On Boston College

The College of Arts and Science

Environmental Studies Program

A Proposal to Build a Green Roof on the New Margot Connell Recreation Complex

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Environmental Studies Senior Seminar

Spring 2019

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Abstract:

This research paper aims at reviewing the sustainability of the new recreational facility on lower Boston College campus, in order to determine if the building is a good candidate for a green roof. As the Boston College campus continues to grow, we believe it is imperative to explore sustainable development and implement energy saving, environmentally friendly infrastructure. A green roof system is an extension of an already existing roof. Green roofs are proven to provide natural heat and cooling insulation, support stormwater drainage and stormwater storage, increase air quality, stimulate biodiversity in urban areas, and most importantly provide opportunities for social gathering and environmental education. In this paper the researchers focused on three areas of sustainable development: potential economic incentives, whether or not green roofs will have a positive effect on the well being of the Boston College community, and what design will work best for the current infrastructure. In order to answer these questions, we collected data from case studies, conducted a survey in order to gather information on the Boston College community, and met with architects involved with the construction of the new Margot Connell Recreation Complex. Once the data was compiled, the researchers determined that a green roof would not have a significant effect on utility costs from heating and cooling. However, evidence suggested a green roof would reduce flooding in lower campus, provide natural fire retardation, increase local biodiversity, and provide a safe space for students and faculty to interact and socialize. It is recommended that the results of this study and the proposed green roof plan are considered by the Construction Managers and the Office of Sustainability.

Keywords: green roof, flooding, rainwater harvesting

Introduction

Figure 1: Boston College prior to 1957

Founded in 1863, Boston College has been a constantly changing and expanding university. Before 1957 the Lower Campus we know today was a small reservoir, which is displayed above (Figure 1). While our initial focus was reducing energy demands of heating and cooling systems, we quickly realized a green roof structure would have a larger impact on municipal issues; specifically storm water management. Considering the facts that Lower Campus is topographically lower than the rest of campus, and that it was built on top of an old reservoir, it is prone to extreme flooding. Continuous incidents of flooding can have many consequences including damages to infrastructure, drowning of crops, and impending danger to the Boston College community. According to U.S. Climate Data, Boston averages 43.76 inches of rainfall per year. As the threat of climate change continues to escalate, scientists have statistical evidence suggesting weather will become more extreme and precipitation levels will rise. A professor from UMass Boston School for the Environment, Paul Kirshen, predicts that flooding will only continue to become more pervasive as sea levels rise and storms become more severe because of our mistreatment of the planet. Now we know the best way to avoid these risks would be to change our lifestyle, but this starts with education.

In the Spring of 2017, Boston College began building a new recreation complex on Lower Campus, shortly after demolishing Edmonds Hall into rubble. At the time, the new recreation complex was not an imminent reality for students. Now, fast forward, two years later you can see this massive structure coming to life. Standing four stories high, this 244,000-square-foot complex is set to be complete in the Summer of 2019.

Throughout our research to evaluate the potential of implementing a green roof at Boston College we had three driving questions to assess the success it could have on campus. Our extensive research allowed us to examine these questions deeply and come to the conclusion that a green roof is a feasible and incredibly beneficial design for the Margot Connell Recreation Complex. For the purposes of our study, we decided to focus on the following questions:

1. What, if any, are the psychological benefits of being in nature, and how will a green roof impact the social well being of the Boston College community?
2. Are green roofs a sound economic investment: will it reduce or increase utility and maintenance costs or will it have a significant impact on stormwater management ?
3. Is it possible to build a green roof on existing infrastructure, if so, where is the best location and what is the best design for the proposed area?

Literature Review

A report in the *International Advanced Research Journal in Science, Engineering and Technology* by Tapaswini Mohapatra Samant titled "Green roofs pertaining to Storm Water Management in Urban Areas: Greening the city with Green Roofs" evaluates the pros and cons of green roofs, and the impact of stormwater. This report was extremely helpful in determining the type of green roof that would be most successful on Boston College's campus in regards to flooding. It also helped to evaluate the best course of action for stormwater management that benefits how to move forward with a rain harvesting system. Green roofs have the capacity to absorb 50% of the annual rainfall through retention and evapotranspiration (Tapaswini, 2015). This report shines light on the fact that green roofs aren't a new concept, but can be dated back to the Roman Empire. This highlights how using native plants for a green roof can help aid in its success and longevity. Extensive green roofs typically use low lying native plants, which contributes to their need for little maintenance. During an extensive green roofs first year it requires the most amount of attention. The plants must be watered and fertilized until they are matured. After the first year the only maintenance required is a couple of visits a year to weed and perform safety inspections.

In a study conducted by H.F Castleton, a thorough investigation determined the potential benefits and risks of green roof infrastructure. The study discussed the potential benefits of green roofs with regards to reduction of energy use through better insulation, density and moisture content (Castleton 2010). The review begins by explaining how green roofs largely reduce the proportion of solar radiation that reaches the roof structure and offer increased insulation value. This feature is incredibly valuable as buildings account for around half of primary energy consumption, emphasizing their contribution of CO_2 emissions (Castleton, 2010). The insulating effect was determined to be the most significant in both the summer and winter months, however, the article points out that these energy savings are most realized by older buildings that lack the density of modern infrastructure. As you can see from the figure below, modern, well-insulated roofs save around 2% annually from the implementation of a green roof. On the other hand, the older, non-insulated buildings saved from 31-44% a year (Castleton, 2010). This was particularly important for our study, as the Margot Connell Recreation Complex will be a state of the art facility. As a result, the energy savings from implementing a green roof should not be considered important to this study when compared to other social, environmental and economic benefits.

Roof construction	*U*-Value without green roof (W/m^2 K)	*U*-Value with green roof (W/m^2 K)	Annual energy saving % for heating	Annual energy saving % for cooling	Total annual energy saving
Well insulated	0.26–0.4	0.24–0.34	8–9%	0	2%
Moderately insulated	0.74–0.80	0.55–0.59	13%	0–4%	3–7%
Non insulated	7.76–18.18	1.73–1.99	45–46%	22–45%	31–44%

Figure 2: Energy savings with and without a green roof between well, moderately and non insulated buildings (Castleton, 2010).

