology while being less limited by weight restrictions and construction and maintenance costs (Green Roofs for Healthy Cities 2013a, 9). While extensive and intensive categories are frequently used and recognized in green roofs literature, only some authors include semi-intensive green roofs in their discussions and research (Berardi et al. 2014).

- Toronto's largest publicly accessible green roof
- 37,000 sq.ft podium green roof
- Vegetation: sedums, taller bulbs, perennials, and grasses

Figure 8: Semi-intensive green roof at Toronto City Hall. PRWeb 2011

Intensive

Intensive green roofs are most similar to roof top gardens, which use planters and soil, as they share aesthetic similarities with conventional landscaped gardens at ground level. With substrate depths that go beyond 6 inches, intensive green roofs can support increased vegetation size and diversity. This type of green roof is often designed and utilized as an accessible space. This allows for a broader range of features and benefits than other forms of green roofs such as food production and increased biodiversity. However, the increased complexity of these green roofs result in the "intensive" maintenance demands required in sustaining them (Getter and Rowe 2006; Oberndorfer et al. 2007). Further, intensive roofs are the most costly to design and install which contributes to this category of green roofs being less prominent than its counterparts (Berardi et al. 2014).

- Private commercial retrofit
- 2,310 sq.ft
- 100 percent of total roof area covered
- Vegetation: 52 types of plants including grasses, shrubs, herbs and trees

Figure 9: Intensive green roof at ESRI Canada Ltd., 12 Concorde Place. City of Toronto 2014

2.6 Features of green roofs the contribute to sustainable development

Green roofs impact the visual characteristics of the urban landscapes by masking structures with green, natural features (Jungels et al. 2013). Beyond aesthetics, scholars, municipalities and industry advocates suggest that green roof technology has become a recognized approach to help alleviate complex environmental problems that exist in cities. Increasing density and intensification of urban centres places greater stress on infrastructure that provides and manages water, energy and sewer services (Clark et al. 2008). By replacing typically unused spaces with green infrastructure, green roofs assist existing infrastructure while offering environmental, social and economic advantages that contribute to more sustainable urban development (Getter and Rowe 2006).

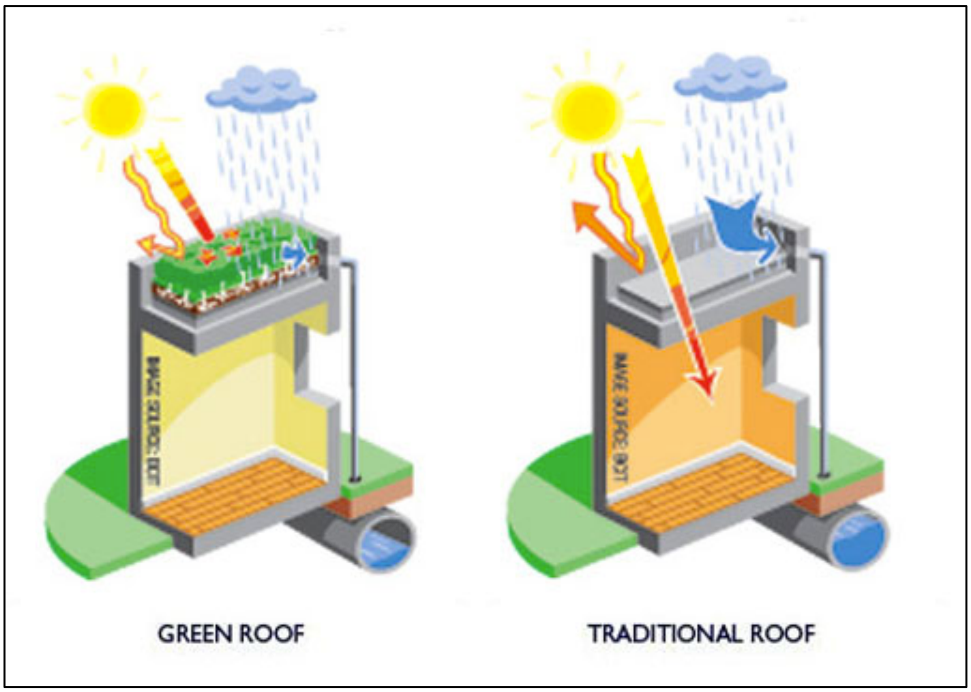

Figure 10: Comparison of a green roof's features compared to a traditional roof. British Columbia Institute of Technology

Improved stormwater management

Many authors recognize improved stormwater management as the most significant environmental benefit of green roofs as they assist in reducing the rate and volume of precipitation discharged from a building's rooftop (Berardi et al. 2014). Depending on precipitation patterns along with the depth, slope, and composition of a green roof, extensive roofs can retain up to 65 percent and intensive roofs above 90 percent of stormwater runoff along with delaying any runoff by several hours (DeNardo et al. 2005) (Berardi et al. 2014, 421; US GSA 2011, 13; Stovin et al. 2013). This reduces stress not only on existing infrastructure, but also on the natural environment by mitigating the erosion of receiving streams (Austin 2014).

As cities increase the proportion of impermeable surfaces, issues of flooding and water contamination are more prevalent when existing stormwater management systems become overburdened (Doshi et al. 2005, Oberndorfer et al. 2007). Expanding conventional techniques such as ponds and reservoirs, sand filters and constructed wetlands can be difficult in existing dense urban landscapes due to land requirements (Mentens et al. 2005) (Berndtsson 2010; Orberndorfer et al. 2007). Further, anticipation of increasing frequency and intensity of precipitation events due to climate change is cause for further concern regarding flooding (Arnell 1999; Bates et al. 2008) (Berntsson 2010).

Stormwater management is particularly important for cities with combined sewer systems (sewage and wastewater). Combined sewage overflow (CSO) occurs when infrastructure is overloaded leading to the contamination of fresh water sources with pollutants characteristic of raw sewage such as suspended soils, trace metals and coliform organisms (Doshie et al. 2005). It is estimated that in the United States, over 10 trillion gallons of untreated runoff enters into receiving waters annually (Snodgrass McIntyre 2010, 25). Reducing the threat of flooding and CSO keeps water safer for humans and wildlife, lessens demand on existing infrastructure and may be able to save municipalities, developers and private owners financial costs (Moran et al. 2005) (Oberndorfer et al. 2007) (Carter and Fowler 2008; Sproul et al. 2013)

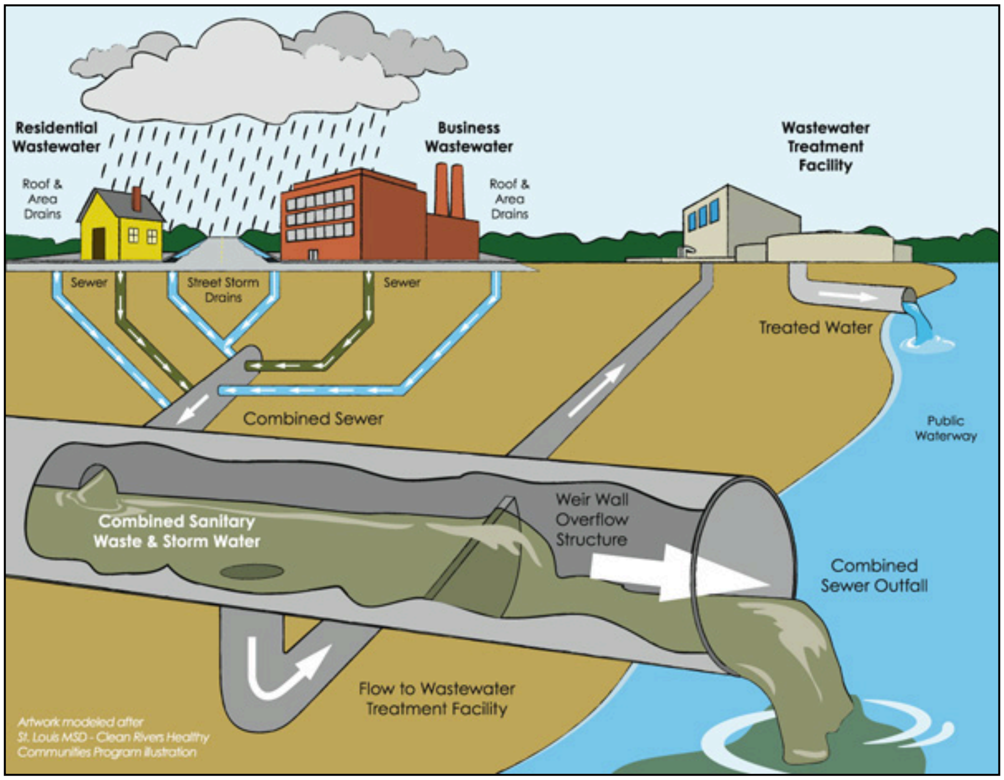

Figure 11: Diagram of a combined sewer system. Green Learning Station 2011

Urban Heat Island effect & reduced energy consumption

Green roofs are also recognized for limiting the temperature fluctuations in buildings and the ambient air around the rooftop. While black top roofs generally absorb 80 percent of incoming sunlight, the composition of green roofs reduces the absorption of direct solar radiation (Berardi et al. 2014; Sproul et al. 2013, 4). Further cooling is due to the precipitation retained by vegetation and the growing medium. As water is heated and changes from liquid to gas through transpiration, it cools the surrounding air (Onmura et al. 2001) (Carter and Keeler 2007).

