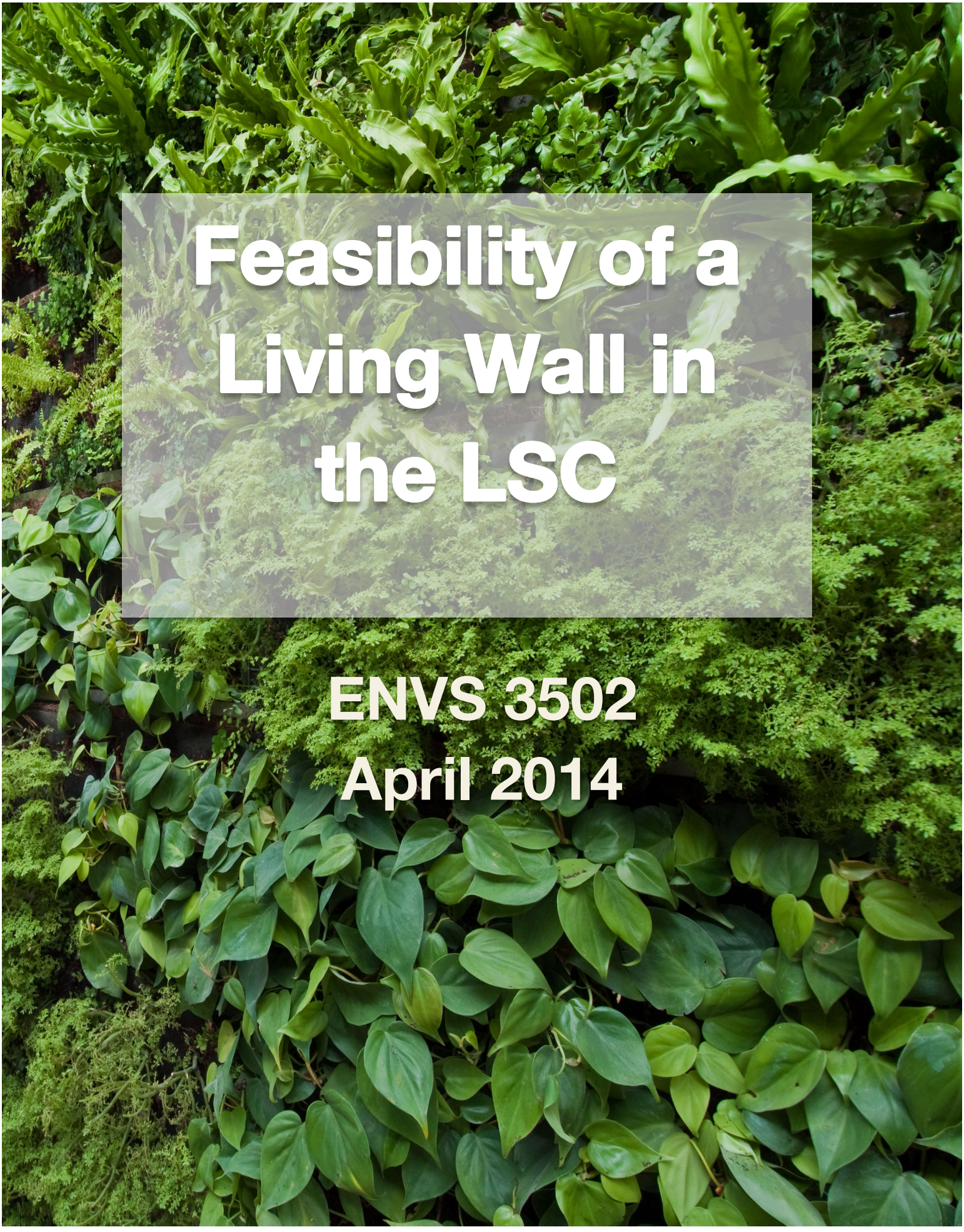

Feasibility of a Living Wall in the LSC

ENVS 3502

April 2014

Authors' Details

Samantha Miles
BSc Biology

Hope Perez
BA Environment, Sustainability, & Society
Sociology & Social Anthropology

Michelle McGee
BA Sustainability
International Developmental Studies

Joanna Brenchley
BS Environmental Science
Environment, Sustainability, & Society

Brady Crewe
BA Environment, Sustainability, & Society (Honors)
International Development Studies

Table of Contents

Executive Summary

Sustainable architecture is becoming increasingly popular on university campuses. Living walls provide institutions the opportunity to improve existing infrastructure while implementing sustainable technology. Not only do living walls improve indoor air quality, they contribute to a healthier, more comforting indoor environment.

Dalhousie began renovating the Life Sciences Centre (LSC) in 2008. While several small retrofits have been completed to improve the space, little has been done to improve the aesthetics of the building. The current design is predominately concrete, with very little green space or natural light. In order to improve the learning environment for faculty and students, this report proposes the implementation of a living wall in LSC. A living wall is a vertical garden that filters toxins out of the air using a unique biofilter.

To determine the feasibility of a living wall, a literature review and two case studies were conducted. This research reaffirmed our predictions concerning the benefits of indoor green space. These finding were developed into a framework that assessed potential cost, ideal plant species and the technology required to ensure a living wall would be successful.

Based on the research and the framework, it is very clear that a living wall in the LSC would be a great investment for Dalhousie. Although, the proposed space in the LSC would require additional technology to improve access to natural light to ensure the survival of living wall. Similar technology was successfully utilized on the NSCC campus.

Finally, this report suggests that Dalhousie begin by constructing a test wall in the proposed location. This wall would be on a smaller scale and would allow Dalhousie to determine which plants work best. Additionally, we encourage the university to conduct a more in-depth cost-benefit analysis of a living wall.

1. Introduction

The Life Science Centre located at 1355 Oxford St is almost entirely concrete with few windows, a confusing labyrinth of tunnels, hallways and staircases and a notably cold and unfriendly stone facade. Opening over 40 years ago, the Life Sciences Centre (LSC) is home to the largest collection of academic researchers in Atlantic Canada. Over 200 researchers, 450 graduate students and 3,000 undergraduate students use the LSC regularly. In addition, besides the small 'food court' on the second floor, there is nowhere to sit, socialize or connect with fellow staff or students.

The Life Science Centre (LSC) has recently undergone its first major retrofit since the building was built over 40 years ago. In 2008, Dalhousie began the LSC retrofit project, with a budget of $28.7 million and a timeline of roughly 3 years to complete. However, for a building with such an ambitious retrofit, just recently completed, it is surprisingly difficult to see where the money went. Not only is there a complete lack of green, and indoor environmental quality, but little if any attention has been paid to aesthetic improvements, one of the most important factors in student health and wellbeing (Kaplan 2001). An improvement that could potentially build on the original objectives of the 2008 retrofit, while providing additional benefits in the realm of aesthetic appeal, could be a living wall installation.

