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Characterization of Green Roofs and their Potential Effects on the Union College Campus

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By

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ABSTRACT

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A green roof is the construction of protective layers and vegetation on the roof of a building. Green roofs are capable of providing ecological benefits to the environment as well as economic advantages for the client. Therefore, my thesis will explore the characterization features of green roofs by focusing on the layers they are made up of, the different types of green roofs, and the benefits they can provide.

Although this technology is relatively new to the United States in comparison to places such as Germany, where green roofs have been extensively used for over 40 years, there is a great push by the sustainability movement to implement them around the United States. One particular area where green roofs are gaining a strong foothold is in major cities and urban areas due to their ability to: mitigate storm water runoff and the heat island effect; provide a habitat for wildlife, purify the air, and act as a noise reduction; and result in energy savings and an expanded lifespan. Because of these advantages, colleges and universities are also pushing for their construction. Therefore, using available literature and appropriate case studies, I determined whether it would be beneficial for Union College to implement a green roof on one of the buildings (College Park Hall) and concluded that despite many ecological benefits that would be provided from its construction, in terms of an economic standpoint, it would not be cost effective for the College.

DEDICATION

I dedicate my thesis to my parents who have always encouraged me to chase my dreams and have supported all of my passions.

I would also like to dedicate my thesis to Union‘s Academic Opportunity Program (AOP), because they made it possible for me to attend Union College.

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The idea to write my thesis would never have been possible if Professor Mohammad Mafi had not ignited a spark of interest in the topic of environmentally friendly buildings. Without him, I would have never known of the existence of green roofs and the potential benefits they can provide. So therefore, I would like to thank him for all he has taught me both about green roofs and life. I would also like to thank my advisor Professor Thomas Jewell, whom my thesis would not been possible without the help I received from him. I would also like to thank him for allowing me to write on this topic and for the support I received from him throughout this whole process. Lastly, I would also like to especially thank Paul Matarazzo of the Campus Facilities Department for dedicating his time to answering my many questions concerning College Park Hall‘s rooftop and for collecting and sending me more information than I could have ever imagined

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INTRODUCTION

1.1 What is a Green Roof and Why?

As the sustainability movement becomes more prevalent around the world and expands beyond the betterment of existing products to directly affecting different forms of everyday living, the roofing industry as well as construction in general is also affected (Cassidy 4, Gibbs *et al.* 1). Within these industries, green roofs and sustainable buildings have been growing in popularity due to the advantages they are capable of providing in all different types of environments. According to the United States Office of the Federal Environmental Executive, a branch developed by the Council on Environmental Quality (CEQ) within the Federal government's Executive Office, a "green or sustainable building is the practice of designing, constructing, operating, maintaining, and removing buildings in ways that conserve natural resources and reduce pollution." But the definition for a green roof is more focused stating that a green roof is a "system in an extension of the existing roof which involves a high quality water proofing and root repellant system, a drainage system, a filter cloth, a lightweight growing medium and plants… [put simply] green roof development involves the creation of "contained" green space on top of a human-made structure" (Nolan). Although there is a growing awareness of their existence and a greater focus being placed on "green or sustainable buildings," the United States is still very much behind many parts of Europe including Germany, where revival of green roofs began approximately 40 years ago (Peck 8, Sonne 59, Wark and Wark 1, More than Meets the Eye). None-the-less, there are now several North American based companies and a multitude of researchers making information more accessible and the construction of green roof technology more attractive to consumers (Wark and Wark 1).

With the increased availability of information regarding green roofs, building owners are learning of the benefits they can provide as an alternative to traditional roofing methods. Some of the benefits include (but are not limited to) additional insulation to reduce heating, ventilation, and air-conditioning (HVAC) costs; mitigation of storm-water runoff; air purification; a habitat for wildlife; a roofing membrane protecting layer;

and the ability to fragment the monotonous black tar rooftops leading to a reduction of urban cities' heat island effects (Energy Efficiency). Likewise, the technology, which is now also being recognized as a pro-active environmental solution stepping towards a more sustainable world and can earn Leadership in Energy and Environmental Design (LEED) points when seeking certification (What LEED Is, LiveRoof). According to Cantor making that shift from conventional to green roofs has "the power to transform cities from unhealthy, stressful, overheated environments to healthier, more sustainable communities," (8) which will provide an overall better atmosphere for all residents living in the surrounding areas.