These characteristics assist in mitigating the urban heat island effect that occurs in cities around the world. Dense urban environments can be as much as 10°C warmer than surrounding peripheral and rural areas (CHMC 2006, 10). The landscapes of urban areas are covered with dark impervious surfaces that absorb greater amounts of solar energy and retain it for longer periods of time. By incorporating green roofs into the urban fabric, the concentration of dark surfaces that contribute to the heating of urban areas are reduced (Susca et al. 2011).

However, to realize a reduction in the UHI, a significant proportion of roofs in a concentrated area must be green (Doshi et al. 2005). A study conducted by Bass (2002) ran a simulation model and found that if 50 percent of available roofs in Toronto were replaced by green roofs, the city could reduce temperatures by as much as 2°C (Oberndorfer et al. 2007). Another study estimated that if 100 percent of available roofs over 350 sq.m were 75 percent covered with green roofs, initial energy savings of $79,800,000 could be achieved with annual savings of $12,320,000 for Toronto (Doshi et al. 2005, ii-iii).

The cooling features of green roofs also reduce the energy consumption of buildings. The floors immediately below the roof require less energy to cool in warmer weather. In the winter the additional mass of green roofs helps to insulate the building, particularly if they are older buildings with limited insulation (Berardi et al. 2014). The same study that estimated UHI saving in Toronto also estimated green roofs could generate initial energy savings of $68,700,000 with annual savings of $21,560,000 (Doshi et al. 2005, iii).

Reduced energy production

By reducing temperatures outside a structure and limiting temperature flux within it, less energy is required for air conditioning and heating devices. This in turn can reduce a structure's energy consumption and on a broader scale possibly lessen demand on the production of energy from sources like coal and natural gas production. As these resources release carbon dioxide (CO_2) emissions, limiting their use can aid the improvement of air quality and help mitigate the impacts of climate change (Getter et al. 2009).

Air quality improvement and carbon sequestering

Depending on the design and vegetation used, green roofs can absorb pollutants and further improve air quality. Among pollutants absorbed are nitrous dioxide, sulphur dioxide and particle pollution (Yang et al. 2008). Additionally, CO_2 can be drawn into carbon sinks created by intensive green roof vegetation such as trees and other biomass.

Researchers have recognized that the embodied energy in the manufacturing of green roofs generates more carbon compared to conventional roofs. Further, the production process of polymers often used for extensive green roofs contributes to air pollution. However, over a green roof's lifespan, carbon sequestering and reduced energy should more than compensate for CO_2 costs, while air pollution from polymers is balanced after an average of 25 years (Bianchini and Hewage 2012, 153; Getter et al. 2009). In Toronto, it was estimated that air quality improvements from green roofs could contribute to annual savings $2.5 million (Doshi et al. 2005, iii).

In addition to the vegetation's functional benefits on green roofs, green roofs improve the aesthetics and increase biodiversity in urban areas. Many dense cities have limited room to reintroduce green space, yet rooftops are generally underutilized areas with the potential to be greened (Jim 2012). Research indicates that humans are predisposed to being happier and healthier when exposed to natural features (Doshi et al. 2005). By designing green roofs as spaces that can be used for communal activities or urban agriculture, it becomes an amenity that would otherwise be unavailable (Chen 2013) (Berardi et al. 2014).

Further, by increasing the amount and variety of natural vegetation in urban centres, green roofs can contribute to a city's biodiversity strategy (Brenneisen 2006). Some sustainability advocates claim that green roofs are the best way to restore biodiversity in cities (Carus 2009). It is possible to increase and protect diversity in plants species as well as provide habitats for organism such as insects and birds. However, the value and diversity of habitats created on green roofs is below what natural habitats can offer (Bianchini and Hewage 2012).

Extended lifespan

Relative to black roofs, green roofs provide superior protection to the waterproof membrane that they cover. By extending the lifespan of the membrane, the time between replacing green roofs is much longer. This saves significant roof replacement costs and also reduces the frequency of materials that go to waste at the end of a roof's life. In America, the current rate is between 6 to 9 million tons of roofing material disposed of in landfills each year (Cavanuagh 2008) (Snodgrass and McIntyre 2010, 32).

Section 3 – Municipal green roof strategies

The following section outlines significant factors that have contributed to Toronto's current green roof strategy. Firms with development projects that are subject to the City's Green Roof By-law are financially responsible for designing, installing and maintaining a building's green roof. I based my research on these circumstances, but from my interviews it became clear that my assumptions on the opinions of development firms were inaccurate. My research also led to my belief that mandatory use has increased green roofs coverage in the city. However, I remain uncertain whether the City's current strategy is the most effective approach to doing so.

3.1 The formation of Toronto's green roof strategy

Toronto's green roof strategy is different from other major cities in North America. The City's Eco-Roof Incentive Program is similar to other programs in municipalities that incentivise the construction of green roofs. However, Toronto also utilizes the Green Roof By-law to mandate the use of green roofs on applicable projects. Currently Port Coquitlam, British Columbia is the only other municipality to mandate the use of green roofs, which is done to specifically increase the coverage of green roofs on commercial and industrial buildings (Tattersall 2007).

The development of policy and programs designed to encourage green roofs in Toronto have evolved over the past decades. While green roofs were first mentioned earlier in several municipal documents, Toronto's current strategy is the result of advocacy and lobbying, pilot projects, stakeholder workshops and cost-benefit reports. Collectively these components allowed Toronto City Council to carry out a consensus based approach that produced enough knowledge, confidence and support that the City felt it could mandate the use of green roofs (Loder 2011).

Toronto is home to "Green Roofs for Healthy Cities" (GRHC), the largest advocacy organization for green roofs in North America. Established in 1999 as a non-profit by a group of private and public researchers, GRHC is now involved in promoting green roofs and other forms of living architecture in Toronto as well as around the world (Carter and Fowler 2008). Through advocacy, education, highlighting quality projects and providing training for professional development, GRHC has raised awareness of green roofs and helped facilitate the formation of Toronto's green roof strategy (Green Roofs for Healthy Cities 2014).

References to green roofs are found in various documents that guide planning and environmental policy in Toronto. The first formal recognition of green roofs in Toronto was in 2000 in the City's Environmental Plan. This identified a need for an approach to encourage green roofs and rooftops gardens. Following this, the Wet Weather Flow Master Plan and Toronto's Official Plan both made mention of green roofs as a possible solution to address water quality and management and the urban heat island effect (City of Toronto) (Doshi et al. 2005; CMHC 2006; Loder 2011). Further support for green roofs was carried forward in the Toronto Clean Air and Climate Change Plan and Toronto Green Development Standard (TGS) that guides the City's green building policy (City of Toronto) (Loder 2011).

Complementing the work carried out by GRHC and the City has been various reports and research that contributed to Toronto's green roof policy. The most extensive of such documents is the cost-benefit study, commissioned by the City and carried out by

Ryerson University (Doshi et al. 2005) to evaluate the potential use of green roofs in Toronto. The report generated a deeper understanding in the technology available, the potential roof space available and the possible monetary costs and savings that could be realized from benefits including improved stormwater management, air quality and the urban heat island effect.

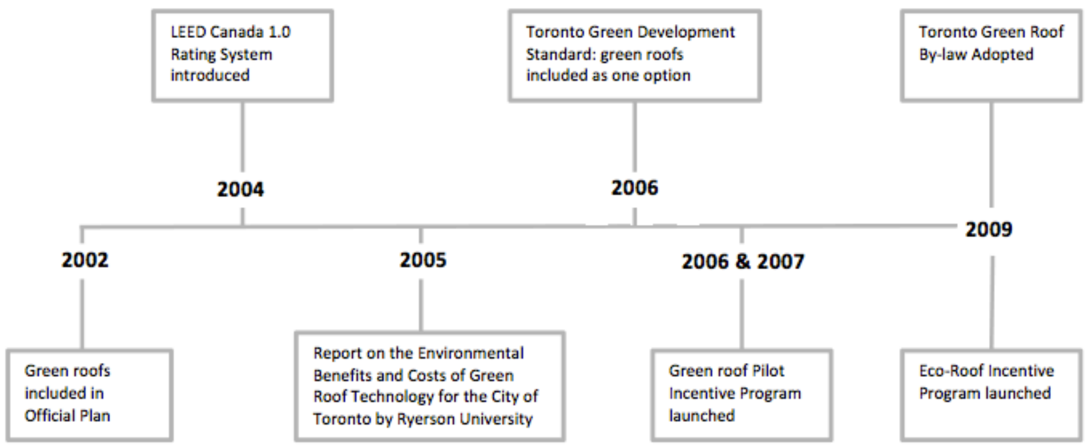

Figure 12: Timeline of green roof policy development. Re Loder 2011

3.2 Components of Toronto's green roof strategy

Toronto Green Roof By-law

Toronto's City Council adopted the Green Roof By-law in 2009 impacting all applicable institutional, commercial and residential buildings. The By-law came into effect in January 2010 and requires new developments with a minimum Gross Floor Area (GFA) of 2,000m^2 to cover a portion of roof space with a green roof. Minimum graduated cover requirements vary based on the total size of the roof and range between 20 to 60 percent. The application to industrial buildings was delayed until 2012 and has a reduced green roof coverage requirement of 10 percent (City of Toronto 2009).