A recent paper by Dongying Li et al. titled "Moving beyond the neighborhood: Daily exposure to nature and adolescents' mood" details the psychological effects of nature. Green spaces have shown to help adolescents escape stress and develop social capacities. They have also proven to be a great space to build positive emotions and self esteem (D. Li, 2018). They wanted to more closely examine this linkage. In order to examine the effect nature has on mood, they first used satellite images and Google Street View to appropriately assess the concentration of nature in a certain area (D. Li, 2018). Further, to evaluate mood disturbances in the individuals tested they adopted the Profile of Mood States scale, which helps measure "mood disturbances as a global measure of feelings of tension, depression, anger, fatigue, and vigor" (D. Li, 2018). You can see from the figure below that they are tested over a period of four days, and wear a GPS to track their location. All of these different emotions were lumped together into one total mood disturbance score. The lower the mood disturbance score, the better the mood the individual is in.

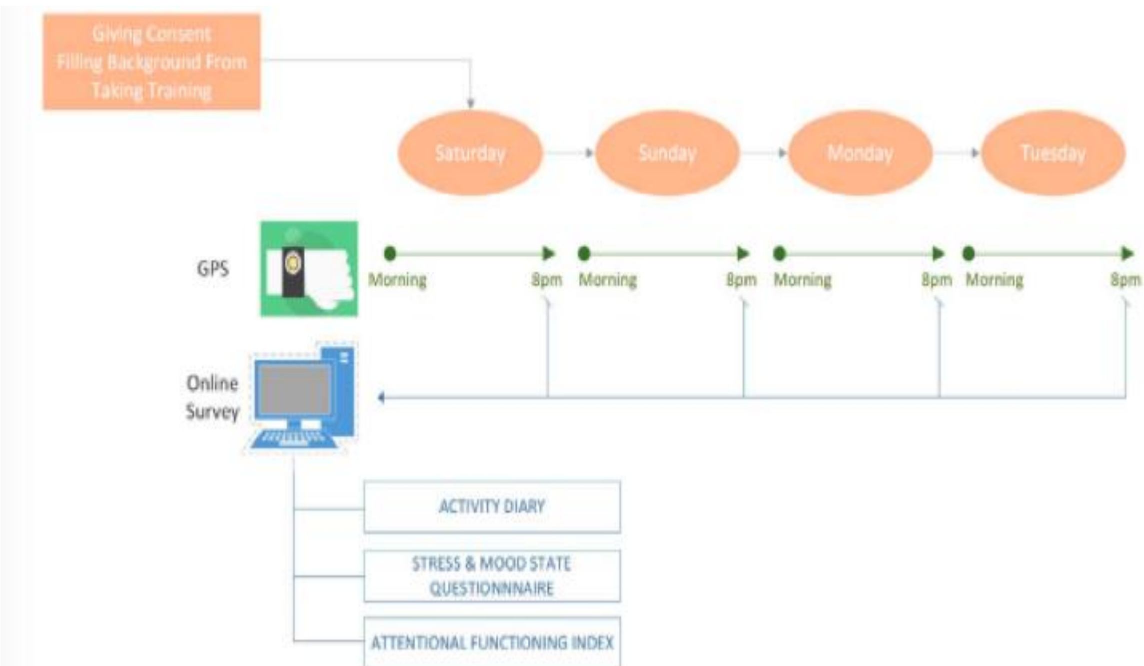

Figure 3: This shows the testing period and information collected by Li's study (D. Li, 2018).

The study found that the concentration of nature was associated significantly and negatively with depression, anger, fatigue and overall mood. This supports the hypothesis that the more an individual was around nature, the less he/she was depressed, angry, fatigued and was more likely to be in a better overall mood (D. Li, 2018). If you look at the table below you can see the relative correlation values for each emotion.

	Tension	Depression	Anger	Fatigue	Vigor	Mood disturbance
Nature concentration	−0.03	−0.09*	−0.16**	−0.12**	0.02	−0.13**

* Significant at the 0.05 level.
** Significant at the 0.01 level.

Figure 4: Bivariate correlation between concentration of nature and the indices of mood (D. Li, 2018).

While this study was conducted on adolescents, we believe its implications still apply at Boston College. Most college students are legal adults, however, mental health is still a big concern at Boston College and other universities. We believe that this study represents how a green roof can have an incredibly positive effect on the mood of our fellow classmates.

In addition to collecting data on the sociological and economic effects of green roofs, it was important we studied different types of green roof structures in order to determine what system would be best suited for the proposed area. We consulted Green Roofs For Healthy Cities, a non-profit professional industry organization, in order to understand the building standards and associated risks of green roof structures. The organization provided plans and insight as to how to specifically prevent wind damage, an impending threat to the new recreation facility, and provided us with design plans intended to optimize the efficiency of green roof structures.

In order to determine what type of green roof structure, extensive or intensive, we consulted the journal, *Renewable and Sustainable Energy Reviews*. This journal provided us with general design considerations and system requirements. In the article, *Wind Design Standard for vegetative Roofing Systems*, the author argues all vegetative roofing systems shall comply with the following: roof structure, building height, slope, positive pressure building systems (HVAC equipment), roof top projections, membrane requirements, membrane perimeter and angle change attachment, parapet height, and threat of wind erosion (Green Roofs For Healthy Cities, 2016). Using the data they collected from their own studies, we were able to consider all the elements a proposed roof must have in order to withstand a green roof structure. This data drew brought us to our conclusion: the new recreation facility, with 80,000 sq/ft of available flat roof space, would be the best location for a low maintenance, high efficiency green roof.