Besides the environmental benefits that green roofs can provide, such as storm water management, reduction of the heat island effect, and reducing pollutants in the atmosphere and in rainwater, they can also provide economic and health benefits (Banting *et al.* ii, Gibbs *et al.* 1, Liu and Baskaran 3, Oberndorfer *et al.* 823, Sonne 1, Green Roofs, Introduction to Green Roofs). The economic savings, according to Peck mostly come from the reduced HVAC costs because "green roofs insulation qualities help to conserve and temper the extraordinary pull of energy required to run air conditioning and heating systems in commercial buildings and homes, thereby saving money" (Peck 16, Greensulate). However there is also the potential from saving from an extended roof lifetime because "vegetated areas heat up much less than exposed surfaces of asphalt or bitumen" (Introduction to Green Roofs). Because green roofs provide additional layers of protection overtop the roof membrane, the actual roof is less exposed to the elements and can therefore last longer and require less maintenance reconstruction of the roof over the years (Sonne 1, Green Roof Types). These economic savings combined with the health benefits that come from more green spaces, improved air quality, noise reduction, and moderations in air temperature (Nolan, Greensulate, Green Roof Types, More than Meets the Eye) make green roofs an appealing option to a variety of people. One company that specializes in green roof construction lists on their website a selection of their clients it includes, private homeowners, universities, high schools, living communities, condominiums, and businesses thus showing how green roofs appeal to all different portions of the construction industry (Greensulate).

1.2 Project Purpose and Objectives

This research project will examine the role of green roofs in the present-day society, the layers they are composed of, the different types of green roofs that can be built, and the ecological and economic benefits they are capable of providing after they are constructed. The paper will also end with a formal recommendation on how the college should proceed when considering the possible construction of a green roof on Union College's College Park Hall (CPH) dormitory. By using appropriate literature and case studies to make comparisons among Union College and other schools, it will allow me to make the best possible recommendation that I can. This paper will also touch on the objectives that are listed in the table below (Table 1.1).

Table 1.1: The table provides supplemental objectives that this research paper will aim to touch upon while still obtaining its other major goals.

Number	Objectives
1	To provide the Environmental Science Program and Campus Facilities department with a study on green roof technology if a green roof construction project were to be considered in the future on College Park Hall or the campus as a whole.
2	To evaluate different case studies for other buildings that have adopted green roofs and determine whether what their motives were for constructing a green roof and how it has impacted the environment as a whole.
3	To create an awareness of environmental sustainability through the writing of this paper well as to provide knowledge for a proactive solution for the current environmental issues.
4	To end with a formal recommendation on how Union College should proceed with talk of green roofs based off of benefits that it would be capable of providing the school in term of an economic standpoint and ecological perspective.

1.3 Green Roof Layers

Green roofs are roofs with vegetation (Cantor 14, More than Meets the Eye, Ipswich Case Study). In the current marketplace there are three types of the green roofs that can be constructed: extensive, semi-intensive, and intensive (Cantor 14, Peck 26, Green Roof Types). Since all three types have major characterization differences, this section and the following section of the paper will focus on consolidating information in regards to their identification process. In spite of the differences between the three types, they are all

composed of 6 essential layers: a waterproofing membrane, a root repellent layer, a drainage layer, a filter cloth to contain the roots and the growing medium, the growing medium itself, and lastly the plants (Peck 26, Banting *el al.* 40, Getter and Rowe 1277 – 1278, Oberndorfer *et al.* 824, Wark and Wark 4-5, King County Case Study, Ipswich River Case Study, Green Roof Specifications). These different layers can be seen in the cross-section image below (Figure 1.1), which diagrams and labels the layers.

Figure 1.1: This figure (taken from www.lid-stormwater.net) illustrates the different layers that are necessary to build a green roof. The layers (from bottom to top) are: the original roof, a waterproofing membrane (roofing membrane), membrane protection and root barrier, insulation (not necessary in all cases), a drainage layer and root barrier layer, the growing medium, and lastly the vegetation.

