Greening New Heights –

A Feasibility Analysis of a Green Roof on the Life Sciences Center

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Abstract

The purpose of this investigation was to conduct a feasibility analysis on implementing a green roof on the Life Sciences Centre (LSC) at Dalhousie University. The different types of green roofs, intensive and extensive, as well as plant species that would benefit a green roof in this climate were examined. The methods used consisted of non-probabilistic snowball sampling to contact knowledgeable people in this subject matter, document analysis for background information, a literature review and a feasibility analysis. Throughout our investigation it was discussed that a green roof on the LSC would be beneficial, but the size of our plot chosen for this project is not large enough to create a significant impact. It would decrease energy cost by $13.83 a year, based on similar green roofs energy savings. Beyond this there are numerous other indirect benefits that will be discussed further on, such as doubling the life span of the roof. Some of these benefits cannot be quantified and therefore is concluded that this research could be a starting point for further implementation of green roofs on the Life Sciences Centre or other older buildings on campus. It is recommended that further research be conducted into the addition of green roofs on the Dalhousie campus and the greater Halifax community.

1.0 Introduction

A green roof is an extension on to an existing roof that consists of numerous layers such as waterproofing and protective barriers with a top layer of plants and growing vegetation (Figure 1) (Miller, 2008). There are many different ways to set up a green roof, depending on the building, the purpose of the roof and the climate, with options for the different layers. Green roofs are designed for protection of the underlying rooftop and to help replace the vegetative footprint that the building took away when initially built (Green Roofs for Healthy Cities, 2005). Today, green roofs are also classified into two types, extensive and intensive (Miller, 2008).

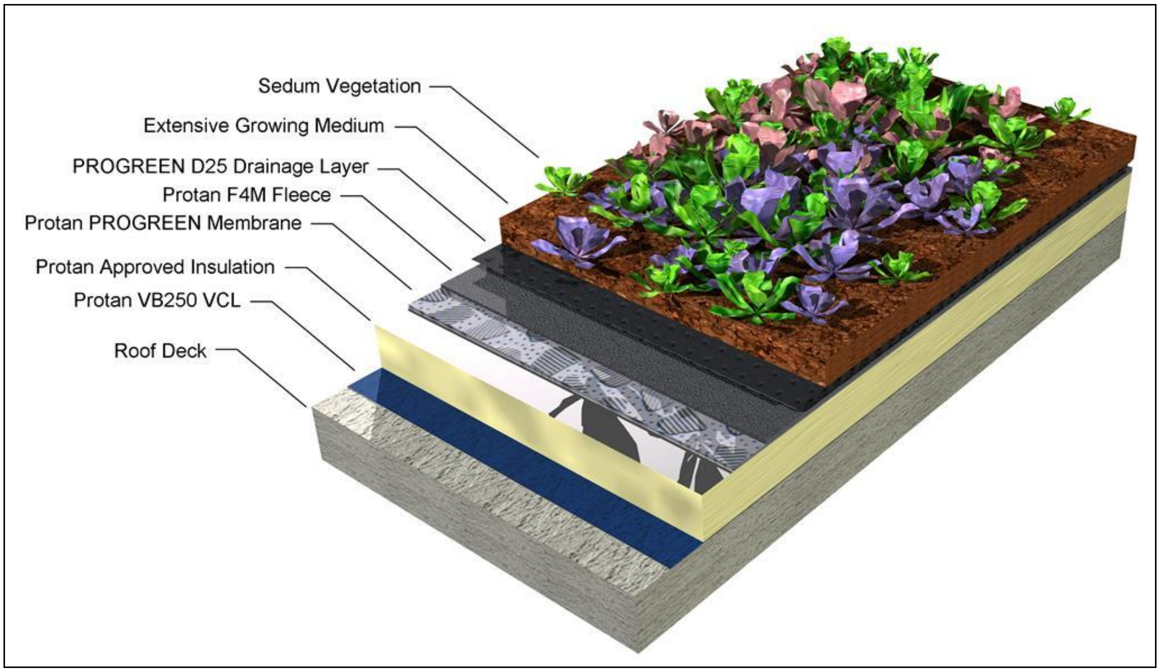

Figure 1- An example of the layers required for a green roofing system (Protan, 2008)

1.1 Extensive Green Roofs

An extensive green roof is the simpler of the two types of green roofs in that it is shallower and designed to not require as much maintenance or regular access (Miller, 2008). They are no more than 15 cm in depth (Miller, 2008) and have a wet weight of 72.6-169.4 kg/m^2 (Banting *et al*., 2005). The habitat is most suited for desert-like, hearty plants that thrive in shallow soils (Miller, 2008). A properly designed extensive green roof can provide a durable, low maintenance system that offers all the benefits of a green roof; these will be discussed later on (Miller, 2008).

1.2 Intensive Green Roofs

Intensive green roofs have deeper soil layers ranging from 15 to 60 cm (Miller, 2008). This greater depth in soil allows for a wider range of plant diversity, that can include scrubs and trees and a more complex ecosystem can develop (Banting *et al.*, 2005). Intensive roofs also have a greater weight due to the increase in soil and plant biomass, with a wet weight that can range from 290-967 kg/m^2, which is more than four times as much as extensive green roofs (Banting *et al*., 2005). Due to the more complex ecosystem, regular maintenance is required and often irrigation systems are implemented (Peck and Kuhn, 2002). Many of these roofs are accessible, making their maintenance easier (***Figure 2***).

1.3 Green Roof Structure and Comparison

The main difference between the two types of green roofs is the top vegetative layer. The underneath layers are the same to provide adequate protection and drainage. The waterproofing layer is to protect the underlying roof of the building from water damage, and can consist of a range of materials such as polyvinyl chloride (PVC), thermal polyolefin or polymer modified bituminous sheet membranes (Miller, 2008). A protective, barrier layer is needed on top of the waterproofing layer to protect it from root damage from the growth of the plants (Miller, 2008). The drainage layer is very important to maintain optimal growing conditions in the medium after heavy rainfall and to reduce erosion and build up of stagnant water (Miller, 2008). The plants and vegetation will also need of a nourishing layer for growth support that provides their initial nutrient requirements (Miller, 2008). See ***Table 1*** for a summary of the characteristics for extensive and intensive green roofs.

Table 1- Comparing intensive and extensive green roofs

Type	General	Advantages	Disadvantages
Extensive	Thin growing medium; little or no irrigation; stressful conditions for plants; low plant diversity.	• Lightweight; roof generally does not require reinforcement. • Suitable for large areas. • Suitable for roofs with 0 - 30° (slope). • Low maintenance and long life. • Often no need for irrigation and specialized drainage systems. • Less technical expertise needed. • Often suitable for retrofit projects. • Can leave vegetation to grow spontaneously. • Relatively inexpensive. • Looks more natural. • Easier for planning authority to demand as a condition of planning approvals.	• Less energy efficiency and storm water retention benefits. • More limited choice of plants. • Usually no access for recreation or other uses.
Intensive	Deep soil; irrigation system; more favorable conditions for plants; high plant diversity; ***often accessible***.	• Greater diversity of plants and habitats. • Good insulation properties. • Can simulate a wildlife garden on the ground. • Can be made very attractive visually. • Often accessible, with more diverse utilization of the roof. i.e. for recreation, growing food, as open space. • More energy efficiency and storm water retention capability. • Longer membrane life.	• Greater weight loading on roof. • Need for irrigation and drainage systems requiring energy, water, materials. • Higher capital & maintenance costs. • More complex systems and expertise

Along with the two types of green roofs discussed above, there are three main types of systems or technologies that can be used, a complete system, a modular system and a pre-cultivated system. A complete system is one that can be added on to a roof at any time during or after construction of a green roof (GRHC, 2005). It consists all of the underlying, protective layers and allows for the greatest diversity for them as well as for the vegetation used in the uppermost layer. A modular system is one that is grown off site and placed on top of an existing roof and therefore not grown in (GRHC, 2005). The plants are grown in trays when they are fully grown in soil depths most commonly ranging from 7.5 to 30 cm (GRHC, 2005). The underlying water proofing layers are still necessary. A pre-cultivated system is also grown off site and comes in a roll of interlocking tiles (GRHC, 2005). It can be placed on top of almost any roof system but does not allow for a wide variety of barrier membranes and plant type (GRHC, 2005).

