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Abstract

Dalhousie University has had a history of substandard air quality and occupant discomfort in the Life Sciences Center, which has prompted the investigation of implementing green design technologies into the proposed Dalhousie Science Commons.

The main objectives of the study were to identify the three most feasible green technologies, submit them to a thorough analysis, and provide this information in a meaningful form to aid interested parties in further decision making and to initiate further action on this project.

The most feasible green design principles that applied to the proposed Dalhousie Science Commons were divided into several categories. These categories were based upon functionality and were chosen based upon site limitations, input from Dan Jackson, *PhD, Research & Development Coordinator, Faculty of Science, Dalhousie University*, interviews with Facilities Management, a survey of undergraduate science students, and a literature review. As a result of our research methods we chose to focus on Heating, Ventilation and Air Conditioning (HVAC) systems, Energy Efficient Lighting, and Green Roofs. After evaluating the technological, social, economic and environmental feasibility of each design principle, it was determined that numerous benefits could be had by their adoption. We recognize, though, that further investigation is required since certain details of the project are yet unknown.

It was determined that the best course of action was to provide a comprehensive background on what was determined to be the most feasible technologies as a starting point for further action. If our recommendations are taken, and further action is taken to implement green design technologies into the proposed Dalhousie Science Commons, many environmental, social, and economical benefits will certainly follow.

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Introduction

Issue of sustainability

While many definitions of sustainability exist, it is often understood that a sustainable environment will allow people to meet the needs of today without compromising the ability of future generations to meet their own needs (Bruntland, 1987). This requires satisfying the triple bottom line, which involves seeking strategies that incorporate long-term economic, social, and environmental considerations. As our world's living systems and resources are in decline, it is imperative to consider sustainability planning a priority.

As stated by Tittley (2000) universities are places for exploration and learning; therefore, they have the potential to provide a unique opportunity to share effective ideas for creating a more sustainable campus. Campus sustainability projects around the world have addressed this issue by setting out to prioritize green principles in several aspects of their design and function. Greening the campus involves not just changes in the way the university is designed, but also increasing environmental awareness and action on campus. These practices can be incorporated in the operational practices and processes of a campus, as well as in the human communities of the campus and surrounding areas.

Sustainability in context

A suggestion has been made to add a new building, the Science Commons[1], to the Dalhousie campus. This building would not only showcase green technology, but would provide an integrative learning environment to Dalhousie students. Green building design is an essential component of sound environmental practices, and represents a holistic and integrative process. In complying with the goals of sustainability, green design strives to balance environmental responsibility, resource efficiency, and occupant comfort and well-being (LEED, 2002).

The Dalhousie Science Commons is proposed to be located between the Oceanography, Psychology and Biology departments of the Life Sciences Center (LSC). A footprint of the proposed building is included in Appendix B. Currently, there is a courtyard located where the Dalhousie Science Commons will be located. This courtyard is approximately 16,800 square feet in size. The LSC already provides solid walls around the area where the Dalhousie Science Commons will be located.

The LSC has always been subject to ventilation problems, and other such issues, that students and faculty alike have complained about. Besides its physical attachment, the proposed Dalhousie Science Commons would be completely separate from this building. Methods to incorporate proper ventilation, energy efficiency, and other green design aspects should be considered when planning the design of this building. Dan Jackson, *PhD, Research & Development Coordinator, Faculty of Science, Dalhousie University,* has suggested that the new building could potentially be used to help alleviate current ventilation problems within the LSC. Mr. Jackson also proposed that the building be modeled after a biodome-like structure, and include a partial glass and green roof.

The problem

A problem is an unresolved question that presents unusual difficulties, uncertainties, and doubts about how best to proceed towards solving it. Clearly stated, our researchable problem is to assess the feasibility of incorporating specific green design aspects, including an HVAC system, efficient lighting technologies, and a green roof, within the proposed Dalhousie Science Commons. This problem is assessed at the proximate level, whereby we investigate the cause of the symptoms (conventional building design resulting in negative environmental and social impacts), and suggest opportunities related to preventing these symptoms (green design methods).

1-Key terms can be found in Appendix A.

Importance and rational

Green design should be considered a priority when building a structure; it not only creates ideals of environmental responsibility, it also provides comfort and well-being to those who utilize the space. There are a number of environmental problems associated with what is now considered conventional building design. Conventional buildings provide the atmosphere with an immense load of harmful pollutants that cause urban air quality problems, while also affecting climate change. In the United States conventional buildings are said to account for 49% of sulfur dioxide emissions, 25% of nitrous oxide emissions, 10% of particulate emissions, and 35% of carbon dioxide emissions (LEED, 2002). Carbon dioxide is emitted in four stages of building: manufacturing, construction, operation, and demolition (Seo and Hwang, 2001). Green design can decrease carbon emissions in each stage mentioned above.

Operating costs are lowered with the use of green design principles. Most people are now attracted to green building design, which in turn increases building marketability. Additionally, people who work within and utilize the buildings have been found to be more productive. A good example that can be applied to the proposed Dalhousie Science Commons has been found within a study, initiated by the Rocky Mountain Institute, which investigated students in daylit schools. It was found that these students consistently scored higher on tests than students in schools using conventional lighting fixtures (RMI, 2003). Studies have also shown that employees in green design buildings are absent less and have a better quality of work (LEED, 2003).

The University of British Columbia can be looked upon as a university with a great commitment to building green. The CK Choi building exemplifies what a green design building can mean to a campus community. The architects and the University made design decisions based upon considerations of the immediate and long term impacts on the environment. There were four key design issues being addressed in the planning of the facility: reducing impact and consumption, embodied energy in construction, operating energy over time, and livable working space.

The facility reduced impact and consumption through composting toilets. They embodied energy in construction through the use of reused timbers from the Armouries building previously located across the street and reused red brick cladding from the streets of Vancouver. Benefits in reduced greenhouse gas emissions are important as are the savings to the earth's limited supply of natural resources (Larquain, 1995). The operating energy over time was decreased by the use of daylighting, and the use of manual light switches, and control systems that will dim lights if adequate daylight is available or turns off lights if a room is vacant. A reduction in operating energy also occurred because of the elimination of a traditional ducted air system. The building relies on natural ventilation with a few fans to assist when necessary, it has operable windows and fresh air vents under each window to allow a continual flushing of fresh air through the building. In total, the energy saved from the Choi Building in one year will power four Vancouver residences (Larquain, 1995). The working space is livable because of great lighting, fresh air, and overall great air quality.

In implementing green design, the Dalhousie Science Commons could obtain similar benefits seen within the Choi Building. The facility could potentially alleviate much of the environmental impacts that conventional design inflicts upon the environment, while substantially reducing long-term operating costs. The building interiors could create an atmosphere for better learning and more satisfied students. Lastly, the facility could be an influential demonstration to students, the local community, and other green design projects.

Objectives

The issue of addressing green principles in the Dalhousie Science Commons has a large scope; therefore, the objectives we considered for this project were chosen because they are representative requirements. An objective is seen as a task or point of focus that will be directly addressed as a component of preparation that will allow us to reach an attainable goal (Palys, 2002).

Primary objectives

- Identify the three most feasible design options to investigate according to student surveys, interviews, and case studies
- Through successively more detailed analysis and investigation, improve the understanding of feasibility potential according to environmental, social, economic, and technological considerations
- Provide this information in a series of easy to understand figures, and present key pros and cons that will aid interested parties in assessing each technology's viability for the project
- Develop suggestions for future steps to be taken towards achieving a more detailed analysis and propositions for future study

Secondary objectives

- To reduce the environmental impact of building structures on the local environment
- To allow Dalhousie University to be looked at as an example of an institute that incorporated green design principles in their campus
- Allow Dalhousie University to uphold its obligation to the signing of the Talloires Declaration, demonstrating the universities commitment to sustainability in higher education
- To provide an educational experience to students and staff at Dalhousie University
- To raise awareness concerning sustainable design

Research questions

- Who is interested in the implementation of green design aspects (i.e. who is this project aimed for)?
- What is the function/purpose of the new facility?
- What design aspects would be most beneficial environmentally, socially, and economically, while considering technological constraints such as climatic factors, building size, and functionality?
- What benefits are associated with green design?

This report defines and researches existing green design aspects and technology principles in order to reach a consensus on the most feasible options in the case of the proposed Dalhousie Science Commons. This research is aimed to provide information that can be used to inform the people designing**,** constructing**,** and utilizing the facility. Furthermore, the project anticipates that these findings will be used as a showcase to green technology in other construction projects at Dalhousie, within Nova Scotia, and other projects anywhere that are of a similar nature.

Methods

Due to the extensive scope of green design, it was not possible to provide an exhaustive list of all green design strategies available for this project. Instead, the focus was narrowed to include three design components that were considered the most desirable for investigation. This was accomplished through both qualitative and quantitative strategies based upon inputs from key supporting actors (interviewees and students), literature reviews, a feasibility analysis, and a case-study analysis. In employing these various methodologies, it was expected that we would increase the reliability of our research methods and ensure that future research could obtain similar information if repeated.

For the purpose of this project, the nominal definition (the issue being dealt with) has been defined as green design aspects. Using primarily inductive techniques to research our stated problem, we felt that the resulting feasibility of the green aspects (environmental, social, economic, and technological) provided the best indicators for demonstrating the epistemic relationship between our nominal definition and operational definition. Palys claims that "to demonstrate validity, you must show that your particular operationalization accomplishes the purpose for which you intended to use it (Palys, 2002)." Through the techniques employed below, we aimed to make comparisons between various available green design options, which resulted in the selection of the most feasible selections. Since this was the desired outcome of the project, the comparison seems to be a valid research method.

Green design selection

Initial contact was made with Dan Jackson through an in-person interview on January 24, 2005. As a form of purposive sampling, Mr. Jackson, a core actor within this study, was intentionally sought due to his interest in the implementation of green design for the new Dalhousie Science Commons. Mr. Jackson supplied us with information regarding two of the preferred design aspects, both of which were selected as targets for investigation in this study.

Our last selection of the three design components to be investigated was based upon student surveys to obtain quantitative data. Our sampling population for this survey consisted of all Dalhousie students present within the Life Sciences Center from February 28-March 2, 2005. 128 students were randomly sampled through a self-administered questionnaire (Appendix C) to allow for their opinions to be expressed in terms of what green design aspects they would like the building to display. This population of students within the LSC was targeted for the questionnaire because it was decided that these students would be the ones who would potentially utilize the facility the most.

For ethical considerations, the questionnaire included a comment on the intent of the project. Additionally, the questionnaires were completely voluntary and anonymous and, therefore, a written consent form was not required (See Ethics Review Form, Appendix D). The questions were primarily closed/structured and consisted of both single response and rating-scale format. A separate sheet of paper requesting e-mails was provided for students who desired to know the results of the questionnaire.

Inferential statistics were applied to the data obtained from student surveys in order to determine the most preferred green design aspect to be incorporated into the building. This was achieved using Microsoft Excel to determine the frequency of responses, of which were then displayed graphically using bar and pie charts. Although a sample size of 128 is considered statistically non-significant when considering the entire Dalhousie student population of 13,500 students, for purposes of this study in determining overall opinions, this was not deemed necessary.

Questions were phrased using neutral and context appropriate wording as according to Palys (2002). For example, rather then use the words "green" or "sustainable" when referring to design technology, we used "environmentally friendly" which is more widely understood. The format of the questionnaire was simple and easy to follow to prevent errors. As well, researchers were present when questionnaires were administered to answer questions and clarify misunderstandings.

Triangulation

Since the three green design selections based upon the input provided by Mr. Jackson and Dalhousie students are expansive (e.g. efficient lighting includes a number of available design options), these methods were critical in determining what components of each selection were to be investigated. Triangulation through interactive interviews, archival literature reviews/case study analyses, and a feasibility analysis was employed as a means to:

- Explore the options available for each design aspect selected;
- Understand the necessary components of green design that must be investigated in order to properly evaluate the options available;
- Gain insight concerning the pros and cons of each component available;
- Empirically demonstrate reliability and validity of the research methods employed.

Interviews

A pre-determined set of interview questions (unique to each interviewee; Appendix E) were administered to: Mike Pullen, a LEED-accredited architect based in Bangor, Maine; Carolyn Green, Facilities Management Architect at Dalhousie University; and Jeff Sawler, Facilities Management HVAC specialist at Dalhousie University. Interview questions were given one week in advance in order for the interviewees to become familiar with the subject matter.

Preliminary interview questions were open-ended in order to gain insight based solely on the interviewees' perspectives and to allow for flexibility in responses. Subsequent questions became more structured in a funneling approach for acquiring more specific responses. The interviewee was lastly offered the chance to provide comments and concerns that had not been addressed. As Palys (2002) has stated, it is often difficult to quantify open-ended questions; however, the objective was to gain insight.