The General Services Administration (GSA) published a report to compare costs of green roofs with the benefits they provide. This cost benefit analysis gave us information to ensure that implementing a green roof on the Boston College campus would be beneficial. It also gave insight into evaluating if a green roof would be a sound economic investment for Boston College. As previously mentioned green roofs on newer buildings have a very slim margin for cost saving when it comes to heating and cooling, because of technological advancements that have enhanced the quality of insulation. That being said, our main focus for examining economic benefits is measured through long term savings that a green roof provides. Green roofs are typically $10.30 to $12.50 more expensive per square-foot than conventional black roofs, but the cost per square-foot decreases as the size of the roof increases (GSA, 2011). Although green roofs cost more to install than a traditional roof, they tend to have a longer lifespan and don't need renovations as frequently. Another long term benefit of incorporating a green roof is its capacity to retain water. Having this design helps to manage the damage stormwater can cause, which will be effective in reducing the costs to fix infrastructure over time.

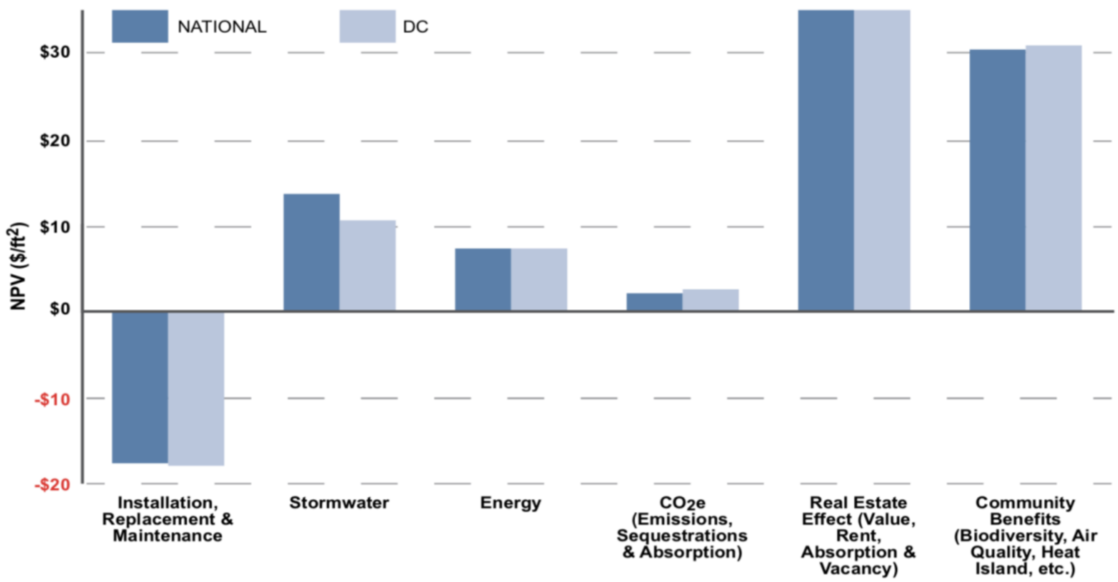

Figure 5

The above figure represents the cost benefits of a green roof over a 50 year period. It compares the cost benefit of a green roof in D.C. with the benefits on a national scale. The graph displays the information stated above about the high costs of building a green roof, but it is also important to note that these are high upfront costs. The cost to maintain the roof after it is constructed is minimal, and the benefits from storm water retention and the potential for recycled water reuse, creates another economic incentive. Considering the climate in D.C. is similar to Boston, this graph serves as a good indicator for the overall economic benefits of a green roof.

The Guardian posted an article titled "Rainwater Harvesting: using the weather to pay your bills". This article explains that rainwater harvesting is a cheaper alternative to a greywater system. Harvesting rainwater allows for a plethora of opportunities for where to use the water. Rainwater harvesting systems are more simple than greywater systems, and they also are more environmentally friendly. The rainwater that falls from the sky hasn't yet been used by humans, as a result, it contains less bacteria and contaminants. Technology has allowed for rainwater harvesting systems to be used both in the home and outdoors. Obviously the one downside to this alternative is you must rely on precipitation in order to obtain water, but it also reminds people not to waste resources unnecessarily. There is also the option to use the main water system during periods of little rain. For all these advantages rainwater harvesting can provide, we decided that the Margot Connell Recreation Center would be a good candidate. Harvesting rainwater helps to cut down water costs, and also allows the precious resource to be used where it is needed.

Methods

We created an online survey that was released to the Boston College community. The purpose of this study was to determine whether there was a need for more areas on campus for social gathering, studying, and relaxation. The first section of the survey consisted of six questions asking participants to state their graduating year and/or occupation, and answer questions about where they go on campus to socialize, relax, or study. In addition, we asked whether or not they believed there were enough spaces for students and faculty to spend leisurely time (See figure 7,8,9). The second section of the study included a short definition of what a green roof system is, and included an image of an existing urban green roof. This section was followed by nine questions geared at understanding participants existing knowledge of green roofs and sustainable infrastructure. Participants were given the option to select “Yes, I agree”, “No, I do not agree” and “I do not know”. The survey concluded with a question regarding whether or not the participant felt that Boston College is a good candidate for a green roof, and whether or not they would spend time there. The survey was a form of social listening and allowed us to gather qualitative data on the Boston College community. The results were then analyzed in order to determine whether or not there was a need for more accessible outdoor spaces on campus.

In order to determine whether or not a green roof would be a good economic investment for Boston College, we looked at case studies from around the world. We discovered that, as a developed country, the United States has fallen short when it comes to sustainable infrastructure. The cases we used investigated the effects of green roofs on uninsulated roofs, highly insulated roofs, and domestic homes. We then focused our research on the cost benefit analysis of green roof systems, using the Net Present Value Model (NPV) (Castleton, 2010). This model takes in the Life Cycle Cost (LCC) and compares it to that of conventional flat roof systems, both black top and white top. A NPV is calculated by "estimating all future cash flows of a particular project and is discounted back to a one single price relative to the present day using the present value formula." (Castleton, 2010). When calculating the NPV we have to consider the following: roof age, area, total costs including watering, vegetation and other material costs, average maintenance cost per year, and technology repairs (mechanical repairs, plumbing repairs, and labor costs). The United States General Services Administration, determines the green roof NPV using a 4.4% interest rate over a period of 50 years (Castleton, 2010). In addition to the NPV model, we then focused on our attention on the potential for long term investments like municipal uses such as stormwater management and stormwater storage.

