A Rooftop Garden at 129 Lake Street:
A Feasibility Study of the Installation of a Green Roof on Brighton Campus

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Abstract:

With the increase in ecological sympathies, people are beginning to shift towards resources and methods that will both decrease their ecological footprint as well as help the environment. One method that consumers are beginning to utilize in conjunction with construction is green roofing. There are myriad benefits to installing a green roof whether it is on one's house or office building, or a university building. This paper will look at a case study of the roof of 129 Lake St, Brighton Campus, at Boston College to determine the feasibility of installing a rooftop garden. Below, we shall examine the types of green roofs available, the benefits to installing a green roof, and what procedures are necessary for installation before more closely conducting a cost-benefit analysis as the information pertains specifically to this case. We will present our conclusions about the feasibility and make recommendations for the future in terms of expanding the use of green roofs around the Boston College campus.

INTRODUCTION:

Green roofs can replicate open space conditions during storm events. The effectiveness of green roofs directly correlates with the thickness of the system—especially the thickness and properties of the green roof growing media. Nature, to a certain extent, can be replicated on top of buildings depending on how strong the roof is. They act a type of insulator for roofs in that they mimic a thermal mass or heat sink in which they slowly absorb and hold energy from sunlight releasing it when the ambient air-cools. In this way, the roof acts as a type of heat-storage battery and reduces the heating and cooling demands within the building at certain times and seasons. It has been observed that energy savings will be maximized in low buildings during warmer seasons. Studies show that the green roof market has yet to fully penetrate the North American market due to the high initial costs of construction and long-term maintenance costs. However, as will be described later in the analysis, there are many different types of green roofs that both businesses and consumers can utilize in order to fulfill their needs. Furthermore, many cities in the United States are affected by the heat island effect and also need to fight storm water management issues. Installing green roofs are an ideal solution or could be used to mitigate in improving the urban environment and retain storm water run-off. However, despite the great benefits, many realize on the short-term economical consideration for the project. Many building owners make their decisions based primarily on a financial comparison of additional costs for installing and maintaining green roofs with the additional benefits that they would receive. Green roofs could be better promoted if there were a greater list of extended benefits or by a cost reduction for the building owner.

METHODS:

The methods of the Roof Top Garden study are centered around determining feasibility. Originally, we had hopes and aspirations to make a large park-like garden on the roof of 129 Lake Street, complete with outdoor seating and vegetable plants that could be used in food on campus. However, we soon found that our aspirations were a little too high. The roof of 129 Lake Street is neither publicly accessible nor can it sustain a heavy, intensive garden. Instead, we decided to focus on a particular part of the roof to install a simpler garden, which could act as a test for rooftop gardens on Boston College's campus. After accessing the roof and talking with the head of the grounds department Scott McCoy, as well as the building architect, the particular rooftop to be used was chosen. The thought process behind using this roof included looking at size, sunlight exposure, visibility to the public, and accessibility. Because access to the roof of 129 Lake Street is not public, we went with the smallest, most manageable section of the rooftop that will require little maintenance but is still beneficial to the building and to the public. This roof will hopefully be a good estimate of the costs and benefits of a small sized green roof, enabling BC to see the possibilities for more green roofs in the future. We then met with the green roof company LiveRoof in order to show them the site and get estimates of pricing. Through talking with Ben Lucas, the specialist for the company, it was determined that we would use the most basic type of roof top gardens, costing the least and requiring the least amount of maintenance. This decision was made for a variety of reasons: the roof of the building is made from rubber and cannot hold too much weight; the roof must be accessed from an elevator, a flight of stairs and then a ladder; water is not very easily accessible. This system is very low maintenance , but it still provides benefits and will be a good test of the possibilities that green roofs have. After determining the type of garden, the measurements of the space were sent to LiveRoof, who then gave us a more exact estimate based on size and type of plants. We met with John MacDonald of BC's Energy department. He gave us the monetized costs of water and energy that 129 Lake Street incurs each month. Looking at those figures, along with the estimated cuts in energy use as given to us by LiveRoof, we were able to quantify how much money in energy costs would be saved. The total costs and benefits were then calculated, giving a precise cost-benefit analysis of rooftop gardens, particularly focused on the site of 129 Lake Street.

