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Greening the Rowe Roof: A Feasibility Analysis

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Table of Contents

Abstract:

In light of the growing academic interest in using full cost accounting in feasibility analyses to aid decision-makers, this report sets out to critically examine the feasibility of installing the proposed green roof on the Kenneth C. Rowe Management Building and the barriers that prevented its installation.

Our concurrent, mixed methods approach included literature reviews, case studies, interviews and surveys. We then applied the information gleaned to conduct a quantitative feasibility analysis which consisted of environmental/health, social/aesthetic and economic aspects that were weighted based on student survey results.

We found that the main barriers to the installation of the green roof were economic. The green roof was not installed since the only option considered – intensive accessible with planters – was the most expensive one, and economic short-run concerns outweighed social and environmental concerns due to overall budget cuts.

Yet, a holistic appraisal of the environmental, social and economic feasibility indicates that it is more feasible in the long-run to install an intensive accessible green roof without planters than to maintain a conventional roof, and that the possibility of having a green roof on campus gathered an overwhelmingly positive response from students. We therefore conclude our project with site-specific recommendations on how to increase the long-run feasibility of a green roof on the Rowe building.

Introduction:

Dalhousie University recently constructed the Kenneth C. Rowe Management Building (hereinafter referred to as the Rowe Building) with a "sustainable, environmentally responsible design" that includes many environmentally sound features, one of which is the potential for the development of a green roof (Dalhousie University, 2006). Despite the adoption of many of these environmentally sustainable and sensitive measures, mentions of a green roof remain only in the blueprints, and from below there is no sign of greenery on the bare roof of the new building. Given the university's apparent interest in making the Rowe Building a model of sound environmental design, questions have been raised around the omission of the green roof. This report is a response to the absence of a green roof on the Rowe Building despite the fact that it was designed and constructed with the capacity to support one.

Research Problem

The research included in this report addresses the following: the institutional barriers that prevented the development of a green roof on the Rowe Building; whether or not the current use of the roof is efficient; and whether or not it would be environmentally, socially, and economically beneficial to install a green roof on the building in the future.

Investigation into this subject is important and timely due to the original incorporation of a green roof into the Rowe Building's plans and the recentness of the building's construction. Thus, it remains a relevant topic for Dalhousie University decision-makers to consider. Furthermore, this case study is an excellent setting in which to apply long-term environmental, social, and economic cost-benefit analysis, since the problem was rejected as infeasible under a short-run economic analysis.

Purpose of the Research

The purpose of this study is to uncover the institutional barriers that prevented the installation of a green roof on the Rowe building, and then to evaluate the environmental, social, and economic costs and benefits of installing a green roof on the Rowe Building, resulting in a comprehensive feasibility analysis that will help guide the actions of relevant decision-makers.

The report therefore begins with an explanation of why the green roof was not installed, based on interviews. These reasons are then placed in context with student responses to the potential installation of a green roof. This enables examination of whether or not student interests were represented in the decision-making process. These qualitative measures of student interest and barriers to installation are followed by an analysis of the current context and problems with it and the establishment of criteria based on student surveys. These criteria are then applied quantitatively to assess the feasibility of installing a green roof on the Rowe building. This research is summarized and examined in a discussion of the findings which forms the basis of our concluding recommendations.

It is hoped that the results of this report are considered not only in regards to the Rowe Building, but are also used for the design and construction of future buildings on the university campus. Similarly, it is hoped that the information presented in this report is of value to Dalhousie University and other institutions undertaking sustainability audits and initiatives.

Background Information: Green Roof Literature Review

A green roof is a roof that has been designed and constructed to support vegetation. The technology and healthy market for its construction are already well established in European countries such as Germany, France, Austria, and Switzerland, where governments provided legislative and financial support for green roof initiatives (GRHC, 2005).

Green roofs range in complexity from extensive to intensive, with common features of waterproofing, water-repellent, and drainage systems; a filter cloth; a lightweight growing medium; and plants (GRHC, 2005). Plant selection for all green roofs is determined by the purpose of the roof, climate and other environmental conditions, soil depth and richness, maintenance requirements, and aesthetic considerations (EKF, 2005).

Extensive green roofs are generally not intended for public access (although some otherwise extensive green roofs are accessible) and are relatively low in weight, maintenance requirements, and cost (EEC, 2002). Although the complexity of green roof construction increases with greater roof slope, extensive green roofs have been installed at up to a 45 degree pitch (EKF, 2005). Extensive green roof plants ideally have the following qualities: low growth height, rapid growth/spreading, high drought tolerance, fibrous roots, no special irrigation or nutritional requirements, low maintenance needs, and do not generate airborne seeds (EKF, 2005). Moss, sedum, herbs and grasses are well-suited for extensive green roofs (IGRA, 2006).

Intensive green roofs are publicly accessible, can support greater plant diversity, and are associated with greater weight, maintenance requirements, and cost (EEC, 2002). Intensive green roofs can accommodate lawn, perennials, bushes, trees, and additional decorative or functional features and structures (IGRA, 2006).

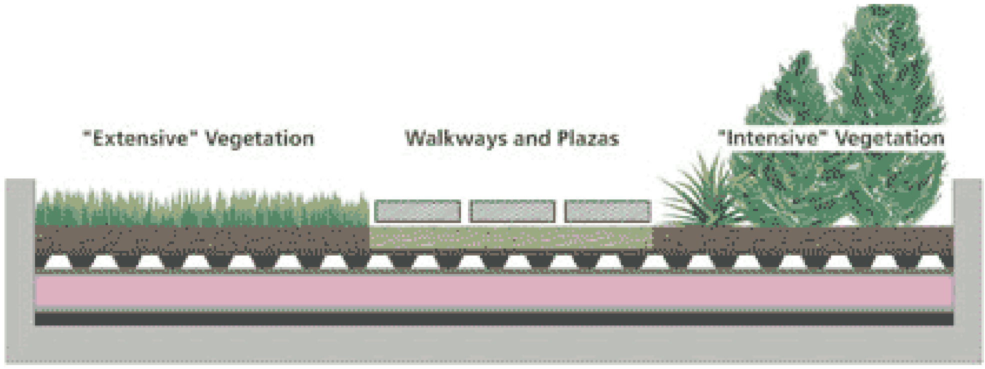


Figure A: Representation of an extensive green roof and an intensive green roof. (Greenroofs.org, 2001)

There are many environmental, economic, and social benefits associated with green roofs. Environmental benefits include: reduced energy consumption for heating and cooling due to thermal insulation; improved air quality, including reduction in smog, filtration of airborne particulates, and increased carbon dioxide/oxygen exchange; reduced urban heat island effect; lowered levels of greenhouse gases in the atmosphere due to reduced emissions and increased carbon sinks; improved water quality due to filtration and reduction of storm water runoff; sound insulation; creation of microclimates; opportunities to recycle waste through composting; preservation of habitat and biodiversity; reduced waste due to longer material lifespan; and increased environmental awareness (GRHC, 2005).

Economic benefits include: private and community cost saving, including on energy, infrastructure, and health-care costs; increased property value; job creation; investment opportunities; increased tourism, improvements to employee productivity (GRHC, 2005); and the potential for an import/export market of green roof technologies (EEC, 2002). Social benefits include: promotion and restoration of physical and emotional/mental health through improved air quality, horticultural therapy, and passive experiences with nature; aesthetic value; space for amenities or food production; recreation; and contribution to progressive public and environmental policy changes (GRHC, 2005). A green roof would also have unique benefits on a university campus because it could be used for research purposes and *Campus as a Living Laboratory* initiatives.

Green roofs also face certain barriers and disadvantages. Despite a proven return on investment (GRHC, 2005), high initial financial costs are a deterrent (EEC, 2001). The slope and loading capacity of existing roofs provide barriers to retrofitting (EEC, 2002). Although maintenance and replacement costs are generally reduced by green roofs (due to a longer material lifespan) (GRHC, 2005), intensive green roofs vary considerably in complexity and may require high levels of maintenance in the form of irrigation and/or fertilization (IGRA, 2006). There are also some concerns over safety (EEC, 2001). Depending on the types of plants chosen for the roof, there is the potential for an increased risk of fire (Snodgrass, 2006) and an increase in plant allergens in the air (EKF, 2005). There is also some concern that water will leak into buildings (EEC, 2001).

The “complicated engineering and logistics associated with their installation” is a limitation of conventional built-in-place green roofs (Markham and Walles, 2003: 58). However, recent developments in modular technology – in which green roof components are already prepared in portable, interlocking grids prior to installation (GRHC, 2005) – “promise to address these limitations and reduce project costs by simplifying the green roof system, while maintaining the environmental benefits” (Markham and Walles, 2003: 58).

Finally, green roof technology in Canada is further limited by a lack of knowledge and awareness, lack of public investment or incentives, and a lack of green roof data specific to Canadian climates (EEC, 2002). The National Research Council’s Institute for Research in Construction is performing studies in Ottawa and Toronto to address this limitation (EEC, 2002).

Methods:

We employed the use of triangulation in order to maximize the use of the concurrent and sequential mixed methods approach in our project concerning the feasibility of installing a green roof on the Rowe Building. Our methods will be discussed in two sections, according to the sequence in which they were researched. Our approach began with concurrent qualitative and quantitative variables and then progressed sequentially to a quantitative approach in our feasibility study. We conducted interviews with key actors, questioned two hundred students with surveys, and measured and analyzed the environmental, social, and economic costs and benefits for the five possible different roof types.

Our interviews and surveys are bound by many limitations as well as by our self-implemented delimitations. Our research is limited by various factors, including the potential reception of diplomatic answers to interview questions to protect personal, institutional and/or company integrity; the inaccessibility of certain information because of our students status; our lack of experience in the environmental problem solving field; the possibility of statistical error and impossibility of predicting certain outcomes; and a lack of current literature due to the newness of the topic. One consequence of these limitations was that not all interviews were successfully completed, either because of geographical distance, lack of time or because of institutional barriers.

This study will confine itself to analyzing the feasibility of presently installing five different roof types on a 30 ft x 40 ft plot on the Seymour Street side of the Rowe building. Criteria used to assess feasibility will be limited to environmental/health, social/aesthetic and economic. We found that calculating the feasibility of only one type of green roof was severely limiting our research and did not provide enough scope to advise the administration on the implementation of a green roof. Therefore, we decided to broaden the feasibility calculations to five different roof types. We choose five roof types based on the results of our surveys given to students. One of the overarching results from the surveys found that students were most interested in a green roof if it were accessible to them. Therefore, we made three of the five roof types accessible to students. We also included a conventional roof type and an inaccessible option in order to conduct accurate comparisons and contrasts.