To ensure that Dal students have an amazing student experience, we need to create better places on campus for all aspects of university life. It's vital that our campus evolves to keep pace with increasing enrolment, changing technology and a variety of student's needs. Vertical greening offers an outstanding number of public and private benefits including aesthetic, social, ecological and environmental.

A living wall is a low maintenance, vertical garden that can be installed on an interior or exterior wall of a building. They have a variety of benefits from improving an interior aesthetic to gaining LEED certification points. Green walls can contribute to the energy efficiency of a building by absorbing solar radiation and thus lessening the cooling requirements of a building in the warmer months. Additionally, they have been proven to ease stress, fatigue, and increase productivity. Other potential health benefits are derived from the wall's ability to dampen noise pollution, and improve air quality (van den Berg, 2010).

Our study focused on a single wall in the atrium of the LSC. This wall was chosen due to the central location, large size and we feel the benefits of a living wall will far outweigh the benefits of the large screen projection currently on this wall. This project did not include studying the feasibility of any additional/complementary infrastructure such as seating, skylights, etc. Instead,

it is focused solely on the implementation of a living wall, within the constraints of the current indoor environment. First, we conducted a literature review to determine the benefits and challenges of implementing a living wall. We will then limit our scope to three case studies (St Mary's and NSCC), to make an appropriate selection of the components of a successful living wall installation. Our study did not include surveys, interviews or any other measures traditionally used to determine desirability, rather, it focused solely on the feasibility of the installation. That being said, a primary limitation of our study was the inability to attain a comprehensive understanding of Dalhousie budgetary constraints and liberties. Therefore, an installation that is 'feasible' will be defined as one that can be installed and maintained without any extraordinary expense (in comparison to the framework determined by case studies), while also fitting into the structural context of the space.

In conducting the present study, our goal was to deepen our understanding of why certain indoor green spaces may be connected to stress and mental health. Our research question delves into the feasibility of living walls, as an approach for a healthy urban environment in the LSC and what benefits it would have on the staff and students using this building.

1.1 Objectives

The primary goal of our research was to study the potential installation of indoor green space in the LSC. More specifically, this final report discusses the available technology and feasibility of a living wall in this space.

Overall, our research seeks a better understanding of:

- The importance of indoor living space on health and productivity for students and faculty.
- The materials required for a successful indoor living wall.
- The feasibility of implementing a living wall in the LSC.

This information will be presented using the following deliverables:

- A literature review to assess the technology and benefits of living walls.
- Case studies of buildings with living walls to address the feasibility and maintenance required.
- Guidelines for the appropriate plants and infrastructure for a successful living wall in the LSC.
- A final report that contains all of our research and recommendations.
- A Pecha Kucha presentation that will give an overview of our findings and recommendations.

Invite Dalhousie executives to Pecha Kucha night and sending our final proposal to Dalhousie architecture committee and other board members

2. Methods

Firstly, we conducted a literature review to assess the technology and benefits of living walls. We then conducted two case studies of institutional buildings with living walls to address the feasibility and maintenance required. We examined the living wall in the St. Mary's University Atrium and the living wall in the NSCC Centre for the Built Environment on the Waterfront Campus. We held an interview with the Director of Maintenance and asked him a list of general knowledge questions pertaining to the wall. Similarly, we corresponded with the Landscape Specialist at NSCC and asked the same questions. These questions were focused on obtaining information about various characteristics of their living walls, including:

- Size
- Installation costs
- Maintenance costs
- Appropriate temperature
- Technology utilized
- Plants used
- Date installed
- Location
- Benefits

We then used this knowledge to create a framework that outlines the ideal characteristics of a living wall. We looked at what made the case study walls successful and created categories that we could then use to analyse the potential of hosting a living wall in the area we chose in the LSC. As a group, we decided that this wall would be best for the implementation of a living wall because it is in the area that several wings of the building converge. Furthermore, despite the limited seating, it tends to be a place where people sit and have a break.

To create the feasibility framework, we looked at the two case studies and outlined the criteria that were most important to analyse. We chose these criteria to be:

- Location and Size
- Cost

- Plant Species
- Technology
- Lighting
- Temperature and Humidity
- Maintenance

These become the skeleton of our framework. To analyse whether a living wall is feasible in the LSC, we went through the criteria and comparing the conditions in the Dalhousie building to those in the St. Mary's University Atrium and NSCC's Centre for the Built Environment, using them as "ideal walls".

3. Literature Review

A multitude of research findings have indicated urban green spaces can be used as a resource in promoting public health. These studies show there is an interesting dynamic between architecture and the natural environment. Researchers have suggested that green spaces promote overall general health by restoring mental fatigue and aiding in stress management (Kaplan, 2001). Stress-induced illnesses are currently a global problem. According to the World Health Organization (WHO), mental health disorders and cardiovascular diseases are expected to be the two major contributors to illnesses in all parts of the world, with mental health disorders calculated for all age groups and both sexes, by the year 2020 (WHO, 2008). People often deliberately seek environments that they find appealing for relaxing, to allow them to recover from demanding situations and tasks, and natural environments are frequently sought for this purpose (Grahn et al., 2010). Today most research results' converge, indicating a positive connection between how often or how long people stay in urban parks or nature areas and restoration from stress and mental fatigue (Grahn et al., 2010).

Vertical greening systems can be classified into façade greenings and living walls systems according to their growing method. Green facades have historically been used mainly for ornamental or horticultural purposes, and involve the establishment of climbing vegetation which is rooted in the ground or planters, and which is then trained to grow directly on wall surfaces or on an overlying wire or trellis framework (Dunnett and Kingsbury, 2008; Köhler, 2008). Living walls or green walls are distinct from green facades in that they support vegetation that is either rooted on the walls or in substrate attached the wall itself, rather than being rooted at the base of the wall (Köhler, 2008).

Green walls are a component of urban green infrastructure and contribute to a range of ecosystem services including, habitat provision for urban biodiversity, intercepting precipitation and reducing run-off rates, screening out aerial particulate matter and improving air quality, attenuating noise, contributing to psychological well-being and improving the aesthetics of the cityscape (Cameron, Taylor & Emmett, 2013). The role of green infrastructure in city cooling, reducing energy loads on buildings and improving human thermal comfort has warranted much attention over the last two decades, largely driven by concerns over climate change and urban expansion (Pauleit et al., 2005).