In order to determine the feasibility of this project we spoke with architects, construction site managers, and botanists. The lead project manager of the upcoming Margot Connell Recreation Facility gave us a tour of the construction site, which we concluded would be the best building on campus to implement a green roof structure. In addition, he shared construction blueprints, which allowed us to analyze the slope of the roof, the roof's depth, and available space and access points (See Figure 12 &13). With the blue prints we were able to determine what type of green roof, intensive or extensive, would work best for the existing building. Lastly, we spoke with architects and botanists, in addition to collecting online research, in order to understand what vegetative species would work best for the given environment, and how to make the proposed green roof low maintenance and cost effective.

Results

Economic Conclusions

Through extensive research, and consideration to the Net Present Value Model and the Life Cost Cycle, we concluded that green roof systems have significantly larger upfront costs than a conventional roof. However, this conclusion was expected. When considering the energy saving benefits of green roofs, our data was less conclusive. For example, energy saving benefits are dependent on the climate, substrate thickness, location in accordance to the sun, vegetation type, building age, and local utility rates (Kantor, 2017). Because the Margot Connell Recreation facility is still under construction we were unable to determine whether or not a green roof would have a significant impact on overall energy consumption. In addition, because the building is brand new, it is built to the best standards, and already has energy efficient heating and cooling systems in place. Therefore, we have reached the conclusion that a green roof would not cause a significant reduction in energy for heating and cooling.

Despite reaching the conclusion that a green roof on the new recreation facility will not reduce utility costs, we did discover there are significant municipal incentives associated with green roof systems. We elaborate more on this theory in the discussion section.

Green Roof Design Conclusions

We have concluded that an extensive green roof, rather than an intensive green roof, is recommended for the new recreation facility on lower campus. An extensive green roof has a "thin substrate layer with low level planting, typically sedum or lawn" (Castleton, 2010). This is our recommendation due to the fact that extensive green roof structures are lightweight and low maintenance. In comparison, an intensive green roof structure has a deeper substrate layer in order to allow deep rooting plants like trees and shrubs. Figure 6 illustrates the required elements of an extensive green roof. In our proposal we recommend sedum vegetation and native grasses. Sedum are low maintenance, low lying plants, that offer coverages and roof membrane protection (Castleton, 2010). It is imperative that the vegetation we propose is able to withstand the elements, specifically wind exposure. There are reported cases of green roofs falling apart when exposed to extreme weather. However, Sedum landscaping will help avoid these complications.

According to the Green Roof Center, an extensive green roof system costs between \$67.29 and \$112 per m_2. These calculations are dependent on whether or not the roof is a new build, or being retrofitted. Since the new recreation facility is already built, we are proposing Boston College retrofits the current infrastructure. Based on a case study on various retrofitting projects in Manchester, the estimated supply and installation cost would be around \$72/m2 for a green roof on the Margot Connell Recreation Complex (Drivers, 2009).

Figure 6: Extensive Green Roof Requirement, highlighting the different components of infrastructure

Survey Results

Our survey participants were not evenly distributed across class years. Looking at figure 6, you can see that 66.7% of our respondents were seniors. Freshman were our second highest portion of respondents at 14.2%.

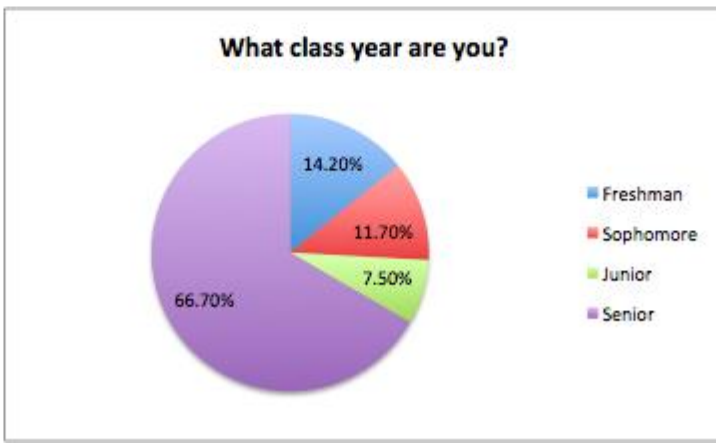

Figure 6

Our survey showed us that there is a clear need for places to sit, relax and socialize at Boston College. 92.5% of Boston College students struggled to find a place to sit in a dining hall or Boston College cafe. Further, 68.3% of students surveyed believed Boston College does *not* have enough space for students to socialize. Only 8.3% of students thought Boston College had ample socialization space. See the figures 7 and 8 below.