The following are the five different roof types discussed:

- Current roof (conventional)
- Extensive, inaccessible
- Extensive, accessible
- Intensive, accessible with no planters
- Intensive, accessible with planters

Methods 1: Interviews and Surveys

After organizing a comprehensive list of the important and influential people involved in general green roof building, bureaucratic decision making for the Rowe building, architectural design of the building, and in the School of Resource and Environmental Studies (SRES), group members conducted interviews via email, phone, or in person, depending on their availability. By interviewing the architects and contractors of the Rowe Building, we aim to investigate the general benefits and costs implied by including a green roof in the designs, construction and final product, as well as site-specific details. We will also discover both internal (institutional) and external (environmental and otherwise) influences and inhibitors involved in the decision-making processes where it is decided to include a green roof.

The following key actors were interviewed:

- Leif Fuchs, architect at John Dobbs and Associates
- Philip Lee, Facilities Management, Dalhousie University
- Kendall Taylor, MRAIC, LEED AP Project Manager, Capital Projects – Buildings, Real Property & Asset Management
- Brenda Smart, Administrative Assistant for Dr. Karen Beazley, SRES
- Dr. Karen Beazley, Director of SRES
- Ron Stubbert, Dean of Management's Administrative Assistant, Dalhousie University
- Pomerleau Inc., Contractor
- Shore, Tilbe, Irwin and Partners, Architect

- John Dobbs and Associates, Architect

Complete interviews with questions can be found in Appendix 3.

Our research also included non-probabilistically surveying two hundred students to fulfill a purposive quota of two student populations within Dalhousie University: one hundred students who use the Rowe Building and one hundred students who do not. The results of the surveys enable us to examine whether or not student interests were represented in the decision-making process, based student interest and perceived use of a green roof, and what factors are most influential in determining desirability. After formulating and pilot testing the two different survey models, we made small modifications to our questions to ensure that pertinent data was collected while minimizing the effects of our biases.

We chose to sample two hundred students because we felt it was a good sample of the Dalhousie University students and especially of students who frequent the Rowe building. Surveys were delivered on three separate days at three separate times in order to avoid overlap. Our haphazard approach to surveying students led to a non-response bias, as only sampling units that were interested in completing the survey agreed to participate. Furthermore, there may have been a response bias because respondents could have been influenced by the presence of the surveyors to display a positive attitude towards green roofs. We attempted to minimize the effects of these biases by designing our survey to be neutral and by attempting to display a neutral attitude towards green roofs when administering the survey. We also made it clear to students that participating in the survey was completely voluntary and ensured anonymity of participants. Samples of the surveys can be viewed in Appendices 1 and 2.

Methods 2: Feasibility Analysis

We employed quantitative methods in order to compare the costs and benefits of the five different roof types to determine which roof type is most environmentally, socially and economically beneficial and which most costly.

Current System and Context

Construction of the Rowe Building was completed in September 2005. It was built to accommodate 1,500 students from the four management schools: business administration, library and information studies, public administration, and resource and environmental studies. The 121,000 square feet, seven-storey building was built over a period of three years on a $25 million budget. It was funded by the *Management Without Boarders* campaign and by donations from over 500 supporters (Dalhousie University, 2006).

The Rowe Building was designed by architectural companies *John Dobbs & Associates Inc*. and *Shore, Tilbe, Irwin and Partners*, and was constructed by *Herve Pomerleau Inc* (Dalhousie University, 2006). It was designed to meet the U.S. Green Building Council's criteria for Leadership in Energy and Environmental Design (LEED) silver certification and was therefore "constructed using a sustainable, environmentally responsible design" that includes: low-flush plumbing; the use of recycled materials; low-VOC healthy finishes; occupancy sensors for lighting control; a water source heat pump system; a five-floor atrium for natural light; operable windows, dynamic thermal storage; a thermal insulation envelope; an energy target of 40-50% of the Model National Energy Code for Buildings; and, most importantly, *the potential for green roof development* (Dalhousie University, 2006).

The total area of the building's roof is approximately 6135 square feet. Approximately 40% of the surface of the roof is permanently covered with mechanical equipment and, with the exception of a skylight, the rest of the roof is currently unused (Lee, 2006). The area designated for the green roof is a section 30 x 40 feet large on the South-facing side of roof (Fuchs, 2006); however, a green roof has not yet been installed. Currently, there are no green roofs on any Dalhousie University buildings.

Problems with Current System

The current use of roof space is inefficient (since approximately 60% of the roof is currently unused), and there is therefore opportunity for improvement of the current system. A feasibility analysis of the costs and benefits of installing a green roof was deemed to be warranted and was therefore undertaken for three main reasons. First, a green roof was originally incorporated into the design of the Rowe Building, thus making it a reasonable potential alternative to the current system. Second, green roofs have been associated with numerous benefits, thus calling for increased investigation into the particular benefits that a green roof could provide for the Rowe Building. Finally, student surveys have indicated that there is support for the installation of a green roof on the building, thus implying that the current context may be conducive to such an endeavour.

Criteria

The following three criteria were selected for a feasibility analysis: environmental (including health considerations), social, and economic. These criteria were chosen to most accurately reflect the true triple bottom line. It is important to incorporate full cost-benefit accounting into the feasibility analysis because Dalhousie University is a progressive institution and should thus be provided with information that comprehensively reflects true costs and benefits as the basis for decisions. The criteria were weighted in the feasibility analysis according to the weighting of importance that they were given by students in student surveys. Accordingly, social criteria are weighted as 52%, environmental criteria are weighted at 41% (36% for general environmental criteria and 5% for air quality and health criteria), and economic criteria are weighted at 7%. Although many administrative decisions are typically based primarily on economic considerations, the majority of students that were surveyed indicated that they are more concerned with social and environmental considerations than they are with economic considerations regarding this issue. Since students pay tuition and therefore ultimately contribute significantly to financing projects undertaken by the university, it is therefore assumed that these survey results imply that higher economic costs are acceptable to most students if they result in recognizable social and environmental benefits.

Methods Used for Analysis of Environmental Costs and Benefits

The environmental costs and benefits of five different roof types (accessible with rooftop planters, intensive and accessible green roof, extensive and accessible green roof, extensive an inaccessible green roof, and conventional roof) were quantified and measured relative to one another to determine which roof type is most environmentally beneficial and which roof type is most environmentally costly. Each roof was given a score out of 100 for each of several weighted environmental criteria. The roof that accrued the highest amount of each particular cost or benefit received a score of 100 for that cost or benefit and the other roof types were measured relative to it. Please see the tables 3 – 5 in the results section of this report for tables indicating the numerical scores for comparison of the relative environmental costs and benefits of the different types of roofs.

Environmental Benefits: *Environmental* Subcategory

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

a) Storm-water retention and water filtration (30%)
b) Reduction in energy consumption (30%)
c) Preservation of biodiversity (15%)
d) Preservation of habitat (15%)
e) Moderation of urban heat island effect (10%)

Storm-water retention and water filtration and reduction in energy consumption are weighted the highest because they are two of the most commonly referred to environmental benefits of a green roof. Furthermore, reductions in energy consumption translate to economic savings, thus making it an even more significant benefit. Preservation of biodiversity and preservation of habitat are weighted less because they are environmental benefits that can also be achieved through other means rather than installing a green roof. Finally, moderation of the urban heat island effect is weighted the least because green roof cover on multiple buildings would be necessary in order for there to be a significant effect.

Please see *Comparison of the Relative Environmental Benefits of Different Types of Roofs* in Table 3 of the Results section of this report for a summary of the scores given to each roof type.

a) Storm Water Retention and Water Filtration

Where there is vegetation, water is stored in the soil before being taken up by the plants and returned to the atmosphere through transpiration and evaporation. It is through this mechanism that green roofs retain storm water. Storm water retention results in less runoff and therefore reduces the pollution of local water sources. Any water that does runoff is slowed, thus decreasing the stress on sewer systems during peak flow periods. Furthermore, water than 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).

Since the capacity for storm water retention and water filtration is primarily dependent on the amount of soil present, conventional roofs do not retain any storm water. An intensive green roof retains the most storm water because larger plants can take up greater quantities of water from the soil. Due to less plant diversity and smaller plants, an extensive green roof retains slightly less water. Because an accessible rooftop patio with planters has much less soil coverage than a typical green roof, it is given a significantly lower score.

b) Reduction in Energy Consumption

Green roofs have insulating properties that can reduce energy consumption for heating and cooling. In fact, 20 cm of soil with a 20-40 cm layer of thick grass has the combined insulation value of 15 cm of mineral wool. The temperature of a gravel roof can increase by as much as 25 °C to between 60-80 °C. Conversely, the temperature of a roof that is covered in grass would not rise above 25 °C. It is for this reason that rooms under a green roof are at least 3 - 4 °C cooler than the air outside when outdoor temperatures range between 25-30 °C (GRHC, 2005).

Since soil and plant cover is the primary determinant of the additional insulating potential of a green roof over a conventional roof, an intensive green roof provides the most insulation, followed by an extensive green roof. A rooftop patio with planters has a much lower insulating potential, as exposed conventional roof would exist between the planters, allowing heat to enter during the summer and escape during the winter. A conventional alone roof does not provide any additional beyond the insulation that is placed beneath it (that could also be placed beneath a green roof) and is scored accordingly.

c) Preservation of Biodiversity

An intensive green roof has the greatest plant diversity and therefore receives the highest score for preservation of biodiversity. Extensive green roofs tend to be limited to low-growing and low maintenance plant varieties and therefore receive a lower score. A rooftop patio with planters receives a lower score than either type of green roof because planters would not be able to accommodate as great a variety of vegetation as could be planted in a larger area covered with soil (due to reduced room for root growth, limited space for larger plants, the tendency to plant all similar plants in the same planter so that one plant species does not out-compete the other, etc.). Furthermore, more species of birds, insects, and very small mammals (i.e. squirrels or chipmunks) would be found on a green roof than on a rooftop patio with planters, therefore further reducing that roof type's score. A conventional rooftop would have no benefits for the preservation of biodiversity.

d) Preservation of Habitat

The inaccessible extensive green roof receives the highest score for preservation of habitat because the absence of human visitors to the roof would encourage more animals to use the roof as habitat and the fact that it would be relatively undisturbed habitat increases its value. Accessible green roofs, both extensive and intensive, receive a slightly reduced score due to the increased presence of human visitors to the roof. An accessible rooftop patio with planters receives the second lowest score because of the separation of the vegetation into planters – thus interrupting the habitat by dividing it into smaller, isolated segments rather than providing a larger, cohesive area of habitat – combined with the human presence associated with its accessibility. A conventional roof does not preserve any natural habitat.

e) Moderation of the Urban Heat Island Effect

The 'urban heat island effect' refers to the difference in temperature between a city and the countryside. The effect is primarily caused by the absorption and re-radiation of the heat from solar radiation by hard and reflective surfaces in cities, including conventional roofs. Plants have a cooling effect on their surroundings due to their use of heat energy in the process of evapotranspiration. They absorb approximately 592 kcal of heat energy per L of water evaporated. Therefore, one m^2 of vegetation can evaporate over 0.5L of water on a hot day through the daily dew and evaporation cycle, and can evaporate up to 700 L of water annually. Dr. Brad Bass et al. found that the city of Toronto could reduce its urban heat island effect by 1-2° C if just 5% of the city's roof area was converted to green roofs (GRHC, 2005).