Feasibility analysis

For conducting a feasibility analysis, we investigated components available for the three design selections. In defining feasibility, we have selected four measurements for consideration: environmental, social, economical, and technological. A design component has been deemed feasible based upon the following criteria:

Environmental
o The systems/materials selected must promote energy efficiency and result in less CO2 emissions o Materials incorporated in system or design should reduce pollutant emissions o The amount of embodied energy in the building materials must be kept to a minimum o Waste by-products of the materials (during manufacturing through end use) should be minimal and the material should be easily recycled or reused o Materials must be sustainable (i.e. the materials are produced sustainably, producing minimal environmental damage)
Social
• Health o Toxic particulates and pollutants should be eliminated or reduced to lowest concentrations o Materials must be resistant to fungal or bacterial growth • Safety o Materials must be fire retardant and fall within acceptable safety standards set by the Federal and Provincial building codes • Productivity o The systems must promote optimal human occupancy comfort (with regards to ventilation, heating and cooling levels) o The appearance of any system materials and components should appeal to the eye (where applicable) to provide an atmosphere conducive to education and learning • Education/involvement o The design components (if appropriate) should enable students and faculty to engage in on-site learning activities
Economical

o Within budgetary constraints; limited up-front cost (in comparison to conventional systems) o Reduced annual energy consumption o Attractive/reasonable payback periods (considering Dalhousie has an investment pay-back period of 5 years) *** It should be noted that it is very difficult to determine true costs, which would require an extensive cost analysis where all factors of a given building project are evaluated and compared over its economic life.**
Technological
o Technology status: technologies that are currently in use and have demonstrated research and development (rather than technologies that have yet to be commercialized and tested) o The design aspects are suitable for colder climates o The design aspects are suitable for the size and function of the building

Table 1: Summary of measurements used to create feasibility tables.

Research based upon literature reviews, as well as interview input (described above), enabled us to omit design components that did not adequately meet the above feasibility criteria in Table1. This allowed our research to focus on the most desirable components that would be recommended for incorporation within the Science Commons.

While it was not within the scope of this project to create a feasibility analysis table for all components available (with the exception of green roofs as only two options exist), tables were created for those selected for recommendation. The tables depict the pros and cons in terms of each feasibility measurement (environmental, social, economical, and technological) investigated for each component.

Case-study analysis

As a form of exploratory research, a number of case studies were investigated initially to put the project in context and formulate ideas about green design principles and technology. This involved reading articles and information on other institutional-type green buildings. Once the three areas of focus were determined for this study, five specific case studies were investigated to illustrate how the green technologies we were researching were being utilized and integrated into other buildings.

Assumptions

Several assumptions have been made in the collection and presentation of our findings. The first being that certain factors which have the potential to greatly influence the implementation of green design within this particular facility (such as demographic constraints and local/regional design standards) have not been thoroughly considered. Furthermore, while extensive research and feasibility comparisons have been made for all possible design components, those which have been selected for recommendation are ultimately based upon the group member's opinions in what constitutes the term 'feasibility'. Palys (2002) has stated that all research is subject to our own ideologies, and it is therefore difficult to minimize researcher bias.

Limitations

The greatest limitations to our research were time and background experience. The project was conducted over the span of a semester, which results in a limited amount of work than can be accomplished. Background knowledge was also a factor that limited the project because no group members had significant knowledge on building specifications, engineering principles, or architecture in general; therefore we were only able to work within our realm of understanding. Our survey population was also limited because we could not survey all students who use the Life Sciences Center, or even a large portion of them. This was both limited by time and logistics.

We were also limited to working within the university's guidelines. For example, we were not able to choose the site location of the Science Commons. Our lack of information concerning budgets, desired square footage, and other specifics about the building itself limited the information we could provide about feasibility, costs, and benefits. For this reason, any cost or energy saving estimates were given as a range and can only provide a general idea. If more time was available, it may have been possible to incorporate more methodology such as computer programming and modeling to determine more precisely the feasibility of certain aspects (i.e. DOE2 model to determine daylight intensity in the site location, prospect of geothermal heating, etc.)

Delimitations

Time constraints of one semester limited our focus to three aspects of green design rather then all possible aspects that could be incorporated into the building. This meant covering fewer subjects, but in greater detail. We also limited whom we selected for interviews; that being based on their involvement with the Science Commons project, their architectural knowledge, and their availability. Interviewing only those knowledgeable on the subject may miss the opportunity to discuss other important issues with should-be actors such as the Faculty of Alumni, who are part of the designing committee. However, for the scope of this project interviewees were experts chosen to help us narrow our field of green design principles.

We designed our feasibility analysis to use literature as the primary source of information. Rather then interviewing experts in each area of focus, we based our analysis on case studies, journal articles, websites, and other available sources. This was largely due to time constraints. However, because we had little information about the building specifics, any professional cost estimates or similar information would have been difficult to obtain from interviews. Using multiple literary sources, we were able to give a range of information rather then focus on an interview from a single source.

<u>Results</u>

After interviewing Dan Jackson, it became clear that areas of concern for green design principles to Dalhousie authorities are heating, ventilation, and air conditioning systems (HVAC systems) as well as a living aspect (green roof or living wall). Following questionnaire administration, it was determined that 64% of surveyed students were in support of a new Science Commons, and 94% expressed that green design should be incorporated in this new structure

(Appendix E). When asked their opinion on which green design aspects would be most desirable for showcase, 24.6% expressed interest in efficient lighting alternatives, followed by improved air quality and living aspects (Figure 1). As a direct result, the areas that were investigated in more depth included HVAC options, environmentally friendly lighting options, and green roofs.

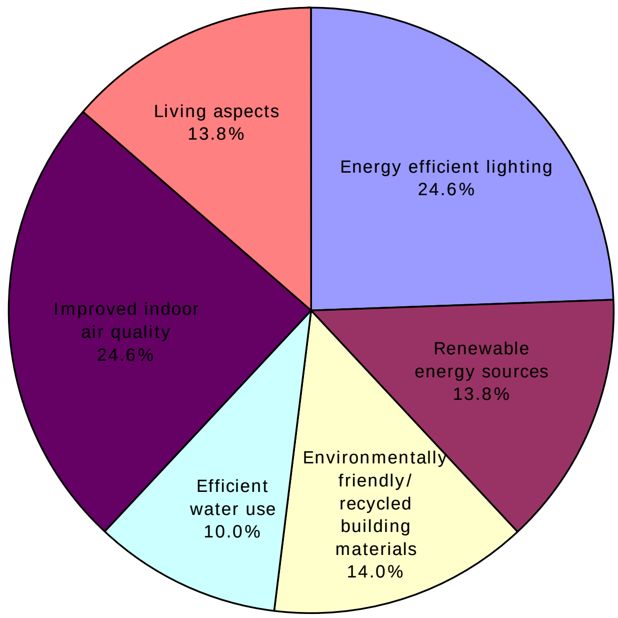

Figure 1: Desired green design aspects based upon student surveys.

Following the interviews, feasibility analysis, and case-study analysis, several options for each of the three design aspects presented themselves as appropriate for the Science Commons. The following information specifies what components were selected, while the succeeding *Discussion* section demonstrates why the specific options were selected.

HVAC

The HVAC analysis resulted in critically analyzing all options available for HVAC systems. Dalhousie currently operates a Central Heating and Cooling Plant (CHCP) located on Seymour Street, which operates high-power steam and chill water systems to provide Dalhousie's heating and cooling needs (Sawler, 2005). Steam is generated in this plant using boilers that burn Bunker C oil. While Bunker C is perhaps the cheapest fuel available, it is also one of the most polluting (Environment Canada, 2002). Of additional concern are the chiller components of the CHCP, which utilize a freon compound known as R-22 (also HCFC-22); thought to seriously contribute to the destruction of stratospheric ozone (Freedman, 2005).

According to Jeff Sawler, foreman of Dalhousie's HVAC Instrumentation shop, "if Dalhousie plans to construct a new building, the heating and cooling systems will more than likely be operated by the CHCP". Therefore, several options that were initially considered for this project (high efficiency condensing boilers and enthalpy/energy heat recovery) were dismissed for further investigation, and this project has not been able to investigate cleaner fuel and refrigerant methods. This report does, however, provide valuable information on passive measure techniques, such as heating through solar gain and increased insulation due to green roof construction, which may potentially reduce the active heating requirements of the facility.

Primary consideration has therefore been given to proper ventilation techniques, since this was also sited as a priority by Mr. Jackson. It was determined that three components of HVAC systems would work together the most efficiently for this task. An Underfloor Air Distribution (UFAD) system has been selected for consideration as the primary air distributor. This system will encompass a number of components to further enhance its efficient ventilation ability, including a Variable Air Volume (VAV) handler for air distribution, and more efficient fan blades, known as Axial Air flow fans for air circulation.

Efficient Lighting

Dalhousie University uses an assortment of lighting fixtures varying in efficiency, within the Life Sciences Center, including T8, T12 fluorescent and incandescent bulbs. While it would perhaps be beneficial for the University to consider exclusive use of T8 fluorescent bulbs for the new Science Commons, the focus for this project was placed primarily on natural sources of lighting, since it was specified by Mr. Jackson that the new facility would preferably incorporate extensive window coverage. It was therefore determined that passive solar energy would be the best recommendation to put forward for construction in the facility. Passive solar energy is best accompanied by glass double façade, user operable controls, such as blinds, and automated controls such as varied artificial lighting. Like many other systems of a building, lighting has been determined to be most efficient and the best green alternative when several components are combined.

Green Roof

Finally, a popular living aspect in green design is known as a green roof, which was selected for investigation in this study. There are several variations of a green roof, each with varying maintenance requirements and available features. For the purposes of a new science commons, the extensive form of a green roof is more available economically and technologically, and was found to be socially and environmentally beneficial as well.

Discussion

This portion of the report aims to provide a justification for selecting the components within the three areas of focus. The following is discussed: an overview of the technological logistics of each component with comparisons to conventional systems; pros and cons concerning the feasibility measurements presented in tabular form; and case studies representing each of the components to demonstrate the functionality and appropriateness within similar institutions.

Since so many topics are covered in this report, it would not be practical to explain each one in depth. Instead, definitions, explanations, and brief descriptions of the systems are offered, and are complimented by suggestions for further research. The information discussed in this section should be viewed only as a starting point to access information; more extensive research will be required including: commissioning, proper design modeling, and compliance with federal and provincial building standards and codes.

HVAC

Heating, ventilating, and air-conditioning (HVAC) systems are responsible for controlling the humidity, temperature, and airflow of delivered air to occupants within a building (NRC, 2003). These systems are generally comprised of heating and cooling units, a humidifier, air filters, and fans, which treat and move air throughout a building (LEED, 2002). Many high performance "green" HVAC options are currently available and have the ability to greatly reduce energy consumption since HVAC systems are responsible for consuming approximately 40-50% of a building's energy demand (CBE, 2004). Additionally, several models of HVAC systems and components have the ability to greatly improve Indoor Air Quality (IAQ). As was previously mentioned, there has been ongoing concern about the current IAQ within Dalhousie's Life Sciences Centre, and it is anticipated that the three HVAC systems and components we have selected for incorporation into the new Science Commons will not only improve air quality within this facility, but within the existing Life Sciences Centre.

Underfloor Air Distribution (UFAD)

Dalhousie currently employs what is referred to as mixing-type air distribution, in which the ventilation systems supply air to, and remove air from extensive ductwork at ceiling level (Figure 2; Sawler, 2005). These systems are designed to promote complete mixing of supply air with room air, thereby maintaining the entire volume (ceiling to floor) of air in the occupied space at the desired set-point temperature and evenly distributing ventilated air (CBE, 2004).

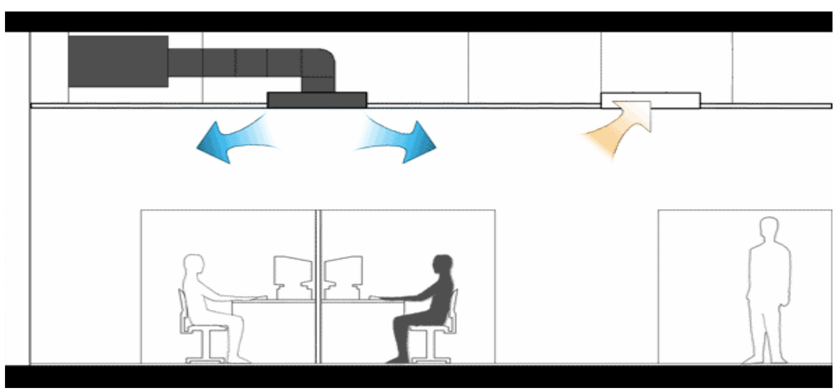

Figure 2: Conventional overhead air distribution with distributed air entering and exiting at ceiling level through an overhead ducted plenum (CBE, 2004).

Recent studies at the Center for the Built Environment (CBE), a National Science Foundation/Industry/University cooperative research center at the University of California at Berkeley, indicate that Underfloor Air Distribution (UFAD) systems are gaining significant popularity as an alternative to these conventional overhead systems for both green and conventional design considerations. UFAD systems offer potential benefits of reduced energy use, improved thermal comfort, improved indoor air quality, and improved flexibility for office moves (Table 2).

UFAD utilizes the open space known as the underfloor plenum, located between the bottommost concrete slab and a raised access floor to deliver conditioned air directly into the occupied zone of a building (Figure 3; Sawler, 2005). This air can be delivered through a variety of supply outlets located either at floor level, most commonly through floor diffusers, or as part of a task/ambient conditioning (TAC) system with outlets located on desktops. The distributed air then exits at ceiling level.