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000 - 4999 m	20%
5,000 – 9,999 m	30%
10,000 – 14,999 m	40%
15,000 – 19,999 m	50%
20,000 m or greater	60%

Table 4: Green Roof Coverage Requirements for institutional, commercial and residential buildings. City of Toronto 2009

The By-law defines available roof space by taking into consideration space allotted for private terraces, renewable energy such as photovoltaic panels and outdoor amenity space (to a maximum of $2m^2$ per unit). Exceptions to the By-law exist and are present for various cases. If a building features a tower on top of a podium and the floor plate on the tower is less than $750m^2$, then it is excluded from the roof space that is calculated and considered available. Residential buildings under six storeys (or 20 metres in height) are also exempt from the By-law. Additionally, an application for an Exemption or Variance can be made for projects the By-law pertains to. The application must be approved by the City's Chief Planner and a cash-in-lieu payment of $\$200/m^2$ of exempted roof space must be paid which goes towards the City's incentive program (City of Toronto 2009).

Eco-Roof Incentive Program

Along with introducing the Green Roof By-law in 2009, the City also launched its revised incentive program known as the Eco-Roof Incentive Program[1] (City of Toronto 2013). The Green Roof Incentive Pilot Program was created in 2006 and was originally funded and administered by Toronto Water. Building on evidence from the Ryerson University study (Doshi et al. 2005), it was decided that the potential benefits from

[1] The development firms that participated in my research had projects subject to the Green Roof By-law. However, no participant had applied for funding through the Eco-Roof Incentive Program for installing a green roof. Therefore, minimal attention is given to the Eco-Roof Incentive Program beyond this section of the paper.

improved stormwater management warranted the encouragement of green roofs on new and existing buildings. The initial budget of the program was $200,000 and offered applicants willing to cover their roof surface with a minimum of 50 percent green roof a subsidy of $10 per sq.m ($1 per sq.ft) (City of Toronto 2013). The program was open to all property owners with structures that could support a green roof and resulted in 16 grants being allotted. With the average cost of a green roof between $10 to $24 per sq.ft, the green roof industry criticized the incentives as being far too low in relation to the cost (Green Roof for Healthy Cities 2008) (Loder 2011, 65).

Following the pilot project, the program was rebranded as the Eco-Roof Incentive Program. The intent of the program is to incorporate new technologies to create more sustainable buildings while generating green jobs. The intended applicants for the program continues to be building's with the potential for retrofitting and new projects not subject to the By-law. Funding available for green roof projects was raised to encourage use and address criticism. Currently available funding is at $75 per sq.m with a maximum of $100,000 per applicant (City of Toronto 2013, 4).

The program also expanded its focus from improving stormwater management practices to include reducing the urban heat island effect (City of Toronto 2013). As a result, incentives have been extended to funding white roofs projects as well. White roofs lack the diverse range of benefits of green roofs, however they are less expensive and roughly three times more effective at reflecting incident sunlight. This keeps white roofs cooler resulting in lower ambient air temperature and reduced heat transfer into the building helping to reduce the urban heat island effect (Sproul et al. 2013, 5).

3.3 Municipal aspirations to transforming urban infrastructure

In the context of this paper, infrastructure is defined as the physical components such as sewers, roads and water that are essential to servicing and sustaining a city (City of Toronto, 2014b). As cities look to become more efficient with resources and prepare for the impacts of climate change, there is a growing opportunity in transitioning from grey to green infrastructure. Municipalities can intiate the transition to green infrastructure through investment, regulation and policies (Carter and Fowler 2008; Meck et al. 2012). However, cities often lack the finance, management skills and political will to actualize a shift form grey infrastructure to green (Macomber 2013). Instead, private sector investment is often necessary to realize and financially support an alternative approach to infrastructure (Meck e al. 2012).

Cities around the world are using policy to encourage green roofs to help improve the sustainability of buildings due to their significant resource consumption and negative environmental impacts (Berardi et al. 2014). Green roofs are best analyzed in this context by looking at the transition of certain European countries in adopting this technology. Years of research collected on design and performance contributed to raising environmental awareness and driving the green roof market in countries like Germany. However, initial mobilization of private sector investment with incentives and regulation was critical to reaching this point. By recognizing the similarities and drawing on the European experience with green roofs, Canadian cities can build on the lessons learned. The same market forces and social circumstance may not exist as in Europe, but there is evidence that Canadian and other North American municipalities are recognizing and implementing strategies to encourage green roofs (CMHC 2006).

In North America and around the world, programs and policies encouraging green roofs are driven by the high values of public benefits associated with their use. For developers, municipalities and the general public, policies provide protocols to advise and direct the implementation of a city's future plan (Hodge and Gordon 2007, 181). The green roof strategies adopted in respective cities are reflective of the unique resources, local climate, and political position (CHMC 2006). However, there is always some environmental concern motivating and providing the political justification for the implementation of green roof policies in urban areas. There are a wide range of reasons that cities regulate green roofs including energy consumption, air and water pollution and climate change. Generally the most common features of green roof's that motivates cities are typically increasing biodiversity, reducing in the urban heat island effect and improving stormwater runoff management (Carter and Fowler 2008).

Toronto's efforts to encourage the use of green roofs is part of a larger strategy to reduce environmental problems, utilize alternative forms of green infrastructure and increase green space in dense urban areas of the city. The City recognizes green roofs as a way to reduce urban temperatures and replace lost green spaces in the city (CMHC 2006). Further, green roofs are regarded as a viable alternative to traditional stormwater management practices. The Canadian Mortgage and Housing Corporation (2006) notes that Toronto's interest in improving stormwater management is primarily driven by health concerns and the financial costs of contamination caused by combined sewer overflow. In Toronto it was estimated that green roofs would initially save over $150 million on stormwater and CSO with additional CSO annual savings of $750 million (Doshi et al. 2005, iii). In July 2013, the flooding that occurred in the Greater Toronto

Area became Ontario’s most expensive natural disaster at $940 million (Insurance Bureau of Canada 2014). With the Toronto Environment Office (2012) expecting a significant increase in rainfall during July and August by 80 percent and 50 percent respectively by 2040-2049 (10-11), the greening of Toronto should have increasing value in the coming years (Claus and Rousseau 2012).

3.4 Incentives and standards for encouraging the use of green roofs

Municipalities use direct and indirect incentives to subsidize the costs and encourage the installation of green roofs. The implementation of incentives to reduce costs is an effort to influence and encourage preferred social and environmental development patterns such as the use of green roofs (Revesz and Stavins 2004) (Carter and Fowler 2008, 155-156). This is particularly relevant in North America’s green roof market as additional costs compared to black and white roofs are noted as a significant deterrent for developers and private owners to use green roofs (Getter and Rowe 2006; Green Roofs for Healthy Cities 2013).

Direct financial incentive

Offering direct financial incentives for the construction of green roofs is one of the simplest strategies available to cities. Direct financial incentives assist in covering costs of green roofs, but often bind developers and private owners to conditions in order to qualify and receive funding (Carter and Fowler 2008). Stipulations include performance standards like water-retention capacity, construction standards such as depth of growing medium and a contract committing the building owner to conduct necessary maintenance to sustain the green roof (CMHC 2006). Using direct financial incentives helps overcome the financial obstacles of incorporating green roofs. Additionally, it also makes it easier to calculate the return of investment and be able to monetize benefits associated with green roofs (Snodgrass and McIntyre 2010).

Many of the North American cities leading in the use of green roofs such as Washington, Philadelphia, Chicago and Portland have incentive programs (Snodgrass and McIntyre 2010). However, Toronto's direct incentive policy, the Eco-Roof Incentive Program, is distinct as it offers a $/m^2 amount (Carter and Fowler 2008). The City helps subsidize the cost of qualifying projects that are either retrofits or fall outside the requirements of the Green Roof By-law. To address the budgetary challenges, the program draws from grant money as well the cash-in-lieu payments from projects that have been exempted from the Green Roofs By-law (City of Toronto 2009).

A policy focused on direct incentives can be effective, however it requires a municipality to incur additional financial responsibilities, which includes adequate finances to support the incentive's funding. Some research indicates that the benefits of green roofs validate the use of incentives to subsidize the cost installing private green roofs (Claus and Rousseau 2012). However, there are various examples of cities in Germany where roof subsidy programs were adopted, but later cancelled due to constraints on the municipal budget (Ngan 2004) (Carter and Fowler 2008).

Indirect financial incentives

The use of indirect economic incentives is the most common strategy to encourage the use of green roofs. Municipalities offer other benefits that financially support projects using green roofs instead of directly assisting developers and private building owners with the financing of green roofs. Examples of indirect incentives include stormwater credit fees, expedited processing of development approval applications and density bonusing. These incentives allow developers and private building owners to consider the use of green roofs based on their site's characteristics while reducing the financial stress a municipality may face with direct incentives (Carter and Fowler 2008).

While major cities including Chicago and Portland use indirect incentives, that is currently not part of Toronto's green roof strategy. The City does not charge stormwater management fees, but instead tightly regulates stormwater with guidelines (City of Toronto 2013a). Further, as Loder (2011) notes, the practice of density bonusing is a familiar one in the city of Toronto under Section 37. However, green buildings are not recognized as a public good and therefore green roofs do not qualify.