1.4 Background on Green Roofs

Although green roofs have increased in popularity recently, they are not a new invention and can date back to at least 500 B.C with the Hanging Gardens of Babylon (Dinsdale *et al*., 2006). As one of the seven wonders of the ancient world, the gardens covered over 2,000m^2 on top of a watertight foundation. Scientists believe they were for aesthetic purposes as they consisted of trees, blooming bushes and climbing plants (Dinsdale *et al*., 2006). The modern green roofs originated from Iceland where sod roofs and walls are very good at insulating small houses in extreme weather (Peck and Kuhn, 2002). In the past 100 years the popularity of green roofs has increased, starting in Germany and spreading worldwide. Today they are mostly used for environmental and economical benefits in cities (Peck and Kuhn, 2002).

With the current global environmental crisis, implementing sustainable and environmentally friendly resources is becoming more popular. Green roofs are one way to reduce negative impacts while also having additional positive effects on the environment. They have been known to reduce heat island effects define and save energy by insulating buildings, as well as improving the local air quality and the management of storm water (Dinsdale *et al*., 2006). In addition, they are aesthetically pleasing and can provide a nice environment for public use, while promoting local, native biodiversity. The addition of a green roof on the Life Sciences Centre (LSC) would make an older building more energy efficient and more appealing to today's changing environmental views. Investigating the feasibility of a green roof on campus will not only promote the campus Green Movement, but also hopefully provide information about adding a green roof to older buildings that were not originally designed for one.

1.5 Project Purpose

The purpose of this investigation is to assess the feasibility of implementing a green roof on the Life Sciences Centre (LSC) of Dalhousie University, by gathering information about other green roofs on universities and older buildings. This will be accomplished by conducting a feasibility analysis in the course of a cost analysis and a benefit analysis. The cost analysis will investigate the costs of implementing the two different types of green roofs; intensive and extensive, and the benefit analysis will investigate the social, economic and environmental benefits of each roof. Based on these results it will be decided which type of green roof will be more effective on the LSC.

1.6 Project Importance

There are numerous barriers that prevent the development of green roofs because their implementation in North America is still relatively new. The biggest deterrent is the high up-front costs associated with the implementation of a green roof. Despite this, however, there are numerous benefits that result over the long term after implementation that should be considered. A long-term feasibility analysis of green roof implementation would consider these benefits. This project is economically beneficial but is also environmentally and socially important as well. Not only does the Dalhousie campus lack native biodiversity and proper green spaces around the campus but it is also an older building and extremely energy inefficient. The LSC has a large number of flat roofs on top of the various wings that could be used to hold a green roof therefore making the building more efficient.

This investigation is important because the university is currently looking for funds to increase the energy efficiency of the LSC building and fix the roof. A green roof would be appropriate to achieve both of these goals. Also, students, faculty members and the public often complain about the LSC's cold looking exterior. A green roof would provide the public, students and faculty with positive aesthetics, along with a large range of environmental benefits. The Halifax Regional Municipality is currently looking at green roofs with the overall goal of decreasing the municipality's ecological footprint (Ranalli *et al*.). More research is needed in the area for green roof promotion to obtain knowledge on what vegetation is suitable for this climate. A green roof on the LSC would aid in contributing to this knowledge for Halifax and other places of similar climate.

1.7 The Life Science Centre: A Brief Overview

The Life Sciences Centre (LSC) was built in 1971. Ray Affleck of the firm Affleck, Desbarats in Montreal was the main designer of the building. Since being built, the LSC had major renovations done in 1991 and none have been performed since (Harris & Osicki, Date Unavailable). The LSC is 405,000 square feet and is home to the biology, oceanography, psychology and earth sciences departments. Up to 34% of the entire building is devoted to research, while the rest are used for classes or administration (Pelham, 2009). The building has a concrete exterior and has been described by various people as having a maze-like interior thus making it hard to navigate around the building (Harris & Osicki).

In March of 2009 Tony Clement, the Minster of Industry, announced the Knowledge Infrastructure Program which compromises a 2 billion dollar federal fund supporting the enhancement of post-secondary institutions across Canada. Marty Leonard, the acting Dean of Science expressed concerns about losing potential graduate students and other opportunities because they expressed their distaste for the LSC and could not imagine spending years in a building like it (Pelham, 2009).

Dalhousie is requesting 33 million dollars to commence renovations and other projects on the LSC (Pelham, 2009). If the Nova Scotia government agrees to match the funding, this request for renovations will be sent to the federal government. If the plans are approved, the renovations would include switching to energy efficient lighting, improving building ventilation and fixing the roof (Pelham, 2009). The proposed project meets the eligibility requirements for this fund. If Dalhousie is approved, renovations could start as early as July 2009 (Pelham, 2009). A green roof could be an integral part of these proposed renovations and could improve the aesthetics of the LSC.

1.8 Environment, Sustainability and Society Program

The Dalhousie College of Sustainability is introducing a new program in September of 2009 called the Environment, Sustainability and Society program. It is designed to allow students to not only focus on a discipline of their choice but to provide them with a deep understanding of sustainability challenges (Dalhousie Environment, Sustainability & Society, 2009). A green roof on the Dalhousie Campus, particularly the LSC, would provide students with an insight into the benefits of a green roofing system. It would also provide the campus and the city of Halifax with a creative way of expanding the area for aesthetics while increasing urban agricultural and the natural biodiversity.

1.9 Halifax Regional Municipality

The Halifax Regional Municipality (HRM) produced a Community Energy Plan (CEP) in the fall of 2007 to reduce energy costs and benefit the environment, with an overall goal of promoting a healthy, sustainable and vibrant community (Ranalli). To achieve this goal, the plan included numerous ideas. Of the ones listed, two pertained to the built environment (Halifax Regional Municipality, 2009):

- The improvement of the energy efficiency of buildings
- Increased infrastructure efficiency

The HRM recognizes that visible technologies like green roofs could improve the energy efficiency of local buildings (Halifax Regional Municipality, 2009) The HRM plans to encourage green roof construction and is considering promoting sustainable construction and LEED requirements for new buildings. Green roofs will help meet those standards. This long term environmental plan will generate more awareness of environmental problems and resolutions at differing sectors (Canadian Mortgage and Housing Corporation, 2006). Dr. Jeremy Lundholm of Saint Mary's University has been researching green roofs in the Halifax area. He has suggested that reducing the growth medium and using native plants can reduce the overall weight and cost of a green roof. He hopes that reducing the waste and cost will provide greater prospects for both new and existing buildings to include green roofs in their design or renovations (Canadian Mortgage and Housing Corporation, 2006).

The effectiveness of the implementation of green roofs cannot be measured at this time because the green roof movement is just beginning in the Halifax area. Halifax is currently at what the Canadian Mortgage and Housing Corporation calls Phase 2 of developing green roof policies and plans (***Table 2***). Currently the HRM is seeking creative methods to promote green roofs, which may involve meetings with the community and players involved to gain support for green roofs. Strengths and weaknesses are outlined and funding sources will also be explored during this stage. The municipality is on its way to Phase 3; involving the development of a plan of action based on what has been discovered in the previous phase (Canadian Mortgage and Housing Corporation, 2006).

Table 2- The six phases in developing green roof policies and programs. Adapted from Canadian Mortgage and Housing Corporation, 2006.