Green walls can contribute to the energy efficiency of a building by absorbing solar radiation and thus lessening the cooling requirements of a building in the warmer months. Additionally, they have been proven to ease stress, fatigue, and increase productivity. Other potential health benefits are derived from the wall's ability to dampen noise pollution, and improve air quality

(van den Berg, 2010). Office workers are reported to be less tired and more healthy when they have access to plants or window views, and prefer work environments with living plants and window views, compensating for a lack of window view by decorating with more indoor plants (Raanaas et al., 2011). Its been noted in literature for over twenty years that exposure to plants may have a restorative effect on attention during breaks from work (Kaplan, 1989).

Greening the inside of buildings can be an opportunity to combine nature and pre-existing industrial areas. Indoor plants can significantly improve indoor air quality, not only because plants can absorb carbon dioxide and release oxygen through photosynthesis, but also plants can reduce air-borne contaminants such as nitrogen oxides, volatile organic compound (VOCs), and dust (Wolverton & Wolverton, 1993). An experiment conducted by Ottelé et al. (2010) in the Delft University of Technology, demonstrated that indoor vegetation and plants could reduce number of particulates (<10 mm) in the air, which have been known to cause long terms threats to human health.

4. Case Studies Results

4.1 Saint Mary's University

Table 1.0 St. Mary's University case study on their living green wall located in Atrium building since 2009

Size	4 stories, 20x40 feet
Installation Cost	approximately $300,000 (CAD)
Maintenance Cost	approximately $15,000 (CAD)
Appropriate Temperature	21-22 ° C
Technology Utilized	"synthetic rooting media" with a water pump that nourishes plants from the top of the structure
Plants Used	approximately 1,000 plants, 14 tropical species
Date Installed	2009
Location	Atrium Building/Global Learning Commons on Saint Mary's campus that connects the Science Building, Patrick Power Library and Burke Building
Benefit to community	• improved air quality • reduces heating/cooling demands • reduces energy costs • visually appealing • relieves stress of faculty and students • helps to create a creative and social learning environment

5.1.1 Summary

In 2009, Saint Mary's University constructed a living wall in Atrium Building, also known as the Global Learning Commons. Characterized by its open concept design and focus on natural light, the Atrium reflects the most recent trends in sustainable architecture. In addition to the living wall, the building was constructed using sustainable materials and has a green roof. The living wall was designed by Nedlaw Living Walls Inc. and cost approximately $300,000 (CAN) to construct (Gary Schmeisser, personal communication, March 17, 2014).

Figure 1.0 St.Mary's University living wall

This was only a small fraction of the $17.5 million used to construct the entire building. As a main focal point, the wall had a two to three year warranty (Michael McCann, personal communication, March 21, 2014). In the initial years, Facilities Management faced several issues, including minor leaks. Since then, the wall has thrived in it's environment. Not only has the wall improved the indoor air quality, it has helped to create a social and creative learning environment (Gary Schmeisser, personal communication, March 17, 2014).

The technology used to create the wall was designed and pioneered by Nedlaw Living Walls Inc. Their unique three stage process combines biofiltration, phytoremediation and hydroponics to remove volatile organic compounds (VOCs) from the air. The ventilation system has fans that draw air from the indoor environment through the plant layer. Biofiltration simply means using plants to break down a contaminant (in this case air) into it's compositional components such as carbon dioxide, water and oxygen. The living wall is a closed system because the plant layer and soil is able to contain and eliminate toxins. In very basic terms, this constitutes the phytoremediation phase. Lastly, pumps circulate

water from the bottom of the wall to the top, in order to water and provide nutrients for the plant layer. The living wall in the Atrium uses a synthetic rooting medium to hold plants in place. In order for the plants to work properly, the humidity of the surrounding areas needs to be moist. If the water pumps malfunction, the ventilation system stops and will eventually dry out the plants. According to the Nedlaw website, one pass through their biofilter can remove up to 90% of harmful chemicals in the air. The Atrium living wall also uses a series of lights to ensure that all plants are able to photosynthesize. It is likely that the LSC will have to use similar lighting technology to ensure the plants are able to survive.

The wall requires relatively low maintenance and the university has not hired extra staff to care for the living wall. That being said, Gallant Interior Plants was hired to assist minting the living wall. Maintenance staff inspects the conductivity of the water, checks the fertilizers, and clear dead foliage (Michael McCann, personal communication, March 21, 2014). Dr. Susan Bjornson, is a professor and researcher at Saint Mary's University that specializes in beneficial insects and arthropods used in biological pest control. Along with a team of researchers, Bjornson conducted a study in order to discover what insects would be most beneficial to the living wall's environment. Biological pest control is a more sustainable solution to pesticides. Conventional pesticides are often toxic and harmful in an indoor environment. Two insects were selected for the living wall in the Atrium, the two-spotted lady beetle (A*dalia bipunctata*) and the Mealybug Destroyer (*Cryptolaemus montrouzieri*). A beneficial predatory species, these insects eat hazardous aphids that invade the plant environment. Maintenance staff is responsible for introducing more of these beneficial insects to the living wall when appropriate.

4.2 NSCC

Table 2.0 NSCC case study on their living green wall located in Atrium building since 2010

Size	4 stories, 42 x 24 feet
Installation costs	Information not disclosed
Maintenance costs	Information not disclosed
Appropriate temperature	20-22 ° C
Technology Utilized	• Hydroponics: a method of growing plants using a mineral solution in water, without soil. Mesh-like material holds plants in place • Two submersible pumps along with PVC piping leading the water up and over the wall • Fans that circulate the air, as well as help keep the temperature around the wall comfortable
Plants used	Tropical plants
Date installed	2010
Location	NSCC Waterfront Center for the Built Environment
Benefit to community	• Cooling effect • Soothing sound of trickling water • Visual appeal • Healthier, cleaner air • Better sense of community, offers a gathering place • Brings interest from other schools

5.2.1 Summary

The studied wall was installed with the building in 2010 in the Center for the Built Environment at NSCC Waterfront campus. It measures 42' in height and 24' in length and is 4 stories high. The plants were chosen based on several criteria. Firstly, the goal was to provide a clean, natural experience so the plants had to reflect these criteria. The other important variables were rooting structure, which is very important for wall stability and nutrient uptake and leaf form. The plants are bare rooted, which means that they are removed from soil and secured to the wall structure. NSCC is still working to find which plants work best, using a trial and error method. The most important element in the success of a living wall is the maintenance, namely the watering. The NSCC wall uses a system called hydroponics, where the plants are not in soil and receive all of their nutrients from the water. It is therefore imperative that water is circulated sufficiently. This is done using a series of pumps. NSCC also expects to add a flow sensor, which will be programmed to trigger an alarm read on internally on their computers to help keep optimum water levels. There are also a number of fans around the wall to increase the circulation of fresh air. The location that was chosen for this wall had enough natural light, but we were informed that there are a number of options for equipping the walls with additional lighting.