Process of Conducting a Cost-Benefit Analysis

The initial step of conducting an accurate cost benefit analysis for the project would be to figure out which type of roof works best. Customized options are often more costly in terms of construction, but in the long-term provide the greatest amount of cost savings. For a given area of a single project, in our case, the section of the roof of 129 Lake Street, the ecological effect due to water retention can be increased by spending more funds and by building an intensive green roof rather than an extensive one. However, if Boston College were to decide to build green roofs on other buildings, it would be best to optimize the benefits by investing a given budget in extensive green roofs rather than in intensive ones. This is a more valid option because the benefits would not only be ecological ones like water retention and the mitigation of the heat island effect but also include the expansion of the roof life, increased energy savings, smog and noise reduction, air quality, and aesthetics improvements (Bruening). In order to understand how the costs are calculated, one must first understand the direct correlation between ecological effects of the green roofs with their corresponding costs. Primarily, all the construction results in a substantial interference in the local ecology. If but partial restoration of the ecological damage is to be achieved with the installation of the green roof, then the vegetation must be of the highest quality in order to reach their economic value. Even though the green roof ecosystems that are installed on structures have resulted in high ecological value, there is still the economic price to be wary of. As will be noted later, the green roof with the highest return on investment over the long-term is the in-place, multi-course constructed green roofs, or as some call it, the extensive green roof. These systems are able to deliver the necessary long-term investment goals of many buildings (Bruening).

Green Roof Types: Extensive Vs. Intensive

Green roofs come in all shapes and sizes with a great variety of the shrubbery that they include. For instance, a green roof could be as simple as a 2-inch covering of hardy, alpine-like groundcover, which is an example of an extensive system, or a complex as a fully accessible park complete with trees, which is an example of an intensive system (EPA, 2013). Extensive green roofs generally contain lighter weight variety of plants suitable for an alpine environment. The goal is to design a system that requires as little maintenance or human intervention as possible. Furthermore, plants that can adapt to extreme climates tend to make good choices. These systems are the most cost-effective since their lightweight nature requires the least amount of any added structural support for the roof (EPA, 2013). On the other side of the spectrum, an intensive green roof could be seen as a man-made park or extravagant garden. These systems have the greatest variety of available plants, including trees and shrubs. Intensive green roofs are more popular with larger scale buildings and businesses that want to see an economic benefit in the long-term to save on energy costs and extending the life of their roofs. In addition, these intensive green roof systems add to the aesthetics of the building, which allow for occupants and the general public to enjoy. However, intensive green roof systems are heavier and require more initial investment along with more maintenance over their lifetime and require a greater deal of structural support to accommodate their weight (EPA, 2013). Despite the nature of the green roof system, whether extensive or intensive, they each are composed of generally the same components as shown in the figure below:

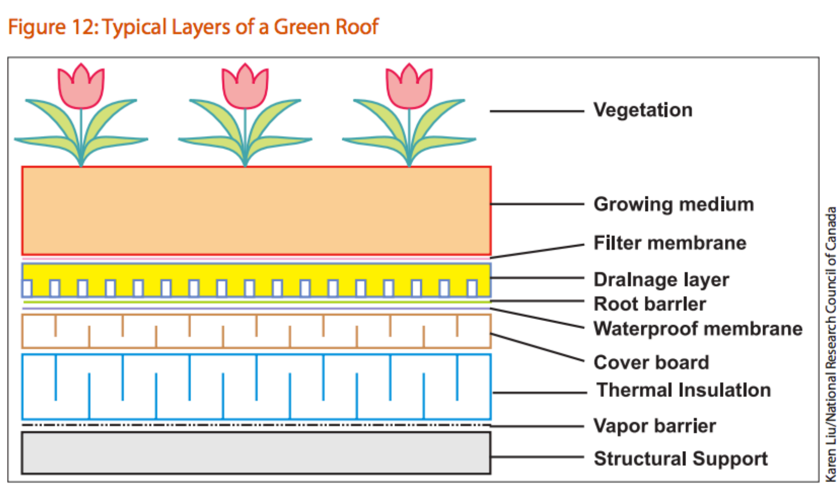

Figure 1: Layers of a typical green roof (Liu, 2003).