Types of standards available to municipalities to encourage green roof use

The use of standards is another option available to municipalities seeking to increase the use of green roofs. As Carter and Fowler (2008) note, a technology standard and a performance standard are the primary options for municipal governments to choose between. A technology standard identifies a specific technology such as green roofs and mandates its use based on a set criteria. In the context of green roofs, this "command and control" style negates the ability of development firms to select whether they wish to include a green roof on their project or not (154).

Performance standards are the alternative and set measurable results that must be adhered to rather than specifying the exact technology or practice. Such values can include urban greening requirements, targets for stormwater management and minimum reflective capacity for rooftops. In some cases, cities will suggest a technology such as green roofs as a best management practice to meeting the requirements. However, the development firms and building owners ultimately decide what methods to utilize (Carter and Fowler 2008).

In the case of Toronto, a technology standard has been implemented and is enforced through the building permit application process via a By-law (City of Toronto, 2014). While the use of a technology standard is unique among major North American cities, other cities around the world have also implanted mandatory green roof use. In Basel, Switzerland, new buildings with flat roofs above 500m^2 are required to use a green roof with set standards for the depth and composition of growing medium to address concerns of biodiversity loss (Brenneisen 2006, 26). In Linz, Austria, the minimum roof size is even smaller as new buildings with roofs larger that 100m^2 are subject to green roofs (Ngan 2004) (Carter and Fowler 2008, 154). Tokyo, Japan has also implemented a technology standard that requires new private buildings with roof tops larger than 1000m^2 to have at least 20 covered by green roof (Carter and Fowler 2008, 154).

City	Country	Date	Minimum Roof Size (sq.m)	Coverage Requirements	Subsidy Available
Toronto	Canada	2009	2,000	20% - 60%	No
Port Coquitlam, B.C	Canada	2006	5,000	75%	No
Basel	Switzerland	2002	500	Biodiversity Standards	n/a
Copenhagen	Denmark	2010	n/a	Performance Standards	No
Linz	Austria	1985	100	80%	Yes
Tokyo	Japan	2001	1,000	20%	No

Table 5: Select cities that mandate green roof use

3.5 Acceptance of mandated green roof use

My research focused on attitudes towards the Green Roof By-law and how the By-law impacts a firm's approach to projects that require a green roof. Among development firms that participated in my research there was a range in opinions regarding the City's Green Roof By-law. The development approval process and policy are influential tools for cities to stimulate the use of green roofs. However, their effectiveness is impacted by institutional support, objectives of the green roof policy and the city's local climate (Carter and Fowler 2008).

For development firms in Toronto, participants explained that their respective firms were not opposed to the By-law and that it was an accepted reality of doing business in the city. Since all developers have to use green roofs it is not an obstacle or an impediment. Several participants indicated that their respective firm's preference would have been to choose whether to use green roofs or not (participants A, B & D, personal communication). However, one participant acknowledged that it is likely that fewer projects would have included green roofs, and the amount of green roof coverage would have been reduced if the By-law had not been enacted (participant B, personal communication).

Potential advantages of mandating the use of green roofs with a By-law are stimulating a competitive and innovative local green roof industry and establishing a critical mass of green roof coverage helping to generate, economic, social and environmental benefits for the city. At the same time, Toronto has also risked resentment and a minimal compliance from development firms required to adhere to the policy due to additional costs and lack of choice (Snodgrass and McIntyre 2010). Based on the sample of development firms I questioned, it appears the By-law has increased the use of green roofs, but has also resulted in development firms doing the bare minimum to meet standards. Prior to the By-law, two of the firms had previously used a green roof (participants B & D, personal communication). However with the implementation of the By-law, all firms have now seen an increase in the use of green roofs. For three firms, the required use has not only increased the prominence of green roofs in their projects, but also appears to have been a catalyst to further exploring the possible uses and benefits of green roofs (participants B, C & D, personal communication).

Firms that used green roofs prior to the By-law did so when pursuing LEED accredited projects. These participants also identified sustainability as a core component of their respective firms' corporate philosophy and practice. These firms continue to raise internal benchmarks for sustainable and environmentally conscious practices such as energy efficiency, reduced water use and responsible souring of building materials. Select firms also have an internally mandated attainment of certain LEED designations (participants B, C & D, personal communication). While there are a variety of ways to acquire points for LEED qualification, the mandated use of green roofs contributes to accreditation points on projects

Alternatively, for one firm, green roofs are currently used with minimal intention beyond meeting the City's By-law and TGS (participant A, personal communication). This reflects the concern of using a mandatory technology standard for green roofs as it may result in minimal compliance (Snodgrass and McIntyre 2010). As the participant explained, the firm would have preferred to be given building performance standards such as water retention or roof reflective capacity that needed to be met. This would have allowed the developer to explore alternative approaches rather than being directed with no options (participant A, personal communication).

This opinion of frustration was reflected by media sources following Toronto City Council's decision to pass the Green Roof By-law. The development industry was described as frustrated by a lack of choice and were concerned that the By-law limited opportunities for other building features that contribute to environmental protection and resource conservation (Belford 2009; Mordant 2009). When a technology standard mandates the use of one method, it potentially hinders innovation and the application of other technologies (Carter and Fowler 2008).

3.6 Successfully increasing green roof use with Toronto's By-law

Based on the opinions of participants, it appears that the Green Roof By-law is necessary to meet the City's objective of increasing green roof coverage in Toronto. While the majority of participants indicated their firms would likely incorporate green roofs into projects regardless, I suspect it would be to a lesser degree with one participating firm likely not using them at all. Since coming into effect in 2010, 1.2 million square metres of new green roof area have been added across the city (Cirillo 2012, 21). According to GRHC's membership survey (2013), Toronto was fourth among North American cities in the amount of square footage of green roof installed in 2012. Washington, Chicago, New York City and Philadelphia round out the other top five cities and are recognized by GRHC for their efforts in supporting the implementation of green roofs through incentives and standards (2013).

Drawing on the literature and discussions with development firms in Toronto, it seems that increasing the use of green roofs in urban environments is best achieved with incentives and standards. It remains difficult to assess whether the combination of mandatory compliance through a technology standard along with a direct incentive program is the most effective for the City to achieve its goal of promoting green roofs. However, my research gave me the impression that there would be far less green roof coverage if the current strategy were not in place.

Section 4 – Barriers to green roofs as a competitive advantage

This section focuses on the variation between green roof literature and the development firms that participated in my research in recognizing and valuing the private benefits of green roof. Further, my assumptions regarding the costs of green roofs and the possibility of establishing a competitive advantage are compared against my research results. It is clear from my research that many of the private benefits I suspected would be advantageous to development firms are not recognized or not considered in the decision-making by the firms. The costs related to green roofs are not an issue for development firms, however developers appear to have a limited willingness to attempt to value the private benefits of green roofs. As a result, it appears urban agriculture is the only feature of green roofs that certain developers are currently pursuing to gain a competitive advantage.

4.1 The implications of design and intended objectives on the performance of green roofs

Green roof technology is recognized for its capacity to provide benefits beyond what conventional black roofs can achieve. As a result, green roofs are becoming recognized as a form of green infrastructure that contributes to more sustainable urban development. However, there is potential to generalize the features of green roofs as their functions and designs vary from site to site (Snodgrass and McIntyre 2010).

Green roofs can be designed to amplify a particular benefit or function, but it may be at the expense of another feature or possibly require enhancing the complexity of the project (Snodgrass and McIntyre 2010). For example, utilizing a shallow level of growing medium reduces the expenses and simplifies a project. However, the drawback of using a shallow growing medium would be the limit on the types of vegetation that can be used resulting in lost biodiversity and water retention potential (Brenneisen 2006).

Further, some benefits of green roofs will accrue in the immediate vicinity and be available to the owner and users of the building. Others features like a reduction in the urban heat island are only realized when a critical mass of green roof coverage is achieved and occurs on a larger scale (Snodgrass and McIntyre 2010). Green Roofs for Healthy Cities (2013a) claims that green roof technology is one of the few forms of infrastructure that can provide such a range of benefits to a variety of interests in urban centres. However, due to the spectrum of feature associated with green roofs, it is necessary to differentiate whom the benefits apply to and how they should be valued.

4.2 Dividing benefits – public & private/tangible & intangible

The costs and benefits of green roofs are generally divided as they apply to private building owners and externally to the broader public. Doing so makes the features of green roofs easier for investors and decision makers to comprehend (Tomalty et al. 2010). The sum of private and public benefits that accrue can be categorized as the social benefits (Mullen 2013). Given the focus of this paper, emphasis will be on the promoted private benefits and understanding green roofs from the private investment perspective.

The necessity for further categorization between private and public costs and benefits is described in the Ryerson University study (Doshi et al. 2005). In the context of Toronto, the report identified the tangible and intangible costs and benefits that would result from the use of green roofs in the city. At the time, the report strived to offer an accurate and comprehensive impression of the opportunities and drawbacks associated with green roofs and their features. This proved valuable for policy makers at the City of Toronto when considering a strategy for green roofs (Loder 2011).