The intensive green roof receives the highest score because larger plants have the capacity to evapotranspirate greater quantities of water, thus increasing the amount heat energy removed from the air. Extensive green roofs, whether accessible or inaccessible, receive the second highest score due to the degree of plant cover available to moderate the urban heat island effect. The second lowest score is given to the rooftop patio with planters because, although the presence of plants on the roof would help moderate the surrounding temperature, the hard and reflective surfaces of the planters and of the conventional roof between the planters would counteract most of the benefit provided by the plants in this respect. A conventional roof would actually contribute to the urban heat island effect rather than moderate it.

Environmental Benefits: *Air Quality and Health* Subcategory

All plants, including grass, breathe in carbon dioxide (CO_2) and exchange it for oxygen through photosynthesis (Greenroofs, 2005). In addition to removing CO_2 from the air, pollution in the form of air-born particulates is also captured by grass. One square metre of a grass roof is able to remove 0.2 kg of this type of pollution in one year.

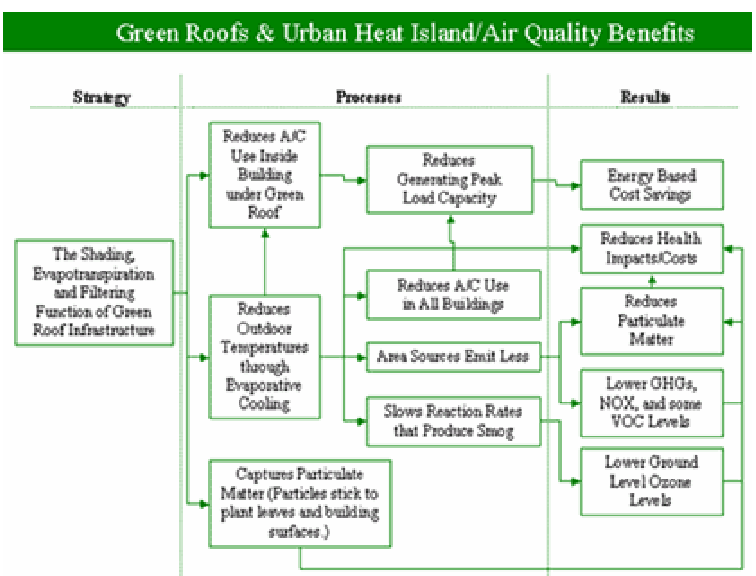
It is possible to estimate the area of grass area needed to soak up a certain amount of CO_2 based on productivity data for temperate grass types (Hannan, 1997). This estimate is based primarily on the assumption that one unit of carbon dioxide produces one unit of cellulose. Given this information, it would take 1182 square metres of grass to soak up 1 tonne of CO_2.

This may, however, be irrelevant as grass only stores CO_2 on a short-term basis: when the grass decomposes, as much CO_2 as was absorbed is released back into the atmosphere (Hannan, 1997). For significant and long-lasting CO_2 absorption, trees should be considered and therefore an intensive green roof would be the most beneficial. 3,413 square metres of average commercial forest would be needed to absorb 1 tonne of carbon dioxide in a year.

The only option that would be relevant to decreasing CO_2, and thus greenhouse gas emissions in the air, would be an intensive green roof. An intensive roof would have trees and shrubs that are capable of storing carbon for long periods of time, versus grass that releases the carbon dioxide back into the air year after year. Although grass would remove particulate matter from the air, other plants are just as, if not more, capable of doing so as well. On a scale of 0 to 100%, the accessible and intensive roof is 100% environmentally beneficial (given the available options) and the two extensive options are each 30% environmentally beneficial. To ensure maximum environmental benefits, trees and large shrubs would be suggested (in either pots or in soil on the roof).

In addition to the potential for CO_2 absorption (where larger plants are contained on the green roof), a green roof can improve air quality by filtering airborne particulates from the air that moves across it. One m^2 of grass roof can remove 0.2 kg of airborne

particulates from the air annually (GRHC, 2005). This environmental benefit also has health benefits and can potentially reduce or mitigate respiratory health problems. It is also worth noting that 1.5 m^2 of uncut grass produces enough oxygen per year through photosynthesis to supply one person with their yearly oxygen intake requirement. This means that uncut grass and other plants on a green roof would have health benefits associated with contribution to the provision of fresh air for us to breathe.



Source: GRHC, 2005.

Environmental Costs: *Environmental* Subcategory

The potential environmental costs of green roofs that will be considered in this feasibility analysis and their weightings are as follows:

a) Water use (30%)
b) Use of fertilizers and pesticides (30%)
c) Generation of waste material (30%)
d) Transportation of materials (10%)

All of the costs are weighted equally except transportation of materials, which is weighted less because it is essentially a one-time cost that primarily applies to when the roof is initially constructed. This cost can also be applied to transportation of materials involved in maintenance, but it would not be a significant cost compared to the others.

Please see *Comparison of the Relative Environmental Costs of Different Types of Roofs* in Table 4 of the Results section of this report for a summary of the scores given to each roof type.

a) Water Use

Intensive green roofs require increased input of water compared to extensive green roofs, and therefore score slightly higher for this cost. A rooftop patio with planters scores significantly less because the need for water would be limited to the vegetation within the planters. Conventional roofs require the least amount of water, although some water is likely still used for maintenance and upkeep (i.e. cleaning).

b) Use of Fertilizers and Pesticides

Regardless or whether it is extensive or intensive, a green roof could be maintained without the use of fertilizers and/or pesticides. In addition, certain types of fertilizers and/or pesticides (if any are used) are more environmentally harmful than others. For example, a chemical fertilizer or pesticide would be more harmful than one that is chemical-free or contains chemicals with a lower toxicity. It is for this reason that a range of scores (from zero to a high score) is given for each of the green roofs. Intensive green roofs typically require more maintenance and therefore the high score is higher for an intensive green roof than it is for an extensive green roof. A rooftop patio with planters scores slightly lower for this cost because a smaller quantity of fertilizers and pesticides would be used, if any were used, due to the smaller amount of plant coverage. A conventional roof does not require the use of any fertilizers or pesticides.

c) Generation of Waste Material

Green roofs generate less waste material than conventional roofs because they last approximately twice as long and most of the materials can be composted (unlike conventional roof materials (e.g. concrete, shingles) that end up in landfills. Therefore, green roofs score half of what a conventional roof does. However, a rooftop patio with planters scores the highest for this cost because it would generate the wastes associated with the planters in addition to the wastes already associated with a conventional roof.

d) Transportation of Materials

The environmental costs associated with the transportation of materials (e.g. fossil fuel consumption, air pollution, etc.) are likely to be higher for green roofs. This is because green roofs are not yet common in this region and therefore the materials required for their installation are currently less readily available and must be transported from farther away. Also, green roofs may require materials from different sources (i.e. soil, different types of plant, construction materials, maintenance supplies, etc. may all need to be acquired from different sources) since there is currently no local "all-in-one" green roof outfit that provides all of the supplies necessary. Since planters and plants come from a separate source other than the source that provides roofing materials, a rooftop patio with planters therefore requires the most materials to be transported from different areas and thus scores the highest for transportation of materials. Extensive green roofs score slightly less than an intensive green roof because a green roof with lower plant diversity likely requires supplies from fewer sources. A conventional roof scores slightly less than an extensive green roof because there is no need to transport vegetation, soil, or other materials associated with green roofs.

Environmental Costs: *Air Quality and Health* Subcategory

There are no environmental costs associated with air quality and health for any of the roof types. There is the potential for some plant allergies to be aggravated if an allergy sufferer were to visit an accessible green roof, however that is considered in the social component of the feasibility analysis because it is only applicable to someone that chooses to visit the green roof.

Please see Table 5 in the Results section of this report for a *Comparison of Net Relative Environmental Costs and Benefits of Different Types of Roof*

Methods Used for Analysis of Social Costs and Benefits

The criteria measured in our social feasibility analysis were determined through the results of our interviews with key decision-makers and student surveys. Decision-makers indicated major concerns over student safety and risk, so this criterion was weighted most heavily. Student surveys indicated the importance of leisure, reputation, and aesthetic value. Due to their qualitative and subjective nature, scores were determined somewhat arbitrarily. This is a potential weakness in our analysis: however, there is a lack of existing research on how to quantitatively measure perceived social costs and benefits. Please see Table 6 in the Results section of this report for the *Social Cost-Benefit Analysis*.

Methods Used for Analysis of Economic Costs and Benefits

Our economic costs were calculated using the official CMHC design guideline cost estimates made in conjunction with the Ontario Association of Architects (Kuhn and Peck, 2004). These costs included: design and specifications, project management, root repelling membrane/pots, plants, guardrail and installation. Economic benefits were negligible due to the low heating and cooling costs of the building, but were nonetheless estimated for the following aspects: heating/cooling savings, longer roof life (counterbalanced by higher replacement cost) and research benefits. When applicable, small estimates were made for benefits that may be incurred in future years: government funding, GHG emissions trading credits and increasing admissions at Dalhousie both through publicity and through increasing the value of the programs offered here. Please see Tables 7 – 10 for the *Economic Cost-Benefit Analysis.*

Methods Used for Consolidation of the Environmental, Social, and Economic Feasibility Analyses

Our final feasibility analysis considered environmental, social and economic aspects. These aspects had each been scored in a variety of ways, so first had to be transformed into scores out of 100. Environmental results were converted into scores out of 100 by setting 50 as the midline, and therefore adding all results giving an economic benefit to 50, and subtracting all results yielding an economic loss from 50. Health and social benefits were determined to only be either positive or neutral. Therefore, scores were transformed by assigning a value of 0 to the results that wouldn't improve environmental health, and assigning more points to those that would have a greater effect on improving environmental health. Economic scores were transformed by assuming that the current method would have no environmental cost or benefit on a 20 year scale[*]. A score of 100 was therefore given to the status quo, and a score of 0 was given to the option with the highest cost. The score for intermediate options was determined by dividing the cost of option by the highest cost, deducting this fraction from 1, and then multiplying that score by 100.