1.3.1 Vegetation

The topmost layer of a green roof is the only visible layer, which is composed of the vegetation. Of all the layers, this is the layer that has the potential of varying the most because different regions will plant different types of vegetation and almost any plant can be grown on a roof. According to one study, "the only limitations are: climate, structural design and maintenance budgets, and the roofscape designer's imagination" (Wark and Wark 4). However, Oberndorfer *et al.* states "that moisture stress and severe drought,

extreme temperatures, high light intensities, and high winds speeds increase the risk of desiccation and physical damage to the vegetation" therefore only very resistant plants can be grown on rooftops (825). With that description their paper continues and describes the types of plant that would thrive in this environment and that includes: having stress-tolerant characteristics; low, mat-forming or compact growth; evergreen foliage or tough, twiggy growth; and other drought-tolerance or avoidance strategies, such as succulent leaves, water storage capacity, or CAM (crassulacean acid metabolism) physiology (825).

Fitting all of these characteristics is the *sedum* species, the one plant that comes highly recommended as the ideal plant to be grown for extensive and semi-intensive green roofs (Cantor 23, Gibbs *et al.* 1, Oberndorfer *et al.* 825, Wark and Wark 4, Green Roof Types). However, mosses, grasses, and even a mixture of herbs have also been suggested as possible vegetation types. In the study conducted Gibbs *et al.* they found that plant with the highest growth index is *Sedum hybridum immergrauch* and likewise recommend using *sedums* (8). In the literature, semi-intensive roofs are less discussed, but generally they are plants that are capable of growing in the same environments but with an increased growing medium, therefore small shrubs and taller grasses are also included. In comparison, intensive green roofs have an even greater thickness of growing medium and can accommodate a "variety of potential plants including *sedums* and perennials to shrubs and small trees, both evergreen and deciduous" (Cantor 23).

1.3.2 Growing Medium

The layer below the vegetation is the growing medium, which is more than just soil in the context of green roofs. As the knowledge of green roofs increases and new industries become involved in the whole process, advancements are being made. One area that has particular progressed is in growing medium that gets used. Currently, the "soil manufacturing industry has developed, lightweight soil mixes…that can weigh about two-thirds to one-half as much [as sandy loam]" (Cantor 23). Wark and Wark describe the growing medium as "distinguish[able from soil] by its mineral content, which is synthetically produced, expanded clay…[and] is considerably less dense and more absorbent than natural mineral, providing the basis for ultra-lightweight planting medium" (4). They then go on to say that the "bulk densities of these mixes [can]

range from 400 kg/m^3 (25lb/ft^3) to 900 kg/m^3 (56 lb/ft^3) for dry mixes [in which the] water absorbencies can be 20–200 percent by weight" (5). In comparison to this study, the City of Chicago website estimates that the growing medium mixture can weigh up to approximate 65lb/ft^3, which is much higher than the other estimate, but still lower than the estimated weight of regular soil (110lb/ft^3) (Green Roof System Layers).

However lightweight the growing medium might be, the synthetic compositions still needs to include the following essential nutrients in order for the vegetation to flourish: "nitrogen, phosphorus, calcium, magnesium, and oxygen" and it should also have the capability of retaining these nutrients and moisture while being porous enough to avoid a build-up of excess water (Green Roof System Layers). Some of the most common materials used to create these mixtures include: "a combination of mineral and organic soil components (composts and mulches); soil mixture of humus; and mineral bulk material mixture with a high or low proportion of organic matter" (Green Roof system Layers). However these are not the only combinations of materials that can be used to make a growing medium mixture. The table below (Table 1.2), provided by the City of Chicago, demonstrates the variety of combinations that can be made for both extensive and intensive green roofs.

Table 1.2: This table represents different custom growing medium mixes of organic and inorganic materials that providers recommend in order to have vigorous growth (source: www.cityofchicago.org)