Physical Components of a Green Roof

Vegetation: Deciding which type of vegetation to include in the system depends on many factors: extensive vs. intensive, building design, local climate, available sunlight, irrigation requirements, and anticipated roof use. Extensive systems tend to have hardy perennials with shallow roots, which require minimal nutrients. Intensive systems, on the other hand, contain plants with deeper roots and tend to require irrigation systems that support a wider variety of plants and shrubbery (EPA, 2013).

Growing Medium: There is quite the debate between which mediums to utilize. Many sources have come to the conclusion that the medium should at least last as long as the roof that it covers. Soil does not necessary need to be the primary organic matter. Different companies have their own formula and mixture for the mediums that they use for their systems (EPA, 2013).

Filter Membrane, Drainage Layer, and Root Barrier

The membrane acts just like a filter. It catches small particles from the excess water that pass through the growing medium. The drainage layer helps the water from the medium to flow to the roof drain. The root barrier protects the roof from excessively long and harmful roots that may damage it (EPA, 2013).

Water Proofing Membrane: The waterproofing membrane's function is to protect the roof from water penetration. The cover board adds an extra layer of protection for the roof from water. The thermal insulation also provides an added layer of protection from moisture while simultaneously insulating the roof for energy conservation. Finally, the vapor barrier also assists in a final layer to protect the roof of any excess water or moisture from the other layers (EPA, 2013).

Reducing Urban Heat Islands: In regards to combatting urban heat islands, each system of green roofs works by providing shade to the surfaces of roofs and evapotranspiration. Transpiration is the process in which plants absorb water through their roots and emit it through their leaves. Evaporation is the conversion of a liquid to a gas, which occurs in the surfaces of vegetation and the surrounding growing medium. These processes together are called evapotranspiration, which cools the air by using heat from the air to evaporate water (EPA, 2013). By installing green roofs on buildings in urban communities, they can help reduce the heat island effect and cool the air.

Shading

The plants on the green roof along with the growing medium work together to block sunlight from reaching the roof, which in turn reduces the surface temperature of the roof. In addition, the plants absorb about 10 to 30 percent of the sunlight for photosynthesis. Furthermore, this combination reduces the amount of energy that gets transmitted back into the atmosphere, which causes the great deal of temperature increases in cities (EPA, 2013).

BENEFITS:

As mentioned earlier, green roofs provide many benefits, environmentally, economically, and socially. Environmental benefits of green roofs include storm water runoff management (flood control), less carbon emissions, better building insulations, reduction in urban heat islands, and better biodiversity. Economic benefits stem from better insulation, lowering heating/cooling costs, and reducing energy costs. Socially, the benefits are based on providing a green space, better quality of life, being aesthetically pleasing, and providing educational tools. In the summertime, green roofs can retain from 70-90% of the precipitation, and in winter, they can retain 25-40% (Green, 2014). This retention filters storm water and helps with flood management, delaying the time runoff occurs in major storms. A study in Canada graphs the runoff of rainwater on a green roof versus a reference roof.