The results from these independent criteria were then added together in two methods: one that was weighted and one where the results were all weighted equally. The weights placed on these various criteria were based on the survey results, where students were asked to weight which criteria

[*] If we were looking at a much longer timeline, then we would have included roofing costs in our calculation

they considered most important when considering the feasibility of a green roof on campus. Fifty-two percent of student responses indicated social/aesthetic factors, 36% showed environmental concerns, 7% were in highest support of economic and 5% of environmental health.

Results

Interviews

The following is a summary of the information gathered during the interview process. Full transcripts of the interviews can be found in Appendix 3.

Leif Fuchs, Architect at John Dobbs and Associates, designer of the Rowe building

The area allotted for green roof development is 30 ft x 40 ft. Original plans for the green roof envisioned more of a rooftop patio with planters than an extensive green roof. Due to the high energy efficiency of the building, energy savings with a green roof would be minimal. The structure was strengthened to hold a green roof. Green roof installation was delayed due to budget cuts.

Kendall Taylor MRAIC, LEED AP Project Manager, Capital Projects

Average cost for an extensive green roof is $12 – $15 per square foot if the structure has already been built to accommodate the added weight.

Philip Lee, Facilities Management

Estimated that the total surface area of the Rowe Building's roof is approximately 6135 square feet and that approximately 40% of it is permanently covered with mechanical equipment, so no green roof could be put in those areas. Of the remaining roof, there is a 25ft x 20ft[*] area on the south end of the building that is currently unused and apparently looks on the diagrams as if it is where the green roof was intended to be placed.

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[*] Regarding the differences in roof sizes given by Philip Lee from Facilities Management and Leif Fuchs, the architect for the building, we decided that the information from the architect was more likely to be correct since Philip Lee only claimed to be providing an estimate. We therefore used a roof size of 30 ft x 40 ft in our feasibility analysis

Brenda Smart, Administrative Assistant for Dr. Karen Beazley

SRES pushed for a green roof. Elevator and power access are installed at the roof, and the roof is also strengthened along Seymour Street. Installation was stalled due to budget cuts.

Dr. Karen Beazley, Director of SRES

Installation was delayed due to budget cuts, difficulties with prioritizing a green roof and a need for outside funding where money would be locked into being used for a green roof. Concerns raised regarding the installation of a green roof included its high maintenance, high level of inputs and high energy expenditure. Fears were also expressed that the project might not be sustainable or done properly, and that this would cause a lack of maintenance. It was stated that there is currently a lack of momentum among the faculty regarding a green roof. People are wary of new technology and fear that the roof might become a liability, for example if it starts causing leaks. The business school is also much larger than the other management schools, and they therefore have more power in these types of decisions. Finally, it is difficult to receive more money for the Rowe building since so much was just invested and the building went over budget. Since these budget cuts were coupled with budget cuts overall from Dalhousie towards Facilities Management, it is unlikely that internal funding will pay for a green roof.

Ron Hubbart, Associate to the Dean of Management

Barriers to installation of a green roof on the Rowe building are the high cost of installation ($30,000-$40,000), and that SRES used its money on a wet lab instead of a green roof. There is no primary driving force for a green roof, and he has not heard it recently mentioned at any staff meetings. He asserts that the driving force needs to be from faculty and not students since students are only here for a few years. This means that if they push for a green roof but do not stay for long enough, we will incur long-term problems with regard to maintenance. Dalhousie currently is not pushing for a green roof, and no one in external relations is looking at raising money for one.

Surveys

(Data Analysis for Social and Environmental Impact of Green Roof on Rowe Building)

Table #1: Results for Survey 1 *(Opinions of Students that use the Kenneth C. Rowe Building) - **refer to Appendix 1 for questions***

Student's Answer	**Question #1**	**Question # 2**	**Question # 3**	**Question # 4**	**Question # 5**	**Question # 6**
A)	94	81	15	37	15	23
B)	6	5	13	39	12	11
C)	~	14	38	16	0	35
D)	~	~	3	3	8	4
E)	~	~	11	3	10	16
F)	~	~	0	2	9	9
G)	~	~	1	~	0	~
H)	~	~	N/A =19	~	4	~
I)	~	~	~	~	29	~
J)	~	~	~	~	6	~

Figure 1: Student Support for the installation of a Green Roof on Top of the Kenneth C. Rowe Building (Survey #1)

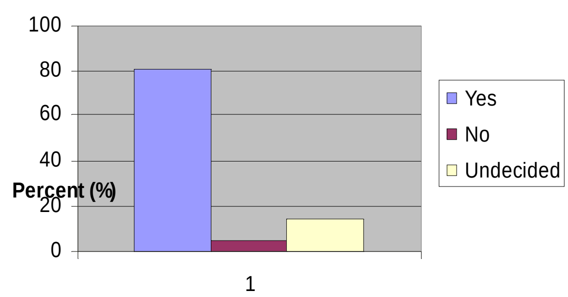


Figure 2: Student Opinions of Specific Green Roof Inclusions (Survey #1)

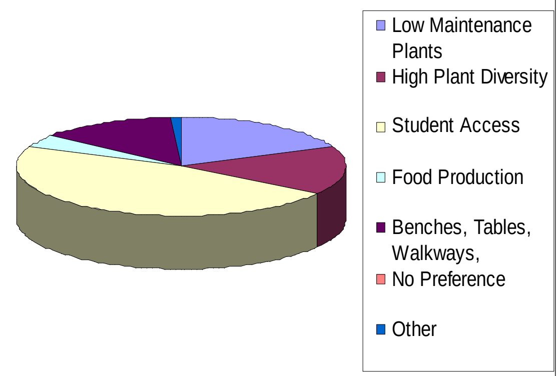


Figure 3: Student Opinions on Visiting a Green Roof on the Kenneth C. Rowe Building (Survey #1)

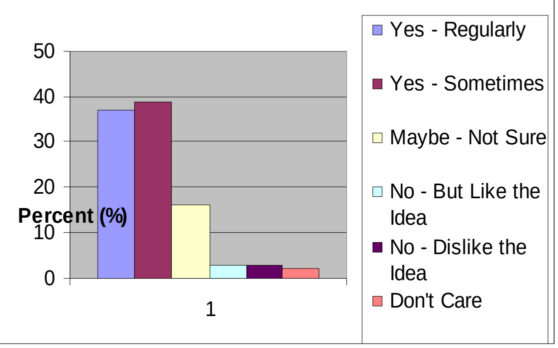


Figure 4: Factors Influencing Student Decisions on Green Roofing (Survey #1)

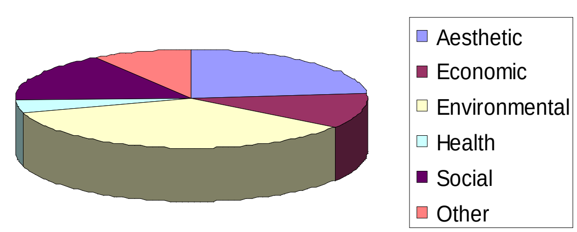


Table #2: Results for Survey 2 (*General Student Interest in Having a Green Roof on Campus) - refer to Appendix 2 for questions*

Student's Answer	Question #1	Question # 2	Question # 3	Question # 4	Question # 5	Question # 6
A)	88	10	12	32	23	25
B)	5	3	19	6	41	36
C)	7	2	36	31	28	32
D)	~	13	8	4	1	1
E)	~	28	7	12	1	2
F)	~	7	3	9	5	4
G)	~	4	1	~	~	~
H)	~	1	~	~	~	~
I)	~	0	~	~	~	~
J)	~	16	~	~	~	~

Figure 5: Student Support for the Installation of a Green Roof on any Building(s) on Campus (Survey #2)

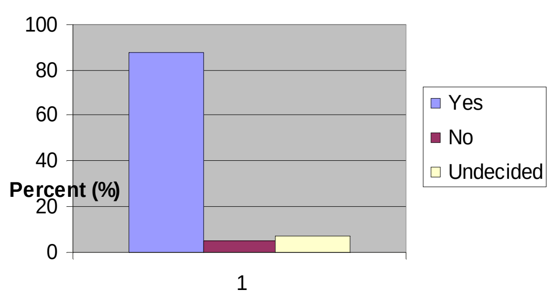


Figure 6: Student Opinions for Specific Inclusions on a Green Roof (Survey #2)

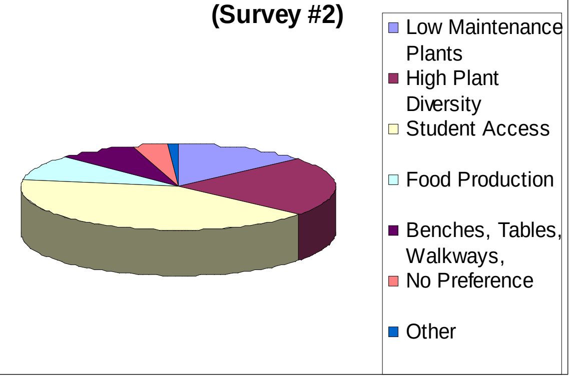


Figure 7: Student Preferences for Which Campus Building to Instal a Green Roof (Survey #2)

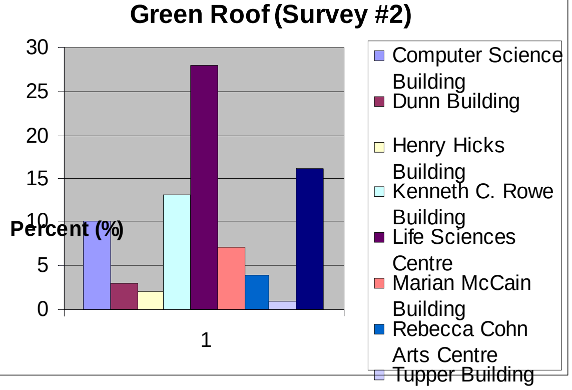


Figure 8: Factors Influencing Student Decisions on Green Roofing (Survey #2)