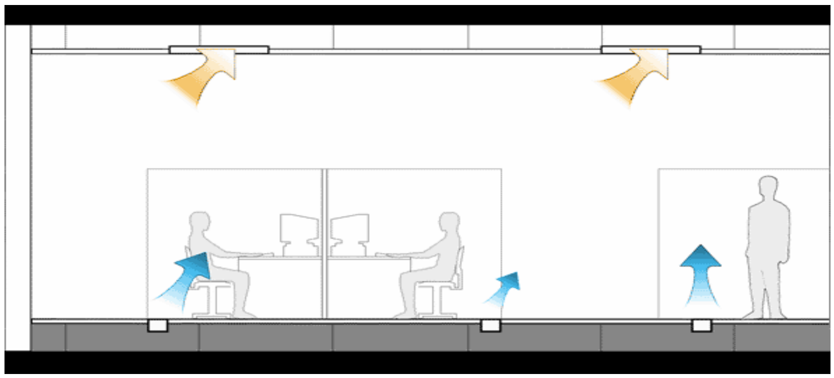

Figure 3: Underfloor Air Distribution with incoming air distributed at floor level and exiting at ceiling level (CBE, 2004).

Variable Air Volume (VAV) System

A Variable Air Volume (VAV) system is one that provides flexible air delivery from controlled dampers in response to the target zone temperature (Air Balancing Co. 2002; Roth *et al,* 2002). It is a widely used system for buildings which have high traffic at certain times of the day and year, and have significantly less traffic at other times (Webster *et al*, 2002). VAV has the ability to detect the load required at that particular time using pneumatic, electric/thermostat, or automated control on a main system (Energy books, 2004). VAV systems are chosen over constant airflow systems because of their notable efficiency, compatibility with UFAD systems, and technologically advanced components. Energy efficiency is obtained through lower fan energy consumption and the targeting of areas that do not fall within specified temperature conditions (Table 3; Webster *et al,* 2002).

VAV systems have been widely distributed since the 1980's including use in large commercial buildings (A team, 2005). In a study done by Kim *et al*, on the optimum duct design for VAV systems, it was found that under the best conditions that energy use during peak hours was as minimal as $0.08755/kWh with off peak hours dropping to $0.05599/kWh (Kim *et al*, 2002). This directly results in economic savings for the institution which invests the greater initial installation cost.

Axial Flow Fans

In the HVAC industry it is believed that the fundamental base of a system is the fan unit. Specifically, an Axial Flow Fan is an efficient form of the propeller fan, with up to 80% improvement in efficiency versus a standard HVAC fan (Table 4; Venta-Axia, 2005). Many efforts have been put into the Axial Flow Fan design to make it appealing to use in HVAC systems. It is known to have a long life span, aerodynamic design of fan propeller and is significantly lighter in weight (TIFAC, 2005). Because the fan can provide dependable airflow and pressure, it works with VAV systems and UFAD systems to further decrease the energy consumption of the entire HVAC system. Unlike many conventional fans, a high-pressure demand will not cause the fan to stall if proper precautions are taken (Venta-axia, 2005). Although the initial cost tends to be more than a conventional fan, the immediate efficiency and guaranteed reliability with an extended projected life span make it a smarter choice for a more sustainable HVAC system and building.

Other considerations

Not directly related to specific HVAC systems or components, but considerations that should be taken into account when keeping efficient operation of HVAC systems in mind include the following:

HVAC Zoning

HVAC Zoning provides thermostatic control of individual areas of a building. The HVAC needs of a large atrium room are much different than those of a classroom or office. Therefore, zoning provides the ability to adjust the effort on the part of the HVAC system to higher load areas. Zoning is also useful in considering the effect of solar heating on one end of a building and not another. It also presents itself as a beneficial choice in rooms where there is higher heat production (e.g. high computer use). Zoning could be used in conjunction with a Variable Air Volume system or could be an alternative with a lower installation cost while still decreasing energy consumption (Tiernan, 2000).

Properly Sizing the HVAC System

A common tendency is to assume that bigger is better for an HVAC system. This thought pattern could lead to inefficient HVAC systems and uncomfortable building conditions including altered humidity levels and extreme temperatures. Choosing a system that has the correct capacity for a building will lead to lower maintenance costs and longer lifespan of all components of the HVAC system. When purchasing a system it is recommended that the manufacturer's size estimations be taken seriously along with their instructions for installation and maintenance. If one uses a rule of thumb that a system is "at least this big" and sets no maximum size, a decrease in the value, effectiveness, and efficiency of the entire system and the building it is in could result (Energy Star, 2005)

HVAC Maintenance

The integrity, efficiency, and effectiveness of an HVAC system is largely based on the maintenance that it receives after initial installation. The indoor air quality provided by the system could be sacrificed due to improper care, defeating the purpose of installing a proper and high quality system. Simply performing regular tasks lowers utility demand of the system, increases the lifespan, and insures the comfort of the building occupants. Neglect leads to increased dust particles in the air as well as altered airflow to high demand areas (Harvard U). Some suggested maintenance strategies that should be considered after installing the recommended UFAD components include selecting high quality filters for air ventilation, replacing filters every one to six months, cleaning and adjusting dampers, and regularly inspecting fans, air ducts, and heating/coiling coils.

	Environmental	Social	Economic	Technological
Underfloor Air Distribution	**PROS**			
	-The displacement ventilation system used in these systems uses 100% outdoor air, therefore, less reliance upon refrigeration equipment to cool the building (Stanke, 2001). -Thermal mass of floor slab can store heat (cooling load) during the day, and release it at night (Stanke, 2001). -Warm weather: decrease cooling coil load; Cold weather: decrease hours of mechanical cooling operation (decrease in energy needs; Toothaer, 2004). -An overall 20-35% energy savings compared to ducted ceiling systems due to maximization of economizer hours (Rumsey, 2002).	-Vertically stratification to provide a better quality of air in the occupied part of the room (Turner, 2001). -Direct control of supply airflow increases degree of comfort occupants receive (Stanke, 2001). -Lower breathing-zone concentrations of pollutants due to the collection of contaminants near ceiling (outside breathing zone; Faulkner, et al., 1995). -Continuous inflow of outdoor air (at ground level), which flushes out stale/stagnant air rather than mixing incoming air (at ceiling) with interior air → cleaner ventilated air for health and productivity (LEED, 2002). -No drafts: low velocity air (Turner, 2001).	-Installation of access flooring \$18 CAD/ m^2 when all initial costs for building are considered; conventional overhead ducting \$24 CAD/m^2 (ASHRAE, 2002). -Reduction in overall building height by app. 10% (no ceiling supply ducts, terminals, or diffusers); can substantially reduce initial construction costs (CBE, 2004). -Heat generated from ceiling lights is removed (since out-vents are at ceiling); this heat is therefore not included when estimating building cooling loads (Faulkner, et al., 1995). -Lower speed air reduces size and energy requirements of mechanical fans, which therefore, reduces costs for fan components and energy associated costs (Rumsey, 2002).	-Computer room; Raised floor of 30-46 cm allows wires/cabling to be located under flooring (Stanke, 2001). -Allow for substantially increased "churn" rates (occupant relocation) due to ease of rewiring (Toothaker, J., 2004).
	CONS			
	-Cold weather: *may* increase heating energy use and/or hours of heating operation due to requirement of warmer supply air depending on building loads (Bauman, 2001).	-Unknown whether dirt/spilled materials, etc. will affect indoor air quality (as incoming air enters from floor; Krepchin, 2001).	-More expensive initial costs to install access flooring (compared to traditional floor-on-slab): \$30 CAD/m^2 (ASHRAE, 2002).	-May add complexity to supply air ducting (Toothaker, 2004). -Relatively new technology; some questions about suitability to all climates and applications remain (Rumsey, 2002). -Spaces with widely variable loads (conference rooms and perimeter spaces) pose design challenge (although VAV designs have provided degree of success; LEED, 2002).

Table 2: Feasibility table for Underfloor Air Distribution.

	Environmental	Social	Economic	Technological
Variable Air Volume System	**PROS**			
	-Achieve net reduction in HVAC energy consumption due to decreased cooling energy. -Blow power of fans reduced at periods of low traffic in room (Roth *et al*, 2002).	-Increases floor space that unit can serve (Roth *et al*, 2002). -Works very well in buildings where occupancy is not constant and traffic varies (Webster *et al*, 2002). -Eliminates recycling of stale air. -Has three forms of control depending on best fit for building. -Can be custom fit to building (Energy books, 2004). -Works with both new construction and retrofit (A-team, 2005).	-Becoming more readily available and much more affordable than many new/untested systems. -Energy efficiency results in direct savings in energy consumption/bills (Energy books, 2004). -On peak rates at $0.08755/kWh; off peak $0.0559/kWh (Kim *et al*, 2002).	-Installers and maintenance teams in field are familiar with VAV. -Named "most promising opportunities for new technologies" (Roth *et al*, 2002). -Works very well with under floor air distribution (Webster *et al*, 2002).
	CONS			
	-Not most efficient system available (Roth *et al*, 2002). -If hot and cold air mix, energy wasted.	-Records of conflicts with comfort and air quality (Energy books, 2004).	-6% increased installation cost vs. normal continuous flow system (Roth *et al*, 2002).	-Requires more extensive duct work. -Several equipment faults found frequently (Roth *et al*, 2002) Requires more extensive duct work. -Several equipment faults found frequently (Roth *et al*, 2002).

Table 3: Feasibility table for Variable Air Volume Systems.

	Environmental	Social	Economic	Technological
Axial Flow Fans	**PROS**			
	-25% higher energy efficiency than conventional fans (ASHRAE, 2002). -Low power consumption vs metallic fans (TIFAC, 2005).	-Designed for large hi-use commercial buildings. -Take up minimal space (Greenheck, 2004. -Light weight. -Fire retardant. -Vibration free (TIFAC, 2005).	-Very durable with long life span. -Consistent quality. -Corrosion and erosion resistant. -Reduced initial costs through immediate energy use cut downs (TIFAC, 2005).	-Work very well with variable air volume systems (Greenheck, 2004). -Aerodynamic design of fan propellers (TIFAC, 2005).
	CONS			
	-Not most efficient available on market (TIFAC, 2005).	-Noise generation if there is imbalance in fan blades (Greenheck, 2004).	-Higher initial purchasing price (TIFAC, 2005).	-Limited operating load capacity. -New technology that may not be familiar to maintenance staff (TIFAC, 2005).

Table 4: Feasibility table for Axial Flow Fans.

Case Study: California State Automobile Association Inter-Insurance Bureau

Image 1: Retrieved from http://www.cbe.berkeley.edu/underfloorair/CSAA.htm

While UFAD has been implemented in a variety of projects, it was beneficial to find a project that was most similar to the target function of the Student Science Commons, that being a workstation facility with computers. The project selected for demonstration is the California State Automobile Association Inter-Insurance Bureau (CSAA), which has successfully incorporated UFAD with Variable Air Volume for the desired energy efficient capacity. The primary desire for using UFAD was due to the high concentration of computers used to support the call center, wherby an access floor could accommodate all power and communications cabling. CSAA has employed UFAD with at least two other projects, and due to the positive results of user productivity and energy savings of approximately 30%, decided to use a UFAD system for this particular project as well. This facility has incorporated swirl diffusers within the flooring, which are able to accommodate individual needs and have been noted as a significant benefit.

Since the Science Commons will be incorporating an extensive zone of computers, UFAD would be most beneficial in order to accommodate the wiring and cabling structures. Additionally, with the option of user control for ventilation and thermal needs, UFAD could potentially increase user comfort and productivity within the computer room and office space.

Case Study: University of Colorado

Image 2: Retrieved from http://blt.colorado.edu.html/bld_comps/vav.html.

The University of Colorado has found great success with a newly installed VAV system. The University of Colorado takes a strong interest in building as a learning tool and have found that having the HVAC system respond to the traffic level in the building and room at the time creates the optimal atmosphere (Colorado U, 2005). The building has rooms that vary in size from small class rooms to a large atrium that are all accommodated by the VAV system as it distributes air to the areas that need it and decreases the pressure of air delivered to other areas.

Since the Science Commons will also accommodate a number of different rooms (large computer atrium, lecture rooms, and office space) similar to the Colorado U facility, it would be unnecessary to distribute air equally within each room. A VAV system will enable the greatest amount of air ventilation within the computer room, where excess heat due to body density and machine use will be required; while less air will be distributed within the lecture halls and offices.

Efficient Lighting

Passive Solar

The Passive Solar Design concept involves building layout, window placement, and exposure to gain and utilizing solar heat and light to optimal effect. If properly implemented passive solar design may reduce or eliminate the need for energy intensive artificial lighting, cooling, and heating. Passive Solar Design elements are flexible and can be implemented into a building with a minimal amount of cost. Virtually any type of architecture can have passive solar implemented during the design process if proper thought is put into site orientation, solar geometry, building technology, and local climate (Table 5; Parekh and Plats, 2002).

Site Orientation

Passive solar orientation places a building on a site in such a way that full advantage of the sun's natural heat is utilized. By facing the long side of a building directly to the south and the short sides to the east and west, the building will capture solar heat in the winter and block solar gain in the summer. The structure can be oriented up to 30 degrees away from due south and lose only 5 percent of the potential savings (U.S DOE, 2000).