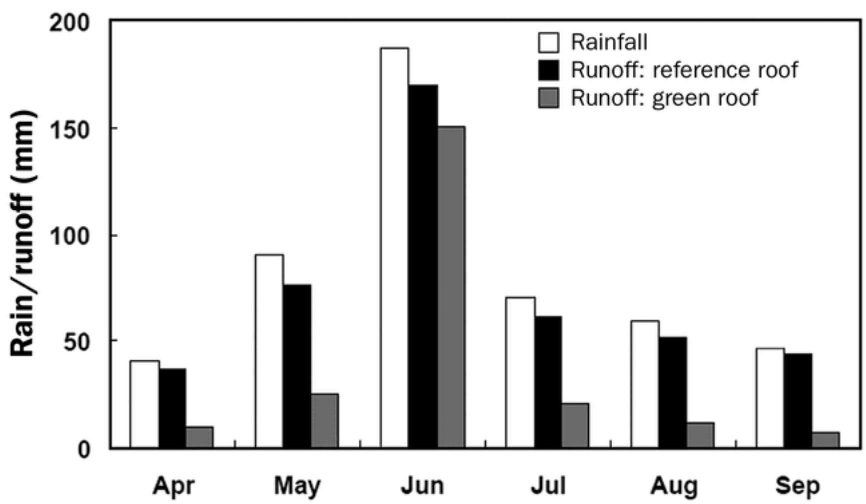

Figure 2: Rainwater runoff comparing a reference roof and a green roof with 15cm of soil (Duffy, 2008).

The LiveRoof system we are have been working with for our case study, will divert 10 gallons of water per minute per linear foot (Lucas, 2014). If set up correctly, one can link a rain garden or bioswale, and there would be no runoff, so the site would not have to connect to the storm sewer system (Lucas, 2014). By not relying on on-site water management systems, the costs of green roofs can be offset by 30-60% (LiveRoof, 2014). Green roofs assist with better heating and cooling inside buildings because they provide better insulation compared to a conventional roof. A field study in Canada suggests that green roofs can reduce energy usage from air conditioning by even 75% (Liu, 2003). The charts below show some measurements of temperatures comparing green roofs and reference roofs in Canada in the summertime:

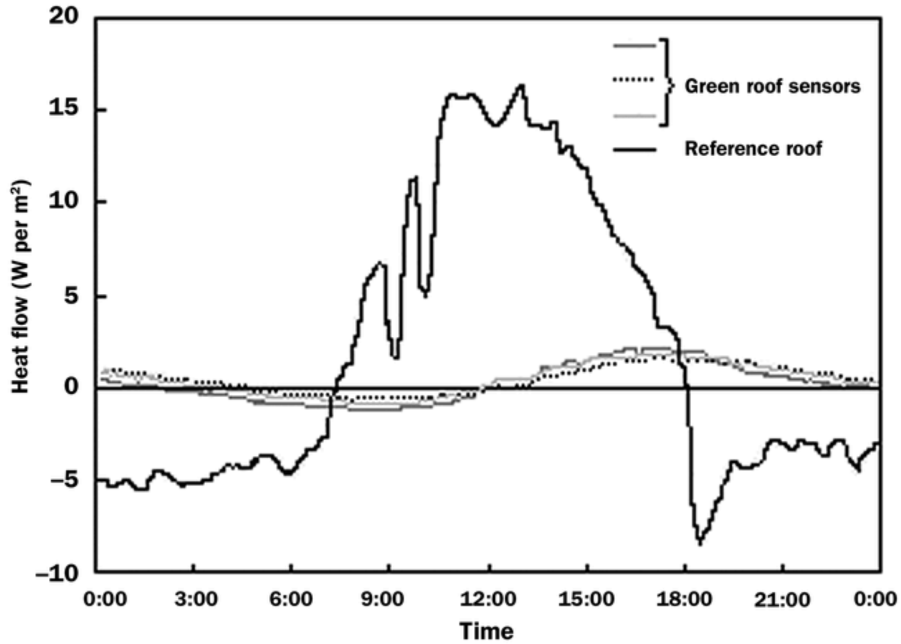

Figure 3: Graph displaying heat of green roof versus heat of a reference roof in Canada on a summer day (Duffy, 2008).