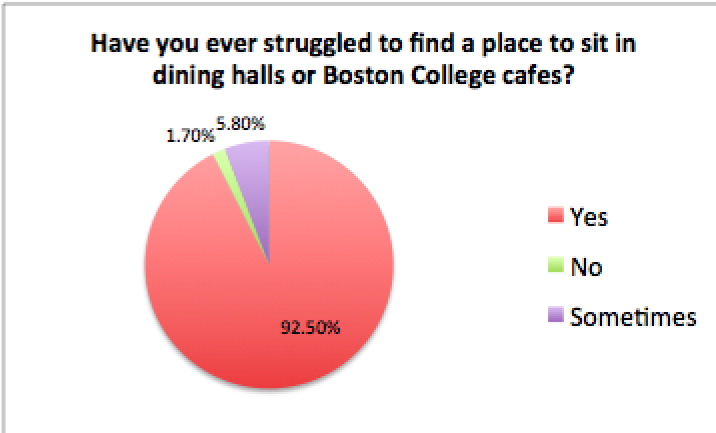

Figure 7

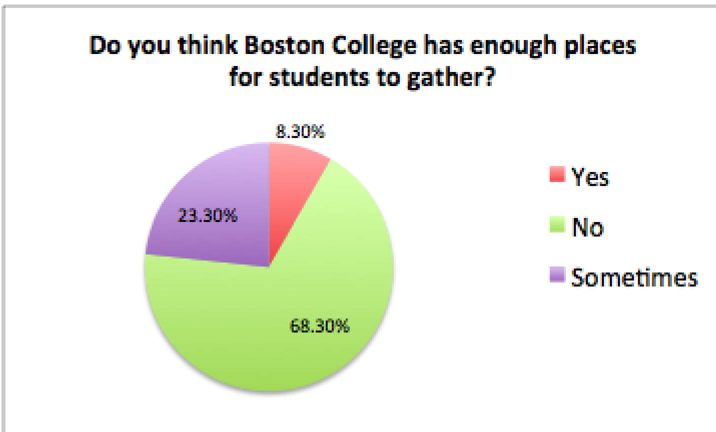

Figure 8

Our survey also showed a clear need for more outdoor space. Students preferred to socialize outdoors relative to other locations on campus. 47.5% of our sample population stated that the outdoors was their favorite place to hangout with friends. See figure 9 below.

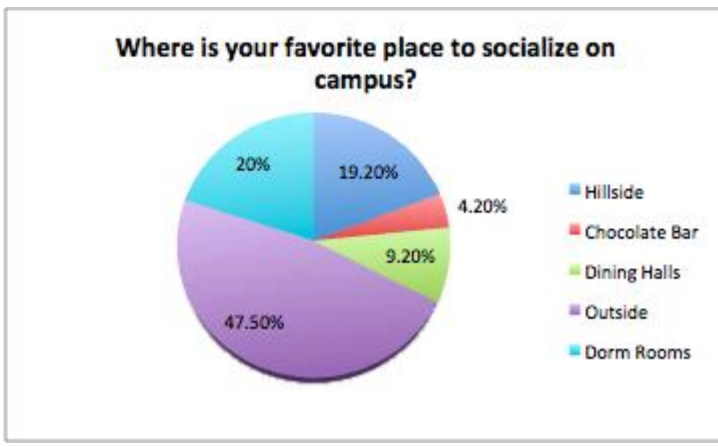

Figure 9

While 45.8% of the students surveyed did not know what a green roof was, once given a brief description they had good perceptions of the idea. Over 75% of students surveyed thought that green roofs improve air quality, energy efficiency, well being and are a good economic investment. See figure 10 below.

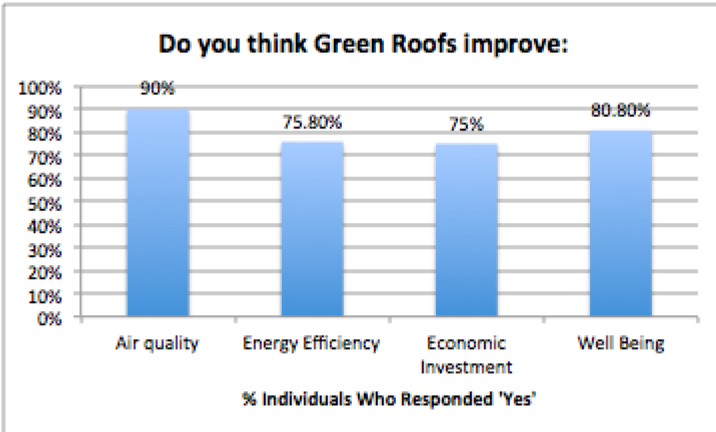

Figure 10

Lastly, 94.2% of our survey participants believed that Boston College should build a Green Roof on campus that is accessible to students. From looking at figure 11 below, you can see that those who didn't reply 'yes' were indifferent.

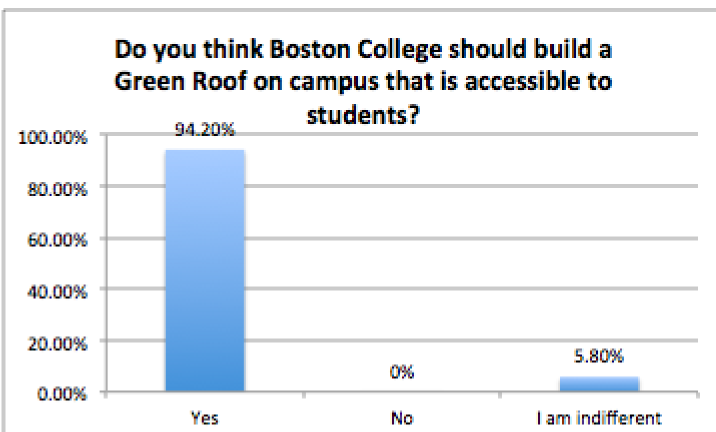

Figure 11

Discussion

Social/Survey

Our survey made it clear to us that a green roof on the new Margot Connell Recreation Complex would not only be accepted by students, but also widely encouraged. Our results show the campus' clear need for additional social spaces, especially ones outdoors. Students already go to the recreation complex to get away from schoolwork – it would be an even better escape if they could also relax with friends in a green space. In addition to being a new fitness center, the Margot Connell building also includes lounge areas, kitchen space, and classrooms. Although the building will provide plenty of indoor space, we believe including an accessible outdoor area for students to gather would only increase the value of the building and encourage students and faculty not only to interact with each other, but also interact with nature and sustainable development.

It is apparent that interactions with nature leave a positive psychological effect on individuals. This green space would give students the perfect opportunity to getaway from their busy day and enjoy some time outside with nature. Our survey supports this natural inclination to be among nature, as most students preferred to socialize outside on campus. It is important to note that Boston College students struggle with mental health, just like any other university. Moreover, the psychological benefits of a green roof would help students cope with stress and other emotions.

While we had a great amount of responses to our survey, the major drawback was that the responses were heavily weighted towards seniors. While we made an effort to approach students on upper campus to help us boost our underclassmen numbers, it did not resolve the massive imbalance. This was mostly due to the effect of our groups' network. Generally, individuals were more willing to take our survey if they knew one of us. Further, many of our friends passed along our survey to their own friends at Boston College who were also likely seniors. This affected the demographics of our survey, and is a flaw within the data.