If the south-facing window area reaches eight to ten percent of floor area, the building can be called "sun tempered." A full-fledged "Passive Solar" building has south facing glass area of 15 to 20 percent of floor area. With this much glass, additional features must be added, such as thermal storage mass and summer shading (U.S Department of Energy, 2000).

Daylighting

Day lighting is a subgroup of passive solar design and is the use of natural lighting in a building through perimeter windows, roof windows, skylights, and/or specialized light pipes. The practice of day lighting involves integration of daylight with electrical lighting, overall building design, mechanical systems, and interior design (BuildingGreen.com, 1999).

Window Selection and Glazing

Windows must be the right size to ensure that that there is an appropriate balance between heat loss and heat gain and so that overheating does not occur. Properly oriented windows can provide day lighting (or natural lighting), which is energy efficient because it reduces reliance on artificial lighting and thus lowers consumption and saves money.

Large expanses of west-facing glass are responsible for a considerable amount of overheating during spring and fall. East and west windows are bombarded with solar heat from the low angle sun as it rises and sets. Houses with good solar orientation also cut cooling costs by reducing wall and window area facing the hot, low angle sun (US DOE, 2000).

Glare can be a concern but there are many ways to eliminate it. Low-emissivity (low-E) coatings on windows, optimum mass to glass ratios, and the utilization of overhangs can help combat glare and overheating (U.S Department of Energy, 2000).

Thermal Heating and Cooling

Thermal mass (materials used to store heat) is a central part of passive solar design. Thermal mass is often confused with insulation, but is distinct from it. Concrete, masonry, water, and wallboard are a few examples of materials that can used to absorb heat from the sun's rays and release this stored heat as temperature drops, stabilizing temperature swings. A downfall of using passive solar and thermal mass to heat a building is that a backup heat source is required when there are long periods with lack of sunshine (U.S Department of Energy, 2000).

Installation of windows that can be opened during the night greatly reduce the need for mechanical cooling because the building can be flushed with cooler outdoor air (U.S Department of Energy, 2000).

Tools

A computer simulation program, such as the Energy-10, is a great tool to help identify the best energy efficient strategies for lighting, heating and cooling a space. A tool that can help to determine the optimum window area and selection for the particular project is RESFEN (U.S Department of Energy, 2000).

Glass Double Façade

A properly designed Glass Double Façade (GDF) has the ability to greatly reduce the amount of energy required by a building's mechanical systems by reducing heat loss in the winter and reducing cooling loads in the summer as well as increasing user comfort and performance via access to natural ventilation and daylight (Table 6). GDF depends upon the implementation of a combination of passive solar design strategies to work, especially in cold climates such as ours. The most important design considerations include excess solar gain which can be mitigated through the careful incorporation of natural ventilation, sufficient thermal mass and adequate shading and window glazing technologies. (Boake, 2001)

Initial costs of GDF have been found to be extremely high, as mush as 70% more in some European examples. Many early articles on GDF form the 1990's have been over optimistic and their benefits have since proven false. As well, some GDF buildings have proved not be very energy efficient or even more energy intensive than their conventional counterparts. This reinforces the principle that for a GDF to work properly the design must, from the outset, properly include additional passive solar strategies in addition to automated controls, shading and natural ventilation to mitigate excessive solar gain and maintain superior user comfort (Oesterle, 2001).

User Operable Controls

Three main user operable controls were considered when designing the feasibility tables: manual blinds, ability to open and close windows, and manual lighting controls.

Manual Blinds

Overheating and glare are the principle parameters that stimulate occupants to manually operate window blinds. Blind use depends on the distance of the occupant from the window, with use falling as distance from the window increases. This can have implications for energy use due to lighting because if the occupant is positioned further from the window increased use of lighting occurs (Newsham, G., 1994).

Windows

The ability to be able to open and close windows creates a large difference on people's performance, mood and general well being. This is because every person has specific preferences when it comes to lighting and thermal comfort that depends on age, sex, race, influence of previous lighting practices, climate, and conditions of local energy costs (Veitch, J., Newsham, G., 1996).

Manual Lighting Controls

Manual lighting controls are most common in the forms of manual dimming and on/off switches. If occupants have the ability to change their lighting conditions according to task or mood, lighting controls can add to occupant comfort and satisfaction (Benya, J, *et. al.,* 2003).

Automated Controls

Three main automated controls were considered when designing the feasibility tables: Automated louvers incorporating GDF vents and lighting controls including automated dimmers and occupant detectors.

Automated Shading and Venting

Excess solar gain and glare are the principle parameters that automated shades account for during the fluctuation of the angle of the sun during the course of a year. The louver system is designed to automatically rotate to control the daylight entering a building. Depending on the intensity of the sunlight, the louver would either provide shade from glare on work stations and prevent excess heating or could be used to redirect sunlight deeper within the building. Solar gain can be absorbed by the louvers which are situated within the GDF, and excess heat could be exhausted via the chimney effect within the buffer during the summer. At night, the louvers can be rotated shut to increase the R-value (heat retention) of the windows and improve the heating quality of the building during the winter months. A vented GDF allows access to natural ventilation, improved air quality and user comfort as well (Boake, 2001).

Automated Lighting Controls

Occupancy detector works on the basis of ultrasonic and infrared detection. When the heat or movement in a room is no longer detected, after a preset time delay, the detector will signal the stem to extinguish the respective lights. Occupancy detectors are most appropriate for low or intermittent-use areas such as storage, hallways and restrooms.

Light level sensors and automated dimmers incorporate a photocell 'eye' that detects the levels of illumination in a room. Threshold values can be set that responds to specific light conditions. These devices can signal the system to either turn on of off lights as well as adjusting their output by means of a continuous dimming system. Continuous dimming systems have a higher cost tan simple on/off systems, but a greater user satisfaction rate due to less noticeable change in lighting levels.

If combined, these automated lighting controls can save about 68% in lighting energy consumption from artificial sources (NRC, 04-2003).

Passive Solar (General)	Environmental	Social	Economic	Technological
	PROS			
	-Decreases dependence on artificial lighting, and thus reduces energy consumption. 40-60% lighting energy savings can be achieved by using natural lighting strategies. (BuildingGreen.com, 1999). -Passive solar can provide energy efficient heating and cooling solutions. -Raw daylight is as efficacious as the most efficient of current electrical sources, at 90-110 lumens per watt (Benya, J, *et. al.,* 2003).	-People are more productive, creative and efficient in naturally lit areas (BuildingGreen.com, 1999). -Provides flicker free light. -It has consistently been shown that people prefer natural light (Benya, J, *et. al.,* 2003).	-Maintenance costs are low, if at all, if only the design aspect of the windows is considered.	-Passive solar and day lighting design is very applicable to institutional buildings with mostly daytime occupancy (BuildingGreen.com, 1999). -Due to the location of the proposed Dalhousie Student Science Commons, glare from ground reflectance won't be a concern (U.S. Dept. of Energy, 2004). -Currently high reflectance paint and ceiling tiles are available to apply to ceilings of buildings, the most important light-reflecting surface in the building structure (U.S. Dept. of Energy, 2004). -Overhangs help prevent overheating and glare (NREL, 2005).
	CONS			
	-This source of lighting is not always readily available thus supplementary measures, such as light bulbs, have to be used in conjunction. This means that energy still has to be used to light the building at times (U.S. Dept. of Energy, 2000).	-Glare can be a problem if windows aren't glazed, or blinds/shades aren't adjustable. - If the occupant isn't oriented at 90• from the window extreme contrast and glare can result (U.S Dept. of Energy, 2004). -If windows aren't placed properly or there are too many windows, overheating on sunny days and radiant cooling on cold nights can occur (Carpenter, S., Kyone, S., 1990).	-To effectively implement passive solar design computer modeling should be used. This can become expensive (BuildingGreen.com, 1999).	-Snow build-up could inhibit this system from being fully utilized (NRC, 2003). -Other structures that are surrounding the location of the proposed Dalhousie Student Science Commons may inhibit maximum utilization of the sun's rays.

Table 5: Feasibility table for Passive Solar.

	Environmental	Social	Economic	Technological
Glass Double Facade	**PROS**			
	-Reduces dependence on energy intensive artificial lighting and mechanical HVAC (Oesterle, 2001). -May reduce energy usage by as much as 45% per year (Omer, 2005). -Allows use of day lighting and natural ventilation via windows that can be opened and chimney effect. -Provides buffer zone between outside environment and indoors which helps to modulate internal temperatures (Boake, 2001).	-Provides better acoustical performance against exterior noise (Oesterle et al, 2001). -Improves indoor climate comfort (Oesterle et al, 2001). -Provides access to natural ventilation and user operable windows (Boake, 2001). -Improves air quality, user comfort and performance (Boake, 2001).	-Lowers energy requirements for building. (Oesterle, 2001). -Can be adopted only on wall where required. For example the southern and northern facing walls may have a double façade while the eastern and western walls may be windowless to reduce heat loss and reduce unwanted solar gain to these directions (Boake, 2001). -Improves worker productivity (Boake, 2001).	-Becoming mainstream in North America. (Boake, 2001). -Requires the implementation of other passive solar technologies as well as facilitating the efficiency mechanical systems (Boake, 2001).
	CONS			
	-Requires the use of mechanical ventilation to facilitate air flow (Oesterle, 2001). -If not properly designed, may become an energy guzzler (Oesterle, 2001).	-Must be carefully designed to provide optimal performance for cold climate, otherwise uncomfortable interior conditions may develop (Oesterle, 2001). -Depends upon the proper integration of site layout, thermal mass, automated controls, appropriate glazing and coatings, shading, and ventilation (Boake, 2001).	-Increases maintenance costs involved in manually cleaning of windows and shads to ensure optimal reflective performance (Boake, 2001). -High initial investment for construction. Added costs may be as much as 70% more than convention single glass wall facades (Oestrele, 2001).	-Current simulations for design and performance of GDF are poor. Requires evaluation of existing designs successes and failures (Oestrele, 2001). -Requires the implementation of additional passive solar technologies to operate properly, increasing the complexity of the systems required (Boake, 2001). -GDF cannot substitute for HVAC (Oestrele, 2001). -Insufficient Ventilation can lead to condensation within GDF or uncomfortable temperature that lead to operable windows having to be closed and an increased reliance on HVAC (Osterle, 2001).

Table 6: Feasibility table for Double Glass Facades.

	Environmental	Social	Economic	Technological
User Operable Controls	**PROS**			
	-When combined with passive solar the electrical use for lighting, heating, and cooling is reduced if artificial lights, heaters, and coolers are turned off when daylight provides adequate illumination (BuildingGreen.com, 1999). -Lights that be can turned off when a space isn't being occupied will reduce energy consumption (as opposed to a building where lights are automatically kept on at all times).	-When people can control their lighting situation large improvements in mood, satisfaction, and comfort are experienced (NRC, 2003). -In a study in Southern California, students were found to have a 7-8% greater improvement in test scores in classrooms with operable windows (BuildingGreen.com, 1999). -People who can manually control blinds can maintain adequate visual and thermal comfort conditions according to their own preferences (Reinhart, C., Voss, K., 2003).	-Increases energy savings (NRC, 2003). -Manual dimming can increase energy savings by 6% (LRC, 1999). -A1 watt reduction in lighting energy will reduce a 1/4 watt of HVAC energy use (Benya, J, *et. al.,* 2003). -Manual lighting controls are less expensive than automatic lighting controls (Benya, J, *et. al.,* 2003). -Lighting controls reduce building operation costs (Benya, J, *et. al.,* 2003).	-1 LEED credit can be obtained for providing an average of1 operable window and 1 lighting control zone every 200 ft^2 (LEED, 2003). -Since this is a building not yet constructed, there is no worry as to whether lighting controls will be compatible with existing lighting equipment. -Manual controls are more reliable than automatic ones since users can adjust them accordingly. This decreases the chance that disgruntled occupants will disable lighting equipment that doesn't adhere to their personal requirements (Benya, J, *et. al.,* 2003).
	CONS			
	-Manual lights still require energy consumption. As it is not possible to light the building all year around in the climate it will be located in, lights must be used. -Workspace/task lighting does not reduce the amount of ambient light required (NRC, 04-2003).		-In the case of newer buildings that usually have good lighting, it may be a waste of money to install user operable lighting controls (IRC, 1999). -Blinds are an extra expense that some may view as unnecessary. -Some advanced manual lighting systems increase construction costs (Benya, J, *et. al.,* 2003).	-Most controls require commissioning to ensure that they operate according to design intent and are adapted properly to the local climate (Benya, J, *et. al.,* 2003).

Table 7: Feasibility table for User Operable Controls.