One person, the Landscape Specialist, maintains the NSCC wall. She is responsible for keeping the wall growing and operational, which includes getting outside help for mechanical issues. She spends between 25-30 hours per month on this wall. These walls have had very positive effects on the surrounding community. Firstly, they remove pollutants and chemicals from the air and expel oxygen rich air. People can feel the difference and thus want to spend more time around the wall. Because of this, as well as the wall's calming effects, groups of people gather around the living wall to socialize and study. Overall, it has created a very healthy, natural work environment.

Figure 2.0 NSCC living wall

5. Assessment of Viability for LSC

This study focused on a single wall in the atrium of the LSC (Figure 3.0). The two case studies have given a lot of valuable information in determining the feasibility of a living green wall in the LSC building. The information along with the literature has given enough data to determine the answer to the research question. Many factors have been considered and taken into account to determine the final outcome.

Figure 3.0 The selected location for the living wall located in the atrium of the LSC

Framework	*Case study 1*	*Case study 2*	*Potential in LSC?*
Location & Size	4 stories	4 stories	Yes, 2 stories
Cost	$300,000	-	Yes
Plant species	Tropical	Tropical	Yes
Technology	Hydroponics	Hydroponics	Yes
Lighting	Natural	Natural & additional	Little natural light, potential for additional lighting
Temperature & Humidity	21-22°1-	20-22°0-	Yes
Maintenance	Less than 5 hours per month	25-30 hours per month	Yes

6.1 Location & Size

Based on literature review and the NSCC and St. Mary's University's case studies, the living wall should be in a central location to maximize the benefits to student and staff health and wellbeing. The Saint Mary's wall is in a central seating area across from the library, providing students with a relaxed and inviting area to study and socialize. The NSCC Waterfront campus's wall that we focused on is in a hallway that gets a large amount of traffic from both students and faculty. Both case study walls measured 4 stories high. The location we chose in the LSC is a location that receives a high quantity of traffic from students and faculty and is the only area where people sit while on break. We therefore decided that it is a central location and thus follows the NSCC and SMU living wall models. Furthermore, it is only 2 stories high, potentially making the installation costs lower than our case studies and making the maintenance more accessible.

6.2 Cost

The cost is an important aspect of measuring the feasibility of the living wall in the LSC. The St. Mary's University wall cost about $300,000 for installation and they spent about $15,000 on maintenance each year. It is important to note that the wall was implemented at the same time as the building. The costs for the NSCC wall was not available. In 2008, budget for Dalhousie's LSC retrofit was approximately 24.8 million dollars. Based on this number, we feel that it would be economically feasible to follow through with the implementation of a living wall.

6.3 Plant species

The most common plants used on a green wall are tropical plants because they adapt well to the inside environment, if they get viable sunlight, sufficient water supply and a suitable temperature they will flourish. Originally it was thought that native plants would be used, however upon further studies it was understood that it was not possible to have a building filled with native plants. This challenge is due to the drastic seasonal climate change that the plants require (such as trees needing to drop their leaves). It was therefore decided that it would be more appropriate to use Mediterranean plants, which are used to warm and dry conditions all season long.

The NSCC went through a trial and error process of determining what plants suit their specific environment. They did so by designing a prop wall that was about 8 feet by 8 feet, allowing them to test out certain plants and gage their success rating. This could be a beneficial way of determining what plants would be most successful in the LSC because it will show which plants adapt well to that certain environment. Many of the plants at NSCC and Saint Mary's were chosen because of their ability to absorb and expel VOC's found in the air. They undergo this process by taking in these chemicals and pollutants through their microbial root hairs and expel clean, oxygen rich air. Once the plants are chosen they go through a difficult process of removing all the soil from the plants roots and placing them on the wall carefully, try to reduce any stress or damage to the rooting system.

6.4 Technology

The NSCC and Saint Mary's living walls both used a hydroponic system. This irrigating system only requires several pumps to circulate water. They both were equipped with two submersible pumps with PVC piping guiding the water up and over the wall. There are fans that circulate the air and also regulate the temperature, it is important to establish control and timing of the watering system. Sensor alarms could be added to notify about various aspects of the wall, such as the water level, temperature change, humidity change, technological failure, or the low level of lightening. Saint Mary's green wall has a built in air ventilation component, allowing for air to be pulled through the wall. They have installed an alarm system notifying if the pump stalls or stops working, allowing time to shut off the ventilation system. NSCC is looking towards adding on an alarm system to update about the water levels, making sure they stay at safe levels and temperatures. The fabric used throughout the green wall is coconut fiber (coir), which is good at water absorption and root anchorage. Behind the fiber are aluminum plenum and moisture barrier, ensuring the plants stay moist and secure. Although there are a number of mechanical parts that make the system operational, the technology is accessible and available so we feel that it could be easily implemented in our selected location.

6.5 Lighting

It is important to understand these microclimatic conditions as well as the amount of light required for plant survival, especially in indoor conditions, which may require supplementary light. The wall in the LSC is not in an area with abundant sources of light, in general the LSC is a dark building with few windows. This could potentially be the biggest drawback to the success of the green wall. The Saint Mary's green wall had to implement additional lighting for the bottom half of their wall because of the lack of light on the first and second stories. The LSC has far fewer windows then the Saint Mary's wall, meaning that the LSC would have to implement an abundance of additional lighting for the plants survival. This will increase costs and raise the energy input going into the wall.

6.6 Temperature & Humidity

The Saint Mary's green wall area has a temperature of 21°C/22°C. The humidity of the area is slightly moister than other areas because they do not want to risk the plants drying out. The temperature of the LSC is appropriate (room temperature at an average of 22°C) for the chosen plant species, though the plants chosen do not need an extreme change from normal temperatures.

6.7 Maintenance

Once the green wall has been constructed and plants have adapted well to their environment, the wall is fairly low-maintenance. The usual requirements of pruning, feeding and watering still apply to living walls. Establishing a well-understood maintenance regime with facilities management personnel, especially at the specification stage, will greatly improve the likelihood of survival of the wall. An existing maintenance staff is capable of handling the wall's duties. The green wall at Saint Mary's is relatively low maintenance is looked after by one maintenance member every three weeks. Their job is to ensure water levels are stable and to introduce more insects or fertilizer where they see fit. The NSCC wall is looked after by a landscape specialist, ensuring the pump system is still working, they also check on and clean the drip line at the top of the wall, ensuring that the flow of water never stops. The NSCC landscape specialist spends between 25-30 hours per month on the wall. The crucial aspect in maintaining their wall is to ensure the water never stops running, since their only source of nutrients come from water they need to be monitored to any diseases or damage every week. Based on the two case studies it has been shown that that varying walls require varying amounts of time and money spent on maintenance. For this reason, it is imperative that Dalhousie finds the system that suits our budgetary constraints.