Environmental & Economic Discussion

Boston College also has a history of shirking from questions regarding divestment. The student body has lobbied for the university to divest its endowment funds from fossil fuels for years, to no avail. An article from the Heights does a great job of highlighting this tension, "After a non-binding referendum on the Undergraduate Government of Boston College elections ballot asking if BC should withhold investments from the fossil fuel industry received 2,005 votes 'yes' and 374 'no,' University Spokesman Jack Dunn said that BC will not comment on student elections, but the school's stance on divestment has not changed" (The Heights, 2019). The current administration does not believe that divestment is the most effective way to limit climate change – but most students perceive this as the university protecting its bottom line. This has left a bit of a wound on the community, and put the university in a place where it is trying to earn students trust back. Further, the university believes that the correct strategy to combat climate change is “to take active steps to reduce energy consumption and enhance sustainability measures” (The Heights, 2019). If this is truly a measure they are committed to, implementing a green roof on the roof of the new recreation complex would be a powerful first step. This would placate the frustrated student body and set a great foundation for future environmentally friendly reform.

In order to select the best possible space for a green roof at Boston College, we met with construction managers and toured different buildings on campus. After careful consideration we concluded the new recreation facility is the best candidate for a green roof. Case studies suggest that green roofs reduce heating and cooling energy demands the most on older infrastructure (Figure 2). However, we believe that the benefits from stormwater management in addition to the potential for creating a social outdoor space, overweigh the potential to reduce utility bills. Stormwater management is a proven benefit of green roof structures. Given the location of lower campus, and the land previously being a reservoir basin, we believe the potential for municipal displacement is invaluable.

Infrastructure Discussion

In total, the new recreation facility is 244,000 square feet with 80,000 square feet of potential flat roof space. The building is broken up into three sections: Section A, Section B, and Section C. There are 3 stories, in addition to a 4th story penthouse straddling Section A & B, with access to the roof. (Figure 12). From the side of the building, or from ground level, it appears that the building has a sloped roof. However, there are 2 meter parapets on the perimeter of the building, and a flat roof behind them (Figure 14 & 15). The blueprints show the roof has a slight negative slope. A sloped roof will allow for maximum stormwater collection, and the potential to reuse collected water in a grey water system or for potential lawn irrigation on upper campus.

As you can see from figures 14 and 15, the roof has an already existing perimeter around the building. Something we considered when writing this paper, was the safety of students and whether creating an interactive green roof was feasible. However, the existing perimeter prevents any potential for accidents. Additional infrastructure can also be added to ensure there is no risk of falling or accidents.

In addition to selecting the area for a green roof structure, we consulted the Green Roofs Healthy City Organization to collect data from cases and experts to determine what additional infrastructure is required for green roofs. As seen in Figure 6, an extensive green roof requires the following materials (from the top down): vegetation, growth substrate, filter layer, drainage layer, and a waterproofing layer with root barrier. Taking into account extreme weather conditions, it is critical that the vegetation planted on the roof can withstand drought and flooding, provides good ground coverage, requires low maintenance and no irrigation system, has rapid multiplication, and short soft roots. As mentioned in the results section, the best species for the proposed green roof is a combination of Sedum and native grasses. One benefit from Sedum is the species has soft roots, therefore the risk of root penetration and infrastructure damage is significantly reduced. While Sedum is able to withstand drought, we recognize precipitation is not an issue in Boston's climate. Several studies suggest diversifying plant species on green roofs maximizes efficiency and durability (Vijayaraghavan, 2015). Therefore, in addition to Sedum, we suggest planting a variety of grass species that thrive in the local climate. In addition, incorporating native landscaping will increase biodiversity, and provide an ecosystem for native invertebrates and bird species.

One draw back from Sedum, is its inability to store excess water (Vijayaraghavan, 2015). However, the existing sloped roof on the recreation facility, allows excess water to collect in one area. In order to manage stormwater, we recommend installing an rainwater harvesting system to make use of the excess water collected by the roof. This water then has the ability to be used in a variety of ways on campus. The collected water can be purified and used as drinking water, or in toilets, or used for crop irrigation on campus. Boston College is known for priding themselves on their vast amounts of luscious green grass, but the grass doesn't just look that way on its own, it requires extensive maintenance. This maintenance requires a massive amount of water to be used, leading to Boston College having a very high water footprint. Irrigation is known to be the biggest consumer of the freshwater we have available, more specifically it expands approximately 70% of the freshwater worldwide. Water is not an expendable resource, so it is important for Boston College to do its part to reduce its water consumption. By using the water from the rainwater harvesting system we will not only alleviate pressure on local municipal systems, but we will also reduce Boston College's environmental water footprint.

Installing a rainwater harvesting system not only provides significant municipal benefits, it will also reduce flooding, reduce maintenance and repair costs, increase the longevity of the green roof system, and increase sustainability on Boston College's campus. In order to increase stormwater retention, it is critical the green roof system includes commercial drainage modular panels, rather than granular drainage materials. Commercial drainage modular are made of "high strength plastic materials (polyethylene or polystyrene) with compartments to store water while allowing the evacuation of excess water" (Vijayaraghavan, 2015). In addition, case studies comparing modular panels to granular materials, suggested that modular panels store 2L of water per m_2 (Vijayaraghavan, 2015). These numbers are not insignificant, and should be seriously considered when analyzing the complete benefits of green roofs structures.