Phase	Description
1	Introduction/Awareness
2	Community Engagement
3	Action Plan Development
4	Technical Research
5	Program and Policy Development
6	Continuous Improvement (focusing on phases 4 & 5)

1.10 Adapting to Halifax's Climate

Halifax weather has extreme patterns that can vary by over 30°C within a 24 hour period. The coast is also occasionally subject to hurricane-like winds. The overall climate is moderate with a great deal of fog and cloud cover that disperses direct sunlight. Jeremy Lundholm and his colleagues at Saint Mary's University have been locating and monitoring green roofs in Halifax. They found 41 green roofs in Halifax of which 65% were intensive. These studies performed by Lundholm and his colleagues will be used to plan green roof trials in order to expand cost-benefit models for green roofs in the Halifax climate. Lundholm suggests that planting several plant species on a green roof may promote best performance in the face of environmental fluctuations. Multiple plant species allows for better water capture and would therefore allow for better storm water retention. When roof surface temperatures of the green roofs were measured, they were 3.5°C cooler than conventional roofs. This is beneficial in reducing the urban heat island effect.

1.11 Previous Green Roof Studies at Dalhousie

In 2006, a feasibility analysis was conducted on the Kenneth C. Rowe Building of Dalhousie. The analysis involved a student survey that included various questions about the opinions of green roofs on campus. Over 80% of the students interviewed were in support of installing a green roof on any building on campus. When the students were asked their preference on which campus building would be the best to install a green roof on, the LSC won with a popular vote of almost 30% (Caron *et al.,* 2006). The students who were interviewed said that the most important aspect of a green roof on campus would be student access. For this reason, an intensive roof was chosen for our project. The two most important benefits influencing the student decisions for a green roofing system were environmental and aesthetic factors (Caron et al., 2006).

2.0 Methods

The overall methods employed for the project relied on triangulation; using a variety of resources and approaches to verify results (Palys and Atchison, 2008). Data collection was conducted through document analysis and interviews. Interviews were conducted through a snowballing effect, starting with Dr. Tarah Wright. The feasibility analysis will proceed by means of a cost analysis and a benefit analysis for each roof type, verifying building and site-specific data with economic factors from the feasibility analysis.

2.1 Data Collection

Document Analysis: Various articles and websites were analyzed and incorporated into our project (see sources). An a priori analysis was conducted to determine the most accurate costs and benefits of the installation of a green roof. Both peer-reviewed articles and websites presented by government organizations and private companies were considered in the search.

Searches included:

- Green roof benefits (economic, social and environmental)
- Green roof costs
- Green roof suppliers/manufacturers websites

- Green roofs on older buildings
- Structural capacity required for a green roof
- Green roofs in Halifax/Nova Scotia/Canada/etc
- Feasibility/Cost-Benefit Analysis of Green roofs

Search Engines included:

- Google
- Dalhousie University Libraries
- Various Databases (Web of Science, Science Direct, etc)

To determine the feasibility of implementing a green roof on campus, Dalhousie information and archives were consulted. The research was undertaken to examine and consider the specific conditions of the Life Sciences Centre.

Resources included:

- *The Buildings of Dalhousie University*; Dalhousie University Archives and Special Collections.
- Blue Print

Interviews:

Various professionals were contacted via telephone, email or in person to determine green roof information and information specific to the LSC. Various questions were asked to those individuals we contacted, as discussed further. Building information was to be obtained from Dalhousie University Facilities Management. Information on green roof systems and plants was found through non-probabilistic snowball sampling techniques. The flow chart below, ***Figure 2*** shows the snowball sampling technique

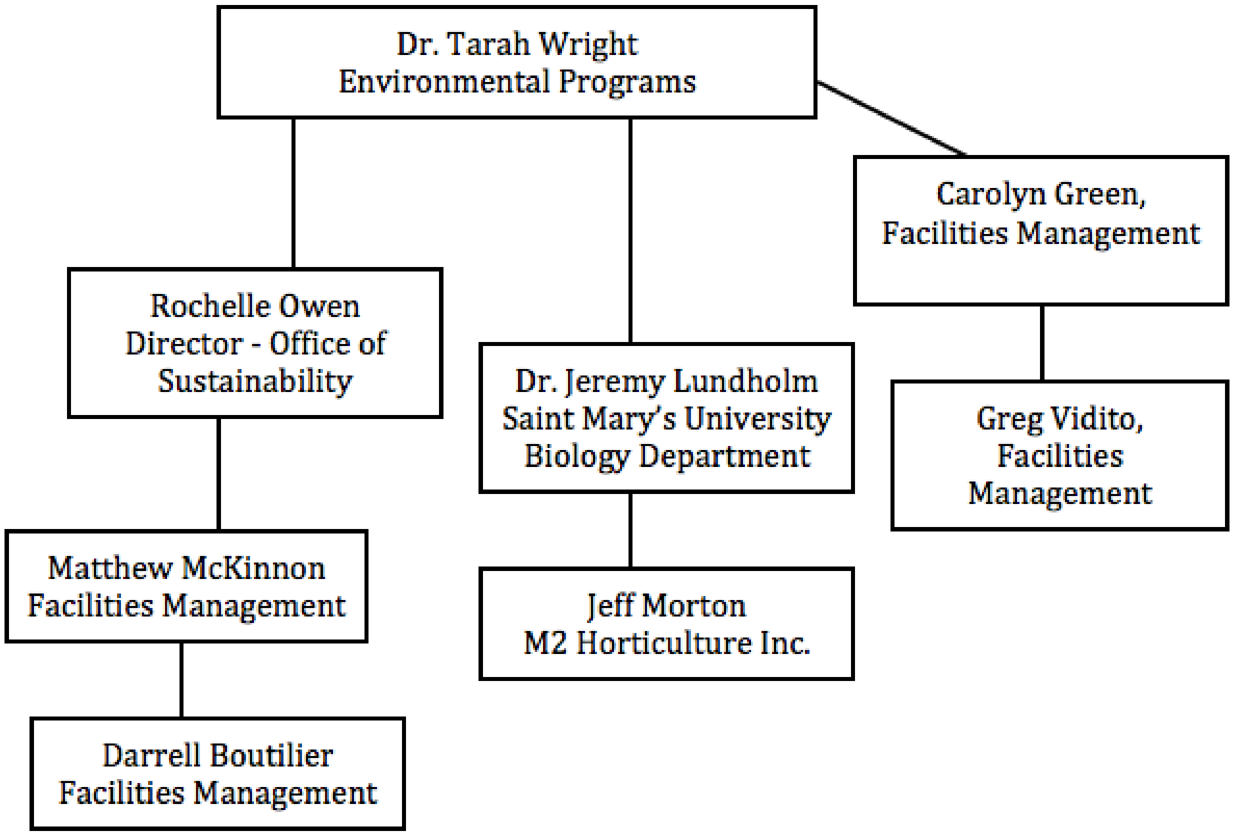

Figure 2 – Flow chart depicting the evolution of interviews conducted using the snowball sampling technique.

The majority of interview questions were set to find general building information about the LSC and green roofs. They remained open ended to ensure that any important factors regarding the structure or roof type were not left out. Leaving some of the questions open ended allowed us to obtain opinions from the various architects and engineers working for Dalhousie to see if it is possible and feasible, in their opinion for a green roof to be installed on the LSC. This was an important step because we are not trained in engineering or architecture and do not have any hands-on experience with green roof installation. Therefore we attempted to obtain as much advice and information on the LSC building structure as possible from professionals familiar with the subject.

2.2 Feasibility Analysis

An economic analysis was conducted to outline the major economic costs and benefits of green roof installation on the LSC. Three green roof types were chosen to gather a range of the costs and benefits associated with a green roof; inaccessible and extensive; accessible and intensive, as well as modular.

An environmental cost and benefit analysis was conducted to gain thorough knowledge through qualitative document analysis. Although some of the environmental costs and benefits have remained the same since the 2006 project, the specific costs and benefits for the proposed site on the LSC were calculated based on the size of the site. Therefore an economic cost and benefit analysis would be the most effective to use in this project as part of a greening the campus initiative. Also, it is likely that the cost of green roof equipment has changed in the past three years due to increased recognition and popularity of the product and its proposed environmental benefits.