However, while some costs and benefits associated with green roofs can be given a monetary value on market-based estimates, others have intangible qualities that prove difficult to quantify. This also true of the ecosystem services that green roofs provide, which are not traded on the market (Green Roofs for Healthy Cities 2013a). Since not all the functions of green roofs can be quantified simply (or at all), certain benefits have 'hard' values and 'soft' values. Hard values such as stormwater management can be measured directly, while soft values such as increased biodiversity are difficult to estimate and calculate (Tomalty et al. 2010).

4.3 Life cycle cost benefit analysis

The intent of the life cycle cost benefit analysis (CBA) is to quantify in monetary terms, as many of the costs and benefits, both current and future, of a prospective decision as feasible. The CBA is an economic evaluation method well suited for assessing projects with varying initial costs and can estimate if they translate into reduced future expenses. Use of the CBA allows various alternatives to be compared at intervals over a set time line (Doshi et al. 2005, Green Roofs for Healthy Cities 2013a). The findings of the CBA can be expressed as a net present value (NPV), which allows direct comparison between competing options. A lower NPV reflects that there are less overall costs associated with a decision (Carter and Keeler 2007).

As the emphasis is on an economic evaluation, it is critical that the costs and benefits attributed to a particular decision be monetized. For costs and benefits that the market currently does not provide adequate value for, it is necessary to establish a monetary value for the feature to be included in the assessment. Future costs and benefits are not considered directly comparable and therefore a discount rate is used to address this incompatibility caused by risk, opportunity cost and time preference (Doshi et al. 2005, Green Roofs for Healthy Cities 2013a).

How it applies?

The CBA is well recognized for evaluating future decisions, particularly with policy and future actions (Arrow et al. 1996) (Carter and Keeler 2007). The evaluation approach is well suited for green roofs as it assesses alternate decisions over a set time horizon. Due to the various features attributed to green roofs, it is necessary to compare the costs and savings from each option (US GSA 2011). This approach is exemplified in Sproul et al.'s (2013) comparison of white, green and black roofs. In addition, variations on growing medium depth, coverage by square foot and associated benefits based on design all influence the costs and benefits of green roofs. The various green roof system scenarios created by adjusting the design features of green roofs can also be compared with a CBA. This is demonstrated in the U.S. General Services Administration's (2011) study, which used three scenarios with varying depths and coverage of growing medium.

The majority of benefits associated with the use of green roofs, both public and private, tend to accrue annually rather than immediately. This characteristic is critical when comparing green roofs against alternative choices such as white and black roofs that are significantly less expensive. As green roofs tend to last twice as long as alternative options, the time span for a CBA is generally set at 40 to 50 years to realize this benefit (Doshi et al. 2005, Sproul et al. 2013).

Critical evaluation

Given the characteristics of green roofs and the CBA, setting an appropriate time horizon for comparing alternatives is essential to realizing the long-term benefits of the options being considered (Doshi et al. 2005). It is also critical to the premise and functionality of the CBA that the monetary costs and benefits of each decision are as accurate and near completed as possible. The more comprehensive the inputs are for an option, the more thorough and accurate an assessment can be.

Works by Bianchini and Hewage 2012, Carter and Keeler 2007 and Tomalty et al. 2010 exemplify the variations in calculation methodology used to establish hard values for some of the soft features of green roofs. While research continues to try to establish innovative valuation techniques, some attributes remain qualitative and are difficult to monetize. The lack in uniformity in valuation techniques combined with the inclusion and exclusion of particular benefits in studies contributes to varying performance results of green roofs (Doshi et al. 2005).

As Claus and Rousseau (2012) note, the variation in methodology of cost-benefit analyses has led to fragmented information available regarding the performance of green roofs. Along with selective inclusion of costs and benefits, data used to contribute to a study often comes from studies using limited pilot plots. The technical characteristics of green roofs are directly influenced by the design of a structure and roof, the climate and local environment of the site, the type of surrounding buildings and voluntary standards or public policies in place. Therefore, while a CBA is the preferred method evaluating greens, it is important to recognize the drawbacks and limitations (Henry and Fracsaria-Lacaoste 2012, Green Roofs for Healthy Cities 2013a).

4.4 Practical implications of green roof costs

In the construction industry, the prevailing assumption is environmental concerns are a luxury, and sustainable structures are either more expensive or less profitable. As long as these assumptions exist, only builders who are both informed and committed will pursue sustainably focused projects (Halliday 2008). While policy and advocacy can contribute to mobilizing development towards more sustainable practices, finding ways to quantify and convey costs and value of a technology like green roofs will encourage their use (Bianchini and Hewage 2012, Peck 2013).

In the case of green roofs, even the simplest and least expensive design (an extensive and inaccessible roof) is initially more expensive than alternative roofing options (Peck and Kuhn 2010). The cost for a green roof is roughly US$10 per square foot for an extensive green roof, which is generally twice the amount of a conventional roof. For an intensive roof, this cost is substantially more at about US$25 per square foot (US Environmental Protection Agency) (Austin 2014, 177). There is a growing opinion that the wide range of private and public benefits can justify the costs, but a full net-benefit assessment of green roofs would substantiate this opinion (Foster et al. 2011, Snodgrass and McIntyre 2010).

The higher installation and maintenance costs of green roofs relative to alternatives roofing options is noted as a drawback in green roof literature (Green Roofs for Healthy Cities 2013). Therefore, I assumed that green roofs would be perceived as an additional cost by development firms that participated in my research. However, in each interview participants quickly dismissed this notion. Prior to the By-law, the use of a green roof over a white or black roof would have qualified with this view. However, once the By-law came into effect, green roofs became a necessary component of a building. For the development firms seeking to incorporate urban agriculture into their fulfilment of the Green Roof By-law requirements, the costs are additional, but contribute to a feature that the firms want to enhance (participants A, B, C & D, personal communication).

Another assumption I made was that the higher costs associated with green roofs would be a point of tension in regards to the Green Roof By-law. Participants also dismissed this perspective and credited it to the residential focus of the firms. High-rise condominium buildings generally have a smaller floor plate relative to other building types such as a mall or a warehouse. Therefore a project's roofing costs are only a minor percentage of the overall budget. Even with the additional costs of using a green roof, it only results in a small increase to a building's costs. Further, any the additional costs that result from the mandatory use of a green roof are passed down to customers and included in the price of a building's suites and maintenance fees (participants A, B, C & D, personal communication).

4.5 The division in the recognition of green roof private benefits

For private building owners and development firms, there are number of private benefits attributed to green roofs in academic, advocacy and municipal reports. The primary obstacle facing private investment in green roofs are costs associated with design, installation, maintenance and any cost attributed to training personnel (Claus and Rousseau 2012; Mullen 2013). However, some researchers argue that under the circumstances they researched, the initial expenses are worthwhile compared to conventional roofs because green roofs are potentially more economical over the roof's life span (Porsche and Köhler 2003; Mullen 2013; Snodgrass and McIntyre 2010). While the variations in green roofs influences numerous characteristics and features, there are a number of ways that developers and building owners can realize benefits (Green Roofs for Healthy Cities 2013a).

To gain insight into the practical application of these private benefits, I asked my research participants about the features of green roofs that his or her firm recognized. I also asked them which characteristics of green roofs customers would value. Based on the experiences and opinions of the sample of firms that participated, it is evident that there is currently a discrepancy between the private benefits identified in green roof literature compared to those recognized by select development firms in Toronto.

Contributes to LEED accreditation

The Leadership in Energy and Environmental Design (LEED) is an internationally recognized rating system intended to measure and evaluate the design and construction of green buildings. Established by the United States Green Building Council in 1998 (Access Point), the LEED rating system seeks to encourage the construction of sustainably minded buildings through a voluntary, market system grounded in established technologies (Katz, 2012).

Mirroring these efforts, the Canadian Green Building Council was created in 2002 and utilizes LEED Canada, a version of the LEED standards adapted to Canadian climatic conditions. Similarly, the focus is on sustainably minded construction practices and the operation of buildings that are healthier and have less negative environmental impacts (CMHC 2006).

As of 2013, over 1,000 building had been LEED certified in Canada (Canadian Green Building Council). As attention on policy for sustainable development grows, there is increasing interest and pressure from agencies to pursue LEED certified buildings (Snodgrass and McIntyre 2010). Green roofs are a recognized technology under the LEED rating system. By incorporating them in a project, designers and developers can gain credits for LEED certification. Energy savings, urban heat island reduction, improved air quality, wildlife habitat provision and improved storm water management are among the recognized benefits that contribute to LEED credits when green roofs are used (CMHC 2006).

There are several reasons why building developers and owners believe LEED is beneficial to business and pursue LEED certified projects. The improved performance and longevity of green buildings increase efficiencies and reduces costs associated with resource consumption, particularly with concerns of raising prices of water and energy (Snodgrass and McIntyre 2010). For office buildings, the business case for greening further extends to the risk of pending environmental regulation and growing demand by tenants for green office space (Tobias and Vavaroutsos 2009).

Additionally, international recognition of LEED and growing awareness of urban environmental issues offers a marketing opportunity for developers and building owners. Sustainability labels such as LEED not only act as an indirect policy that encourages the use of green infrastructure like green roofs, but also allows developers and building owners to align themselves with a standard that promotes environmental values (Berardi et al. 2014).