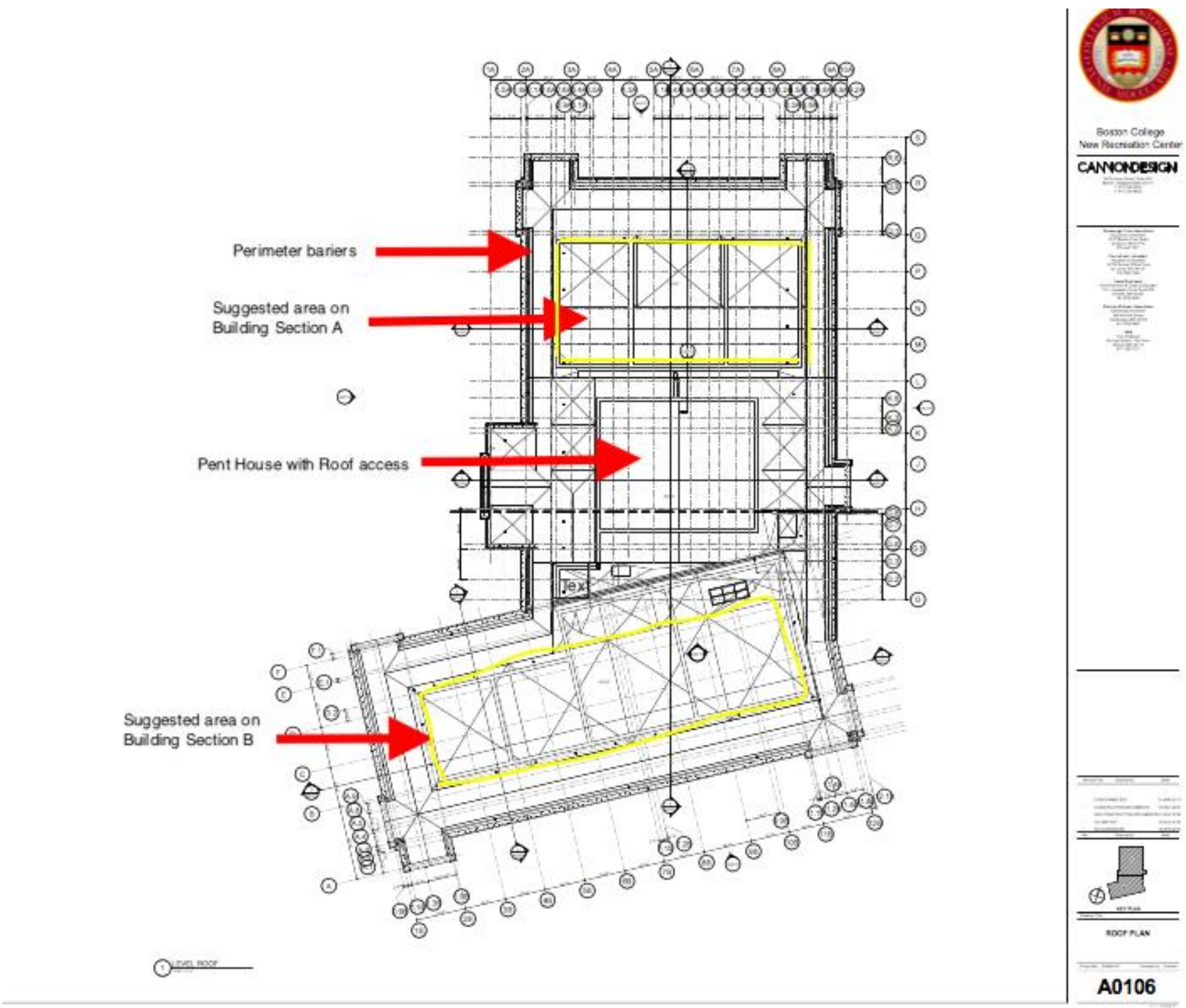

Figure 12: Blueprints of the Boston College New Recreation Center from a birds eye view. The areas in yellow are potential areas for an extensive roof structure. In the center of the blueprint is the pent house which has roof access and holds mechanical equipment.

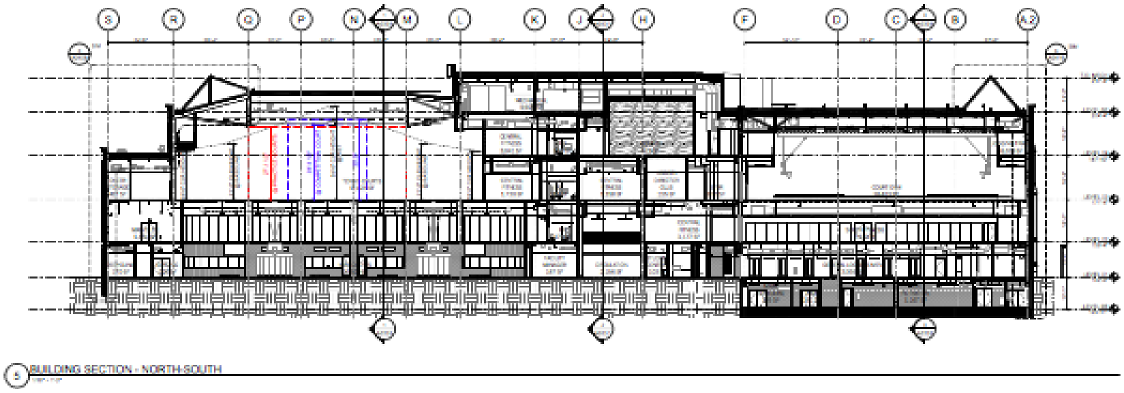

Figure 13: Blueprints of the new Boston College Recreation Center from a side view

Figure 14 & 15: Pictures of the potential roof space, showing the height of the perimeter and the flat roof surface.

Recommendations

Ever to Excel, this is the motto Boston College lives by. We see students and faculty live by this motto everyday when it comes to academics and sports, but where we fall short is in our efforts to become a more sustainable campus. Through our research we have discovered an opportunity for this campus to improve, and make strides towards becoming a greener campus. We recommend Boston College implement an extensive, or low maintenance green roof on the new recreation building, the Margot Connell Recreation Complex. We recommend the roof be designed in a similar fashion as the Burnham Building in Boston, featuring low lying foliage that can withstand direct sunlight. The plants used should be native to New England to ensure they can withstand the climate, so that the roof can be sustained and be as effective as possible. It is also important to note that if fertilizer has to be used it should be organic. Organic fertilizer helps reduce excess nutrients from entering and polluting our watersheds. The other benefit of organic fertilizer is that as the water that isn't absorbed by the green roof makes its way into the rainwater harvesting system it isn’t as polluted and would have a higher potential to become drinking water if it became necessary.