The following costs and benefits will be considered and later discussed in the results section:

Economic Costs:

- Design & Specifications
- Project Administration & Site Review
- Physical Green Roof System
- Re-roofing with root-repelling membrane
- Plants
- Irrigation System

- Installation
- Guardrail
- Maintenance

Economic Benefits:

- Heating/Cooling cost savings
- Further Research opportunities, benefits and funding
- Increased roof protection and greater life span
- Sound Insulation

The following environmental costs and benefits will be considered:

Environmental Costs:

- Water Use
- Generation of Waste
- Use of Fertilizers and Pesticides
- Transportation of Materials

Environmental Benefits:

- Storm water retention
- Preservation of Biodiversity and habitat
- Reduction in energy consumption
- Air quality
- Urban heat island effect

Social Benefits:

- Aesthetic Value
- Research Potential
- Food production

Social Costs:

Social costs are not applicable

3.0 Results

3.1 Site Findings

The location of the proposed green roof was chosen due to its high visibility across campus, especially from the LSC windows and entryways and from the Henry Hicks Academic Building. Also the proposed location is already accessible by means of a private stairway and would not require renovation.

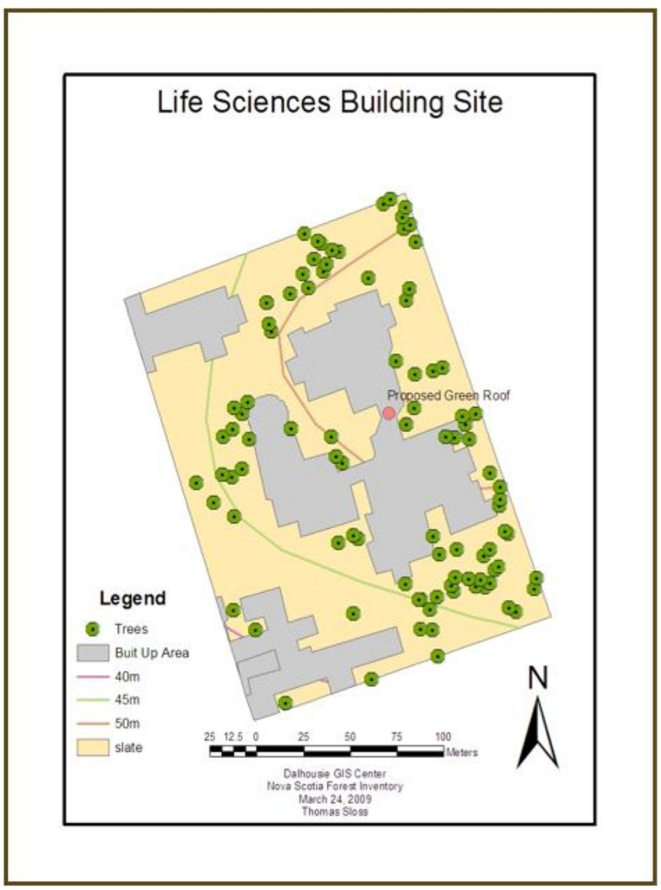

Figure 3 - Image created in Arc GIS of Dalhousie University campus showing elevation, Dalhousie infrastructure, trees and proposed location of the green roof on the LSC.

The structural load determines the type of green roof the building can support because an intensive design requires more of a weight load, compared to an extensive design, as they are more complex as previously mentioned. A structural engineer or architect can determine which type of system is best suited to a facility based on an analysis of the building's structural capacity. The structural capacity of the LSC could not be determined, due to a lack of available information as well as a lack of funding. For these reasons, it was assumed that the section chosen on the LSC could hold a green roof that is of an extensive or intensive roof type.

The LSC blue prints were retrieved from Facilities Management Greg Vidito who is responsible for all of the data and plans for Dalhousie's infrastructure. The scale was given as 1/8" = 1'. This allowed us to determine the plot size by measuring with a ruler of a known distance on the blue prints. Our desired plot was found to be 146 m^2 (1,585.79 ft^2) (See ***Figure 4***).

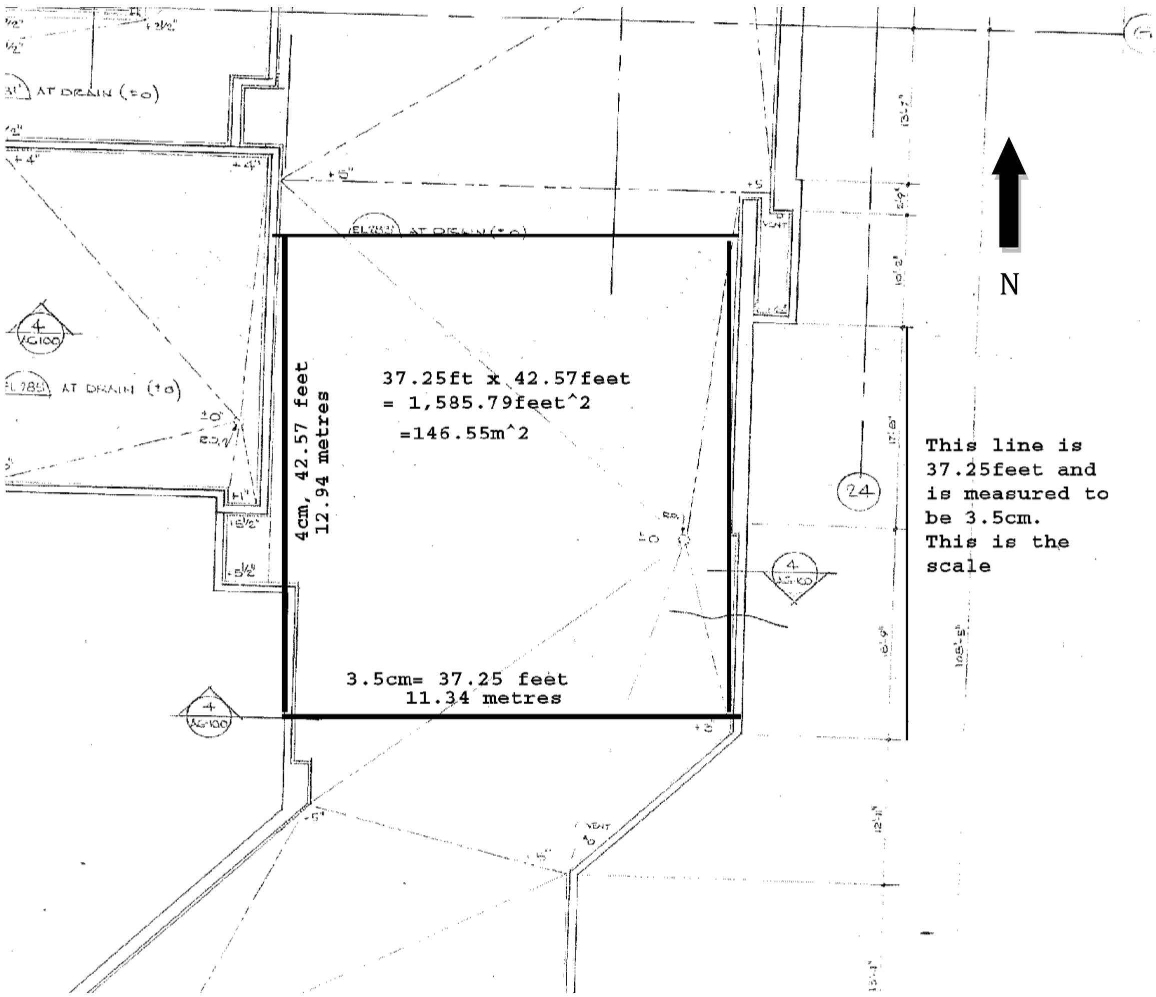

Figure 4 -Roof plot and scale determined from the blue prints provided by Facilities Management (Greg Vidito).