For three participating firms, LEED accreditation is an internal benchmark that is pursued on projects. Green roofs are among many components and practices that count towards achieving LEED recognition. Some participating firms recognized the contribution green roofs have on accreditation and used green roofs for this purpose prior to the By-law. However, now that they are mandatory, the contribution green roofs have on LEED is no longer an incentive for the firms in using a green roof (participants B, C & D, personal communication).

Energy efficiencies

In North America, buildings are responsible for nearly 50 percent of all energy consumed. This is primarily due to energy requirements for ventilation, heating and air conditioning. In residential and commercial buildings in the United States, roughly half of a building's energy use is specifically attributed to air conditioning alone (Green Roofs for Healthy Cities 2013a, 49). Green roofs help improve a structure's energy efficiency by reducing the variability of the temperature inside while reducing the overall energy consumption for buildings in warm and cool climates (Berardi et al. 2014).

There are several mechanisms that contribute to this that includes reducing heat flux through a building's envelope. The building envelope physically separates a building's interior environment from the exterior environment. A green roof can reduce temperature fluctuations resulting in reduced peak demands for cooling and heating by providing an increased level of insulation through a section of the building envelope (Green Roofs for Healthy cities 2013a).

Green roofs also help moderate the temperature on the roof's surface resulting in less flux and keeping it close to the ambient air temperature. Several studies documenting these benefits including Lui and Minor's (2005) work in Toronto, Ontario. Using heat flux transducers, heat gain between a green roof and a similar uncovered reference roof were measured. Findings revealed that heat gain on the green roof was reduced by an average of 10-30% in the winter and 70-90% in the summer (10).

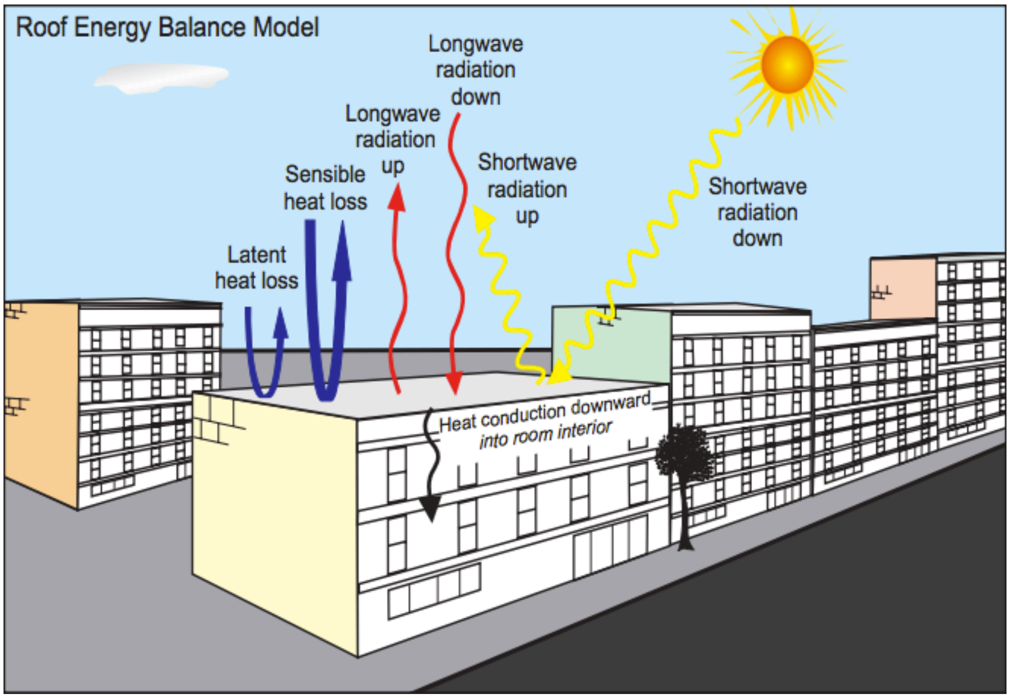

Figure 13: The seven energy fluxes considered in the energy balance model. Gaffin et al. 2010

Albedo is used to rate a surface's aggregate capacity to reflect solar energy expressed as number between 0 and 1. Green roofs are often in the range of 0.25 to 0.3 (Garrison et al. 2012), which is less than white roofs but higher than black roofs. Along with reflecting solar energy, the vegetation on green roofs also radiates heat as long-wave radiation through thermal emissivity. Another important mechanism that contributes to rooftop surface cooling is evapotranspiration. As the vegetation and growing medium is exposed to solar energy, the water it retains is heated. As the water changes from a liquid to a gas, it consumes heat energy as it evaporates cooling the roof surface (Green Roofs for Healthy Cities 2013a).

Critical factors that influence a green roof's capacity to manage heat transfer are vegetation, growing medium, insulation and support layers. However, variety in the type of plants used, growing medium depth and the presence of insulation make it difficult to conclude general estimates on the thermal conductivity of green roofs (Berardi et al. 2014; Moody and Sailor 2013). Since Toronto's Green Roof By-law was enacted, roughly 1.5 million kilowatt hours of energy have been saved in the city (Cirillo 2012, 21).

By reducing the amount of energy consumed, private owners can mitigate future consequence of raising energy prices. However, the energy savings alone are generally not recognized as enough to justify the installation of green roofs. Green roofs are often part of a larger greening strategy that uses technologies and practices that make more significant contributions to energy reductions (Snodgrass and McIntyre 2010).

While the benefit of energy savings is prominent in literature, participants generally did not recognize this as a substantial benefit of green roofs. For the three firms that place a greater emphasis on green development, other building elements were more important. Features such as an energy recovery ventilator system can provide recognizable cost savings due to a significant reduction in energy use. Green roofs, on the other hand, are difficult to directly quantify making it challenging for developers to value. Further, the energy savings from a green roof are only relevant to the first few floors below a building's rooftop. As the projects of participating firms are predominantly high-rises, the relevance of this benefit is diminished (participants B, C & D, personal communication). One participant explained that while the reduced energy use is a feature recognized by the firm, efforts are not made to calculate the savings into decision-making (participant C, personal communication).

Participants explained that for customers, the recognition of energy savings from green roofs is even less relevant. It was also suggested that the majority of customers are generally not interested in or have difficulty understanding benefits that are not visually recognizable. For a customer, it is hard to value an invisible feature such as reduced energy use compared to other very tangible features that contribute to decision making such as suite characteristics. Further, a benefit like reduced energy accrues over a longer period of time than customers generally consider (participants A, B, C & D, personal communication).

Extended membrane lifespan

Another recognized private benefit is the extended lifespan of the waterproof membrane under green roofs as compared to that under conventional black roofs. For extensive green roofs in particular, it is the most substantial economic benefit associated with their use (Carter and Keeler 2007). Rooftops act as a structure's primary barrier to solar radiation and are dominated by the radiative heat forcing from the sun (Carter and Keeler 2007; Sailor 2008). While black and green roofs endure the same exposure, differences in design and composition impact the way solar radiation is managed. This contributes to several benefits associated with green roofs including the capacity to protect the critical waterproof membrane better than black roofs (Snodgrass and McIntyre 2010).

On black roofs, the membrane is regularly exposed to ultraviolet (UV) light causing it to become brittle and susceptible to cracking. This damage is further intensified by the contraction and expansion of the membrane due to fluctuating rooftop temperatures (Oberndorfer et al. 2007). As a result of this stress to the membrane, the assumed lifespan is around 20 years before it requires replacement (Berardi et al 2014, 424). Alternatively, the vegetation and growing medium of green roofs help stabilize the rooftop surface temperature and protects the membrane from UV exposure. The solar radiation is balanced by sensible and latent heat flux from the roof's plants and substrate along with the conduction of heat into the growing medium (Berardi et al. 2014).

While there are variations based on climate, a study conducted in Ottawa, Canada revealed how substantial these fluctuations can be. The study compared the maximum temperature on a green roof and a black roof. The green roof peaked at a surface temperature of 30 °C while its black counterpart reached temperatures above 70 °C. Additionally, the membrane on the green roof reached 30 °C on 18 of the 660 days, while the conventional roof exceeded this temperature 342 days of the study (Lui, 2003, 10).

Estimates vary, but it is generally accepted among academics and within the industry that the life expectancy of a green roof's membrane can be between two to three times longer than that of a black roof (US GSA 2011, 63). In Berlin, Germany there are some roofs that have lasted 90 years without requiring substantial repairs (Porsche and Köhler 2003, 462). In North America, Portland, Oregon boasts an extensive green roof covering an underground parking facility that has functioned without a leak since 1975 (Snodgrass and McIntyre 2010, 32). However, other project examples are limited and overall estimates are difficult to reach as larger scale use only began in the past decade of so ago (Carter and Keeler 2007).

In addition to an extended life expectancy, in certain cases many of the components of a green roof system, including the vegetation and growing medium, can be reused. In Sproul et al.'s work (2013), focus was specifically on extensive roofs and found that salvaging components could reduce the replacement costs to one third of the cost of the first installation (9).

Given that the firms that participated in my research were primarily involved in developing residential condominiums, the practical relevance of the long-term benefit is significantly diminished. A building's ownership structure is fundamental to the benefit of membrane longevity because it is only recognized long-term. For condominium developers, the sale of suites is the final stage of their formal involvement. The fact that a building's green roof needs to be replaced less frequently does not present immediate advantages for a developer. Instead this is likely only recognized by unit owners in later decades through reduced maintenance fees.

