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Feasibility Assessment of Green Roof Application: A Case Study in State University of New York at Buffalo

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Abstract

Plant covered roof systems in any man made building, that are used to reduce heat island effects and insulate buildings are called as Green Roofs. The main goal in this study is to analyze the feasibility of green roof systems for the proposed new engineering building of State University of New York at Buffalo (UB) between Jarvis Hall and Ketter Hall. In addition to this, to decide on if the installation of the green roof system is beneficial. Green roof systems' aesthetically pleasing and visible features to the public and their cost beneficial aspects are going to be dealt. Moreover, other benefits, such as air quality improvement, reduction of air conditioning costs in the building it covers, and stormwater management will be mentioned. Specifically, correlation with the Leadership in Energy and Environmental Design (LEED) Green Building Rating System specifications, the types of green roofs and what differentiates them, the environmental benefits provided by green roofs, extra costs incurred by the construction and maintenance of green roofs, effects for energy savings due to the presence of green roofs, potential rainwater detention by the green roofs and some additional topics will be investigated in this study. The green roof application will be the great opportunity to show that UB's new engineering building is taking initiative in sustainable development. It will decrease the stormwater runoff; it will cause better air quality and a reduction in the heat island effect.

Keywords: *LEED, green roof, sustainable development, heat island effect, stormwater runoff.*

1 Introduction

There are two main types of green roofs; i) intensive and ii) extensive. Intensive roofs are generally more than 20 cm deep which allows for the growth of larger plants such as trees and shrubs. Since it has very large soil thickness and tall plants, above the roof, there is more structural loading imposed by an intensive roof. Extensive roofs on the other hand, contain smaller plants, such as; shrubs, sedums, and herbs. They tend to have lower construction and maintenance costs. Green roofs can be placed on both old and new buildings. Before the application of green roof systems for old building we should carefully ensure that it can withstand the extra structural loading (USDE, 2004). Intensive and extensive green roofs consist of multiple layers in order to provide a growing surface and drainage of excess water on top of the roof, as depicted in Figure 1.

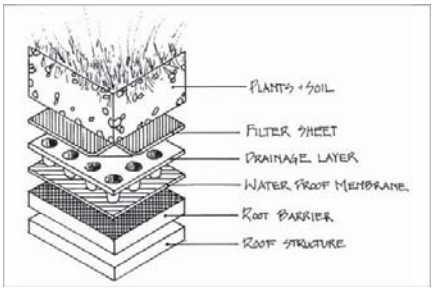


Figure 1. Green roof cross-section (N/NCAet al., 2005).

Between the soil medium and the drainage mat there is a soil filter fabric (geotextiles). This retains the soil and keeps the roots of the vegetation from penetrating the drainage layer and potentially clogging the drainage layer thus reducing its effectiveness (Dinsdale et al., 2006). Geotextiles are permeable fabrics which are engineered to retain a specific grain size from passing through. The drainage mat diverts any excess rain water that is not absorbed by the soil medium or vegetation to roof top drains. Geomembranes are impermeable layers that protect the roof deck from infiltration of water (AWDC, 2007). Multiple sheets of geomembranes can be welded together using a hot rubberized fluid application, this adheres the sheets to make one continuous impenetrable layer protecting the roof deck (Dinsdale et al., 2006). If the membrane, existing or new, contains bitumen or any other organic material, it is crucial to maintain a continuous separation between the membrane and the plant layer, since the membrane will be susceptible to root penetration and micro-organic activity (Peck et al., 2007).

2 Types of Green Roofs

There are three most common systems exist, these are: complete, modular and pre-cultivated vegetative blankets, respectively. ***Complete System*** can be added to the roof either during or post construction. While this roofing system offers the greatest amount of choice in terms of membranes, mediums and plants used,

it does contribute to the highest structural loading which means a higher building cost (Dinsdale et al., 2006). Figure 2 is an example for complete systems application in University of Central Florida. ***Modular Systems*** are not built into the roof but are rather placed on an existing roof. The plants are grown in trays off site and are transported to the roof when they are fully grown. The depth and type of soil is flexible, however, deep soil layers are not common. Typically, a modular system will be within the depth range of 7.5 cm to 30 cm (Dinsdale et al., 2006). Figure 3 shows a diagram of a modular system in The Carnegie Mellon Institute on the campus of the Carnegie Mellon University in Pittsburgh, PA. ***Pre-cultivated Vegetative Blanket system*** is similar to a modular system as it is also grown off-site (Dinsdale et al., 2006). On the other hand, installation of the blankets is different. They typically come in rolled up interlocking tiles that can be placed on any roof (Dinsdale et al., 2006). Figure 4 shows the application in Michigan State University.