7. Analysis & Discussion

The purpose of this study was to investigate the feasibility of a living wall installation in the LSC. This was done by establishing a framework of pragmatic living wall 'needs' that was informed by a literature review and two case studies.

This study has several positive implications. For one, after consulting an extensive array of literature on the benefits of living walls, it was very clear what was lacking; an examination of living walls in theory versus practice. This study attempts to bridge that gap by both acknowledging and moving beyond the rhetoric, and analyzing the successes and failures of living walls in practice. In doing so, we managed to produce a study that explores the feasibility of implementing a living wall in a specific location, a deliverable that can be used to respond to the gap among the literature. In assessing feasibility, a key part of our process was to determine not only what the challenges with implementation were, but also to identify opportunities within the space. In other words, we were responsible for identifying what resources the space/institution had and could capitalize on, and what resources the space/institution needed. According to our findings, there were two prominent challenges with the implementation of the model in the LSC. These included the following:

1) **Lighting.** As was determined from the St. Mary's case study, a significant amount of light is required to make the plants thrive. Despite the fact that the St. Mary's Atrium building is already subject to an abundance of natural light (glass ceiling, two story glass walls, etc.), additional row lighting was deemed necessary to the health of the plants. Because our chosen site in the LSC is exposed to significantly less natural light than the St. Mary's atrium, a more extensive review of auxiliary lighting costs and benefits would have to be conducted to determine feasibility of the location.
2) **Installation Costs.** It has been established through the literature review and case studies that the installation of a living wall represents a significant investment to the university. Because the St. Mary's wall was built along with the building, it could have likely cost less than a large-scale retrofit on an older building like the LSC would. Thus, a comprehensive site analysis would have to take place, to determine the structural challenges and limitations of a living wall installation.

Despite the many benefits of this study, there were also limitations. One prominent limitation included the inability to attain a comprehensive understanding of Dalhousie's budgetary constraints and liberties. It was difficult for us to determine whether the installation costs would be a challenge to implementation without understanding Dalhousie's budget for sustainable

retrofits. On the same thread, it was also difficult to understand what the final cost would be, because it was not feasible for us to do a comprehensive site analysis of the LSC. Because the structural constraints of the building is not publicly available information, we had to largely work around this challenge. Furthermore, our study was enormously dependent on available literature and local case study information that assess living wall installations in detail. There was an abundance of literature promoting the benefits of living walls, but very little that assessed the challenges during the installation process, or the required components for success.

For the sake of time, we delimited our study to analyzing one wall in the LSC, and two local case studies. In the future, there is plenty of opportunity for a more comprehensive study of an installation in the LSC. This is another reason that a report of this nature is extremely advantageous. Its usefulness is not limited to a study of this location but can be referred to during further investigations. These investigations could include applying the established framework to an additional location, either in the LSC or in another building. There is also room for the study to be added upon, in terms of bolstering the literature review, or adding another case study.

8. Conclusion & Future Recommendations

Our project has reached two primary conclusions about the implementation of a living wall in the LSC. The first conclusion was established through a literature review and through the comments from the individuals contacted for the case studies at both SMU and NSCC on the potential benefits and risks of living walls. Through said process, we have determined that Dalhousie staff, students, and additional users of the LSC would benefit from increased health and mental wellbeing, as well as a more aesthetically stimulating learning environment. These secondary health benefits are derived from several proven byproducts of living walls such as improved air quality, and decreased noise pollution.

The second conclusion we reached, through the analysis of comparable case studies (i.e. St. Mary's, and NSCC), was that the implementation of a living wall in the LSC is a feasible option to both improve campus health and wellbeing, and to build upon Dal's already well-established commitment to sustainable values and principles. This commitment is outlined by its very transparent framework of decision-making, which defines four pillars of sustainable action: policy and planning, monitoring, behavior, and retrofit and construction projects. A project like a living wall within the LSC would encompass several of these pillars of sustainable decision making. Despite challenges like costly installation fees and lack of natural light, this study has determined that the potential benefits of a living wall, along with the opportunities currently present in the space (), are enough reason to warrant a more comprehensive investigation. Such an investigation could include a more detailed cost-benefit analysis, or a survey among students of the potential desirability of a wall. Additional recommendations include the installation of a small test wall, such as the one utilized by NSCC. A test wall would determine how plants adapt to the LSC environment, and could be used to choose plants species for a future wall, or establish the optimal temperature, humidity, and light needed for the plants to flourish.

This study is important because of the increasing relevance of living walls in discussions of sustainability. Living walls are an emerging global technology and the success of living walls in countries such as France, Japan, Singapore, the USA and Canada has inspired many local designers to consider living walls in recent building projects.

The growing volume of international research data revealing the positive outcomes of living walls such as the lowering of surface building temperature and urban heat islands, improving urban hydrology and indoor air quality, etc, may increase the confidence of many designers to consider using this technology. The ability of a living wall to offer a more pleasant, healthier and more productive workplace together with lower building energy bills, are incentives that should have particular appeal to both building owners and developers.

Due to the many positive benefits of living walls, they are gaining interest from designers as a new building technology that can help improve our urban environment as well as lower greenhouse gas emissions. Living walls are an emerging technology that can help address climate change and offer a new way to green the built environment.

9. References

Buckhov, N.G., Drozdova, I.S., Bondar, V. (1995). Light response curves of photosynthesis in leaves of sun-type and shade-type plants grown in blue or red light. *Journal of Photochemistry and Photobiology B: Biology* 30, 39–41.

Carter, T., Fowler, L. (2008). Establishing green roof infrastructure through environmental policy instruments. *Environmental Management* 42 (1), 151-164

Cheng, C.Y., Cheung, K.K.S., Chu, L.M. (2010). Thermal performance of a vegetated cladding system on facade walls. *Build. Environ.* 8, 1779-1787

Dunnett, N., Kingsbury, N. (2008). Planting Green Roofs and Living Walls. Timber Press, London.

Grahn, P. et al. (2010). Using affordances as health promoting tool in a therapeutic gardening. In C. Ward Thompson, P. Aspinall, & S. Bell (Eds.), Innovative approaches in researching landscape and health, Open space: People space 2, 120–159

Greaves, L., Kirby, S. & Reid, C. (2006) *Experience research social change.* Toronto: University of Toronto Press Incorporated.