For one participant there was uncertainty about the extended life expectancy because there are presently no existing examples in Toronto or a comparable context (participant D, personal communication). Another participant expressed that value could be seen in this feature as it reflects the quality of the firm's product. The firm may not see monetary benefits, but in the future, if the green roof performs as is suggested, it will lower maintenance fees and enhance the sense of building quality among suite owners. These factors could help enhance the developer's reputation as a sustainable builder, however, without existing examples it is difficult for a firm to anticipate and incorporate this potential value into decisions (participant B, personal communication).

Urban Agriculture

Growing interest in urban agriculture has led to green roofs being used as rooftop gardens and farms. Consistent sun exposure, predominantly flat surfaces and increased protection from pests all contribute to the potential to grow food, especially herbs and vegetables (Chen 2013) (Berardi et al. 2014; US GSA 2011). The primary factors that influence the productivity of green roof gardens include the composition and depth of growing medium, mixture of plants, intensity of farming and irrigation (Tomalty el al. 2010).

For extensive green roofs with less than six inches of growing medium, potential growing tends to be limited to herbs, kale and spinach crops. Other crops require substantially more depth and struggle in levels below 18 inches. Therefore, intensive greens roofs are capable of growing a much wider variety of crops due to a deeper growing medium. However, more complex and intensive green roof gardens require increased load-bearing capacity and access for maintenance (US GSA 2011, 44).

While public benefits such as CO_2 absorption and increased food security are attributed to urban agriculture, private benefits for developers and building owners are present, too (Orbendorfer 2007; Tomalty et al. 2010). For some building owners with large roof surfaces, urban food production is a potential source of revenue. Among cases discussed in Tomalty et al.'s (2010) work is the Fairmont Waterfront Hotel in Vancouver, which saves $25,000 to $30,000 annually by using the herbs grown on the rooftop garden (September and Peck). For others buildings, roof gardens can contribute to property value and marketability since they function as an additional building amenity.

Based on my interviews with select development firms, it appears that urban agriculture has the most interest and value. The three firms that are most active with green roofs all stated that they are currently exploring the use and benefits of urban agriculture through green roofs. The primary appeal is the potential to enhance and facilitate a sense of community for residents. The opportunity for residents to have access to plots to grow local, organic food is also an additional amenity that can contribute to the marketing story of a building (participants B, C & D, personal communication)

Two participants each used a system of planters and soil to create individual plots for residents on buildings (participants C & D, personal communication). This system adheres to the City's green roof construction standards, but does not utilize all the components characteristic of an intensive green roof system for growing produce. Participants explained that the multi-tenant structure of buildings and their own inexperience were the main reasons for using the planter and soil system instead of an intensive green roofs system. An intensive green roof could be designed for a communal garden, but participants explained that it would be a challenge to establish individual plots. It is suspected that building residents would prefer access to a personal private plot rather than a large, shared garden. In addition, uncertainties about cost and design complexity are another factor dissuading developers from using intensive green roofs (Participants C & D, personal communication). As a result, one firm actively using this system on projects also incorporates simpler extensive green roofs to cover any remaining green roof space required for the City's standards (participant C, personal communication).

Improved aesthetics & property value

The visual appearance of green roofs is one of the technology's most distinct and recognizable features. Cities use green roofs to reintroduce green space into heavily urbanized areas by encouraging the replacement of black roofs on existing building and the incorporation of green roofs in the construction of new structures. However, there is growing research indictating that the aesthetic characteristics of green roofs are a valuable benefit in addition to the ecosystem services they provide (Kim et al. 2012).

Studies on the aesthetic benefits of green roofs contribute to a growing body of research and literature on the predisposed preference and positive consequences of people's exposure to natural features (Jungels et al. 2013). Several projects have produced evidence that indicates that people can handle stress better, have improved focus, reduce volatility and think more creatively when they have a connection to nature (Doshi el al. 2005). With improved mental well-being, people are likely to feel more relaxed and restored, which benefits their overall health (Hartig et al. 1991) (Loder 2011) (Orberndorfer et al. 2007). Some researchers have even gone as far as saying that meaningful contact with nature might be just as important as a person's need for interpersonal relationships (Kaplan, 1993) (Doshi et al. 2005).

Depending on its design, a green roof can function as an accessible space for relaxation, recreational activities and social interaction. For building users, a green roof can be used for gardening, sunbathing and socializing. (Doshi et al. 2005). In a study conducted in Toronto, tenants at 401 Richmond Ltd. described their access to the building's green roofs as "an oasis in the city" (Cohnstaedt, Shields, and MacDonald, 2003) (Doshi et al. 2005).

For green roofs that are inaccessible, opportunities are reduced, however there can be aesthetic benefits from having a view of green roofs from inside a building. In another study in Toronto, a participant claimed that his view of a green roof from 30 Charles Street "provided sanity and relief" from the demands of living in an urbanized environment (Bass et al. 2004) (Doshi et al. 2005). Depending on a structure's design, occupants of the immediate building may have a view down onto a green roof. If this is not the case, a view of the green roof and the attributed benefits may only be available to occupants of surrounding buildings. While a study such as Jungels et al. (2013), reveals there are various opinions toward the aesthetics of green roofs, particularly due to vegetation choices, physical, social and mental well-being are still influenced and improved (Claus and Rousseau 2012).

Figure 14: View of the TD Banking Pavilion green roof in Toronto. Green Reason 2014

Loder's (2011) work addresses the impact that green roofs have on employees in case studies of Toronto and Chicago. Her work builds on research that indicates that employees with access to nature experience an improved state of mind while having lower blood pressure, less stress and illness related absences (Rowe 2011) (Claus and Rousseau 2012). Even with only a visual outlet--such as a window view-- to connect with nature, workers appear to have improved concentration and job satisfaction (Doshi et al.

2005). Firms that occupy office buildings can see value in the features that green office spaces have for clients and workers as it has been demonstrated in various case studies. However, the exact value of this benefit remains difficult to quantify (Tobias and Vavaroutsos 2009).

Green roofs have the potential to enhance amenity spaces, improve marketability and increase property value (Doshi et al. 2005). Aesthetics are also an important consideration when designing and anticipating the functionality of a building. However, it can to be difficult to objectively value their economic impacts (Bianchini and Hewage, 2012, 155).

Whether an aesthetic feature generates a return on investment depends on what customers are willing to pay for certain looks and design. Research such as Bianchini and Hewage's (2012) work address the challenges of monetizing the aesthetic benefits of green roofs. However, 1330 Boylston Street, a luxury apartment building in Boston, Massachusetts, is a tangible example that demonstrates potential value. Designed as an inaccessible extensive roof, the building has 25 units and an observation deck that overlook what was previously a white roof. After spending $112,500 to replace the white roof, J.P. Morgan Assets Management estimates the property value has increased by US$2.4 million because the green roof generates between $300-$500 per month in additional revenue from the units with a view of the green roof (Blackwell 2008).

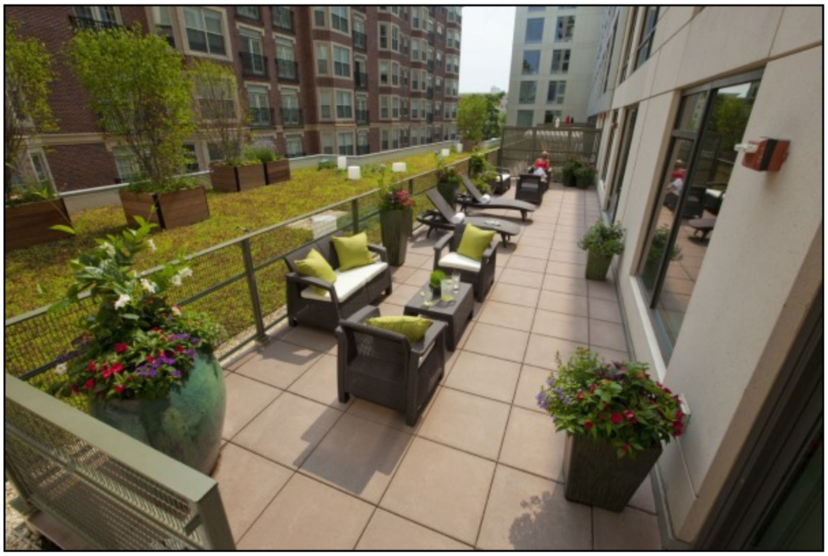

Figure 15: View of units with view of the green roof at 1330 Boylston Street. Blackwell 2008

Participants in my research agreed that green roofs were a visually distinct feature of buildings and preferred aesthetically compared to black and white roofs. Several also felt that potential customers would prefer a view of green roofs instead of alternative roof types. However, the design of a building and the location of the green roof significantly impacts this feature. If a building has a green roof installed on the surface of a building's podium, all the suites in the building's tower may have a view. On the other hand, locating the green roof on the mechanical penthouse of a building would result in a view only available to taller surrounding buildings. Since residents would be without the visual benefit of the green roof, the building's development firm would be deprived of any value from improved aesthetics (participants A, B, C & D, personal communication).