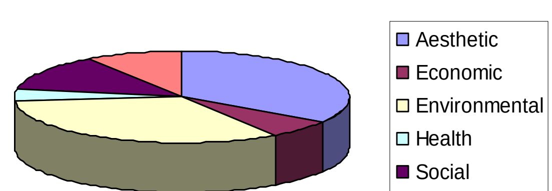


Table #3: Comparison of Relative Environmental Benefits of Different Types of Roofs

	Accessible Rooftop Patio with Planters	Intensive Green Roof (Accessible)	Extensive Green Roof (Accessible)	Extensive Green Roof (Inaccessible)	Conventional Roof	Weighting
Storm-water retention and water filtration	40	100	90	90	0	**30%**
Reduction in energy consumption	20	100	90	90	0	**30%**
Preservation of biodiversity	60	100	80	80	0	**15%**
Preservation of habitat	60	90	90	100	0	**15%**
Moderation of urban heat island effect	20	100	90	90	0	**10%**
Total relative environmental benefits	**38%**	**98.5%**	**88.5%**	**90%**	**0%**	

<u>Table 4:</u> Comparison of the Relative Environmental Costs of Different Types of Roofs

	Accessible Rooftop Patio with Planters	Intensive Green Roof (Accessible)	Extensive Green Roof (Accessible)	Extensive Green Roof (Inaccessible)	Conventional Roof	Weighting
Use of Water	50	100	90	90	10	**30%**
Use of Fertilizers and Pesticides	0-80	0-100	0-90	0-90	0	**30%**
Waste Material Produced by Roof Over Building's Lifetime	100	45	45	45	90	**30%**
Transportation of Materials	100	90	80	80	70	**10%**
Total relative environmental costs	**55 – 79%**	**52.5 – 82.5%**	**48.5 – 75.5%**	**48.5 – 75.5%**	**37%**	

<u>Table 5: Comparison of Net Relative Environmental Costs and Benefits of Different Types of Roofs</u>

	Accessible Rooftop Patio with Planters	Intensive Green Roof (Accessible)	Extensive Green Roof (Accessible)	Extensive Green Roof (Inaccessible)	Conventional Roof
Gross relative environmental benefits	38%	98.5%	88.5%	90%	0%
Gross relative environmental cost	55 – 79%	52.5 – 82.5%	48.5 – 75.5%	48.5 – 75.5%	37%
Net relative environmental effect	**17 – 41%**	**16 – 46% benefit**	**13 – 40% benefit**	**14.5 – 41.5% benefit**	**37% cost**

Table #6: **Social Cost-Benefit Analysis**

Scoring Category	**Conventional roof**	**Extensive - Non Accessible**	**Extensive - Accessible**	**Intensive Accessible with planters**	**Intensive – Accessible no pots**
Safety/Risk (out of 20)	20	18	10	8	8
Leisure (out of 10)	0	1	5	9	9
Reputability (out of 10)	0	6	7	10	10
Aesthetic (out of 10)	0	2	3	9	9
-		**-**	**-**	**-**	**-**
Total	***20***	***28***	***25***	***36***	***36***

Economic Social Cost-Benefit Analysis

(Each of the five roof types is tabled individually (7-10) and results are consolidated in table 11)

Table 7

Inaccessible Extensive

Roof = 30x40 ft; area=1200 ft^2; perimeter=100 ft

Costs

Description	Min. Rate	Max. Rate	Low estimate	Average	High estimate
Design + Specifications	5%	10%	1215	2621.25	4560
Project Management	2.50%	5%	607.5	1223.25	2280
Root repelling membrane	10	15	12000	15000	18000
Planting base	5	10	6000	9000	12000
Plants	1	3	1200	2400	3600
Installation	3	8	3600	6600	9600
Maintenance (only for first 2 years)	1.25	2	1500	1950	2400
			24300	34950	45600
Total Cost of Installation			26122.5	38794.5	52440
Total Cost (after 1 year)			***27622.5***	***40744.5***	***54840***
Total Cost (after 5 years)			***29122.5***	***42694.5***	***57240***
Total Cost (after 20 years)			***29122.5***	***42694.5***	***57240***
Total Cost (after 100 years)			***29122.5***	***42694.5***	***57240***

Benefits

Description	Average
Heating/cooling cost savings	250
Longer Roof Life (counterbalanced by higher replacement cost)	0
Government funding?	0
GHG emissions trading credits?	0
Increase admissions?	30
Publicity?	400
Program value increase?	1000
Research benefits	500
Better water drainage	500
Total	2680

Total

After 1 year	38064.5
After 5 years	40014.5
After 20 years	40014.5

Table 8

Accessible Extensive

Costs	**Min. Rate**	**Max. Rate**	**Low estimate**	**Average**	**High estimate**
Design + Specifications	5%	10%	2340	5175	9120
Project Management	2.50%	5%	1170	2415	4560
Root repelling membrane	10	15	12000	15000	18000
Planting base	5	10	6000	9000	12000
Plants	1	3	1200	2400	3600
Guardrail	20	40	24000	36000	48000
Installation	3	8	3600	6600	9600
			46800	69000	91200
Total Cost of Installation			50310	76590	104880
Maintenance (annual)	1.25	2	625	812.5	1000
Total Cost (after 1 year)			***50935***	***77402.5***	***105880***
Total Cost (after 5 years)			***53435***	***80652.5***	***109880***
Total Cost (after 20 years)			***62810***	***92840***	***124880***

Benefits

Description	**Average**
Heating/cooling cost savings	250
Longer Roof Life (counterbalanced by higher replacement cost)	0
Government funding?	0
GHG emissions trading credits?	0
Increase admissions?	1000
Publicity?	2000
Program value increase?	5000
Research benefits	500
Worker productivity increase?	500
Total	9250

Total

After 1 year	68152.5
After 5 years	71402.5
After 20 years	83590

Table 9

Accessible Intensive

(without planters)

Costs

Description	Min. Rate	Max. Rate	Low estimate	Average	High estimate
Design + Specifications	5%	10%	3480	13815	29880
Project Management	2.50%	5%	1740	6447	14940
Root repelling membrane	10	15	12000	15000	18000
	15	30	18000	27000	36000
Plants	5	150	6000	93000	180000
Guardrail	20	40	24000	36000	48000
Installation	8	14	9600	13200	16800
			69600	184200	298800
Total Cost of Installation			74820	204462	343620
Maintenance (annual)	1.25	2	625	812.5	1000
Total Cost (after 1 year)			***75445***	***205274.5***	***344620***
Total Cost (after 5 years)			***77945***	***208524.5***	***348620***
Total Cost (after 20 years)			***87320***	***220712***	***363620***

Benefits

Description	Average
Heating/cooling cost savings	250
Longer Roof Life (counterbalanced by higher replacement cost)	0
Government funding?	100
GHG emissions trading credits?	100
Increase admissions?	1000
Publicity?	2000
Program value increase?	5000
Research benefits	500
Worker productivity increase?	1000
	9950

Total

After 1 year	195324.5
After 5 years	198574.5
After 20 years	210762

Table 10

Accessible Intensive

(with planters)

Costs

Description	Min. Rate	Max. Rate	Low estimate	Average	High estimate
Design + Specifications	5%	10%	4740	17190	36360
Project Management	2.50%	5%	2370	8022	18180
Root repelling membrane	10	15	12000	15000	18000
	15	30	18000	27000	36000
Plants	20	200	24000	132000	240000
Guardrail	20	40	24000	36000	48000
Installation	14	18	16800	19200	21600
			94800	229200	363600
Total Cost of Installation			101910	254412	418140
Maintenance (annual)	1.25	2	625	812.5	1000
Total Cost (after 1 year)			***102535***	***255224.5***	***419140***
Total Cost (after 5 years)			***105035***	***258474.5***	***423140***
Total Cost (after 20 years)			***114410***	***270662***	***438140***

Benefits

Description	Min. Rate	Max. Rate	Low estimate	Average	High estimate
Heating/cooling cost savings				250	
Longer Roof Life				1000	
Government funding?				100	
GHG emissions trading credits?				100	
Increase admissions?				1500	
Publicity?				2000	
Program value increase?				5000	
Research benefits				500	
Worker productivity increase?				1000	
Total				11450	

Total

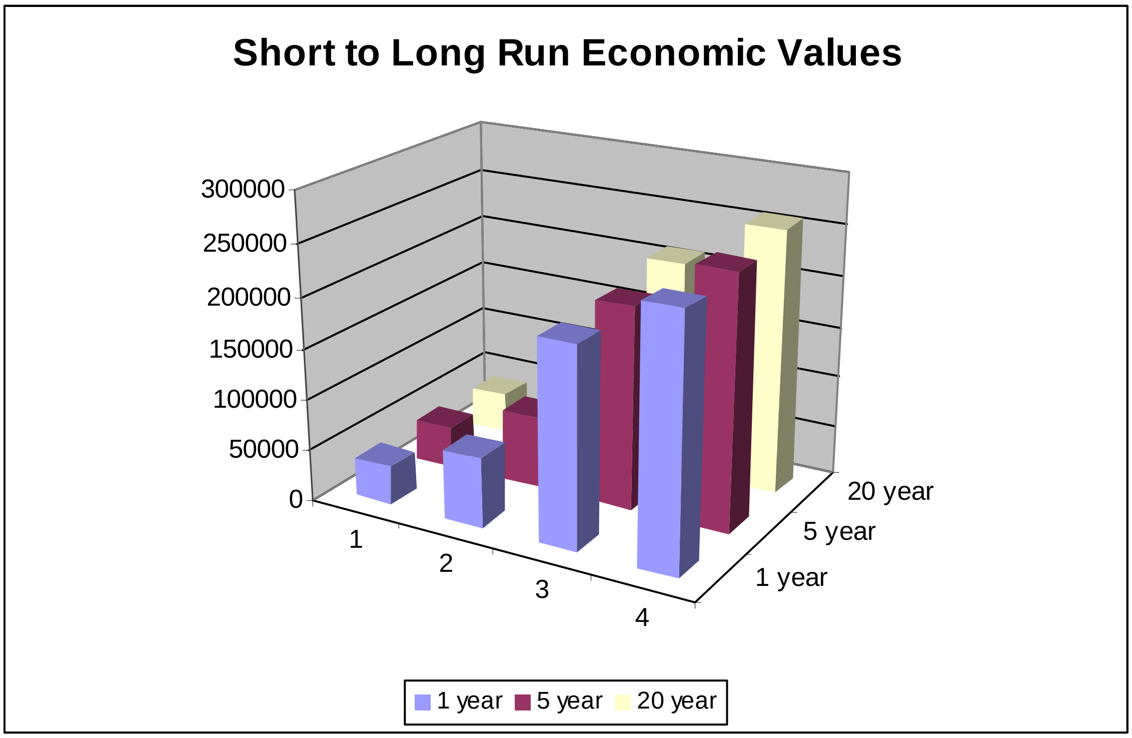
After 1 year	243774.5
After 5 years	247024.5
After 20 years	259212