Figure 5 shows the proposed plot on the LSC roof. The image was taking by a digital camera on the 4th Floor of the Psychology wing at the access door to the roof.

Figure 5 - Desired green roof plot on the LSC (February, 2009 taken by Kayla Blok).

<u>Extensive green roofs:</u>

Soil depth of 1 to 6 inches and a weight load 15 – 50lbs/foot^2 (Great Lakes Water Institute)

<u>Intensive green roofs:</u>

Soil depth is typically 6 to >24 inches and a weight load is 80-150lbs/foot^2 (Great Lakes Water Institute)

Based on the size of our plot, calculations were made between the ranges in weight requirements found in the literature:

(15lb/ foot^2) × (1,585.79foot^2)

=23,787 lbs

It is assumed that our proposed green roof section on the LSC can hold the following weights for the two roof types:

Extensive Green Roof: 23,787lbs-79,290lbs

Intensive Green Roof: 126,863lbs-237,869lbs

3.2 Environmental Benefits

The potential environmental benefits of green roofs that will be considered in this feasibility analysis are as follows:

a) Reduction in energy consumption

Green roofs have insulating properties that reduce energy consumption for heating and cooling. An intensive green roof provides the most insulation compared to an extensive green roof due to the increased amount of vegetation. A modular roof (a roof top with planters) has reduced insulating potential because more square footage is exposed between planters, allowing heat to escape during the winter, and enter during the summer. Lastly, a conventional roof does not provide any additional insulation other than what is installed during construction.

b) Storm-water retention and water filtration

Green roofs are capable of storm water retention; this is made possible by the capture and evaporation of the water by the vegetation. The rate of retention is determined by the thickness of the growing medium, the drainage layer, and the drainage spacing (CMHC 2002). A heavily vegetated green roof with a 20-40 cm

(8-16") thick growing medium can hold between 10-15 cm (4-6") of water (CMHC 2002). Storm water retention results in less runoff and therefore reduces the pollution of local water sources because water is absorbed by flora. Any water that does runoff is slowed, thus decreasing the stress on sewer systems during peak flow periods. Furthermore, water that does run off is naturally filtered and has its temperature moderated by the vegetation. Green roofs can retain 25-40% of the precipitation that falls on them during the winter and 70-90% of it during the summer, and a grass roof with a 4-20 cm layer of growing medium can hold 10-15 cm of water (GRHC, 2005).

According to studies of green roof plots in Chicago, a green roof can reduce storm water runoff by up to 50%. This was quantified in one study of reductions of up to 0.3611gallons/foot^2:

(0.3611gallons) $\times$ (3.78541178 litres/1gallon)

=1.367litres/foot^2 $\times$ (1,585.79 foot^2)

=2,167.77 litres of water retention from the proposed green roof plot (Prairie Ecosystems, 2008).

A series of Chicago test plots found that green roofs halved the amount of storm water runoff (12.4 gallons vs. 25.4 gallons for a 36 sq. ft. plot). Even when the green roof is saturated, the rate of runoff is much slower and there is a several hour delay before runoff exits the roof. This lightens the immediate load on sewer systems. Furthermore, the green roof acts as a filtration system for the water, reducing incident pollutants (Prairie Ecosystems 2008).

An intensive green roof can retain the most storm water because larger plants uptake large quantities of water from the soil. Due to less plant diversity and smaller plants, an extensive green roof retains slightly less water. Modular green roofs will retain less water than an extensive green roof due to planters, therefore conventional roofs will retain no water, as it become run off onto impermeable surfaces.

c) Preservation of biodiversity/habitat

Intensive green roofs can support the highest amount of species diversity whereas extensive has low species diversity, low-growing and low maintenance plant varieties. Modular green roofs cannot accommodate a wide variety of species because they are limited to the dimensions and characteristics of the planters. An important aspect of environmental benefits is to adhere to facilitating the growth of native plant species. Through our research we found species that have succeeded on green roofs in the local community, these include shrubs, grasses, and mosses. The following list shows species, which have high survival rates on green roofs specific to Halifax's climate:

(Recommended by Jeremy Lundholm)
Hairy Goldenrod (*Solidago bicolor*)
Three-toothed Cinquefoi (*Potentilla tridentata*)
Crowberry (*Empetrum nigrum*)
Poverty Oat Grass (*Danthonia spicata*)
Wavy Hair-grass (*Deschampsia flexuosa*)
Golden Root (*Rhodiola rosea*)
Harebell (*Campanula rotundifolia*)
Seaside Plantain (*Plantago maritima*)

In the spring and summer of 2009, he will test the following species:

Canadian Blueberry (*Vaccinium angustifolia*)
Rhodora (*Rhododendron canadense*)
Media Sandspurry (*Spergularia maritima*)
Creeping Juniper (*Juniperus horizontalis*)
Bearberry (*Arctostaphylos uva-ursi*)
Broom Crowberry (*Corema conradii*)

Based on Lundholm's recommendations, Richard LaPaix, a Dalhousie Biology Graduate Student recommended native species that could do well on the proposed green roof in the Halifax climate:

Medium height ericaceous shrubs:
Sweet Low-bush Blueberry (*Vaccinium angustifolium*)
Sheep-laurel (*Kalmia angustifolia*)

Tall shrubs:
Serviceberry (*Amelanchier species*)
Red Baneberry (*Actaea rubra*)
Red Elderberry (*Sambucus racemosa*)

Mosses:
Common Hair-cap Moss (*Polytrichum commune*)
Big Red Stem Moss (*Pleurozium schreberi*)
Stair-step Moss (*Hylocomium splendens*)

In addition, rooftop habitats can play a role in habitat fragmentation prevention in an urban area by connecting isolated habitats. Green spaces also provide essential habitats for insects and other organisms, which depend on these environments. Finally, green roofs can provide new opportunities for urban agriculture. There are many benefits to growing and distributing food locally including; support of the local economy in growing, processing and distributing, increased access to food by everyone, decreased travel costs, and control of soil, fertilizer and pesticides (GHCH 2005). Based on an implemented green roof at the Fairmont Hotel in Vancouver, British Columbia which grows fresh herbs and vegetables on a green roof that is 4,000 square feet, their food savings equate to $0.10/square foot of food production (City of Toronto 2004). For the proposed green roof on the LSC, potential food production savings equal:

$\$0.10/\text{foot}^2 \times (1{,}585.79\ \text{foot}^2)$

=$158.58

d) Air Quality

A green roof will not only absorb heat, decreasing the tendency towards thermal air movement, but will also filter the air moving across it. 1 m^2 (10.76 ft^2) of grass roof can remove up to 2 kg (4.4 lbs) of airborne particulates from the air every year, depending on foliage type (GRHC 2005). Plants convert carbon dioxide, water and sunlight/energy into oxygen and glucose through the process of photosynthesis. This biological process supplies animals and humans with oxygen and food (GRHC 2005). More specifically, 1.5 m^2 (16.15 ft^2) of uncut grass produces enough oxygen per year to supply one human with their yearly oxygen intake requirement (GRHC 2005).

The following are calculations based on the proposed green roof for the LSC:

If the proposed LSC plot contained grass on the entire plot it would remove:

(0.2kg-2kg/year) × (146.55m^2)

=**29.31-293.1kg airborne particulates removed each year**

Number of humans oxygen provided for by un mowed grass :

(146.55m^2) × (1 human with yearly oxygen intake/1.5m^2)

=97.7

=98 humans with a yearly intake requirement of oxygen.

The City of Toronto, 2004 reported that 0.27224kg of CO_2 is reduced for every kilowatt-hour saved as a result of green roof implementation.