The advantage of extensive green roofs is that they require little to no maintenance, but that being said they also can’t be left to their own devices. The quality of the roof plays a massive role in how well it functions. To ensure it is kept clean and in prime condition there would need to be people to check in and support its growth. This provides an opportunity for environmental clubs on campus to incorporate tending to it as part of the clubs mission. We propose the roof be set up in a way similar to a museum. We believe a green roof structure offers

Figure 16: an example of an existing urban extensive green roof structure: This roof incorporates both sedum and grass species which is recommended for the new recreation center. (Stuckmann, Net Constructions)

an opportunity for education surrounding environmental sustainability and eco-friendly infrastructure. We suggest each vegetative species has its own panel highlighting their effect on biodiversity and sustainability practices. Incorporating native landscaping, will give the community a better understanding of the ecosystem they are a part of. The signs would also include information about the benefits of a green roof, details about the rainwater harvesting system, and facts about climate change.

In addition, we believe there is a potential opportunity to dedicate part of the roof to a communal gardening site. We believe gardening not only has the power to bring people together, but it also encourages students and faculty to interact with their food and nature. Sustainability clubs, like UGBC Environmental Caucus, and BC EcoPledge, can adopt a portion of the green roof in addition to holding educational events and conversations. This space has the ability to educate the community about the crisis our planet is facing as we continue to ignore how our lifestyle impacts our fragile ecosystems, and spark a conversation among peers that could result in more green initiatives being incorporated on campus.

While this study analyzes the benefits of green roof structures, we realize there are areas for further study. Our study is based on projected models, and a building under construction. We were unable to determine the current energy consumption, and compare it to what it could be with a green roof structure. However, throughout our research we concluded that the largest economic incentive is municipal water storage and flooding management. We recommended implementing a water collection system that would provide opportunity for recycled water and greywater systems. Further research is required to analyze how that system would be implemented.

References

Berndtsson, Justyna Czemiel. “Green Roof Performance towards Management of Runoff Water Quantity and Quality: A Review.” *Ecological Engineering*, vol. 36, no. 4, 2010, pp. 351–360., doi:10.1016/j.ecoleng.2009.12.014.

“Burnham Building.” *Recover Green Roofs*, www.recovergreenroofs.com/burnham-building-green-roof.

Campus Recreation. “The Margot Connell Recreation Center.” *The Margot Connell Recreation Center - University Advancement | Boston College*, www.bc.edu/bc-web/sites/connell-recreation-center.html.

Carter, Timothy, and Andrew Keeler. “Life-Cycle Cost–Benefit Analysis of Extensive Vegetated Roof Systems.” *Journal of Environmental Management*, vol. 87, no. 3, 2008, pp. 350–363., doi:10.1016/j.jenvman.2007.01.024.

Castleton, H.f., et al. “Green Roofs; Building Energy Savings and the Potential for Retrofit.” *Energy and Buildings*, vol. 42, no. 10, 2010, pp. 1582–1591., doi:10.1016/j.enbuild.2010.05.004.

Data, US Climate. “Temperature - Precipitation - Sunshine - Snowfall.” *Climate Boston - Massachusetts and Weather Averages Boston*, www.usclimatedata.com/climate/boston/massachusetts/united-states/usma0046.

“Design Standards, RP-14 Wind Design Standard.” *Green Roofs for Healthy Cities*, 2016, greenroofs.org/design-standards.

Drivers Jonas Deloitte/Gary Grant, Greater Manchester Green Roof Programme - Guidance Document, 2009.

“Extensive Vegetative Roofs .” *WBDG*, www.wbdg.org/resources/extensive-vegetative-roofs.

Ferguson, Donna. “Rainwater Harvesting: Using the Weather to Pay Your Bills.” *The Guardian*, Guardian News and Media, 22 July 2014, www.theguardian.com/lifeandstyle/2014/jul/22/rainwater-harvesting-using-the-weather-to-pay-your-bills.

General Services Administration, “The Benefits and Challenges of Green Roofs on Public and Commercial Buildings”, *3.0 Cost Analysis Benefit*. May 2011. https://www.gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf

Hunt, Abby. “BC Hesitant About Fossil Fuel Divestment.” The Heights, 25 Feb. 2019, bcheights.com/2019/02/25/bc-hesitant-fossil-fuel-divestment/.

Kantor, D “Life Cycle Cost Analysis of Extensive Green roofs in Switzerland and the Netherlands” *Journal of Living Architecture*, vol. 4, 2017, pp 14-25

Li, Deal, Zhou, Slavenas, and Sullivan. "Moving beyond the Neighborhood: Daily Exposure to Nature and Adolescents’ Mood." Landscape and Urban Planning 173 (2018): 33-43. Web.

Loos, Rachel. “When Noah Won't Be Able to Save the Mods.” *The Heights*, 11 Sept. 2017, bcheights.com/2017/09/11/noah-wont-save-mods/.

netconstructions.de, Michael Probst Stuckmann. “Urban Climate Roof.” *ZinCo Green Roof Systems*, ZinCo GmbH Nürtingen Germany, zinco-greenroof.com/systems/urban-climate-roof.

Samant, Tapaswini Mohapatra. “Green Roofs Pertaining to Storm Water Management in Urban Areas: Greening the City with Green Roofs.” Iarjset, vol. 2, no. 10, 2015, pp. 71–77., doi:10.17148/iarjset.2015.21015.

The Green Roof Centre, Cost of Green Roof. 26.01.2010], Available from: http://www.thegreenroofcentre.co.uk/pages/faq.html.

Vijayaraghavan, K. “Green Roofs: A Critical Review on the Role of Components, Benefits, Limitations and Trends." *Renewable and Sustainable Energy Reviews*, vol. 57, 2016, pp. 740–752., doi:10.1016/j.rser.2015.12.119.