Economic Average Total Estimates of Costs

Table 11

	1 year	5 year	20 year
1- Extensive inaccessible	38064.5	40014.5	40014.5
2- Extensive accessible	68152.5	71402.5	83590
3- Intensive accessible no planters	195324.5	198574.5	210762
4- Intensive accessible planters	243774.5	247024.5	259212
Conventional roof (since we are looking at the short-term, roofing costs are assumed to be 0$)	0	0	0

Figure 9

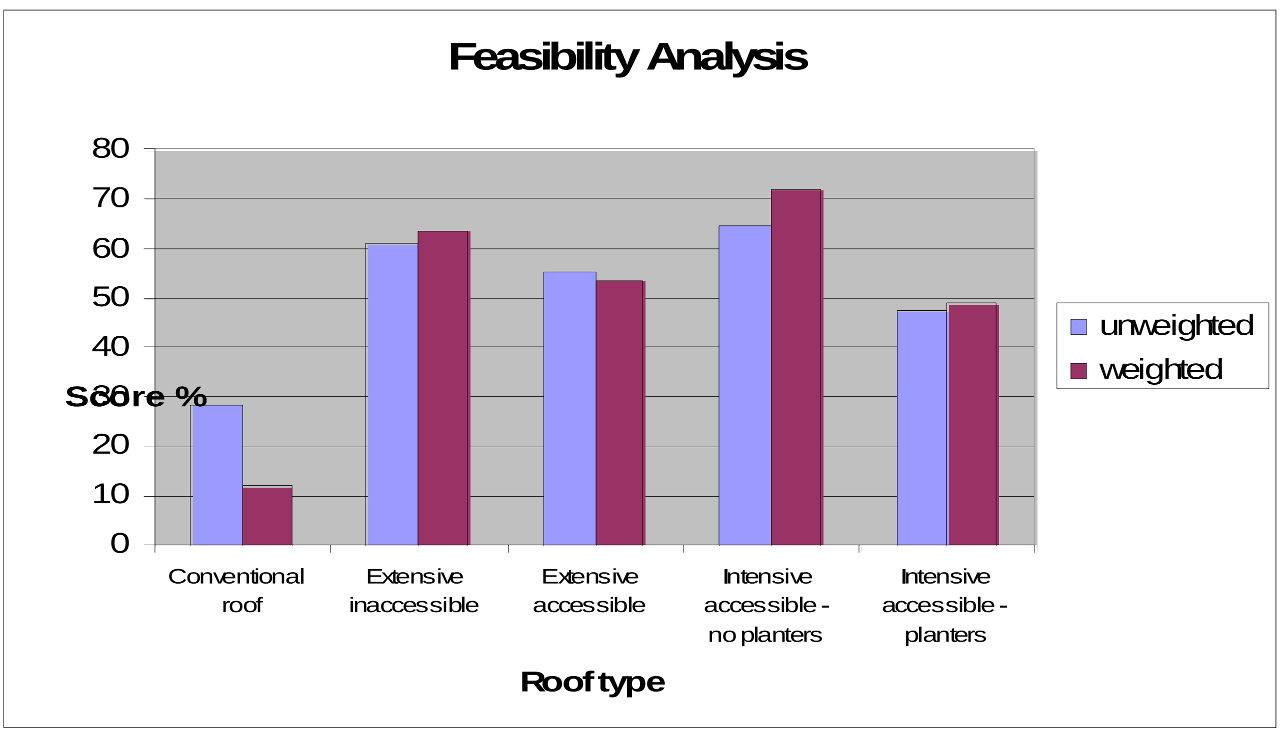


Final Feasibility Analysis

Table 12: Final Feasibility Analysis

	Conventional Roof	Inaccessible extensive	Accessible extensive	Accessible intensive (without planters)	Accessible intensive (with planters)
Social/Aesthetic (52%)	0 %	54%	50%	72%	72%
Environmental (36%)	13%	78 %	56.5 %	81 %	18 %
Health (5%)	0%	30%	30 %	100 %	100 %
Economic (7%)score = 1– (cost / highest cost) *100	100% ($ 0)	94% ($40,015)	72% ($71,403)	5% ($198,574)	0% ($247,025)
TOTAL WEIGHTED:	113 11.68	256 63.43	208.5 53.72	258 71.95	190 48.92

Figure 10: Histogram of Final Feasibility Analysis



Discussion

Summary of Research Question

In our study, we used a mixed methods approach using concurrent qualitative and quantitative surveys. We began with interviews to gather information from key actors regarding why the green roof had not been installed on the Rowe building, and to gather specifics about the site to later use in our feasibility analysis. Our next step was to qualitatively assess student attitudes towards green roofs and what factors they considered most important in analyzing their feasibility, which we later used to weight our feasibility analysis. We used specifics regarding site and student perceptions of feasibility to then quantitatively assess the feasibility of five different options for the roof top: the current roof, extensive inaccessible, extensive accessible and accessible intensive with and without planters. Through our research, we hoped to discover what prevented the green roof from being installed and assess the validity of these concerns through a quantitative analysis of which roofing option was the most feasible.

Significant Findings

1- Interviews

Our interviews gave us both qualitative data about institutional barriers and quantitative data. Quantitative data was used throughout our feasibility analysis to make our analysis site-specific to the 30 x 40 foot area off Seymour Street that was proposed as the site of a green roof.

Key actors involved in the decision-making process as well as the design of the green roof identified the economic and social barriers that prevented the installation of a green roof on the Kenneth C. Rowe Management building. High projected cost of the green roof at $30,000-$40,000 made its installation unfeasible given that Facilities Management faced a 2 percent cut by Dalhousie University and that the building itself was already over budget. Furthermore, the short-run economic basis on which decisions tend to be made further prevented the roof from being constructed. Fears surrounding leaks were stated; however, research at Michigan State University has shown that greening a roof protects it from the main sources of erosion, which are UV radiation, temperature fluctuations and erosive rainfall (MSU, 2004).

Another barrier to installation regarded fears over student safety; however, these concerns can be counter-balanced by the corresponding social benefits of a green roof. Concerns were also voiced over environmental costs of installation. A lack of knowledge about green roofs meant that this project was even more difficult to promote in a faculty with unequal numbers of students in the separate departments. The disconnect between the departments, as well as the power relations accorded to these interactions due to their varying sizes, put SRES at a disadvantage because of its smaller size, and therefore made it even less likely that they could enact their wish for a green roof. A final barrier to installation of the green roof was the perception that a green roof would only be used by SRES students, and was therefore their responsibility to fundraise for. We therefore decided to conduct surveys of the entire student population as well as Management students to determine if they felt they would benefit from having a green roof on campus. The perception that students weren't interested in having a green roof caused faculty members to feel that the project would lose momentum and the green roof wouldn't be maintained, and our survey results were therefore vital for our research process.

2 – Surveys

Our surveys of students indicated an overwhelmingly positive response towards wanting a green roof on campus. This response was even stronger among students who regularly use the Rowe building (94%) than it was for students who do not regularly use the Rowe building (88%). Therefore, the desirability of a green roof isn't limited to SRES students and a large proportion of students overall seem to be strongly in favour of a green roof.

Use rate also wasn't confined to SRES students. 77% of students in the Rowe building said that they would use a green roof and 64% of students who do not use the Rowe building said that they would visit the green roof. Therefore, we believe that installing the green roof should be viewed in terms of its effect on the entire student population, since even people who don't regularly use the Rowe building would be interested in using its proposed green roof.

3 – Feasibility Analysis

a) **Environmental**: Our environmental analysis used the following benefits as criteria: storm-water retention, water filtration, reduction in energy consumption, preservation of biodiversity, habitat preservation and moderation of the urban heat island effect (Table 3). We measured these benefits, and then deducted from them the following costs: water use, fertilizer and pesticide use, waste material and transportation of materials (Table 4). We found that intensive accessible without planters had the highest benefit (16-46%), followed by extensive inaccessible (14.5-41.5%) and extensive green roof (13-40%). The highest economic cost was borne by the conventional roof (-37%), and second highest cost was for an accessible patio with planters (17-41% cost).

b) **Social**: The criterion we investigated were safety, impact on Dalhousie's reputation, The surveys indicated student interest in having student access to the roof, which was gained the most votes by Rowe (38%) and non-Rowe students (36%) alike for which characteristic would be most important to have on an ideal green roof. Student interest in having an accessible roof influenced our weighting of social feasibility of installing a green roof. Our results gave the highest rating out of 50 to intensive accessible roofs (36), second highest to extensive inaccessible (28) and last to extensive accessible (26) (Table 6).

c) **Economic**: Overall, the most economically efficient was the current roof (0$). After 5 years, the second most efficient would be the extensive inaccessible ($40,015), followed by extensive accessible ($71,403), and intensive accessible without planters ($198,575) and then with planters ($247,025).

Final Feasibility Analysis

In the final tabulation, the most feasible option was found to be intensive, accessible roof without planters (Table 12). Interestingly, this option was found to be most feasible both with equal weighting and with the weighting determined by students (Figure 10), which verifies its overall feasibility. The next most feasible option was extensive inaccessible, followed by extensive accessible, intensive accessible with planters and finally, the conventional roof. Clearly, it is more feasible to begin installing a green roof on campus than to leave a conventional cover on a roof specially designed to hold a green roof.

Consideration of Findings in Light of Existing Research

Our case studies of green roofs worldwide revealed the feasibility of installing green roofs in various locations, and allow us to learn from others when thinking about installing one on Dalhousie campus. We therefore hope to show how cities have installed green roofs, what benefits and costs they have incurred in the long-run and how they have addressed various problems by installing a green roof.