If used, the pre-determined energy reductions of 477.73kWh/year**:**

(477.73kWh) × (0.27224kg CO_2 reduced/kWh)

= **130kg of CO_2 that could be prevented from going into the atmosphere each year.**

e) Moderation of urban heat island effect

The urban heat island effect is when a metropolitan area is significantly warmer than its surrounding rural areas. The temperature difference usually is larger at night than during the day and larger in winter than in summer, and is most apparent when winds are weak. The main cause of the urban heat island is modification of the land surface by urban development that expands hard reflective surfaces, such as roofs, which absorb solar radiation and re-radiate it as heat. Waste heat generated by energy usage is a secondary contributor. As population centers grow they tend to modify a greater and greater area of land and have a corresponding increase in average temperature (GHCH 2005). One square metre (10.76 ft^2) of foliage can evaporate over 0.5 litres of water on a hot day and on an annual basis the same area can evaporate up to 700 litres of water (GHCH, 2005).

$(700L/year) \times (146.55m^2)$

=102,585 litres have the potential to be evaporated from the proposed plot per year

An intensive roof would be the most effective at moderating the urban heat island effect, extensive would moderately reduce re-radiation, and modular and conventional would follow respectively. An intensive green roof is more effective because of the higher variety of plant species that are on the roof which increases surface area for heat absorption through this vegetation. The larger plants would have a greater ability for transpiration therefore allowing for a greater cooling effect.

Based on research done by Ranalli *et al.*, the temperatures of 41 green roofs were taken from across the city of Halifax. On average, the green roofs were 3°C cooler than conventional roofs in the city.

3.3 Environmental Costs

a) Water Use

Intensive green roofs would likely require increased input of water compared to extensive green roofs. Vegetables grown on the green roof would also require more water to ensure adequate growth for food production. A rooftop patio with planters would require a limited amount of water use because of the lack of vegetation throughout the space. However, if the green roof included native Nova Scotia plant species little to no water would be required because these species of plants are suited to survive in the regular Nova Scotia climate.

b) Generation of Waste

Green roofs require additional layers for insulation, water proofing membrane, a drainage layer and other levels to prevent water, and soil and plant roots from damaging the roof. Many of these materials are made using various plastics and other materials that would generate wastes and take energy and material to make.

c) Use of Fertilizers and Pesticides

Current legislation in the Halifax Regional Municipality does not permit pesticide or fertilizer use, therefore this type of maintenance is not considered in our scope of research.

d) Transportation of Materials

It is important when designing a green roof that one takes into account the potential associated transportation costs of materials. Because green roofs have only recently increased in popularity, they are not common in many areas; transportation of green roof materials may require transportation of between different regions that may be far away. The use of locally produced materials such as composted soil, nursery-grown plants and wild seedlings would decrease the environmental impact of transportation.

3.4 Economic Benefits

a) Energy Reduction

As mentioned previously in *Environmental Benefits (3.2)* green roofs provide energy reductions that can result in economic savings for the university. Darrell Boutilier of Facilities Management indicated through email that Dalhousie University burns about 14,000,000 litres of bunker C each year to power and heat the Studley, Carleton, and Sexton campuses. The university uses steam produced from the burning of this oil to power all buildings. It also converts the steam to electricity. The LSC uses 1,383,000 litres/year of Bunker C residual fuel oil, which accounts for fewer than 10% of the entire university's supply. The university currently pays $0.3186/litre for this fuel oil. It costs $440,623.80 per year to heat and power the LSC and over $4,460,400 to power and heat the Dalhousie Campuses (Studley, Sexton and Carleton). To find the equivalent in kilowatt-hours (kWh) for the amount of Bunker C fuel oil burned the group went to the literature to find the conversions. The literature provided a range of values in which an average of the found values in kWh were determined (see ***Table 3***).

Table 3 - An average of the number of kilowatt-hours (kWh) that is equivalent to 1 litre of Bunker C residual fuel oil that is burned.

Heritage Gas, 2006	17.362kWh
CH Non-Food Import-Export Corporation	4.05kWh
Neill & Gunter, 2007	11.6kWh
Average	**11.004kWh**

Using this average of 11.004kWh per litre of Bunker C fuel oil we determined that the LSC uses an estimated 15,268,320kWh per year to heat and power the building:

(11.004kWh/litre of bunker C)×(1,383,000 litres/year)= **15,268,320kWh/year**

The University of Toronto and Queens University found that Green roofs saved the following amount of kilowatt-hours per square metre of green roof per year.

Table 4 - The average of the number of kilo-watt hours (kWh) saved per year for every square metre of green roof.

Sources	$kWh/m^2/year$
Queen's University, 2006	2.37
City of Toronto, 2004	4.15
Average	**3.26**

Using this average, the kWh per year saved from the proposed green roof can be determined:

$(3.26kWh/m^2/year) \times (146.55m^2)$ = **477.73kWh/year saved**

= (477.72kWh/year) × (1 litre bunker c fuel oil/11.004kWh)
= 43.416 litres of bunker c fuel oil × ($0.3186/litre)
=$13.83/year saved

(# of years/$13.83) × ($37,911.00)
=<u>2,741.2 years to break even</u> upon installation of the lowest in price roof type (low in-accessible extensive) if only energy costs are considered.

b) Increased Research Benefits and Funding

Green roofs provide increased research potential for faculty, students, and other academic professionals. Dalhousie University has the potential to receive increased research grants to support projects in fields such as botany, urban ecology, and green roof design among others.

c) Increased roof protection and greater life span

The Canadian Green Building Council (CGBC) suggests that the membrane used in the design of green roofs improve the overall lifespan of the roof more than twice that of conventional roofs. Green roofs protect underlying membranes from extreme temperature fluctuations, the negative impact of ultra violet radiation, and accidental damage from pedestrian traffic (CMHC 2002). This results in decreased maintenance and savings in replacement costs, thus diverting waste from landfills (CGBC 2004). The lifetime of a conventional roof is 20 years and the life time of a green roof is 40 years (CMHC 2002).

d) Sound Insulation

Sounds produced on the outside of the building such as machinery, traffic, and airplanes can be absorbed (reflected or deflected) by the soil and vegetation on the green roof. The substrate tends to block lower sound frequencies and the plants block higher frequencies (CMHC 2002). According to a report done by CMHC in 2002, is it estimated that 3.33 decibels of sound can be absorbed by one centimeter of substrate. Therefore an extensive green roof with a 12 cm substrate layer will reduce sound by 40 decibels, and an intensive roof with a 20 cm substrate layer will reduce sound by 46-50 decibels (CMHC, 2005).

3.5 Economic Costs

a) Accessible Intensive Green Roof

(Costs assume an existing building with sufficient loading capacity; roof hatch and ladder access only. The larger the green roof, the cheaper the cost on a square meter basis.)

Table 5- Accessible Intensive Green Roof Costs

Component	**Cost**	**Notes & Variables**
Design & Specifications	5-10% of total roofing project cost.	The number and type of consultants required depends on the size and Complexity of the project.
Project Administration & Site Review	2.5% - 5% of total roofing project cost.	The number and type of consultants required depends on the size and Complexity of the project.
Re-roofing with root-repelling membrane	\$100.00 - \$160.00 per m^2. (\$10.00 - \$15.00 per f^2.)	Cost factors include type of existing roofing to be removed, type of new roofing system to be installed, ease of roof access, and nature of flashing required.
Green Roof System (curbing, drainage layer, filter cloth, growing medium, decking and walkways)	\$160.00 - \$320.00 per m^2. (\$15.00 - \$30.00 per f^2.)	Cost factors include type and depth of growing medium, type and height of curbing, type of decking, and size of project. (cost does not include freestanding planter boxes.)
Plants	\$54.00 - \$2,150.00 per m^2. (\$5.00 - \$200.00 per f^2.)	Cost is completely dependent on the type and size of plant chosen, since virtually any type of plant suitable to the local climate can be accommodated (one tree may cost between \$200.00 - \$500.00.
Irrigation System	\$21.00 - \$43.00 per m^2. (\$2.00 - \$4.00 per f^2.)	Cost factors include type of system used and size of project.
Guardrail/Fencing	\$65.00 - \$130.00 per linear m. (\$20.00 - \$40.00 per lin. ft.)	Cost factors include type of fencing, attachment to roof, and size of project / length required.
Installation / Labor	\$85.00 - \$195.00 per m^2. (\$8.00 - \$18.00 per f^2.)	Cost factors include equipment rental to move materials to and on roof, size of project, complexity of design, and planting techniques used.
Maintenance	\$13.50 - \$21.50 per m^2 (\$1.25 - \$2.00 per f^2annually.	Costs factors include size of project, irrigation system, and size and type of plants used.

b) Inaccessible Extensive

(Costs assume an existing building with sufficient loading capacity; roof hatch and ladder access only. The larger the green roof, the cheaper the cost on a square meter basis.)