	Extensive Soil		**Intensive Soil**		**Drain Material**
	One layer	Multi layered	Soil mixture	Bulk material mixture	
PHYSICAL PROPERTIES					
Water retention (Compressed condition)	min. 25%	min. 35%	min. 50%		min. 15% (without water damming)
Water permeability (Compressed condition)	min. 60 mm/min	min. 0.6 mm/min	min. 0.3 mm/min		min. 180 mm/min
Air content (fully saturated)	min. 25 %		min. 15%	min. 20%	
Weight (density) (fully saturated)	0.8–1.4 g/cm^3	1.0-2.2 g/cm^3	1.4-2.2 g/cm^3	1.0-1.8 g/cm^3	0.8-1.8g/ cm^3 dependent on the material
CHEMICAL PROPERTIES					
pH-value	6.5 - 9.5	6.5 - 8.0	6.5 - 7.5		6.5 - 8.0
Salt content of water extract (recommended, if possible)	max. 1 g/liter				
Initial organic matter	3-8 %		3-6 %	6-12 %	
Nitrogen (N) slightly soluble	max. 60 mg/liter		max. 60 mg/liter		
Phosphorous (P2O5)	max. 150 mg/liter		max. 200 mg/liter		
Potassium (K2O)	min. 150 mg/liter		min. 150 mg/liter		
Magnesium (Mg)	max. 120 mg/liter		max. 120 mg/liter		

1.3.3 Filter Layer

The filter cloth, is the next layer, and goes by a variety of names (including filter cloth, filter fabric, and filter layer) but the general idea is a layer intended to capture loose particles from the growing medium layer above it (Green Roof System Layers, Introduction to Green Roofs). This layer is meant to "separate the bottom of the growing medium from the drainage layer and the water retention system below it…although minimal in thickness, [it] is a critical element because it prevents fine particles of the growing medium from clogging the drainage layers…" (Cantor 26). The filter cloth usually "comprises one or two layers of non-woven geotextitle, where one of the layers may be treated with a root inhibitor" (Wark and Wark 5, Introduction to Green Roofs). This layer ultimately ensures that the drainage layer will function properly and be kept soil free; therefore this layer must be resistant to clogging due to fine particles from the above layer. Figure 1.2 below is an example of a filter fabric sold by a company known as OptiGreen Roof Greening. The fabric is guaranteed to "1) prevent fine particles from forming sludge in the drainage layer and 2) maintain[ing] high water permeability" (Optigreen Products).

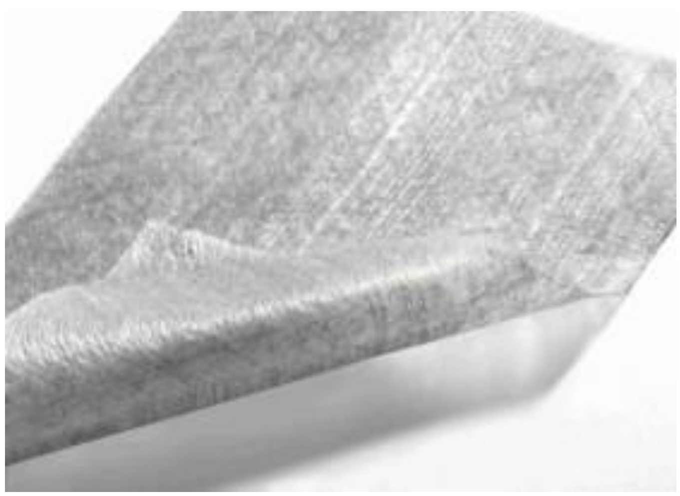

Figure 1.2: This image (taken from www.optigreen-greenroof.com) is of a "filter fleece," which is a type of material that can be used for the filter layer to prevent small particles from percolating down to the drainage layer.

1.3.4 Drainage Layer

Following the filter layer is the drainage layer or the drainage and water retention layer as Cantor labels it. The major function of this layer is to prevent the whole system

from getting overly saturated or forming small ponds. Cantor states that this layer can either be “synthetic or composed of a highly permeable granular mineral material, manufactured or contained in a sheet” and that “depending on the design and goals of the green roof system, the drainage layer will connect either to existing internal area drains or external drains on the roof, and thereby direct water to the existing storm drainage system” therefore ensuring that no more water than necessary will settle on the roof (Cantor 27). Regardless of the materials used to create the layer, its primary function is to be capable of “carry[ing] away excess water” while retaining some for the vegetation to be able to use (Introduction to Green Roofs, Cantor, 26, Green Roof System Layers). The drainage layer often resembles “an egg carton or landscape paver” in order to be able to both store and drain water simultaneously as demonstrated in Figure 1.3 below (Wark and Wark 5).