Kaplan, S. (2001). Meditation, restoration, and the management of mental fatigue. *Environ. Behav.* 33, 480–506.

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge: Cambridge Univ. Press.

Kim, K.J., Kil, M.J., Song, J.S., Yoo, E.H., Son, K.C., Kays, S.J. (2008). Efficiency of volatile formaldehyde removal by indoor plants: contribution of aerial plant parts versus the root-zone. *Journal of the American Society for Horticultural Science* 133, 1–6

Köhler M. (2008). Green façades - a view back and some visions. *Urban Ecosystems* 11:423-36

WHO, 2008. Depression. Programs and Projects. Mental Health. *World Health Organization*. Retrieved from http://www.who.int/mental health/management/depression/definition/en/.

Raanaas, R. et al. (2011). Benefits of indoor plants on attention capacity in an

office setting. Journal of Environmental Psychology 31, 99-105

Randy, S. (2007). 6 things you need to know about green walls. *Building Design & Construction, 83*(1).

Ottelé, M. et al. (2010). Quantifying the deposition of particulate matter on climber vegetation on living walls. *Ecol. Eng.* 36, 154-162.

Pauleit, S., Ennos, R. & Golding, Y. (2005). Modelling the environmental impacts of urban land use and land cover change: a study in Merseyside UK. *Landscape Urban Plan*. 71:295-310

Weinmaster, M. (2009). Are Green Walls as "GREEN" as they look? An introduction to the various technologies and ecological benefits of Green Walls. *J. Green. Build*. 4, 3-18.

Wolverton, B.C. & Wolverton, J.D. (1993). Plants and soil microorganisms: removal of formaldehyde, xylene, and ammonia from the indoor environment. *J. Miss. Acad. Sci.* 38, 11-15.

Wong, N., Tan, A., Chiang, K. & Wong, N. (2010). Acoustics evaluation of vertical greenery systems for building walls. *Build Environ* 45:411-20.

van den Berg, A. E., Maas, J., Verheij, R. A., & Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social science & medicine*, *70*(8), 1203-1210.

Cryptolaemus montrouzieri. (n.d.). *Cryptolaemus montrouzieri*. Retrieved April 5, 2014, from http://www.biocontrol.entomology.cornell.edu/predators/Cryptolaemus.html

Factsheet: Nedlaw living wall, how they work. (n.d.). *Nedlaw Living Walls* . Retrieved April 5, 2014, from http://naturaire.com/wp-content/uploads/nedlaw-living-walls-factsheet-how-they-work.pdf

How it works. (n.d.). *Nedlaw Living Walls*. Retrieved April 5, 2014, from http://naturaire.com/technology/works-2/

Lady beetles. (n.d.). *Lady Beetles*. Retrieved April 5, 2014, from http://www.biocontrol.entomology.cornell.edu/predators/ladybeetles.html

Robicheau, S. (2010, May 19). Atrium Walks the Green Talk. *The Atrium*. Retrieved April 5, 2014, from http://community.smu.ca/atrium/atrium-walks-the-green-talk/

Saint Mary's installs Atlantic Canada's first living wall. (2009, October 2). *The Atrium*. Retrieved April 5, 2014, from http://community.smu.ca/atrium/living-wall-installed-in-atrium/

The Living Wall. (n.d.). *Insects, Saint Mary's University*. Retrieved April 5, 2014, from http://www.smu.ca/projects/livingwall/insects.html

Acknowledgements

We would like to thank the following individuals for their guidance and support of our study. Gary Schmeisser and John Gallant for responding to our emails, Michael McCann for providing his time to meet with group members and answer our questions, Vanessa Lea for providing detailed information on NSCC wall, Tim Amos for assisting in NSCC living wall information and Hendricus for guidance and information during the semester.

Special thanks to Nathan Ayer for his invaluable time and advice throughout this process.

Appendices
Preliminary Proposal

Project Proposal:
"Feasibility of Living Walls as an Approach for a Healthy Urban Learning Environment in the Life Science Centre at Dalhousie University"
ENVS 3502
February 27th 2014

Samantha Miles
Joanna Brenchley
Brady Crewe
Hope Perez
Michelle McGee

Project Definition

In conducting the present study, our goal is to deepen our understanding of why certain indoor green spaces may be connected to stress and mental health. Our research question delves into the feasibility of living walls, as an approach for a healthy urban environment in the LSC and what benefits it would have on the staff and students using this building.

Problem

The LSC has recently undergone its first major retrofit since the building was built over 40 years ago. In 2008, Dalhousie began the LSC retrofit project, with a budget of $28.7 million and a timeline of roughly 3 years to complete. The amenity improvements included enhancing the capacity of a dated electrical, heating, ventilation, and air conditioning system, installing more efficient lighting, and freshly painting the walls. Additionally, a large part of the budget was dedicated to ‘green features’. The retrofit goals included increasing indoor environmental quality, creating new thermal utility sources, increasing the reliability of building systems, and making improvements in air quality, lighting, and temperature control. However, for a building with such an ambitious retrofit, just recently completed, it is surprisingly difficult to see where the money went. Not only is there a complete lack of green, and ‘indoor environmental quality’, but little if any attention has been paid to aesthetic improvements, one of the most important factors in student health and wellbeing. An improvement that could potentially build on the original objectives of the 2008 retrofit, while providing additional benefits in the realm of aesthetic appeal, could be a living wall installation.

A living wall is a low maintenance, vertical garden that can be installed on an interior or exterior wall of a building. They have a variety of benefits from improving an interior aesthetic to gaining LEED certification points. Green walls can contribute to the energy efficiency of a building by absorbing solar radiation and thus lessening the cooling requirements of a building in the warmer months. Additionally, they have been proven to ease stress, fatigue, and increase productivity. Other potential health benefits are derived from the wall’s ability to dampen noise pollution, and improve air quality (van den Berg, 2010).

Living Wall – University of Guelph

Questions

To what extent is the installation of a living wall in the LSC a feasible option for Dalhousie? Additional Questions include: Why should a living wall be considered for the LSC? What are the strengths and limitations of the installation in general? What are the components a successful living wall installation? What are the site-specific strengths and limitations of the LSC to support said components?