Table 6- Inaccessible Extensive Green Roof Costs

Component	Cost	Notes & Variables
Design & Specifications	5% - 10% of total roofing project cost	The number and type of consultants required depends on the size and complexity of the project
Project Administration & Site Review	2.5% - 5% of total roofing project cost.	The number and type of consultants required depends on the size and complexity of the project
Re-roofing with root-repelling membrane	\$100.00 - \$160.00 per m^2. (\$10.00 - \$15.00 per f^2.)	Cost factors include type and depth of growing medium, type of curbing, and size of project.
Green Roof System (curbing, drainage layer, filter cloth, and growing medium).	\$55.00 - \$110.00 per m^2. (\$5.00 - \$10.00 per f^2.)	Cost factors include type and depth of growing medium, type of curbing, and size of project.
Plants	\$11.00 - \$32.00 per m^2. (\$1.00 - \$3.00 per sf.)	Cost factors include time of year, type of plant, and size of plant- seed, plug, or pot.
Installation / Labour	\$32.00 - \$86.00 per m^2 (\$3.00 - \$8.00 per sf.)	Cost factors include equipment rental to move materials to and on the roof (rental of a crane could cost as much as \$4,000.00 per day), size of project, complexity of design, and planting techniques used.
Maintenance	\$13.00 - \$21.00 per m^2 (\$1.25 - \$2.00 per f^2) for the first 2 years only.	Costs factors include size of project, timing of installation, irrigation system, and size and type of plants used.
Irrigation System	\$21.00 - \$43.00 per m^2. (\$2.00 - \$4.00 per f^2).	*Optional, since the roof could be watered by hand. Cost factors include type of system used.

For our project we chose the accessible intensive roof type. The following table compares the total costs for each category of the two different roof types, and the dollar amount per square footage for the proposed plot of 1585 f^2.

Table 7- Roof Cost Comparison (High and Low Range)

Component	In-accessible extensive		Accessible Intensive	
	Low ($)	High ($)	Low ($)	High ($)
Re-roofing with membrane	15,850.00	23,775.00	15,850.00	23,775.00
Green Roof System	7925.00	15,850.00	23775.00	47,550.00
Plants	1585.00	4755.00	7925.00	31,700.00
Irrigation System	3170.00	6340.00	3170.00	6340.00
Guardrail-Fencing	N/A	N/A	31,700.00	63,400.00
Installation/Labor	4755.00	12,680.00	12,680.00	63,400.00
Maintenance	1981.00	3170.00	1981.00	3170.00
Design & Spec	1763.00	6627.00	4854.00	20,447.00
Project Admin & Site Review	862.00	3314.00	2427.00	10,223.00
Total Cost	***37,911.00***	***76,211.00***	***104,362.00***	***235,135.00***
Cost/square foot	**23.91/sq ft**	**48.08/sq ft**	**65.85/sq ft**	**148.35/sq ft**

The alternative to both of these roof types is the modular design; according to Jeff Morton of M2 Horticulture in Truro, NS, this roof type has a standard rate of $15/sq ft. For the proposed site implementation of a modular roof would cost:

$15.00*(1,585.7857square feet) =$23,786.79

3.6 Social Benefits

a) Aesthetic Value

The implementation of a green roof on the Life Sciences Centre would significantly improve the appearance of the building. Green roofs provide vast aesthetic benefits to their surroundings (Peck & Kuhn, 2002). The Life Sciences Centre is commonly considered ugly or lifeless by the Dalhousie community (Dalnews, 2009). A green roof would create more green space while making existing buildings more visually pleasing. Based on 2006 and 2007 studies, the vast majority of both Dalhousie students and faculty support the implementation of a green roof on campus. (Caron et al, 2006) (Copley et al, 2007).

b) Research

The creation of an intensive accessible green roof on campus would assist in research. It would contribute to faculty and student research and allow for greater research possibilities on campus. Even in the Environmental Problem Solving 2 class this year, four different groups would have benefited from a green roof. A green roof could have assisted the two local food co-op groups, and the urban forestry group, and the carbon offset group. Also, a 2007 study showed that Dalhousie professors believe a green roof would enhance existing classes and possibly create new ones, increasing student enrollment (Copley et al, 2007),

c) Food Production

An intensive accessible green roof offers the potential for local food production. The green roof could be gardened to produce vegetables and herbs directly on campus. These would be grown organically due to the pesticide ban in Halifax. The garden could supply university venders and cafeterias with another source of local, organic produce. This would reduce the cost in food purchases and eliminate the environmental costs of transportation.

3.7 Social costs

Extensive research and case study referral has shown there are no noticeable social costs to green roof installation.

4.0 Discussion

4.1 Summary of Research Problem

The purpose of our project was to conduct a feasibility analysis of implementing a green roof on the LSC. This was done through a mixed methods approach of the snowball sampling technique, literature review and document analysis. Once the information had been gathered, the feasibility analysis was conducted by evaluating the costs and benefits for the economic, environmental and social costs impacts of both an inaccessible extensive and an accessible intensive green roof. Through this research it was hoped to be discovered if implementing the proposed green roof on the LSC is feasible and practical.

4.2 General Notes

A green roof would help with numerous green initiatives at Dalhousie University like providing an area for local and on campus food production, providing a way to obtain carbon offset credits as a result of carbon dioxide reduction, increasing the native biodiversity and improving the class labs on campus. Our green roof was also small compared to the size of the LSC and the size of green roofs that are normally installed. A larger sized green roof would likely allow for decreased start up costs because it would cut down on transportation costs and ordering more materials in bulk tends to be less expensive. The benefits would be greater because of the higher coverage. Based on the results of our document analysis that we found, there are increased benefits with increased green roof coverage.

This proposed green roof could be a good stepping stone for researching the barriers and benefits associated with retrofitting an older building with a green roof, however, unless there is compensation from other sources than the university, it may be difficult to implement a project like this due to the high initial costs. Looking at the environmental category alone, the environmental benefits of a green roof far exceed the environmental costs. We feel that Dalhousie has become committed to bettering the campus environment and a project like a green roof would help improve the environment and therefore satisfy the greening of the campus movement. It would also be one step towards making the LSC more energy efficient and more aesthetically pleasing because it is an old building with a concrete exterior. We feel that having it accessible would also provide more benefits because students, faculty and the public would be able to enjoy a unique area containing various plants and could also provide room for outside lectures and labs as well as research.

4.3 Feasibility Analysis

a) Environmental

From an environmental perspective, the benefits include; storm water retention, biodiversity and habitat preservation, reduced energy consumption, improved air quality, and moderation of the urban island effect outweigh the environmental costs; increased water use, waste generation, fertilizer use, and transportation of materials. Overall there are some environmental costs associated with the implementation of green roofs; however the environmental benefits give Dalhousie faculty and students as well as the local community an image of commitment toward environmental and sustainability issues.

b) ***Economic***

Overall, if this analysis were to be used for Dalhousie decision makers the most economically efficient green roof type is the modular design priced at $23,775.00. The second most efficient would be the extensive inaccessible at $76,211.00, followed by intensive accessible at $235,135.00. However, after considering the economic benefits (along with many other environmental and social benefits) our group suggests the implementation of an accessible intensive green roof which would support social, educational, and sustainable initiatives on the Dalhousie University campus.

c) ***Social***

There are many social benefits to implementing a green roof, most of which cannot be quantified. The biggest benefit would be to the aesthetic value of the LSC. At first glance, this seems like it would just make the Dalhousie campus look better, but there are also indirect benefits. In a recent DalNews article, Dr. Marty Leonard, the Dean of Sciences, said that the aesthetics of the LSC had cost the university potential graduate students and academics (DalNews, 2009). This suggests that a green roof on the building could increase enrollment and visiting academics.