	Environmental	Social	Economic	Technological
Automated Controls	**PROS**			
	-When combined with passive solar, the electrical use of artificial ambient lighting is reduced when levels of daylight are high or when the room is vacant of occupants (NRC, 2003).	-Reflective louvers direct daylight to the interior of buildings depending on the angle of the sun and provide shade. This prevents discomfort by excess solar gain (overheating) and glare on workstations (Boake, 2001). -Automated dimmers have a high level of user satisfaction because change in lighting is not very noticeable (DOE, 2003).	-68% annual savings in electrical lighting consumption through the use of automated dimmers and automatic on/off switches (NRC, 2003).	-Improper calibration of dimming controls, poor location of photocell sensors, oversized lighting systems can adversely impact lighting energy efficiency by up to 65% (NRC, 2003). -Automated controls are expensive and add costs to the project (DOE, 2003).
	CONS			
	-Use of Day lighting depends upon availability of natural sunlight. Being close to the coast, Halifax has a relatively high number of overcast and foggy days (NRC, 2003).		-More expensive initial costs to install access flooring (compared to traditional floor-on-slab): $30 CAD/m².	-Occupancy detectors only appropriate for hallways, restrooms, storage areas during periods of normal usage and high traffic (DOE, 2004). -Requires the proper placement of photocell and motion sensors to properly dim or operate electrical lighting (NRC, 2003).

Table 8: Feasibility table for Automated Controls.

Case Study: San Francisco Federal Building

Image 3: Retrieved from: http://www.arup.com/americas/project.cfm?pageid=1618.

The San Francisco Federal is a building currently in the design process that will boast many unique green design principles. The first is that the building's shape will make use of passive solar lighting. Since the building is going to be only 60 feet wide, natural light can penetrate the interior (Dunlop, N., 2005). This reduces lighting costs. The building also will feature sidelighting with dimming control. The building envelope will have single-glazed windows running from 3 feet above the floor to the dropped ceiling. Each window will have miniblinds that help prevent glare from direct sunlight and overheating. All but the north-facing windows will be retrofitted with a solar film, reducing visible light transmission to about 40%. The office areas on the north and south sides will be retrofitted with dimming ballasts (Benya, J, *et. al.,* 2003).

Six months worth of monitoring data of daylight-linked control areas showed annual energy savings of 41% and 30% for the outer rows of lights on the south and north sides of the building respectively (Benya, J, *et. al.,* 2003). This test installation shows substantial energy savings that are available from daylight dimming in side-lit applications.

The concrete of the building is going to be a 50/50 mixture with granulated blast furnace slag. This mixture provides the thermal mass for the building which will cool it, reducing pollution caused by energy production (Dunlop, N., 2005). The building will also use computer-controlled windows and vents that open at night to cool itself using the cool night air. This is expected to halve air conditioning energy use, and the improved climate control will enhance the work environment (Dunlop, N., 2005).

When the building is complete in 2005, the U.S. General Services Administration expects its energy-efficient design solutions to save 50% of the energy used in a traditional building of its size. It will also provide occupants with a naturally lit and ventilated environment that will encourage healthier and more productive staff (ARUP, 2003).

Case Study: Telus Headquarters

Image 4: Retrieved from www.fes.uwaterloo.ca/architecture/ faculty_projects/terri/ds/tectcase.pdf.

The Telus Headquarters was opened for occupancy during the fall of 2001. It is one of the few double skin façades to be completed in North America, being primarily predated by the Occidental Chemical Building. It employs a double skin façade strategy commonly referred to as Twin-Face. This system provides natural ventilation through operable windows in both the exterior and interior façades. In the Telus Building the cavity extends for the full height of the building, the air space acting as a buffer zone between the busy downtown Vancouver site and the interior office environment. Day lighting seems to have been a motivating factor in the design of the façade.

Differentiating the Telus Building from other current and European double skin projects is its unique position as a renovated concrete and masonry structure. Ordinarily such technologically and environmentally outdated structures would be demolished and replaced by a completely new building. The existing structure and skin of the William Farrell Building was able to be retained, effecting significant environmental savings in accordance with the LEEDS Environmental Assessment system.

The interior of the building was gutted. Existing suspended acoustic ceilings and HVAC runs were removed. This effected a cleaning of the interior environment and improved air quality. The exposed concrete ceilings were painted white to assist with day lighting and succeeded in exposing thermal mass. The new outer skin is comprised of a differentially glazed, curtain wall frame, with operable windows, set out from the building to facilitate access to the buffer air space for cleaning.

The William Farrell Building is an eight story brick faced concrete structure. It was originally made to house the company's analog telephone switching gear. With the introduction of digital operating equipment, much of the space in the building became redundant for its intended use. Instead of demolishing the building, Busby and Associates Architects proposed retrofitting the structure. For energy conservation purposes the building was covered with a double glazed aluminum framed curtain wall. This wall acts to reduce ventilation and heating requirements. The cavity between the existing building and the new building is essentially a greenhouse. The interstitial space stores heat in the winter and provides shade and diverts heat from the building in the summer. The cavity is controlled by louvers at the base of the cavity and dampers at the top, to flush the air as required. Photovoltaic cells are linked to the ventilation fans and dampers on the roof.

The double skin acts as a ventilation chimney in warm weather and as an insulation jacket in cool periods. In winter months louvers at the top of the double skin remain closed, trapping a layer of air, allowing the building mass to retain available solar energy, which is then reradiated into the building. The exposed concrete structure acts as a heat sink, helping to reduce temperature fluctuations. In warm weather, with the louvers open, heat building within the double façade causes convection air movement. Assisted by fans, warm air is drawn up and out of the top of the air space, creating negative pressure within the interior, which in turn draws warm air away from the occupied areas.

The envelope helps to modulate internal temperatures. Motorized windows on the new curtain wall, as well as operable existing units, enable the occupant to obtain natural ventilation when possible. The window glass on the curtain wall is fritted at different densities for temperature modulation. Photovoltaic panels are fitted in the new curtain wall and are linked to ventilation fans and dampers on the roof that ventilate the interstitial space. Each workstation is equipped with individually controlled diffusers to allow the flow of fresh air through a forced air plenum under the raised floor. The daylight reflectors allow light to penetrate deep into the building.

Green Roof

In the most basic sense, green roofs are vegetated extensions of the roof of a building. They have been used in Europe for decades now, and their environmental, economic, and societal benefits are now becoming more understood across North America. Not only do they enhance visuals from surrounding buildings, they can also improve air quality and manage storm water runoff, among other things. All green roofs consist of some form of four basic layers: a waterproofing membrane which may contain a root repellant layer, a drainage layer, lightweight growing medium, and a vegetated layer (GRFHC 2004). There are two basic categories of green roofs, intensive and extensive. These are discussed below in addition to Tables 9 and 10, which describe the associated pros and cons of each.

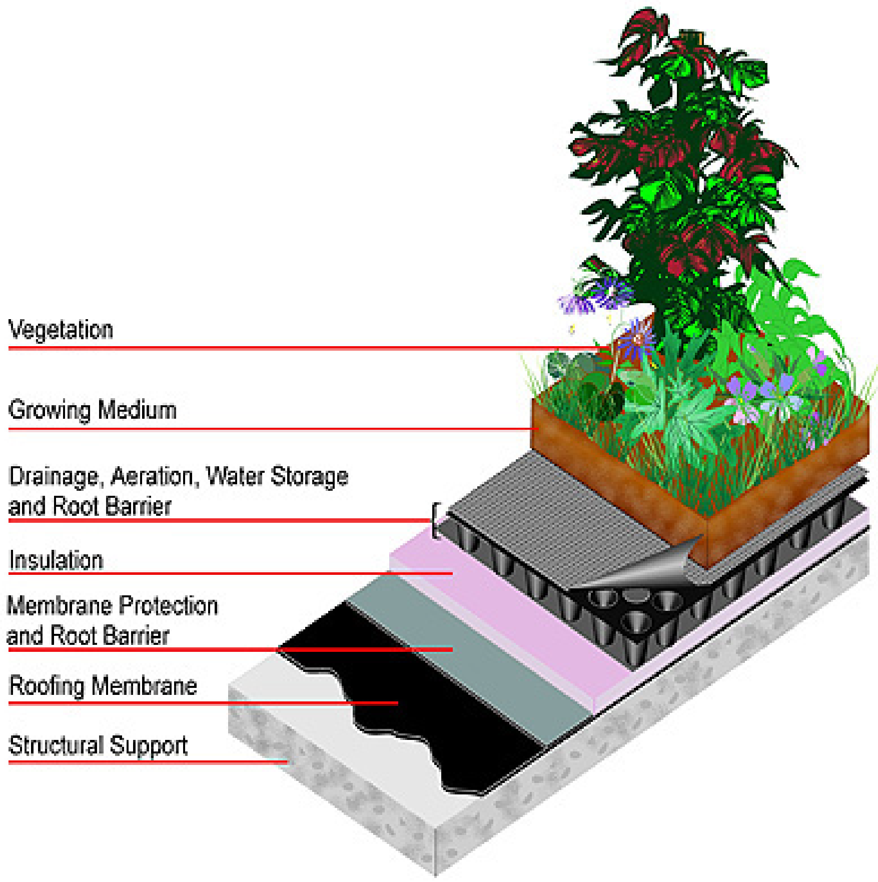

Figure 4: Diagram of green roof layering, (Low Impact Development Centre Inc., 2004).

Benefits

Green roofs can absorb a significant amount of water in urban areas that would otherwise be directed through storm sewers. Water is retained in the growing medium and plants, where it is then returned to the atmosphere by transpiration and evaporation (GRHC 2004). Levels of water retention vary and depend on plant types and soil depth, but it is estimated that a "grass roof with a 4-20 cm (1.6 - 7.9 inches) layer of growing medium can hold 10-15 cm (3.9 - 5.9 inches) of water (GRHC 2004)." Plants also act as natural water filters. The vegetated surface will also absorb carbon dioxide, produce more oxygen, and filter airborne particulates.

Green roofs will also serve to mitigate the "urban heat island" effect. This refers to the temperature increase in urban areas due to heat reflection of hardened surfaces. Vegetated surfaces absorb heat and add moisture to the air. Green roofs in urban areas play a role in overall reduction in green house gases, smog, and urban microclimates (GRHC 2004). The following figure illustrates the role of green roofs in air quality improvement.

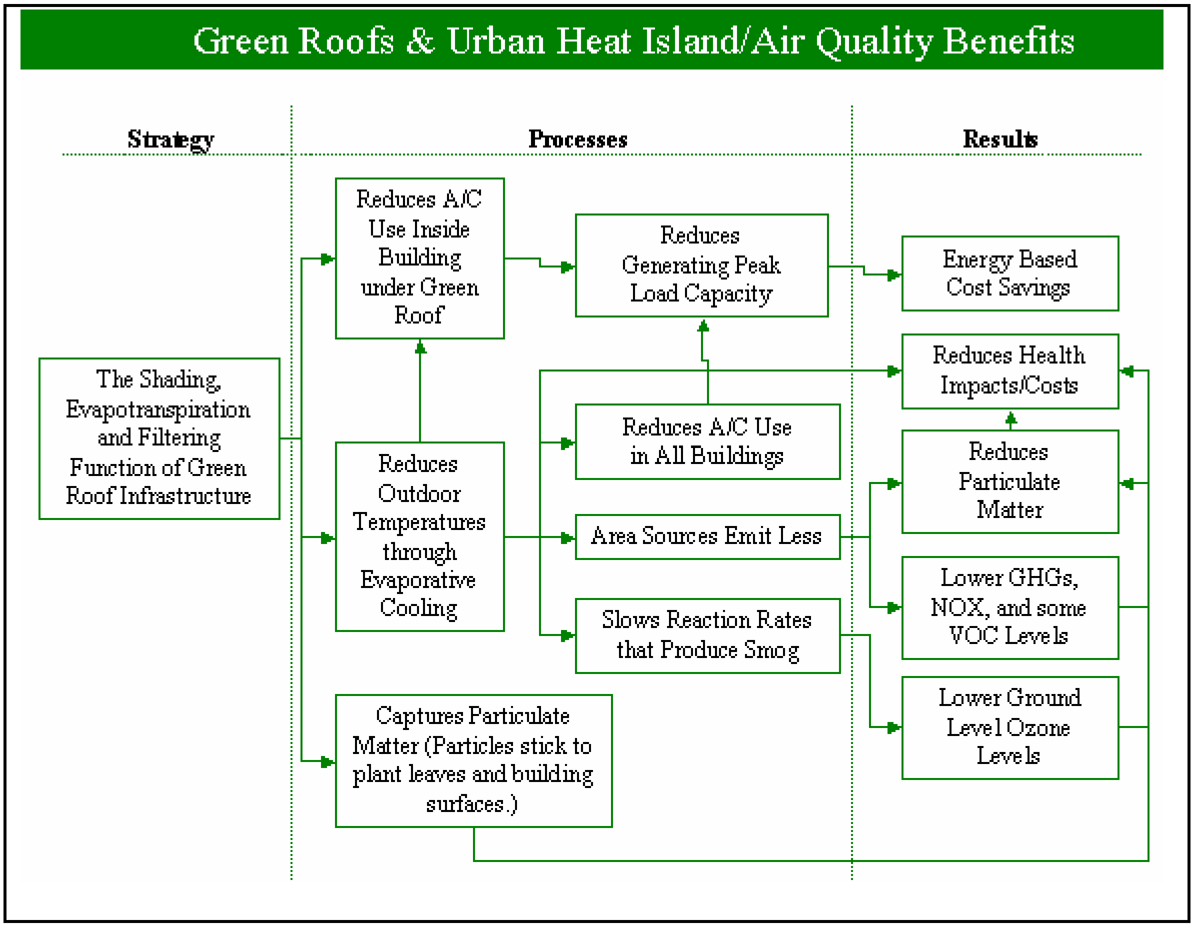

Figure 5: Diagram of the "urban heat island" effect; retrieved from http://www.greenroofs.org/.