Green roofs are also better for the environment in terms of carbon dioxide emissions. According to Ben Lucas from LiveRoof, it is hard to approximate carbon dioxide emissions, but they estimate that for a green roof measuring 10,000 square feet, it can reduce carbon emissions by 5 tons per year. Additionally, green roofs can provide habitats for wildlife, increasing the biodiversity of the area. Increasing biodiversity can lead to improvements in the ecosystem, economic gains, and social benefits (Green Roof Benefits, 2014). Some social benefits from green roofs include the fact that they are aesthetically pleasing. Most people would rather look at trees and grass over black asphalt or concrete. Green roofs can also help with noise reduction in buildings. According to the website of Green Roofs for Healthy Cities, "Green roofs have excellent noise attenuation, especially for low frequency sounds. An extensive green roof can reduce sound from outside by 40 decibels, while an intensive one can reduce sound by 46-50 decibels." Additionally, rooftop gardens make use of recycled materials. LiveRoof's system is composed of 100% recycled plastics (LiveRoof, 2014). Overall, green roofs have several factors that are beneficial aesthetically, monetarily, socially, and environmentally.

COSTS:

The costs of the green roof consist of the initial price for installation as well as the maintenance and irrigation costs. According to the EPA, the costs of green roofs start around $10 for extensive and $25 for intensive (EPA, 2013). Annual maintenance ranges from $.75 to $1.25 (EPA, 2013). This prices obviously vary from company to company. The initial price comes from the cost of the roofing system, the cost of the plants, and the cost of installation. Maintenance and irrigation would be based on the types of plants and the care and water they require. Water costs also vary from place to place, so that would be another variable that contributes to the overall cost of the building. It is obvious that the initial costs of rooftop gardens are quite hefty, yet with the energy savings and other benefits, one hopes to offset these. The EPA mentions a case study at the University of Michigan that gives the cost of a 21,000 square foot green roof to be over $450,000, compared to a conventional roof costing about $335,000. However, the payback on the green roof should amount to about $200,000, making it more cost-effective to install a green roof (EPA, 2013). The intention of green roofs are to offset the initial costs over time, while also being environmentally impactful.

FINDINGS:

This table represents a summary of our findings that show an extensive green roof as the most viable and reasonable option to install at 129 Lake St. An in depth explanation and discussion of this table and other findings is below.

Table 1.

Type of roof	**Extensive**	Semi Intensive	Intensive
Total cost estimate for installation ($/sqft)	**$9,234($11.40)**	$14,540($17.95)	$20,250 ($25)
Irrigation	**none**	periodically	regularly
Maintenance	**occasional**	periodically	regularly
Purpose	**ecological protection layer**	designed green roof	park-like garden
Annual energy savings	**$71.61**	$53.03	$39.40
Return on investment for energy	**0.77%**	0.36%	0.19%
Return on investment for roof replacement*	**2.71%**	1.71%	1.24%

*estimated cost to reroof the current roof is between $4,300-$5,600. An average of $5,000 was used in the calculations.
Green roofs extend the lives of roofs from 20 years to 80 years before needing replacement.

Energy Savings

To determine the most feasible type of green roof to install in terms of energy savings, we used the Green Roof Energy Calculator that Portland State University has developed, to calculate an estimate for the approximate annual energy savings. We did three calculations to see the difference between an extensive green roof versus a semi-intensive or intensive one on our 810sq.ft. section at 129 Lake St. The calculator looks at a number of variables: city, total area of the building's roof and the percentage of it that would have a green roof, whether the building is old or new, whether it has a dark or light roof, whether it is residential or office space, the depth of the soil used on the green roof (Growing Media Depth), and the Leaf Area Index (LAI); a measure of the garden's canopy in relation to the sky to determine density of the garden and values range from 0 as bare ground to 6 as a forest ("Green Roof Energy Calculator", 2013). By including more than just average utility costs, using the calculator gives us a more comprehensive calculation and thus more accurate results.