There is also the potential for food production. Based on a case study in Vancouver, we calculated that our green roof could produce $158 of food annually. A green roof would create recreational space for the students, faculty, and greater university population. It would also enhance the overall educational experience at Dalhousie. A green roof adds beneficial values discussed in this paper which raise the property value of the building. Beyond this it would increase Dalhousie's reputation as a leading sustainable and green university. Finally, a green roof would contribute to the body of knowledge on green roofs in Halifax's climate and possibly influence municipal policy.

4.4 Conceptual Idea

With the knowledge that we have gained from studying the environmental, economic, and social benefits of green roof implementation on the LSC we wanted to provide decision makers with a conceptual idea of what the proposed green roof could look like. This simply provides an image to stimulate idea's about options for green roof design.

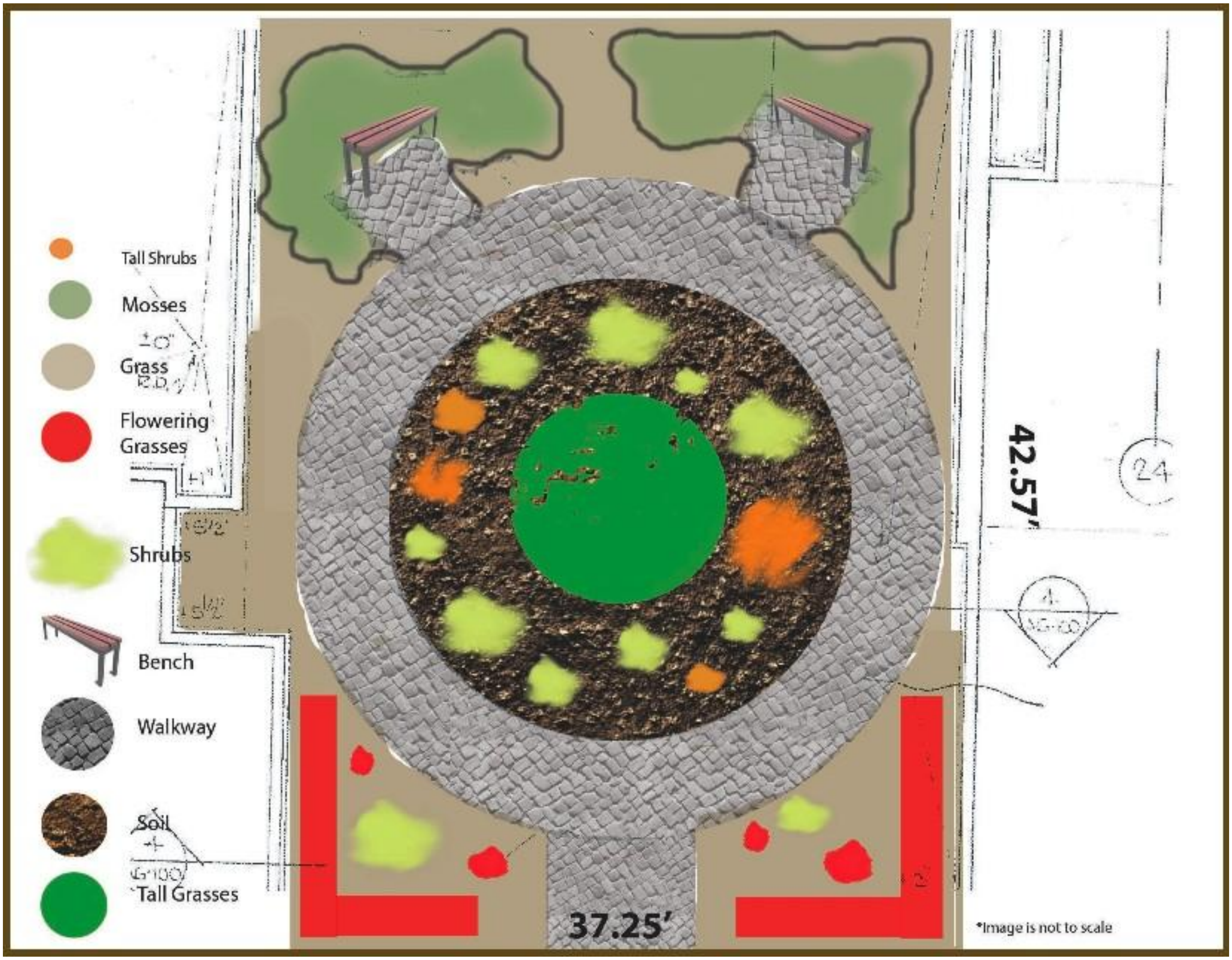

Figure 6 - Conceptual potential green roof design

4.5 Barriers

In undertaking this project we faced numerous barriers that limited our scope and accuracy of results. The biggest factor we ran into in our research was the limited expertise in major components of our scope of work such as the buildings weight capacity that had to be calculated by a structural project engineer. We had planned to do the campus wide survey, then rank the buildings accordingly and finally to conduct feasibility analysis on the most suited building. We attempted to triangulate the data with blue prints and building data from Facilities Management. They told us, however, that they could not provide us with that and to limit ourselves to just one building. After choosing the Life Sciences Centre, Facilities said that they could not give us an interpretation of the blue prints. This required us to determine a scale and plot ourselves. We could not interpret the total roof area or roof slope therefore we can not determine the percentage of roof coverage on the LSC. We also had hoped the building information and construction data would include the structural capacity of the roof. This was not the case, and without hiring a professional engineer we could not know exactly how much the roof can hold. We were also limited to a relatively small section of the LSC roof. Often green roofs are only installed on buildings with a roof area of at least $350m^2$. The LSC meets these requirements but we could not look at all areas of the roof. If however we had more time to research these limiting factors or if a group member was well educated in engineering or architecture we would be able to accurately assess the structural holding capacity of the LSC and calculate the percentage of roof coverage. Thus, limited time was also a barrier in this project.

5.0 Conclusions

Our feasibility analysis showed that there are numerous benefits associated with a proposed green roof on top of the LSC, however, the large upfront costs may deter this project's implementation and provide many barriers. The majority of the benefits that were considered could not be measured by monetary value or would be indirectly beneficial to the campus. The lack of information regarding the LSC's structure and roof capacity also provided barriers. We believe that our feasibility analysis is a step toward further looking at the implementation on a green roof on the LSC and other buildings that were not originally intended to have a green roof on them. We feel that an intensive accessible roof would be the most beneficial option for social and environmental factors even though it is of the highest cost. We hope that the results of this analysis will allow interested persons to consider the benefits retrofitted green roofs on older buildings that are not efficient in energy. We feel that this roof is a huge initiative in sustainability at Dalhousie University and the HRM and would aid in obtaining additional research of green roofs in the Halifax Climate.

5.1 Further Research

- Survey students on the Dalhousie Campus to see if they would be willing to pay an additional fee for installation of a green roof on the Dalhousie Campus.
- Research private and public funding opportunities for the implementation of a green roof or determine if there are tax credits can be awarded after implementation.
- Conduct a feasibility analysis on green roofs that are already implemented in Halifax to obtain measurement of benefits specific to Halifax climate. Use this to re-analyze the feasibility of this or another proposed green roof.
- Investigate the willingness of community groups and students who would be interested in participating in working on a green roof/planting to reduce start up costs.

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