Green roofs also act as additional building insulation. In the summer, this can reduce cooling needs and costs, and in the winter can help retain heat within the building and prevent heat loss. This insulation function increases further when roofs are snow covered, adding to the year round benefits.

Intensive Green Roofs

Often designed for human access or recreation, intensive green roofs are more involved and elaborate than extensive green roofs and contain greater plant variety. Features can include pathways, seating areas, water features, larger plants and trees, and food gardens. This requires an underlying structure that can accommodate greater loads. There is also a significantly higher amount of maintenance and cost involved.

Extensive green roofs

In general, extensive roofs consist of three to seven inches of growing medium depending on plant type, climate, and desired rooftop load. Typically plantings consist of shallow grasses, herbs, or sedum which is a succulent that can store water in its roots and leaves, eliminating the need for the installation of an irrigation system. This type of roof cover is not designed for regular human access other than maintenance checks. Extensive roofs when saturated compare in load to typical gravel roofing, as little as 17 pounds per square foot, and can be used for the same types of buildings but with significant advantages (Greenroofs.com, 2004). For the purposes of this project, it has been determined that extensive green roofing would be the preferred method due to structural loading constraints on which the building would be placed. Since gravel roofing is currently used on the LSC roofs as can be seen in Image 5, extensive roofing would exert relatively equal weight. Image 6 depicts a hypothetical layout of the new structure with a central atrium for drawing in light and the surrounding green roof.

Image 5: Courtyard where proposed Science Commons would be placed (Source: S. Pullen).

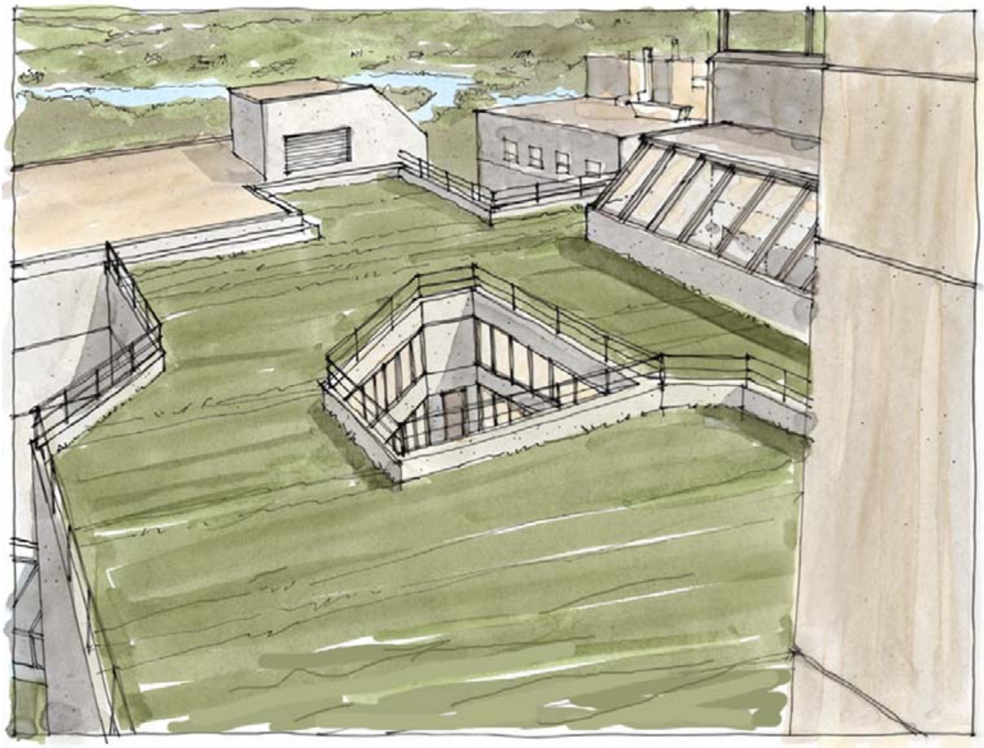

Image 6: Hypothetical sketch of proposed Science Commons with central atrium and green roof (source: S. Pullen).

Green roof components

Membranes and Root Barriers

Waterproofing membranes are essential to any roof structure. There are a variety of types ranging from an applied liquid to organic bitumen products. Root barriers prevent plant roots from penetrating the membrane, and are essential when using organic products or plants with deeper root systems. Many extensive green roof type plants are chosen for their root systems which tend to grow horizontally rather than downwards (Greenroofs.com).

Drainage and Filter Layers

A drainage system will allow excess water to be carried away, while protecting underlying layers. For extensive green roofs, which are shallower and hold less water, this can be combined with a filtration layer. Rounded pebbles may be used, and water-resistant polyester fiber mats or polypropylene- polyethylene sheets are lightweight and will allow water to drain through while holding soil in place (Greenroofs.com).

Growing Medium

The type of growing medium selected depends greatly on climate and plant materials. Soil mixing can be complicated, but the goal is to achieve a growing environment that will not stress the plants, that is lightweight, controls erosion and retains water. Often native soil can be used in combination with soil additives such as clay, peat, wood chips, sand, or humus (Greenroofs.com).

Vegetative Layers

For extensive green roofs, plant materials should be chosen for their shallow root systems, ability to resist wind, drought resistance, low maintenance, local climate, and visual attractiveness. Plants may change with the seasons and for cold climates like Halifax, can become dormant in the winter and need to be able to withstand freezing and thawing. For extensive roofs, plants can be applied in mats, or planted individually and allowed to fill in through growing seasons. Succulents and plants that retain water will function better in heat and drought and are a good choice for extensive green roofs that do not have irrigation systems. There are many varieties of sedums which will stay green through the winter, and flower in the summer, or plants can be chosen to change color with the seasons.

	Environmental	Social	Economic	Technological
	PROS			
Intensive Green Roofs	-Insulate against heat gain and loss of the building. Overall reduction in energy consumption year round. -A typical one-storey building with a simple grass roof and 10 cm of growing medium can reduce summer cooling needs by up to 25% [Environment Canada, greenroofs.org]. -Reduces "urban heat island effect" by moderating the temperature of the surrounding air. -Improve air quality by filtering air, cycling CO_2 and oxygen, and absorbing gas pollutants. -Contributes to reduction in storm water runoff, rain water is absorbed into plants and returned to atmosphere.	-Can be used for recreation or open park space. -Opportunities for food growth and production. -Can be used as an outdoor rooftop classroom. -Improves building aesthetic, particularly for surrounding buildings with rooftop view. -Promotes awareness of green design principles. -Insulates and acts as a barrier for sound. As little as 3" of vegetated cover can reduce sound transmission by 5 decibels [WBDG]. Also reduces sound reflection. -Stabilizes temperatures resulting in greater indoor comfort.	-Energy cost savings due to reduced requirement for artificial climate control.	-Protects underlying roof structure and waterproofing from UV rays, severe weather, and extreme temperatures and extends its life. -Can help slow the spread of fire through the building.
	CONS			
			-Capital costs for installation are high. - Increased costs for maintenance of plants and staff training.	-Complex to install. -Long-term maintenance more substantial than extensive roofs, due to greater plant variety and complexity of roof components. -Requires irrigation and more substantial membrane systems. - Some technology is still relatively new in North American applications (GRHC). - Can require up to two growing seasons before plants reach full coverage (Roofscapes Inc.).

Table 9: Feasibility table for Intensive Green Roofs.

	Environmental	Social	Economic	Technological
	PROS			
Extensive Green Roofs	-Insulate against heat gain and loss of the building. Overall reduction in energy consumption year round. -A typical one-storey building with a simple grass roof and 10 cm of growing medium can reduce summer cooling needs by up to 25% [Environment Canada, greenroofs.org]. -Reduces "urban heat island effect" by moderating the temperature of the surrounding air. -Improve air quality by filtering air, cycling CO_2 and oxygen, and absorbing gas pollutants. -Contributes to reduction in storm water runoff, rain water is absorbed into plant medium and returned to atmosphere. -Organic or recycled materials can be used in construction.	-Can be used for recreation or open park space. -Opportunities for food growth and production. -Can be used as an outdoor rooftop classroom. -Improves building aesthetic, particularly for surrounding buildings with rooftop view. -Promotes awareness of green design principles. -Insulates and acts as a barrier for sound. As little as 3" of vegetated cover can reduce sound transmission by 5 decibels [WBDG]. Also reduces sound reflection. -Stabilizes temperatures resulting in greater indoor comfort.	-Lower capital costs for installation than intensive green roofs.	-Relatively simple installation. -Depending on plant types, little or no need for irrigation and drainage systems. -Low maintenance, plants are self-seeding and require no fertilization. -Can be constructed on sloping roofs (up to 33% grade). -Average weight when saturated is approximately 17 lbs per square foot (comparable to gravel top roof) -Protects underlying roof structure and waterproofing from UV rays, severe weather, and extreme temperatures and extends its life. -Can help slow the spread of fire through the building.
	CONS			
				- Some technology is still relatively new in North American applications. - Plant cover may require some semi-annual maintenance. - Can require up to two growing seasons before plants reach full coverage (Roofscapes Inc.)

Table 10: Feasibility table for Extensive Green Roofs.

Case Study: Waterfall Building

Image 7: Retrieved from http://www.cmhc-schl.gc.ca/en/imquaf/himu/buin_019.cfm**.**

In 2001, a mixed-use project by Hillside Developments Ltd was constructed to house both office and retail uses. The Hillside building is located in Vancouver, British Columbia. For Hillside Developments, the green roof system was intended to meet a number of criteria. Firstly, their aim was to create a recreational space that was aesthetically pleasing and would in turn parallel the revitalization goals of the city. Secondly, the project sought to bring about a general set of benefits to the community. Thirdly, the green roof must be seen by the public and support beautification efforts in the area. Lastly, the space must provide a common or courtyard for the general public.

The total area of the green roof is 3,590 square feet, and contains both intensive and extensive sections. The roof weighs approximately 70 lbs/cubic foot. (CMHC, 2004). Obviously, a primary concern of the architects on the project was the extra weight resulting from the green roof. As a result a reinforced "cast-in-place" concrete and an extra 10% steel reinforcing was placed inside the concrete slabs to support the roof. Due to the extra construction phases, the construction period lasted two full weeks including the formwork and placing of reinforcing steel and concrete (CMHC, 2004). Since weighting may become an issue in the implementation of a green roof here at Dalhousie, this method of construction may be desired.

As mentioned above, the green roof on the Waterfall Building is both extensive and intensive. The extensive plot utilizes both Poa Alpina and Blue Grass. The plant selected for the intensive plots was Rosa Meidiland White (CMHC, 2004). As with most green roofs, a filter cloth is needed over a drainage layer, this comes in the form of a cloth layer called a geotextile. The medium used for growth was installed at thicknesses ranging from two to six inches and yielded a weight of 70 lbs/cubic foot. The growth medium is comprised of humus builder, washed sand, and pumice (CMHC, 2004).

Conclusion

Dalhousie University's Life Science Centre is an example of how institutional structures have been designed in the past; giving little consideration to proper air quality, natural lighting, user comfort, or energy efficiency. The problem of integrating green design principles into the proposed Science Commons becomes a solution to these issues as well as positively addressing social, economic, technological and, of course, environmental aspects.

The most feasible green design principles that applied to the proposed Science Commons were divided into several categories. These categories were based upon functionality and were chosen based upon certain site limitations, input from Dan Jackson and the Dean of Science, interviews with Facilities Management, a survey of undergraduate science students, and a review of current literature and relevant green design case studies.

The scope of our research turned out to be much broader than we first expected. Due to time constraints, the conceptual stage of the project and further limitations, we were unable to examine each green technology in context to the specific site. It was determined that the best course of action was to provide a comprehensive background on what was determined to be the most feasible technologies as a starting point for further action.

Future ENVS 3502 problem solving students should advance our research by evaluating the specific costs and feasibility of each green technology individually and in greater detail. In addition, further research should be conducted in regards to the financial aspect of building a new structure on campus. These include incentives offered by various levels of government and environmental organizations, subsidization via partnerships with private sector businesses to develop and showcase green technologies and general fundraising directed towards Alumni.

This project appears to have achieved catalytic validity, which refers to the degree to which research moves those it studies to understand the world in order for them to transform it (Palys, 2002). The project has been greatly meaningful for all those involved in its creation as it provided a valuable learning experience pertaining not only to green design principles and the operation of institutional building management, but to the effective method in which to conduct research. The data provided in this report is valuable for use by the Department of Science at Dalhousie University as a validation of the effectiveness of green design and as a launching point for further action that is required to make a Green Science Commons a reality. Ultimately, if fruitful, this project will promote an environmentally responsible attitude in students, the community and even other institutions.

Dalhousie has the opportunity not only to become an example to members of the University and the community, but as well to become a leader in green design by setting examples for Universities around the world and extending its' reputation. Dalhousie University is arguably one of Canada's best and most progressive institutions, and accordingly should acknowledge the importance of integrating sustainable green technologies to mitigate our impact upon the planet.