Generally, extensive gardens would have shallow soil since it only needs to support small mosses and grasses versus intensive ones, which need to support rather large trees, bushes and shrubs, thus we varied the depth in each of the calculations to get a more accurate energy savings estimate for each of the three types of green roofs. This variation is also true with the LAI with extensive gardens having low numbers and intensive ones having higher ones. In Table 1, the results of these calculations are shown (See Table 1). Boston College is looking for cost cutting options, as well as environmentally sustainable ones, so the high annual energy savings at $71.61 from installing an extensive roof makes it the best option for the university. Installing a semi-intensive or intensive roof would still create an estimated annual energy savings of $53.03 and $39.40 respectively, but the high upfront installation costs and more decorative purposes of each make an intensive roof the more viable option.

Return on Investment

We also found that extensive gardens give the fastest return on investment for both energy, at .77%, and for roof replacement, at 2.71% (See Table 1). According to Ben Lucas, the representative from LiveRoof with whom we worked, green roofs extend the lives of current roofs from roughly 20 years to roughly 80 years (2014). We used an estimate of $5000 for the cost or reroofing an 810sq.ft. area that would need to be spent every 20 years if Boston College were to keep the current roof as is ("Cost to Install a Shingle Roof", 2014). This would mean, that in a single 80-year period, the university would be spending about $20,000 in reroofing costs, but only about half of that to install an extensive green roof (see below). This savings does not even include the annual energy savings we calculated from an extensive green roof, which in 80 years would save an estimated $5,729. In the long run, Boston College would have an estimated total annual savings (energy plus reroofing) of $196.61. This is quite large considering the proposed section of the roof is only just over 3% of the entire roof. Overall, it would take the university 28.7 years to recoup the costs from the initial investment of installing an extensive roof top garden (as opposed to 48 years for a semi-intensive or 70 years for an intensive). These numbers again show that an extensive roof over an intensive one is clearly the best option for BC.

Installation Costs

The installation costs are quite varied depending on the type of roof installed. Using EPA estimates for the minimum base pricing, the most basic extensive roof can be as low as $10/sq.ft., up to $25 for more intensive roofs. This means that the minimum cost for installing a rooftop garden at 129 Lake St. would be $9,234, and hypothetically, were we to install an intensive roof, the cost would be around $20,250 (See Table 1). However, we also worked with LiveRoof to get another estimate from an actual green roof company. They use a pre-vegetated modular system of installation where tray-like modules are set on the roof complete with drainage systems, soil, and plants grown to maturity already integrated (LiveRoof, 2013). Each specific installer determines the exact price, but using this system in which everything is prepared from the start, the representative, Ben Lucas, estimated a cost or roughly $25/sq.ft (2014).

Maintenance and Roof Use

After speaking with the architect of 129 Lake St. and Scott McCoy from the BC Grounds Department, we learned a little bit more about the capabilities of the roof and the grounds staff. The architect explained to us that the original section of the roof that was proposed for this project does not have the structural integrity to support much of a garden of any kind (2/21/14). It would need additional support to be able to withstand the weight of a garden plus a couple people that would need access for maintaining it, and a small fence would need to be installed along the perimeter for insurance reasons. It was also hard to reach and would be more difficult for grounds staff to tend to the garden. We therefore decided the section of the roof we ultimately chose was a better option. It also has the 4 to 5 hours of sunlight per day that the plants need.

We originally had hoped that this actual garden, though simply a test for evaluating the cost and benefits of installing more roof top gardens throughout campus in the future, could be space that clubs and Environmental Studies classes would care for and use for learning, but the fact that roofs at 129 Lake St. are not publically accessible narrowed down our options for what was feasible. The costs and efforts of making it open to the public are far too high, according to the architect, to be an option between extra structural support, making it handicap accessible and safety requirements for insurance (2/21/14). Therefore, the burden of maintenance falls solely on the university's grounds department. In order to limit the amount of extra work they must do, we needed a garden that would require little to no upkeep. The benefits of an extensive green garden are just that. They do not need an irrigation system and only require weeding two times per month (LiveRoof, 2014). As per Table 1, more intensive roofs are much more practical on buildings that want to create an upscale park-like outdoor space for the public that can include benches, walkways and ponds, especially in urban areas where spending the extra money for installation and upkeep are worth it (IGRA, 2014). These roof top gardens would need irrigation systems, and regular fertilizing, weeding, planting, and pruning.