Scope/Limitations

Our study will focus on a single wall in the atrium of the LSC. It will not include studying the feasibility of any additional/complementary infrastructure such as seating, skylights, etc. Instead, it will focus solely on the implementation of a living wall, within the constraints of the current indoor environment. First, we will conduct a literature review to determine the benefits and challenges of implementing a living wall. We will then limit our scope to three case studies (St Mary's, NSCC, and the Seaport Farmer's Market), to make an appropriate selection of the components of a successful living wall installation. A 'successful' installation will be defined as one, which contributes to the betterment of public health and wellbeing, while maintaining economic viability. Our study will not

include surveys, interviews or any other measures traditionally used to determine desirability, rather, it will focus solely on the feasibility of the installation. That being said, a primary limitation of our study is the inability to attain a comprehensive understanding of Dalhousie budgetary constraints and liberties. Therefore, an installation that is 'feasible' will be defined as one that can be installed and maintained without any extraordinary expense (in comparison to the framework determined by case studies), while also fitting into the structural context of the space. Another limitation is that in creating our framework from case studies, our research is highly dependent on available literature assessing various living wall installations in detail.

A living wall may prove to be highly beneficial to student health and well-being, as well being an economically, socio-politically, and environmentally feasible solution to the currently bleak indoor landscape of the LSC.

Background & Rationale

A multitude of research findings have indicated urban green spaces can be used as a resource in promoting public health. These studies show there is an interesting dynamic between architecture and the natural environment. Researchers have suggested that green spaces promote overall general health by restoring mental fatigue and aiding in stress management (Kaplan, 2001). Stress-induced illnesses are currently a global problem. According to the World Health Organization (WHO), mental health disorders and cardiovascular diseases are expected to be the two major contributors to illnesses in all parts of the world, with mental health disorders calculated for all age groups and both sexes, by the year 2020 (WHO, 2008). People often deliberately seek environments that they find appealing for relaxing, to allow them to recover from demanding situations and tasks, and natural environments are frequently sought for this purpose (Grahn et al., 2010).

Office workers are reported to be less tired and more healthy when they have access to plants or window views, and prefer work environments with living plants and window views, compensating for a lack of window view by decorating with more indoor plants (Raanaas et al., 2011). Its been noted in literature for over twenty years that exposure to plants may have a restorative effect on attention during breaks from work (Kaplan, 1989).

Greening the inside of buildings can be an opportunity to combine nature and pre-existing industrial areas. Indoor plants can significantly improve indoor air quality, not only because plants can absorb carbon dioxide and release oxygen through photosynthesis, but also plants can reduce air-borne contaminants such as nitrogen oxides, volatile organic compound (VOCs), and dust (Wolverton & Wolverton, 1993). An experiment conducted by Ottelé et al. (2010) in the Delft University of Technology, demonstrated that indoor

vegetation and plants could reduce number of particulates (<10 mm) in the air, which have been known to cause long terms threats to human health.

The Life Science Centre located at 1355 Oxford St is almost entirely concrete with few windows, a confusing labyrinth of tunnels, hallways and staircases and a notably cold and unfriendly stone facade. Opening over 40 years ago, the Life Sciences Centre (LSC) is home to the largest collection of academic researchers in Atlantic Canada. Over 200 researchers, 450 graduate students and 3,000 undergraduate students use the LSC regularly. In addition, besides the small 'food court' on the second floor, there is nowhere to sit, socialize or connect with fellow staff or students.

To ensure that Dal students have an amazing student experience, we need to create better places on campus for all aspects of university life. It's vital that our campus evolves to keep pace with increasing enrolment, changing technology and a variety of student's needs. Vertical greening offers an outstanding number of public and private benefits including aesthetic, social, ecological and environmental. This project aims to investigate the feasibility of green living walls, as an approach for a healthy urban environment in the LSC.

Research Methods

Our objective is to determine the feasibility of a living green wall in the LSC. In order to be successful, we must incorporate quantitative and qualitative criteria to ensure a proper outcome. We would undergo a quantitative approach because of the strict characteristics that a living wall requires. For example, measurements and aspects of the indoor environment will be considered to ensure the feasibility of the project's success. We will also conduct qualitative research that will be collected through our three case studies: SMU student library, NSCC and The Seaport Farmers Market. We will gather information from these living walls and use this information to improve upon our project plan. Our methods are more quantitative rather than qualitative because we are looking further at measurements, and numbers rather than meanings and words (Greaves, Kirby & Reid, 2006).

Figure: This is our target wall in the LSC building for constructing a living wall. It is in an area with a high traffic of students and would be seen from two floors of the building. The surrounding area has existing seating but there is room for more.

The information we intend to gather for the next few weeks:

- The mean temperature of the LSC
- The possibility of removing the projector screen from the designated wall
- The quality of light that is emitted into the space
- Ensuring the material of the wall is acceptable for green wall infrastructure
- The amount of maintenance a living wall of this size would need. Would more staff need to be hired?
- The estimated cost of overall project
- Dalhousie's facilities budget and whether it has funds to allocate toward a living wall

We intend to gather this information from maintenance staff in the LSC; this will be a quantitative approach, only gathering facts and measurements. We also would like to talk to the maintenance staff from three different locations: SMU, NSCC and The Seaport Market. The SMU staff would give us information that would help us gather a scope and possible price point for our project. We

also hope to speak with a representative at the NSCC to collect data about the process of implementing a living wall. Though their living wall is on the exterior of the building, it will still be useful knowledge. The final case study at The Seaport Farmers Market would be beneficial to our research because they recently took down their living wall. We would like to investigate why their wall was unsuccessful, this information will be very useful to help us mould our project guidelines and reduce the risk of failure.

With this information, it allows us to answer these questions:

- What types of plants would be the most beneficial: groundcovers, ferns, low shrubs, perennial flowers, edible plants etc.?
- Would a living wall be the most beneficial/feasible in the LSC? Could an alternative green wall be implemented (green facade)? (Randy, 2007)
- What would be the time frame of this project? For living walls, a minimum of 6-12 months are needed for the installation of pre-grown plant panels (Randy, 2007)
- What is the potential cost of the project?
- What is the amount of maintenance and time needed to ensure the health and survival of the plants?

By gathering this information from three separate sources, we will be able to apply it to our project and use it to increase the feasibility of a living wall in the LSC. Having examples of successful and unsuccessful living walls will diversify our knowledge and allow us to be more prepared as we develop our final recommendations.

Some assumptions that we have made:

- Dalhousie has viable means in their budget to support this initiative.
- Dalhousie would be interested in supporting this project to improve the wellbeing of their student body and staff who travel through the LSC building.
- Student would enjoy a living wall in their learning environment.

Philosophical questions that we may ask:

- Could a bio centric view be developed through the addition of green spaces in human infrastructures?
- Would indoor green spaces influence human's anthropocentric view

towards the environment?