Acknowledgements

We would like to thank Tarah Wright and Judi Lipp for their input and assistance with the project and report. We would also like to thank those who have participated in the interviewing process: Dan Jackson, Carolyn Green, Mike Pullen, and Jeff Sawler.

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Appendix A: Key Terms

Actors – Beings that are involved in the issue of concern. There are three types of actors: core actors are continuously and intensively involved with the issue of concern (ex. researchers, architects); supporting actors are less involved but can still exert influence on decisions (ex. interest groups, donors); and should-be actors are beings that are affected by the issue but are not involved or given no voice in the decision making (ex. plants, wildlife).

Archival Sources - Sources in print or written documents, such as books, journal articles, and websites.

Cost-benefit analysis – A quantitative technique used to compare the various costs associated with an investment with the benefits that it proposes to return. A comparison of various possibilities is helpful to gain insight on cost-benefit ranking.

Dalhousie Science Commons – A building concept that is in the planning stages. A building that will be located in the courtyard between the biology, oceanography and psychology wings of the Life Sciences Center (LSC).

Descriptive research - Research that aims to adequately describe some person, situation or group.

Explanatory research - Research that aims to derive causal assertions between two or more variables. This research allows for causal inference.

Exploratory research - Research concerned with achieving new insights on the phenomenon and formulating research questions.

Feasibility, Ecological – Whether ecological components, such as location, amount of light, ecosphere harm, etc., are considered when designing the project. The aim is to ensure that the chosen site is realistic and the least amount of harm done to the environment is ensured.

Feasibility, Economic - Whether expected cost savings, increased revenue, increased profits, and reductions in required investment exceed the costs of developing and operating a proposed system.

Feasibility, Technical - Whether reliable trained personnel, hardware and software are capable of meeting the needs of a proposed system and can be acquired or developed by an organization in the required time.

Feasibility, Social – Whether social values and policies are compatible with the proposed initiative.

Functions of the Science Commons – Elements present that will facilitate learning. Functions could include an atrium complete with multiple computer work stations for independent learning, a library for research, conference rooms for lectures and group work, offices for staff and advisors and labs for teaching use.

Green Design - A design, usually architectural, that conforms to environmentally sound principles of building, material and energy use.

Interactive Sources - Information sources that involve interaction with others, such as interviews, oral histories, questionnaires, and discussions.

Leadership in Energy and Environmental Design - LEED represents a voluntary program developed by the Green Building Council, in which building design and construction is rated on the basis of its capability to meet standards of high-performance and sustainability.

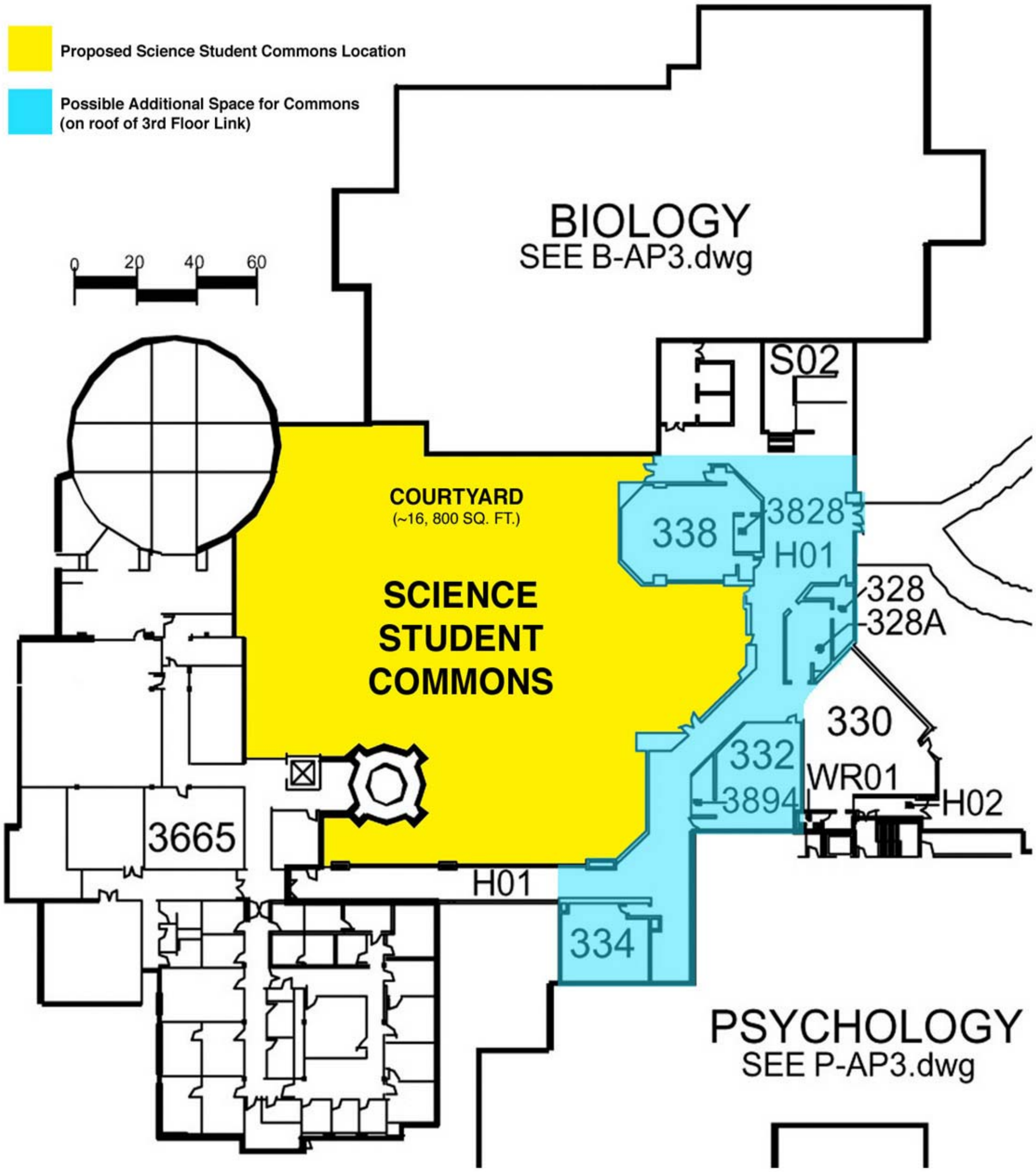
Non-probabilistic sampling – A set of sampling techniques in which the probability of selecting each sampling unit is unknown. Used when a sampling frame is unavailable. This type of sampling is used for relational and explanatory research.

Payback method - The number of years required to pay off the incremental capital cost with energy cost savings.

Probabilistic sampling – A set of sampling techniques that meet two criteria: the probability of sampling is known, and each sampling element in the population has an equal probability of being selected. This type of sampling is used for descriptive research.

Relational research - Research that aims to discover how two or more variables are related to one another.

Appendix B: Building Floor Plan



Appendix C: Student Survey

This survey concerns the Feasibility of Incorporating Green Design Principles in the New Science Student Commons:

1. What program of study are you in? ______________________________________
2. What year of study are you in? ____________________
3. Is a new Science Student Commons important to you?
   a) yes
   b) no
4. Would environmentally friendly design aspects incorporated into the building be important to you?
   a) yes (if so, please proceed to number 5)
   b) no (if not, please explain: ____)
5. Please check the **top three** environmentally friendly design aspects you would prefer to see in a new Science Student Commons, rate your choices **1 (top choice), 2, and 3 (last choice)**

Only rate your top three choices!

____ a). Energy efficient lighting (ex: natural lighting, efficient bulbs)
____ b). Use of renewable energy sources (ex: solar, wind)
____ c). Environmentally friendly/ recycled building materials
____ d). Efficient water use (ex: low flow water taps, use of rainwater)
____ e). Improved indoor air quality (ex: ventilation)
____ f). Incorporating "living" aspects (ex: green roof, living plant wall)
____ g). Other: ____

If you are interested in the results of this survey, please submit your email address on the page attached.

If interested in the results of this survey, please submit your email address below:

1.	**7.**
2.	**8.**
3.	**9.**
4.	**10.**
5.	**11.**
6.	**12.**

Appendix D: Ethics Review Form

Revised January 1, 2005

ENVIRONMENTAL PROGRAMMES
FACULTY OF SCIENCE
DALHOUSIE UNIVERSITY

APPLICATION FOR ETHICS REVIEW OF RESEARCH INVOLVING HUMAN PARTICIPANTS
UNDERGRADUATE THESES AND IN NON-THESIS COURSE PROJECTS

GENERAL INFORMATION

1. Title of Project: Greening the Proposed Science Commons

2. Faculty Supervisor(s): Tarah Wright — Department: Env. Science — Ext: — e-mail: tarah.wright@dal.ca

3. Student Investigator(s) — Department — e-mail — Local Telephone Number:

Student Investigator(s)	Department	e-mail	Local Telephone Number
Ericka Wicks	Env. Sci		
Taryn Moore	Env. Sci		
Marc Franz	Env. Sci		
Erica Ring	Mar. Bio		
Kathy Cooper	Env. Sci		
→ Sara Pullen	Mar. Bio		

4. Level of Project:
Non-thesis Course Project [✓] Undergraduate [ ] Graduate Specify course and number: ENVS 3502

5. a. Indicate the anticipated commencement date for this project: Jan. 31, 2005

b. Indicate the anticipated completion date for this project: March 29, 2005

SUMMARY OF PROPOSED RESEARCH

1. Purpose and Rationale for Proposed Research

Briefly describe the purpose (objectives) and rationale of the proposed project and include any hypothesis(es)/research questions to be investigated.

Our research question is "Which green design principles are feasible to incorporate into the proposed Dalhousie Science Commons?" Our objectives are to make conclusions on feasibility based on findings, to present suggestions to those making executive decisions, have the building design used as an example for other universities, to have a useful and environmentally friendly building for students and staff

2. Methodology/Procedures

a. ***Which of the following procedures will be used? Provide a copy of all materials to be used in this study..***

[ ] Survey(s) or questionnaire(s) (mail-back)
[✓] Survey(s) or questionnaire(s) (in person)
[ ] Computer-administered task(s) or survey(s)]
[✓] Interview(s) (in person)
[ ] Interview(s) (by telephone)
[ ] Focus group(s)
[ ] Audio taping
[ ] Videotaping
[ ] Analysis of secondary data (no involvement with human participants)
[ ] Unobtrusive observations
[ ] Other, specify ______

b. ***Provide a brief, sequential description of the procedures to be used in this study. For studies involving multiple procedures or sessions, the use of a flow chart is recommended.***

1 Primary research
 a) Interviews
 b) Questionnaires
2 Secondary research
 a) Literature review
 b) Investigating other successful projects similar to ours
3 Drawing conclusions and making recommendations

3. Participants Involved in the Study

a. ***Indicate who will be recruited as potential participants in this study.***

Dalhousie Participants:
- [✓] Undergraduate students
- [ ] Graduate students
- [✓] Faculty and/or staff

Non-Dal Participants:
- [ ] Children
- [ ] Adolescents
- [✓] Adults
- [ ] Seniors
- [ ] Persons in Institutional Settings (e.g. Nursing Homes, Correctional Facilities)

[ ] Other (specify) ______________________

b. ***Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. If only one gender is to be recruited, provide a justification for this.***

Dalhousie staff and undergraduate students will be surveyed. Architects and staff will be interviewed.

c. ***How many participants are expected to be involved in this study?*** 100

4. Recruitment Process and Study Location

a. ***From what source(s) will the potential participants be recruited?***

- [ ] Dalhousie University undergraduate and/or graduate classes
- [✓] Other Dalhousie sources (specify) Public areas like the LSC and SUB. ↳ students and staff will be given a questionaire
- [ ] Local School Boards
- [ ] Halifax Community
- [ ] Agencies
- [ ] Businesses, Industries, Professions
- [ ] Health care settings, nursing homes, correctional facilities, etc.
- [ ] Other, specify (e.g. mailing lists) ______________________

b. ***Identify who will recruit potential participants and describe the recruitment process.***
Provide a copy of any materials to be used for recruitment (e.g. posters(s), flyers, advertisement(s), letter(s), telephone and other verbal scripts).

All group members will participate in distributing questionnaires. Group members will select random students from public areas such as the atrium of the Killam Library, the SUB and the food court in the LSC.

5. Compensation of Participants

Will participants receive compensation (financial or otherwise) for participation? Yes [ ] No [✓]
If **Yes**, provide details:

6. Feedback to Participants

Briefly describe the plans for provision of feedback and attach a copy of the feedback letter to be used. Wherever possible, written feedback should be provided to study participants including a statement of appreciation, details about the purpose and predictions of the study, contact information for the researchers, and the ethics review and clearance statement.

Note: When available, a copy of an executive summary of the study outcomes also should be provided to participants.

N/A

POTENTIAL BENEFITS FROM THE STUDY

1. **Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project.**

They will recieve an environmentally friendly learning facility.