Decision

Ultimately, as explained above, our findings show that the most feasible option would be to install an extensive green roof on 129 Lake St. Not only are the monetizing benefits worth the process and investment, but the original concerns about the ability to maintain the garden and keep it looking neat for those that can see it are easily addressed in the low upkeep needed for an extensive roof top garden.

CASE STUDIES:

Rooftop gardens have become a much more prevalent green technology in recent years. Company office buildings, apartment buildings, university campuses, public spaces, and even residential homes are just some of the places green roofs can be found. We looked at case studies that were relevant to our project and other rooftop garden possibilities at Boston College, such as rooftop gardens in the Boston area and rooftop gardens at other colleges and universities. Boston is definitely no California in terms of weather, so many may doubt the ability of a green roof to thrive in this city's environment. However, we were able to find several examples of rooftop gardens in the Boston area-- from the tops of restaurants to the tops of parking garages. A few examples include the Secret Garden in Cambridge, City Hall, the World Trade Center, and some hotels and residential buildings. The Secret Garden is a large, park-like intensive rooftop garden on top of a parking garage in Kendall Square. The Boston City Hall building has a small, 400 square-foot extensive rooftop garden that is open to the public (Greenroofs.com, 2014). The World Trade Center of Boston has an enormous 15,000 square-foot intensive green roof. According to Greenroofs.com, the roof has a roof of sedums created to withstand 90 mph winds. The Four Seasons is equipped with an 8,500 square-feet rooftop garden, visible to hotel guests as well as the surrounding tall buildings (Greenroofs.com, 2014). Similarly, the Clarendon residential building has green rooftops, about 8000 square feet in size, which are visible to many buildings surrounding it, such as Trinity Church and the John Hancock Center (Greenroofs, 2014).

Colleges that have installed green roofs on their campus include Penn State University, Tufts University, Princeton University, Carnegie Mellon University, and Harvard University. Penn State has four rooftop gardens on campus, ranging from 4,200 square feet to 22,000 square feet (Center, 2014). The have a variety of styles ranging from extensive to intensive. Half of them are publicly accessible, with viewing patios. Penn State uses their roofs for the environmental benefits as well as social benefits such as educational tools and tours. A class based on horticulture and green roof technology was developed in 2005, as the first in the country, and makes use of all of the rooftop gardens on campus. Its curriculum focuses on the uses of green roofs, the plants found on green roofs, constructed wetlands, and methods of stormwater management. One of the roofs at Penn State was even designed and planted by this class (Center, 2014). The rooftop garden at Tufts University was installed in 2007 on top of the Tisch Library. It measures approximately 2,000 square feet and is an extensive garden. It was installed as an experimental research tool for the Tufts Green Roof Collaborative as well as a display for all on campus (Greenroofs.com, 2014). Princeton University has a couple different green roofs on campus. The first was on top of Sherrard Hall and the next roofs came with the building of the Butler College Residence buildings on campus. The Butler rooftops were equipped with sensors to monitor energy efficiency and rainwater collection, allowing the roofs to act as living laboratories for the students and faculty (MacPherson, 2009). Carnegie Mellon also has several rooftop gardens, with green roof space totaling over 40,000 square feet. Some of the rooftop gardens at CMU are used for research and education, allowing members of the community to look at the energy efficiency and storm water collection. At the Gates Center rooftop garden, they even have a 10,000 water storage container that collects the runoff from the roof and uses it for flushing toilets in that building (Center, 2014). Another green roof at CMU is on top of the Posner Center, which was able to obtain its LEED certification in 2005 (Center, 2014). Harvard installed a 4,500 square-foot roof in 2009 on top of the Rowland Institute for Science. It is an extensive roof, which is open to the public and acts as an educational tool (Greenroofs.com, 2014). Overall, most of these universities are installing green roofs for aesthetics, green/sustainability reputations, and experimental educational tools. College and university campuses are great locations for rooftop gardens, especially in the relationship between these innovative technologies and the students.