Limitations

- The amount of natural light available in the building
- The types of green wall infrastructure that would available to use on our wall in the LSC
- The amount of money in the Dalhousie budget
- The access to maintenance staff to be responsible for the wall

Delimitations

- The location we choose to put the living wall. We will decide what area would be most beneficial for students and staff while still being viable for the health and survival of the plants.

Schedule & Budget

	Weeks								
	Feb 11	Feb 18	Feb 25	Mar 4	Mar 11	Mar 17	Mar 24	Apr 1	Apr 8
Develop proposal	ALL	ALL	ALL						
Literature Review: effects of living walls			J	J					
Literature Review: case studies			M, B, S	M, B, S					
Designing framework				S, H					
Analysis					J, B				
Writing					ALL	ALL			
Editing							H		
Pecha Kucha preparation							ALL		
Proofreading									M

J=Joanna, M=Michelle, B=Brady, S=Samantha, H=Hope

The first portion of our project will be a literature review, which will be

divided into two portions. Firstly, we will be looking into the effects that a living wall can have on the surrounding community. Preliminary research has found that there are possible health benefits including an increased state of mental wellbeing, an increased level of concentration and a decrease in stress level (van den Berg, 2010). Furthermore, living walls have been shown to increase the building's energy efficiency and air quality. Our findings in the current literature of potential benefits and drawbacks will aid toward the final decision of whether a living wall is suitable in Dalhousie's LSC. Joanna will be responsible for this step throughout the weeks of February 25th to March 4th. In the second part of the literature review, we will be looking into 3 case studies of buildings in the local area that have or had living walls installed. The 3 cases are at St. Mary's University, Nova Scotia Community College and the Seaport Farmer's Market. Each Michelle, Brady and Samantha will take on a case study to look into.

Using the found information, our group will develop a framework, which will help us assess whether it is feasible to install a living wall in the LSC. The framework will include quantitative categories such as installation cost, maintenance cost and appropriate temperature as well as qualitative indicators such as benefit to community and practicality. Samantha and Hope will work together to develop the feasibility framework and have it completed by March 11th. We recognize and expect that these criteria be subject to change with our increasing knowledge of the success or failure of other living walls.

The next step will be to run the living wall in the LSC through the criteria of the feasibility framework and decide, based on these terms, whether the LSC is a suitable host for the project in question. This job will be carried out by Brady and Joanna and is to be completed by March 18th.

Writing the final report will require the efforts of the entire group. Similarly to the writing of the proposal, the parts will be divided up taking each other's strengths into consideration. The draft report will be submitted to Hope by March 24th, giving her time to sort out any major problems by the Pecha Kucha presentation on April 1st. While she works on the full report, the rest of the team members will prepare the slides and speech. After the Pecha Kucha, the report will be very close to being finished and Michelle will do the final proofreading before the due date on April 11th.

Due to the nature of our study being a literature review and case study analysis, there will be no costs associated with our project.

Research Deliverables

The primary goal of our research is to study the potential implementation of indoor green space in the LSC. More specifically, our final report will discuss the available technology and feasibility of a living wall in this space.

Overall, our research seeks a better understanding of:

- The importance of indoor living space on health and productivity for students and faculty.
- The materials required for a successful indoor living wall.
- The feasibility of implementing green space in the LSC.

This information will be presented using the following deliverables:

- A literature review to assess the technology and benefits of living walls.
- Case studies of buildings with living walls to address the feasibility and maintenance required.
- Guidelines for the appropriate plants and infrastructure for a successful living wall in the LSC.
- A final report that contains all of our research and recommendations.
- A Pecha Kucha presentation that will give an overview of our findings and recommendations.

Project Communication plan

The target audiences for this study are Dalhousie University and its community, as well as other universities or large institutions. Primarily, assuming that a living wall in the LSC proves to be feasible, we would like to communicate to the Dalhousie executives why they should pursue it. Furthermore, we would like to inform them on the challenges that they may face throughout the process. For this purpose, we will contact members of the executive by e-mail and invite them to the Pecha Kucha presentation on April 11th. We would also like to communicate to the students and faculty of Dalhousie, particularly those who spend a plethora of time in the LSC, that there are ways in which their day-to-day lives can be improved. We feel that, should the Dalhousie community be better informed about the projects going on at other universities in our city, they will be more likely to see its importance in our own institution. To get the word

out to the student body, we will contact several Dalhousie student-run social media sites and request that our project be posted. Finally, should we gain positive results; we think it would be important to share these with other universities so that they may consider looking into the feasibility of living walls in their own spaces. In our final report, we plan to include several visuals so that our audience can truly picture the project and grasp the aesthetic value that it will contribute. These visuals consist of a spatial map of the area, images of what the project will look like and pictures of the living walls in our respective case studies.

Because we have several different target audiences, the measurement of our success in communicating with them will be different. For the Dalhousie executives, we would be satisfied if they recognized our project as being accurate enough to look further into the possibility of installing a living wall in the LSC. Ideally, we would have a brief meeting with them to gauge their attitudes towards to project. In terms of reaching out to the Dalhousie community as well as that of other universities, we feel as though putting the word out there about projects like ours, as well as others going on at different universities is enough, and we would consider that a success in itself.

References

Grahn, P. et al. (2010). Using affordances as health promoting tool in a therapeutic gardening. In C. Ward Thompson, P. Aspinall, & S. Bell (Eds.), Innovative approaches in researching landscape and health, Open space: People space 2, 120–159

Greaves, L., Kirby, S. & Reid, C. (2006) *Experience research social change.* Toronto: University of Toronto Press Incorporated.

Kaplan, S. (2001). Meditation, restoration, and the management of mental fatigue. Environ. Behav. 33, 480–506.

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. Cambridge: Cambridge Univ. Press.

WHO, 2008. Depression. Programs and Projects. Mental Health. *World Health Organization*. Retrieved from http://www.who.int/mental health/management/depression/definition/en/.

Raanaas, R. et al. (2011). Benefits of indoor plants on attention capacity in an office setting. Journal of Environmental Psychology 31, 99-105

Randy, S. (2007). 6 things you need to know about green walls. *Building Design & Construction, 83*(1).

Ottelé, M. et al. (2010). Quantifying the deposition of particulate matter on climber vegetation on living walls. *Ecol. Eng.* 36, 154-162.

Wolverton, B.C. & Wolverton, J.D. (1993). Plants and soil microorganisms: removal of formaldehyde, xylene, and ammonia from the indoor environment. *J. Miss. Acad. Sci.* 38, 11-15.

van den Berg, A. E., Maas, J., Verheij, R. A., & Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social science & medicine*, *70*(8), 1203-1210.