Figure 2. Complete systems application in University of Central Florida (Greenroofs.com, 2006)



Figure 3. Modular green roof systems (Greenroofs.com, 2006)



Figure 4. Pre-cultivated blanket layer application in Michigan State University (Greenroofs.com, 2006)

3 Benefits of Green Roofs

There are seven main benefits to having a green roof. They include *increased energy efficiency, an increase in air quality, a decrease in heat island effect, temperature regulation both on the roof and surrounding areas, stormwater retention, an increase in roof lifespan and a LEED point. Reducing energy demands* of a building lowers the air-conditioning costs for that building and it reduces the strain on the earth's fragile environment by reducing pollution. Green roofs can help reduce global warming by distributing additional biomass in cities. Through photosynthesis, plants convert CO_2, water and solar energy into oxygen and glucose, thus reducing CO_2 emissions into the atmosphere. Green roofs can help the local air quality by reducing smog and by producing oxygen. Smog reduction occurs in two ways: reducing the particulate matter in the air, and lowering the ambient temperature (Dinsdale et al., 2006).

As it is known very well, *heat island* effect means the excess warmth of urban areas compared to their non-urbanized surroundings. Surface and atmospheric modifications due to urbanization lead to an urban thermal climate that is warmer than the surrounding rural areas, this situation happens especially at night, before

the sun rise. The difference between the maximum "peak" temperature and the baseline rural temperature is known as the heat island "intensity" (Dinsdale et al., 2006). Heat island intensity can be reduced by green roofs. In order to increase vegetation and soil in cities, green roofs can be used as a good opportunity. Hence, green roofs provide the required evaporative surface for natural energy consumption, without using up valuable space. Additionally, they can significantly reduce the near-surface *air temperature*, thus reducing air-conditioning costs and pollution.

Locally green roofs can potentially alleviate overloading of municipal sewer systems by stabilizing water flow and reducing *stormwater* runoff from 70% to 90% annually (Perry, 2003; Sherman, 2005). The vegetation placed on top of a roof prolongs the life span of the roof in three ways. Firstly, it protects the layers and outer membrane of the roof from ultra-violet rays. This essentially slows down the wear of the roofing material. Secondly, it protects the roof from punctures, rips and other physical damage (Dinsdale et al., 2006). Life span of the green roofs is 50 years (Lehner et al., 1999). Finally, the green roof protects the roof from extreme temperature changes as the plants absorb much of the heat and use the energy for photosynthesis in summer months (Newton et al., 2004). Expansion and stresses on the roofing material is another problem that shortens the life span of the roof. Energy absorption by the green roof plants prevents this problem, so that they are beneficial. Leadership in Energy & Environmental Design (LEED) is a rating system that has been developed in the United States and is now being implemented in Canada by the Canada Green Building Council (CaGBC). Green roofs can facilitate a significant improvement in the LEED rating of a building, contributing at least 6 credits (HGCI, 2007) and at most 15 credits (Kalwall Corporation, 2007) under the system, depending on design and level of integration with other building systems. Table 1 shows Leed ratings and points.

Table 1. LEED Ratings and Points (Kibert et al., 2005).

Certified	Silver	Gold	Platinum	TOTAL POSSIBLE
26	33	39	52	69

4 Results and Findings

The different layers used in a green roof can contribute to noise reduction. This benefit is more applicable to buildings close to highways and airports. However, for the new engineering building of UB, there is no noise problem. Three criteria, which are cost savings to UB, benefit to UB and Highly Valued benefits to UB, were used to rank the benefits, and benefits are listed in Table 2. Primary credit impacts were calculated in accordance with the new engineering building site, recourses and functionality of the building. Results of the research show that significant numbers of LEED points are gained by the usage of green roof. Table 3 shows LEED credits, categories and points for the New Engineering building at UB calculated within this research. Results in Table 3 were

assembled according to researches regarding the LEED rating system (HGCI, 2007; N/NCA et al., 2005; NRMCA, 2006; Kalwall Corporation, 2007).

Table 2. Summary of main benefits as they pertain to University at Buffalo.

Summary of Benefits	Cost Savings to UB	Benefit to UB	Highly Valued Benefits to UB
Temperature Regulation		☺	
Energy Efficiency	☺	☺	
Air Quality		☺	
Stormwater Management		☺	
Roof Lifespan	☺	☺	
Therapy		☺	☺
Public Relations		☺	☺
Airborne Species Habitat		☺	

Table 3. LEED Credit Impacts.

Primary Credit Impacts			
Credits	**Categories**	**Requirements**	**Points**
5.1	Sustainable Sites	Protect or Restore Open Space	1
6.1, 6.2	Sustainable Sites	Stormwater Management Rate, Quantity, Treatment	2
7.2	Sustainable Sites	Design to Reduce Heat Islands (Roof)	1
1.1	Water Efficiency	Water-Efficient Landscaping	1
1.0	Innovation and Design	Innovation in Design	1
Secondary Credit Impacts			
Credits	**Categories**	**Requirements**	**Points**
1.0	Energy and Atmosphere	Optimizing Energy Performance	2
4	Energy and Atmosphere	Ozone Depletion	1
4.1, 4.2	Materials and Resources	Recycled Content (roof system components)	2
5.1, 5.2	Materials and Resources	Local/Regional Materials (roof components, plants)	2
2	Water Efficiency	Innovative Wastewater Technologies	1
3.1, 3.2	Water Efficiency	Water Use Reduction (20%, 30%)	2
TOTAL DERIVED POSSIBLE LEED POINTS :		**6 + 10 =**	**16**