RECOMMENDATIONS

The process of developing our case study on 129 Lake Street has been beneficial when thinking about other places on campus that could benefit from a green roof. As shown through previous examples, college campuses are an excellent place for green roofs because many of the buildings have large and flat roofs. We see a lot of potential at Boston College for green roof use. There is a large opportunity to implement green roofs on campus with the construction of several new buildings that will be a part of BC's "ten year plan."

As shown in our case study one of the major benefits of a green roof is its ability to control storm water runoff, which in turn helps greatly with flood control. Boston College was built where a reservoir once was and because of this the distribution of storm water can be difficult. Lower campus is notorious for poor storm water drainage. The flooding becomes an issue during major storms and even in the spring when the snow melts and drains from buildings. BC has a very extensive ten-year plan that includes several new buildings being constructed on lower campus. We recommend incorporating green roofs into their new designs because this could help manage storm water flooding on lower campus as well as provide longevity for the new roofs.

One of the most beneficial things about a green roof being constructed on a new building is it can help achieve LEED certification. LEED stands for Leadership in Energy and

Environmental Design, which is accredited under the U.S. Green Building Council (Christie, 2014). LEED certification is a collection of rating systems used to determine the level of environmental responsibility and efficiency a building has achieved. Being LEED certified provides many environmental and energy benefits as well as tax incentives to those who achieve the proper standards (Christie, 2014). The LEED certification is essentially the standard nationally for environmentally conscious buildings. LEED has a strong emphasis on the building's sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality (Christie, 2014). The rating system is based on a point accumulation system. Points are awarded based on eight different categories. Green roofs fall under the water and energy use category. At most green roofs can earn a building 7 points towards their LEED certification, which is nearly 20% of the points necessary for minimum certification (Christie, 2014).

According to LiveRoof, a green roof has a lot of potential credits in many different areas. Some of which include storm water design, heat island effect, water efficiency landscaping, optimizing energy performance, construction waste management, regional materials, and rapidly renewable materials. All of these categories can earn 1 to 2 points towards LEED certification (LiveRoof and LEED).

We saw flood management on lower campus and LEED certification as benefits to the university's function as a whole, but we also wanted to consider what a green roof could do specifically do for the student of Boston College. As mentioned earlier many colleges have implemented green roofs on several buildings on campus. At Penn State they tried to maximize the use of their green roof by using it as a interactive learning tool. They have four green roofs on campus 2 are intensive with public access while 2 are purely there for energy efficiency (Plant Science). They have found a great way to implement their campus green roofs into the course options at the university. The Eco-Roof and Green Technologies course is offered to students every spring semester. Using their institution's green roofs as an interactive classroom students are able to learn about green roofs functions as well as future developments in the field (Plant Science).

Over the past four years BC has put in a large effort to expand its environmental sciences program. In 2010 the geosciences department was changed to environmental studies and in the fall of 2014 there will be an environmental studies major at the university. Penn State's example of using their green roofs as a learning tool is inspiring and something Boston College should take into consideration. The opportunity to develop the environmental studies program with an interactive hands-on course is something a cutting edge university might find hard to pass up. Overall our study has proven that there are several economic, energy, and environmental benefits to having a green roof. Green roofs are aesthetically pleasing and something that could really make BC's campus stand out. By implementing our sample site on 129-Lake Street we aim to provide an example of what a green roof could do for BC. Our intent has been to use our case study as a means to get a large-scale green roof on BC's campus.

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