Further complicating the determination of the value of improved aesthetics is the division in markets being served. One participant's firm primarily deals with customers that are investors rather than end users. For this market, the possible view of a green roof is not considered to be important (participant A, personal communication). Other participants with a higher proportion of end users felt their customers may perceive a green roof as a positive and appreciate a view of one. Yet even with this, participants explained that green roofs are not a priority for most customers. Other factors such as location, suite finishes and appliances are generally considered more important to customers (participants B, C & D, personal communication).

Noise reduction

There is fairly recent research into noise reduction as a private benefit. Findings reveal that the composition of green roofs helps insulate rooftops and absorb incoming sound. Compared to black roofs, green roofs have superior sound insulation properties that are useful in environments dominated by hard surfaces that characteristically reflect noise. This is due to the porous nature of growing medium used for both extensive and intensive green roofs. Sound enters the growing medium and interacts with the particles, and losing its intensity (Van Renterghem and Botteldooren 2011).

The key factors that influence a green roof's capacity to reduce noise are the types of plants, proportion of rooftop coverage and the growing medium's depth and composition (Green Roofs for Healthy Cities 2013a). For buildings exposed to noise pollution from automobiles, elevated trains, and air traffic, noise reduction may have private value. However, it seems this benefit is limited to the upper levels of buildings, particularly those that are directly under noise (such as flight paths). (Tomalty et al. 2010, US GSA 2011). In their study, Van Renterghem and Botteldooren (2011) identified the challenges of researching the applications of this benefit. This was also noted in Tomalty et al.'s (2010) work that mentions few research studies have focused on this feature.

In San Bruno, California, an office building owned by GAP Inc. utilized a semi-intensive roof to reduce the noise of overhead air traffic that contributed to sound attenuation benefits worth an estimated US$305,500 in property value (Tomalty et al. 2010). Among participating Toronto development firms however, noise reduction was not a feature that is considered. While the city does experience noise from traffic, the firms' projects are generally not exposed to noise from trains or airplane traffic overhead (participants A, B, C & D, personal communication).

Marketability

In Canada there is growing interest in green and environmentally friendly products and services by the public and mass media. Included in this interest are environmental considerations and features in the built environment. As consumption patterns and demands of customers and clients shift, and municipalities pursue a more sustainable development, green buildings and features such as green roofs can be desirable attributes. Along with the tangible and intangible functions discussed above, it is argued that green roofs can improve the marketability and the real estate value of a structure (Tomalty et al. 2010).

Greens roofs are visually distinct and highlight the green characteristics of a structure, which are otherwise often invisible. By functioning as a perceptible indicator of awareness and concern for the environment, green roofs can be used by developers, private owners, institutions and cities to enhance their brand value (Tobias and Vavaroutsos 2009; Tomalty et al. 2010). However, compared to other features of green roofs, the potential of increased marketability is often overlooked. This is due in part to the number of factors which influence value, together with the difficulty of measuring it. (Oberndorfer et al. 2007; Tomalty et al. 2010; US GSA 2011).

In Tomalty et al.'s (2010) work, marketability is included among the soft benefits calculated to give a hard, monetary value. The formula used to estimate the value of marketability is based on the publicity a site would receive due to having a green roof. Publicity is valued as the amount that radio, television and print advertisement would otherwise cost to highlight the roof. Results of improved marketability for developers and private owners may be recognized by the pace building suites are purchased at along with the attraction and improved retention of tenants.

The participating firms were clear that no formal methodology of valuation is used to consider the possibility of increased marketability of a green roof. Further, participants were sceptical that simply having a green roof would improve the marketability of a building. Participants agreed that a visible green roof would likely generate a positive reaction from customers due to the assumption that the green roof provides an environmental benefit. Further, for firms which emphasize sustainability, it was important to incorporate green roofs that are visible and encourage interaction with residents (participants B, C & D, personal communication). However, firms also explained that a green roof is low on a customer's priority list of suite and building features (participants A, B, C & D, personal communication).

Further limiting the marketing benefit of green roofs is the required use for projects subject to the By-law. Having a green roof is no longer a unique feature to a building in Toronto. Two participants noted that the interpretation of the By-law and the use of a green roof could be used to establish a competitive advantage (participants B & C, personal communication). However, the reality of having a green roof on a building was generally not recognized as a feature that would draw additional attention to a building and generate benefits such as higher inventory turnover (participants A, B, C & D, personal communication).

4.6 Establishing a competitive advantage through urban agriculture

Based on my research, it appears that urban agriculture is the only feature of green roofs that development firms see as an opportunity to differentiate their product and establish a competitive advantage. Firms that identify sustainably as a core component of their practice have a higher awareness and interest in green roofs. While firms are fairly aware of the attributed private benefits of green roofs, their consideration seems to be limited by the lack of practical examples and difficulty in quantifying the benefits. The urban agriculture potential of green roofs is where the majority of participating firms are focusing on differentiating their product. For developers, urban agriculture is a way to provide a tangible amenity that builds on the idea of sustainability and enhances a sense of community among residents by beautifying an area and bringing residents together (participant B, C & D, personal communication).

Figure 16: Rooftop herb garden at Fairmont Royal York Hotel. Oyster 2012

Additionally, all participants agreed that the visual characteristics of green roofs provide a positive attribute and would be a consideration for customers of most of the firms. I suspected that there is a significant opportunity to use green roofs to enhance the aesthetics of amenity spaces, or provide an improved view from the window of a building's suites. However, research participants explained their belief that views and exposure to green roofs would still be ranked relatively low in importance to their customers when compared to other features and amenities of a building and suites. Another obstacle to the use of green roofs in this manner is the impact a building's design has on the places a green roof can be used. As a result, improved aesthetics is not considered a priority feature to establish a competitive advantage (participants A, B, C & D, personal communication).

Section 5 – Conclusion

Toronto is among several other major North American cities leading in the use of green roofs. The city provides a unique environment to explore the use of green roofs as it is the only major municipality in North America currently mandating their use. By exploring how the City's strategy impacts and is perceived by development firms and building owners, I gained insight into the realities of the practical use of green roofs. Further, I was able to compare the first hand experiences of developer with the private green benefits identified in green roof literature.

I designed my research objective based on the understanding I developed from reviewing a variety of journals and literature focused on green roofs. As I carried out my primary research with select development firms in Toronto, it became clear that several of the key assumptions I made about the opinions and approaches to green roofs were incorrect. Specifically, these were my expectations that the costs of green roofs would be an issue with development firms and that there is a recognized opportunity to gain a competitive advantage through the aesthetic benefit of green roofs.

Since all buildings subject to Toronto's Green Roof By-law require a portion of the roof to be covered, simply having a green roof is no longer a unique quality. My research revealed that the participating firms that recognized sustainability as a component of their corporate philosophy were pursuing the urban agricultural opportunities associated with green roofs. For these firms, this was the only green feature they believed they could currently use to differentiate their product and gain a competitive advantage.

The intent of my research was to address a sample of Toronto's development industry. My initial objective was to speak with firms involved in office, retail and residential development. However, the participants I met with were all primarily representative of residential condominium developers. Clearly, there is an opportunity for more research on green roofs as they relate to commercial and office development. My research supported my suspicion that the approach of developers to the notion of green roofs is highly dependent on the building type and the expectation that green roof use will generate private benefits. In particular, I expect that developers of office buildings will focus on the employee related benefits that are discussed in Loder's (2011) work.

The emphasis of this paper was also on the Green Roof By-law, which is only one component of Toronto's green roof strategy. My research participants did not have projects involved with the Eco-Roof Incentive Program so it was not relevant to my paper. However, I suspect applicants to the Eco-Roof Incentive Program are more interested in the benefits of green roofs as it is a voluntary program. I believe there is an opportunity to establish case studies for participants of the program. Primary research could be conducted on the motivations and results of participants that applied for retrofit and new buildings projects.

Toronto's green roof strategy ensures that green roofs will be part of the city's urban fabric for the future. If research and understanding of green roof technology further substantiates the benefits of green roofs, the use of green roofs in Toronto will likely increase. My research provides insight into the realities faced by development firms which incorporate green roofs into their projects. The trends I recognized are not reflective of the entire development community in Toronto, but may be indicative of the future use of green roofs by private investment in the city.

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Appendix A - List of Potential Toronto Development Firms

Developer	Residential	Office	Retail
Allied Properties REIT		X	
Brookfield Office Properties		X	
Cadillac Fairview Corporation	X	X	X
Camrost-Felcorp	X		
Concord Pacific	X		
Context	X		
Crestford	X		
Daniels	X		
Empire	X		
First Capital			X
Freed Developments	X		
Great Gulf Companies	X	X	X
Greenpark	X		
H&R Developments	X		
Lamb Development	X		
Lanterra	X		
Liberty Development	X		
Menkes	X	X	X
Minto	X		
Monarch	X		
Oxford	X	X	X
Pemberton Group	X		
Pinnacle International	X	X	X
Plazacorp	X		
RioCan			X
Streetcar Developments	X		
TAS Design	X		
Times Group	X	X	X
Tridel Condominiums	X		
United Lands	X	X	X

Appendix B - List of Interview Participants

1. **Great Gulf** – Michael Fox (Development Manager)

2. **Minto** – Wells Baker (Sustainable Development) & Roya Khaleeli (Sustainable Design Professional)

3. **TAS Design** – Ali Saneinejad (Director Project Development)

4. **Tridel** – Subhi Alsayed (Innovation Manager)