Cities and communities alike have been leaders in green roofs across North America. Portland, Oregon has been a prime leader in the green roofing movement. Their original motivation was to fight sewer overflow, which is pollution their water. They have created a policy that “all new city-owned buildings are required to be built with a green roof that covers at least 70 percent of the roof… When practical, all roof replacements must also include a green roof.” Portland has already built approximately two acres of green roofs, and has committed to double that. (TGR: Making Green Roofs Happen) Chicago, Illinois started building green roofs in a reaction to growing concern of the urban heat island effect on air quality, public health, and aesthetics. The city offers financial incentives for builders including green roofs in their plans. "As of June 2004, Chicago has more than 80 green roofs over municipal and private buildings in various stages of installation. The total area of these roofs is over [90 thousand square metres]." (TGR: Making Green Roofs Happen) Basel, Switzerland installed 85,000 m^2 of green roof in 1996/1997, which resulted in covering 15 percent of city flat roofs. Munster, Germany by 2002 had 12,000 m2 of green roof and Stuttgart, Germany has greened 105,000 m^2 of its rooftops.

Toronto, for example, has a number of green roofs gracing the tops of their buildings. Toronto Botanical Gardens installed a 130 m^2 green roof on an existing building in 2005. "The Sears Merchandise Lofts Building in downtown Toronto was converted from a department store to a multi-residential condominium building with a 929 m^2 intensive green roof that was installed in 2000 with accessible public pathways, decks and 8 garden beds. Mountain Equipment Co-Op in downtown Toronto installed an extensive green roof of 600 m^2 during the construction of the building in 1998." Earth Rangers Centre in Woodbridge just north of Toronto is using their 1,394 m^2 green roof to lead education, wildlife rehab, & research centre (TGR: Our Experience).

Universities have also begun to follow the initiatives of cities. Understandably, universities are often a community or small city in them selves. Universities are microcosms of society; they are institutions, which import and export goods and services, they produce waste and consume energy, include a governmental system on many levels, and there is a sense of belonging to a specific community. Harvard University has an extensive green roof of 465 m^2. University of Maryland in Shady Grove this year has put in a roof of 1.7 k m^2. Michigan State University in 2000 put in a green roof of 178 m^2, and a second one in 2004 at 325 m^2. The university in Basel, Switzerland has covered an area of 1 k m^2.

"Ryerson University in downtown Toronto constructed a 743 m^2 green roof during the construction of the new Engineering building in 2004. The University of Ontario located in Oshawa, just east of Toronto in 2004 installed two green roofs that total 836 m^2. York University in north Toronto, in 2001 installed a 1,874 m^2 green roof during the construction of the Computer Sciences Building. It is inaccessible but is part of the site's storm water management solution." (TGR: Our Experience)

Beyond physical implementation of green roofs at institutions, there are a number of research projects currently underway to assess the feasibility of a green roof on individual campuses. (Green Roof Plants: Research and Development) North American leaders in current green roof research include Saint Mary's University, Penn State University, and North Carolina State University. These thorough assessments are needed as climates and building types vary across campuses.

Penn State has researched in great detail, including roof membrane testing, building heat flux and energy use, storm water runoff, and plant growth and spread. Their study showed that green roofs retain over 45 percent of rainwater. (Penn State Green Roof Research, 2004) Another piece of their research includes 6 test buildings for green roofs, 3 with and 3 without green roofs. For these test areas they will collect data on rainfall, solar radiation and temperature.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 11: Photo from Penn State University research on green roofs illustrating roof

Water runoff with and without vegetation filtration. (Penn State, 2004).

Research at North Carolina University focused on water runoff quality. Their studies found that green roofs reduced water runoff by over 50 percent. (Moran et al., 2005) They also concluded that the gaps remaining in this field of research is the relationship between the soil medium used and the plant growth, climate-dependent water retention, and soil moisture content. Saint Mary's University has recently received funding to study environmental benefits of green roofs in a maritime climate by using test roof plots. Environmental factors they will be focusing on include reductions in building energy consumption and storm-water runoff specific to climate.

Interestingly, there are no examples found which considered social indicators within the research. Many projects focus primarily on environmental benefits, and secondly on economic factors. There were no indications of assessing the feasibility of a green roof based on sustainability, incorporating social, economic and environmental factors. In Dalhousie University's 2005 Environmental Problem Solving: 3502 class there was a thorough analysis done of the possibility of implementing a green roof on top of the future commons area, and this analysis looked at sustainability in depth. (Cooper et al., 2005)

We therefore hope that Dalhousie University can learn from the strengths and weaknesses of the aforementioned approaches to installing green roofs and research of green roofs. Now that we have investigated implications for other green roofs worldwide, we will now look at implications of our research towards our specific site.

Implications

According to our results, Dalhousie should seriously consider installing an intensive, accessible green roof without planters on the Kenneth C. Rowe Management Building since this option is far more desirable in the long-run than the current roof. We also believe that our feasibility analysis has yielded some theoretical and practical recommendations pertaining to the specific site:

- Use plants that are native, drought-resistant succulents.
- Sectional design will decrease current cost of roof maintenance, available as Green Grid Modular System (McCullough, 2001)
- Install guardrails to address safety concerns.
- Seek short-term installation funds externally if they are unavailable through Dalhousie; in the long run, the benefits of having a green roof far outweigh the costs.
- Submit fundraising proposals to the Canadian Government, Ecology Action Centre and environmentally-conscious companies in Halifax.
- Seek private funding from neighbouring households in return for having open neighbourhood access to the green roof. (this strategy was successfully employed in fundraising for the Computer Science Building; neighbours gave money in exchange for open public access to computer accounts within the building)
- Install roof starting with small parts if economic concerns prevent the roof from being installed in its entirety. These small sections can act as test spots for later initiatives, and can help to garner support throughout the community. It may even be beneficial to start small, and begin with extensive, inaccessible plots until support is gathered enough to put in some more expensive roof options.
- Encourage publicity of green roof through summer theatre performances on roof, press releases, Dalhousie recruitment literature.

Conclusions

Our project identified barriers to the installation of a green roof to be primarily economic, and social and technological concerns that tended to be economized. We believe that our feasibility analysis is thorough, and shows that, through the use of full cost accounting, the benefits accrued from the installation of a green roof far outweigh the initial costs. We have also proven that the most feasible roof option for the Rowe building is an intensive accessible roof without planters.

It is hoped that the results of this report are considered not only in regards to the Rowe Building, but are also used for the design and construction of future buildings on the university campus. Furthermore, it is hoped that the information presented in this report is of value to Dalhousie University and other institutions undertaking sustainability audits and initiatives. We hope that this project also supports research into quantifying qualitative variables in feasibility analyses and of proving the feasibility of green roof initiatives.

Recommendations for further research

- Assess feasibility of greening roofs on the Performing Arts Centre, LSC and Risley Hall.

- Research various models of decision-making and management in order to determine which styles are most effective in the long-run.

- Investigate various methods of quantifying social and aesthetic benefits. Social aspects of feasibility were found to be lacking in many of our aforementioned case studies. We believe that such effects must be included in order to create a thorough feasibility analysis, especially since 52% of student surveys indicated social and aesthetic criterion as their first consideration when deciding whether or not they were interested in having a green roof on campus.

- Investigate which community groups and associations would be interested in funding the installation of a green roof, and map their interests in it to build consensus about what should be included in the final design for the green roof.

- Investigate possibility of growing plants that can be sold for economic benefit. These might include either plants that can be used to make ink, or plants that can be sold for food. Some groups may be looking for a site that can be used for urban gardening, and may be willing to pay Dalhousie to rent this site in the summer, and proceeds can be used to maintain the roof year-round.

We would like to thank all the students surveyed, and all the individuals interviewed for their time and consideration.

Appendix 1

Opinions of Students that Use the Kenneth C. Rowe Building Regularly Regarding Green Roofs

A green roof is a roof that has been constructed or retrofitted that supports vegetation (i.e. green space on a roof).

1. Do you use the Kenneth C. Rowe Building regularly?
    a) Yes
    b) No
2. Would you support the installation of a green roof on top of the Kenneth C. Rowe Building?
    a) Yes
    b) No (Skip to question 4)
3. If you would support the installation of a green roof, which type would you prefer?
    a) A green roof that contains low-growing, lower maintenance plants (e.g. grasses, moss, herbs)
    b) A green roof that contains a greater plant diversity (e.g., lawn, perennials, bushes, trees)
    c) A green roof that contains a flower garden
    d) A green roof that students can access
    e) A green roof that can produce food (e.g. vegetable garden)
    f) A green roof with additional non-plant features (e.g. benches, tables, walkways, etc.)
    g) No preference
    h) All of the above
    i) Other: ____
4. If there was an accessible green roof on the Kenneth C. Rowe Building, would you visit/use it?
    a) Yes – Regularly
    b) Yes – Occasionally
    c) Maybe
    d) No – But like the idea of having one anyway
    e) No – Indifferent to the idea
    f) No – Dislike the idea
5. Would you like to see green roofs on any other building(s) on campus?
    a) Yes
    b) No (Skip to 7)
6. If yes, which ones?
    a) Computer Science Building
    b) Dunn Building
    c) Henry Hicks Building
    d) Life Sciences Centre
    e) Marian McCain Building
    f) Rebecca Cohn Arts Centre
    g) Tupper Building
    h) Weldon Law Building
    i) Any of the above
    j) All of the above

k) Other: ________________________________

7. What factor(s) influenced your answer to the questions 2 and 5?
    a) Aesthetic
    b) Economic
    c) Environmental
    d) Health
    e) Social
    f) All of the above
    g) Other: ________________________________

Comments:
____
____
____
____

<u>Appendix 2</u>

Interest of General Student Population in Having a Green Roof Installed on Campus

A green roof is a roof that has been constructed or retrofitted that supports vegetation (i.e. green space on a roof).