2. **Identify and describe any known or anticipated benefits to society from this study.**

Since Dalhousie is a leader in the community this building could be used as an example when other buildings will be built

POTENTIAL RISKS TO PARTICIPANTS FROM THE STUDY

1. **For each procedure used in this study, provide a description of any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social, economic, legal, etc. risks/stressors**

   [✓] No known or anticipated risks
   Explain why no risks are anticipated: No names will be collected from the questionnaires. Results will be quantitatively analyzed + organized

   [ ] Minimal risk
   Description of risks:

   [ ] Greater than minimal risk
   Description of risks:

2. **Describe the procedures or safeguards in place to protect the physical and psychological health of the participants in light of the risks/stresses identified in Question 1.**

No names will be collected from the questionnaires. Results will be quantitatively analyzed + organized. As far as the interviews go, we are just collecting ideas on architectural features from people. This information, if explicitly used, will not be harmful to the person interviewed.

INFORMED CONSENT PROCESS

Refer to: http://pre.ethics.gc.ca/english/policystatement/section2.cfm

1. **What process will be used to inform the potential participants about the study details and to obtain their consent for participation?**

   [ ] Information letter with written consent form; provide a copy
   [ ] Information letter with verbal consent; provide a copy
   [ ] Information/cover letter; provide a copy
   [ ] Other (specify) None

2. **If written consent cannot be obtained from the potential participants, provide a justification.**

   The research involves no more than minimal risk to the subjects. Names of questionnaire participants will not be taken. The waiver or alteration is unlikely to adversely affect the rights and welfare of the subjects

ANONYMITY OF PARTICIPANTS AND CONFIDENTIALITY OF DATA

1. **Explain the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.**

   No names will be collected from questionnaire participants. Interviews are voluntary

2. **Describe the procedures for securing written records, questionnaires, video/audio tapes and electronic data, etc.**

   Interviews + questionnaires will be kept confidential and results are quantitatively organized.

3. **Indicate how long the data will be securely stored, the storage location, and the method to be used for final disposition of the data.**

   [✓] Paper Records
   - [ ] Confidential shredding after ______ years
   - [ ] Data will be retained indefinitely in a secure location
   - [✓] Data will be retained until completion of specific course.

   [ ] Audio/Video Recordings
   - [ ] Erasing of audio/video tapes after ______ years
   - [ ] Data will be retained indefinitely in a secure location
   - [ ] Data will be retained until completion of specific course.

   [ ] Electronic Data
   - [ ] Erasing of electronic data after ______ years
   - [ ] Data will be retained indefinitely in a secure location
   - [✓] Data will be retained until completion of specific course.

   [ ] Other ______________________________
   (Provide details on type, retention period and final disposition, if applicable)

   Specify storage location: ENVS 3502 Portfolio

ATTACHMENTS

Please **check** below all appendices that are attached as part of your application package:

[ ] **Recruitment Materials**: A copy of any poster(s), flyer(s), advertisement(s), letter(s), telephone or other verbal script(s) used to recruit/gain access to participants.
[ ] **Information Letter and Consent Form(s)**. Used in studies involving interaction with participants (e.g. interviews, testing, etc.)
[ ] **Information/Cover Letter(s)**. Used in studies involving surveys or questionnaires.
[ ] Parent Information Letter and Permission Form for studies involving minors.
[✓] **Materials**: A copy of all survey(s), questionnaire(s), interview questions, interview themes/sample questions for open-ended interviews, focus group questions, or any standardized tests used to collect data.

SIGNATURES OF RESEARCHERS

Signature of Student Investigator(s)	Date
Tawyn Moore	26 Jan/05
Ericka Wicks (Ericka Wicks)	Jan. 26, 2005
Kathy Cooper	26 Jan / 05
[illegible]	26 Jan/05
[illegible]	26 Jan 05
Sara Pullin	30 Jan 05

FOR ENVIRONMENTAL PROGRAMMES USE ONLY:

Ethics proposal been checked for eligibility according to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans

Signature Date

Appendix E: Introduction letter, Interview Questions (sample), and Thank-you letter

Date

Dear:

From the Environmental Problem Solving class (ENVS 3501) at Dalhousie University, we would like to request your time for an interview regarding green building design for a proposed *Science Student Commons*. This building is to be built within the next four years and will be located within the Life Sciences Centre, Dalhousie University. The building will feature a computer facility, lecture rooms, and office space. We are hoping to collect information specifically on three aspects of green design that could potentially be incorporate in the building: green roof, efficient lighting features, and an efficient HVAC system.

You have been selected as our resident expert on the matter of "green building design", and we would be very grateful to have the opportunity to meet with you to discuss this project further. On the following page are the questions that we would like to ask you. If you are available for an interview, or have any questions or concerns regarding the project, please call or e-mail to the attention of Sara Pullen ( ).

Sincerely,

Sara Pullen
Ericka Wicks
Kathy Cooper
Marc Franz
Taryn Moore
Erica Ring

Interview Questions

Name:
Title:
Date:

Do you feel the University is the appropriate environment for promoting the newest green technology and for going above and beyond the norm? If so, why?

In your opinion, what are the most effective means of achieving sustainability on campus (in terms of green design)

- reduction of energy use
- incorporation of living components (i.e. green roof)
- buying local materials
- improved air quality
- improved construction practices
- use of recycled materials
- other

In your opinion, what is the greatest barrier as an obstacle for the incorporation of green design?

Do you think the University can make green buildings without additional cost? What would be some of the most cost-effective aspects to look into in your opinion?

Do you have any suggestions as to what models/examples we should investigate for each design aspect? For example, we are investigating Underfloor Air Distribution for an HVAC system, are there any other HVAC systems we should investigate?

How best do you feel these three design aspects (green roof, efficient lighting, and HVAC systems) can work with the social and personal well-being of the users? Please offer any examples that come to mind. For example, improved air quality from a proper/efficient HVAC system to improve the health of users.

Are you aware of what the current time specification for investment pay-back is at Dalhousie University (e.g. 5-10 years)?

Are any decisions left to the architects (i.e. materials used)? Is there a way to devise a set of specifications that should be met (in terms of green design)?
Are you aware of any policy obstructions that may hinder the use of any green design aspects? (i.e. Fed law obstructs University from buying regionally- illegal to give geographic preference when bidding for projects over $100,000)

Are you aware of any building constrictions that need to be taken into account? For example, weight loading, drainage, etc.?

Are there any others you would suggest our group meet with? Perhaps any members on the Building Design Committee or those familiar with the building codes and policies?

Additional info/comments:

Letter of Thanks

Date

Address of interviewee

Dear:

From the Environmental Problem Solving class (ENVS 3501) at Dalhousie University, we would like to gratefully thank-you for your time in completing the interview conducted on (date). The information you provided will be of great assistance in the development of a feasibility analysis on green design construction at Dalhousie. We hope to generate enough information from experts such as yourself in the field of green design in order to narrow our research to three green design aspects.

Should you desire any follow-up information regarding this project, please do not hesitate to contact us at the attention of Sara Pullen ( ). Thank-you for your time and consideration in assisting us with this project.

Sincerely,

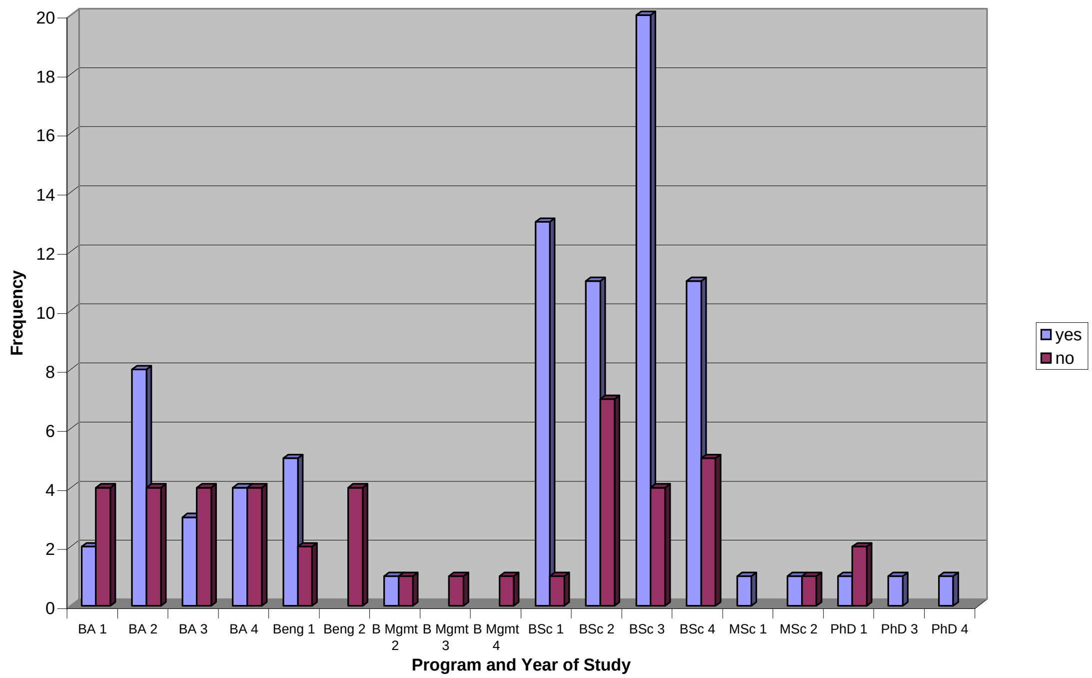
Sara Pullen
Ericka Wicks
Kathy Cooper
Marc Franz
Taryn Moore
Erica Ring

Appendix F: Survey Results

Question #3: Is a new Science Student Commons important to Dalhousie students?

Program	**Year of study**	**Yes**	**No**
BA	1	2	4
	2	8	4
	3	3	4
	4	4	4
BEng	1	5	2
	2		4
BMgmt	2	1	1
	3		1
	4		1
BSc	1	13	1
	2	11	7
	3	20	4
	4	11	5
MSc	1	1	
	2	1	1
PhD	1	1	2
	3	1	
	4	1	
Total		83	45

Question #3: Is a new Science Student Commons Important to Dalhousie Students?

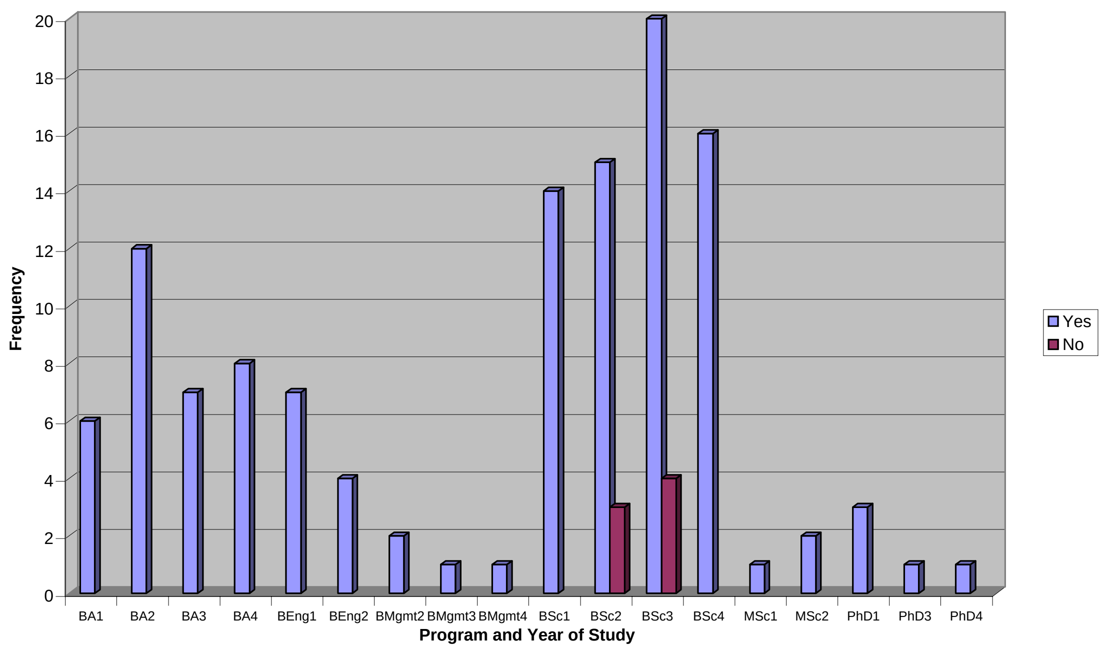


Question #4: Is incorporating environmentally friendly design aspects into the Science Student Commons important to Dalhousie students?

Program	Year of study	Yes	No
BA	1	6	
	2	12	
	3	7	
	4	8	
BEng	1	7	
	2	4	
BMgmt	2	2	
	3	1	
	4	1	
BSc	1	14	
	2	15	3
	3	20	4
	4	16	
MSc	1	1	
	2	2	
PhD	1	3	
	3	1	
	4	1	

Total		121	7

Question #4: Is Incorporating Environmentally Friendly Design Aspects into the Science Student Commons Important to Dalhousie Students?



Question #5: Environmentally friendly design aspects chosen by Dalhousie students.

Option	**Frequency**	**%**
Energy efficient lighting	177	24.6
Use of renewable energy sources	99	13.8
Use of environmentally friendly/recycled building materials	101	14.0
Efficient water use	72	10.0
Improved indoor air quality	177	24.6
Living aspects	99	13.8
Total	719	100