Plant selections for the green roof are shown in Figures 5, 6 and 7, in accordance with the western New York climate. Osmunda and Trillium are local plants. Moreover, Sedums are extensively cultivated as garden plants, due to their attractive appearance and hardiness. The various species differ in their requirements; some are cold-hardy but do not tolerate heat, some require heat but do not tolerate cold (Snodgrass, 2006). Osmunda is native to the Americas and eastern Asia, growing in moist woodlands. In North America it occurs from southern Labrador west to Ontario. Height is 20-45 cm tall (Brickell, 1998). Trillium is a genus of about 40-50 species of perennial herbaceous flowering plants, native to temperate regions of North America and Asia. They used to be

treated in the family Trilliaceae or Trillium family, a part of the Liliales or Lily order (Case, 1997).



Figure 5. Sedum plant (Snodgrass, 2006)

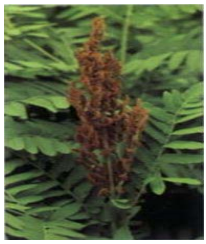


Figure 6. Osmunda plant (Brickell, 1998)



Figure 7. Trillium plant (Case, 1997)

Rainfall data and potential rain water retention by a green roof of new engineering building at UB were calculated according to Chow et al., 1988, Luckett (2007) and AWDC, 2007. From that point of view run off coefficient for the green roof of new engineering building at UB was calculated in Table 4.

Table 4. Potential rain water retention by a green roof of new engineering building at UB.

Roof	Green roof surface area (sq meters)	6000
Rain Fall	Regional 10 year storm (cm of rainfall)	15
Growth Media	Growth Media depth (inches)	20
	Dry Weight (kg per cubic m)	0.64
	Saturated Weight (kg per cubic m)	1
Moisture Retention Fabric	Moisture retention fabric dry weight (kg/sq m)	7.3
	Moisture retention fabric saturated weight (kg/sq m)	8.8
Drainage Core	Top diameter of cups (cm)	0.65
	Bottom diameter of cups (cm)	0.65
	Cup height (cm)	1.30
	Number of cups per sq meters	872
	Water retained (lt per sq m)	**93**
	Total (lt) retained	**561682.4**
	Run off coefficient	**0.39**

For this study ***dimensions of the proposed building*** (see Figure 8.) are assumed as 100 m in length by 92.3 m in width, with a gap in south-east corner, 50 m in length by 58.8 m in width. Green Roof area = (92.3 m x 100 m) – (55.8 m x 50 m) = 6440 m^2, it can be assumed that planted green roof area is approximately 90% of this value, say it is 6000 m^2.

Estimated cost for the proposed green roof at UB ranges from \$6-\$45 per square foot, including \$1.5 per sq ft maintenance cost. This value can be converted into \$65-\$500 per square meter. Unit prices were derived according to Belan et al. (2004) and Lehner et al. (1999). According to sample green roof data total green roof area will be 6000 m^2. Hence, total cost for the new engineering building ranges from \$390,000-\$3,000,000. Since green roofs reduce air-conditioning costs, this value will be amortized in the future. Additionally mean life span for Green Roofs are 50 years. Therefore, there will be no frequent replacement or maintenance expense.



Figure 8. Plan view, aerial photo, of new engineering building area at UB (Google, 2007)

5 Conclusions

According to the results of the study, the green roof application will be the great opportunity to show that UB's new engineering building is taking initiative in sustainable development. Additionally, green roof system will decrease the stormwater run off, it will cause better air quality and a reduction in the heat island effect. According to sample calculation, there will be more than 60 % water retention by the usage of green roof systems within the area that is covered by the new engineering building. There is a great correlation between Green Roof systems and LEED certification. Green Roof systems are prosperous to gain points from Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources categories of LEED Certificate, respectively. Moreover, in both hot and cold seasons, there will be a tremendously heat insulation in the building. This situation will directly affect the expenses of air conditioning and heating of the building, fortunately, energy and money are going to be conserved. Although, the estimated cost ranges from \$6-\$45 per square foot, the cheapest option may be preferred for the new engineering building. Preferred system may be either the usage of Modular systems or Pre-cultivated blanket layer application as an Extensive Type Green Roofs. These systems have less labor and material cost and very easy to apply, even for the old buildings. The cost per sq ft may decrease down to \$10. For the plant selection, in accordance with the LEED requirements, some local plants are suggested in this study. These plants are, Trillium and Osmunda, respectively, additionally Sedum plants may also be used. Moreover, as an aesthetical benefit of Green Roof application,

new engineering building of UB will have a very attractive appearance in North Campus of UB. Consequently, all these benefits are the proofs that the application of the Green Roof Systems on UB's new engineering building is very feasible, and it is a great opportunity for UB to have LEED certificated contemporary and sustainable building.

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