1. Would you support the installation of a green roof on any building(s) on campus?
    a. Yes
    b. No (Skip to question 4)
2. If yes, which ones?
    a. Computer Science Building
    b. Dunn Building
    c. Henry Hicks Building
    d. Kenneth C. Rowe Building
    e. Life Sciences Centre
    f. Marian McCain Building
    g. Rebecca Cohn Arts Centre
    h. Tupper Building
    i. Weldon Law Building
    j. Any of the above
    k. All of the above
    l. Other: ____
3. If you would support the installation of a green roof, which type would you prefer?
    a. A green roof that contains low-growing, lower maintenance plants (e.g. grasses, moss, herbs)
    b. A green roof that contains a greater plant diversity (e.g., lawn, perennials, bushes, trees)
    c. A green roof that students can access
    d. A green roof that can produce food (e.g. vegetable garden)
    e. A green roof with additional non-plant features (e.g. benches, tables, walkways)
    f. No preference
    g. All of the above
    h. Other: ____
4. What factor(s) most influenced your answers about whether or not you would support green roof installation on campus?
    a. Aesthetic
    b. Economic
    c. Environmental
    d. Health
    e. Social
    f. All of the above
    g. Other: ____
5. If there was an accessible green roof on the Kenneth C. Rowe Building, would you visit/use it?
    a. Yes – Regularly
    b. Yes – Occasionally
    c. Maybe
    d. No – But like the idea of having one anyway

   e. No – Indifferent to the idea
   f. No – Dislike the idea
6. If there was an accessible green roof on another building, would you visit/use it?
   a. Yes – Regularly
   b. Yes – Occasionally
   c. Maybe
   d. Only if it was on one of the buildings that I indicated for question 2
   e. No – But I like the idea of having one anyway
   f. No – Indifferent to the idea
   g. No – Dislike the idea

Comments: ____

Appendix 3: Interviews

Leif Fuchs, architect at John Dobbs and Associates:

1. Who pushed for the integration of green roofs into the plans for the Rowe building?

----One of the schools of the faculty of management (School of Resource and Environmental Studies) was looking for an exterior patio with an opportunity to plant flowers and herbs. In addition the faculty wanted an exterior area for barbecues and the like. The site is completely filled by the building, so the roof was the only place to go.

2. Did any structural changes have to be made to the plans to account for the added weight of a green roof?

----Only very minor- the structure is a suspended concrete slab, so there is a bit of extra reinforcing in the designated area.

3. What is the size of the area designed for the green roof on the Rowe building?

----The area is about 30 ft x 40 ft.

4. Was the green roof meant to be intensive or extensive?

----This would be up the user; we only provided some space for it. In our discussions with the user groups, the plans were described more as a patio with big planters than a "green roof".

5. Do you know the estimated energy savings of having a green roof? If so, what are they?

----In our case the area is too small to make this a consideration (even if it were a continuous green roof rather than just planters and pavers). There is a lot of research out there about this topic which you should check out. A lot of it comes from Germany where green roofs are a lot more common than around here. But energy savings are not the reason to install a green roof. During the heating season, the soil will be wet most of the time, which destroys the insulating effect of the dirt. In the summer though, evaporation can cool the roof down, which reduces the need for air conditioning. But if the soil dries out, the effect is not very strong. The most common argument for green roofs in a country like Germany is to reduce the amount of rain water directed to sewers, by keeping the water on-site.

6. Why was the installation of a green roof on the Rowe building delayed?
----To bring the project in on budget, numerous cuts to the original program were made, and this was one of them.

Additional Information:

It turns out the concept of the 'roof meadow' to cover the entire roof area never went beyond the 'nice idea' stage. The cost vs. benefit was the main consideration. There is no direct pay-back to the owner for this feature. We focused our efforts on sustainability measures that reduce the maintenance and operational costs of the building.

Best of luck with your project!

Philip Lee - Summary

I called Philip Lee from Facilities Management to find out what the surface area of the green roof would be. He told me that the total surface area of the Rowe Building's roof is approximately 6135 square feet and that approximately 40% of it is permanently covered with mechanical equipment, so no green roof could be put in those areas. Of the remaining roof, there is a 25ft x 20ft area on the south end of the building that is currently unused and apparently looks on the diagrams as if it is where the green roof was intended to be placed. (He said there are what seem to be some plants drawn there on the diagram.) He also pointed out that since it is south facing it would get the most sun and so it would make the most sense to put a green roof there.
According to Philip Lee's estimates, there is also a 22ft x 60ft section on the east side of the roof, as well as a 40ft x10ft section on the lower terrace, that both appear to be currently unused.

Kendall Taylor MRAIC, LEED AP Project Manager, Capital Projects – Buildings, Real Property & Asset Management

---------------EMAIL #1 Amber Mitchell -------------

Mr. Taylor,

I am a third year Environmental Science student at Dalhousie University. My

Environmental Problem Solving class is assessing campus sustainability in different areas, and my group is conducting a study to determine the feasibility of installing a green roof on the Dalhousie's newly constructed Kenneth C. Rowe Management building. (As you may already know, the building was originally designed to support a green roof but one was never installed.)

I am currently analyzing the economic costs/benefits of installing a green roof on the building. If I find out the surface area of the roof in question, would you be able to provide me with some estimates, or refer me to someone who can? In particular, I am looking for general estimates of the financial costs involved in the installation and maintenance of an extensive green roof and of an intensive green roof. I was also hoping that you may be able to inform me of the whereabouts of any already existing green roofs in the HRM that you may know of. I would greatly appreciate it if you could help me find out some of this information, or if you could provide me with any other information that you think may be relevant.

Thank you very much for your time!

Sincerely,

Amber Mitchell

----- EMAIL #2: Response from Kendall Taylor -----

Hello Amber,

It is not difficult to address the costs of the Green Roof (you could expect to pay \$12-15/ ft^2 if the structure has already been designed to accommodate). The difficulty is in reviewing the benefits as they relate to the type of building and the structure. Is it air conditioned?

I doubt the Dalhousie building was designed to accommodate an intensive green roof.

I was the designer for the BIO Energy centre in /Dartmouth which was the first Extensive system in Atlantic Canada.

If you are looking for other information you can try Green roofs for Healthy Cities; BCIT-Maureen Connelly; or Karen Liu at NRC in Ottawa. If you 'google' them you should find some links.

Hope this helps,

I spoke to several of the students at your school recently one of which was Zoe Caron.

I am a director of the Canadian Green Building Council. Let me know who your professor is, I would like to connect and maybe come and talk about green roofs and Green buildings in general.

----- EMAIL #3: A follow-up email from me to Kendall Taylor -----

Hello again,

Thank you for responding so quickly to my previous email. It is funny that you mentioned Zoe Caron, because she is another member of the group that is working on this particular project for our class.

I have 3 more questions to ask you...

1) Are there any green roof contractors, manufacturers, suppliers, etc. in Atlantic Canada that you could provide contact information for?

2) Just for comparison's sake, what is the approximate price (per square foot) of an intensive green roof?

3) If I or anyone else in my group thinks of any more questions to ask you, would you be willing to accept phone calls?

My professor's name is Gregor MacAskill (gregormacaskill@eastlink.ca). I think it would be great if you shared some of your knowledge about green buildings with Dalhousie students! This semester is pretty much over, but if you are ever interested in speaking to students in future semesters then I am sure Dalhousie environmental science students and professors would love the idea. The usual professor for this course is Tarah Wright (tarah.wright@dal.ca), but I believe she is still on maternity leave.

Thanks again!

Amber

----- EMAIL #4: Kendall Taylor's Response -----

To answer your questions;

1. You can contact Garth Bradshaw at 866-0255. He was the contractor for the green roof at BIO. Two prominent manufacturers are 'Soprema' and 'Hydrotech'.
2. I really do not know what intensive systems would cost. You are obviously looking at 3 times the amount of soil therefore 3 times the amount of weight on the structure. You can plant larger species and probably absorb more rain water but other than that I doubt the increased costs would offer any other benefits. Light weight extensive systems are the way of the future.
3. You can certainly contact me

Brenda Smart, Administrative Assistant for Karen Beazley

What role has SRES had in the implementation of green building technology on campus?

---SRES has fought for a green roof. They were strongly involved in the design of the Rowe Building. Every Faculty in the new building was asked about their needs for the building, and I think that everyone's needs were mostly met, except for the last round of budget cuts.

Were faculties brought together so that their needs could be negotiated?

---Yes, they continued to have many meetings. I found the dynamics between the different faculties very interesting.

Who pushed for the integration of green roofs into the plans for the Rowe building?

---SRES

Did any structural changes have to be made to the plans to account for the added weight of a green roof?

---Yes, they added extra support throughout the area between the back staircase and the skylights of the atrium.

Did they make any other changes to their plans to account for a green roof?

---Yes, it's fully designed to hold one. They led power lines to the roof and installed water for an irrigation system. There's a back staircase that leads all the way to the top, and an elevator to the roof so that they won't have to lug dirt up the stairs. I really wish that they had put in a green roof, and I ask them every so often how they're doing with getting one. The view off the top of that building would be just amazing, and I would love to just walk up the stairs this spring and enjoy my lunch in a roof-top garden.

Do you know if they have plans to bring in picnic benches and other things so that people can enjoy their time up there, or if they were just planning on putting in plants?

---I don’t think that they ever got around to designing the actual gardens themselves. I think that that was one of the things that were cut from the budget.

Why was the installation of a green roof on the Rowe building delayed?

---They ran out of money.

Did the whole building go over budget?

---Yes, it went over-budget and they made many cuts to the building.

I think that the problem is that many people only look at the very short-term when they try to handle their money. Also, when people hear about something new and green, they’re often scared to try it.

Do you know what the next stage is for SRES in trying to get a green roof on the building?

---I think that they’re talking about writing a research proposal.

Have cost-benefit analyses been conducted for the implementation of green roofs on campus?

---Not as far as I know. I think that they’re talking about putting one together, but everyone’s always so busy.

Is there research benefits associated with housing SRES in a LEED-certified building with a green roof?

---Yes. My understanding is that this is one of the main reasons that they want to put on a green roof. To get the students to work on the plants.

Thank you for your time.

Dr. Karen Beazley

1. How can we be most successful in figuring out why the green roof wasn’t installed, and figure out if it’s feasible?

- talk to key actors
- summarize stumbling blocks
- look at current context
- look into submissions for funding
- prepare a preliminary feasibility analysis

2. Why was installation delayed?

- budget cuts
- hard to prioritize
- need a source of outside funding where money would be locked into being used for a green roof

3. What concerns are there about having a green roof?

- high maintenance
- important inputs
- too intensive
- high energy expenditure
- lack of maintenance
- might not be done properly
- lack of sustainability of project
- might be a liability (Leaks)
- lack of time and energy
- fear of new technology

- lack of momentum
- unequal power between departments, since business school is much larger than the other ones
- difficult to receive more money for the Rowe building, since so much was just invested and the building went over budget
- budget cuts for Facilities Management

Ron Hubbart, Associate to the Dean of Management

1. What are the barriers to the installation of a green roof on the Rowe building?

- high cost of installation ($30,000-$40,000)
- SRES used its money on a wet lab instead of a green roof
- Lack of a driving force (and this has to come from faculty not students since students are only here for a few years and then leave). If there is no primary driving force, then problems will arise in the long-run due to a lack of maintenance.
- Dalhousie isn't pushing for it, and no one is looking into external relations

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