The drainage layer is designed based on the: “structural load capacity of the roof, the desired vegetation per design, water permeability, and storage capacity” (Green Roof System Layers). Some of them are also constructed in conjunction with the fabric layer, meaning that they are combined to form a larger layer (Introduction to Green Roofs). Overall though, the drainage layer of most green roofs should be able to retain “35-45 percent moisture, by volume. For comparison, most retention sheets hold about 0.25 inches of water per inch of thickness (0.64 cm/cm), with typical sheets retaining between 0.1 and 0.5 gallons per square foot (4.1 to 20.4L/m^2)” (Cantor 26)

Figure 1.3: This image (taken from www.ecobrooklyn.com) is of a synthetic version of the drainage layer. The inserts on the mat are intended to hold water for later use by the plants while the excess is capable of draining away.

1.3.5 Root Protection Layer

The next layer down is the root protection layer. This layer is "needed to prevent roots from penetrating into the waterproofing and causing leaks… [therefore] it is often made of thermoplastic membranes, but copper foil and root-retardant chemicals have been used with some assemblies" that will prevent the whole system from getting damaged (Cantor 27). This compares to Wark and Wark who list the different materials that can be use for this layer as a: "slab of lightweight concrete, sheet of rigid insulation, thick plastic sheet, copper foil, or a combination of these, depending on the particular design and green roof application" (5). While in his book, Cantor seems to stress the importance of having a root protection layer, Wark and Wark state that "some green roof systems do not necessarily require a protective layer" most likely due to a shallow growing medium that will not be capable of sustaining deep rooted plants that could damage the roofing membrane (5).

Figure 1.4: This root protection layer is made up of a thermoplastic membrane made from LDPE (plastic) and is suppose to be impermeable to protect the underlying waterproofing layer. This specific product is called FLW-400 and is recommended to be used on shallow green roofs. (This image was taken from www.greenuptheroof.com).

1.3.6 Insulation (Optional)

Although displayed in Figure 1.1, this layer is often considered as optional depending on the designer and region in which the green roof is being constructed. If

additional insulation were desired, it would be placed between the root protection layer and the waterproofing membrane or between the structural support and the waterproofing membrane. This layer would “prevent water stored in the green roof system from extracting heat in the winter or cool air in the summer” (Introduction to Green Roofs). However, the insulation “must be lightweight but have great compressive strength, so that is not crushed or squeezed out of shape by the weight of the materials (as well as people) above it (Cantor 27). Therefore the material of choice that is most commonly used on green roofs is polystyrene and polyisocyanurate (Cantor 27).

1.3.7 Waterproofing Membrane

Prior to reaching the roof deck or the structural support, there is a final essential layer which is critical in the formation of green roofs. This layer is the waterproofing layer that prevents water from settling on the roof and causing leaks into the interior of the building. The waterproofing layer “can be installed with any kind of waterproofing system, but single-ply membranes have become very popular in recent years and are specified by nearly all green roof companies for their cost-effectiveness and simplicity” (Wark and Wark 5). According to Cantor though the most common type of material used for the creation of this layer is polymer modified bitumen, which is often prohibited in many urban areas because of the odor it releases and the fire hazard (27). Therefore other materials that are commonly used are “(1) thermoplastics such as polyvinyl chloride (PVC) or thermal polyolefin (TPO), (2) EPDM rubber, and (3) liquid applied polyurethane” (Cantor 27). Any liquid-applied membrane must be applied directly to the roof and are believed to be the superior method for waterproofing a roof and for easiest maintenance (Introduction to Green Roofs).

1.4 Types of Green Roofs

Presently in the industry there are three major types of green roofs: extensive, semi-intensive (also referred to as hybrids), and intensive. Although all three have similar layers, as described above, they are categorized differently due to their variations in weight, costs, maintenance necessity, growing medium thicknesses, and of course, type of vegetation. Another distinction in regards to green roofs that needs to be noted is the difference between ‘green roofs’ and rooftop gardens. Rooftop gardens, which are

commonly confused with green roofs, are planted grown in containers and placed on the roof of the building. This varies drastically from green roofs because the plants are not incorporated into the layers of the roof. Therefore, this portion of the paper will concentrate on making distinctions between the different types of green roof systems that are available for construction.

1.4.1 Extensive Green Roofs

Of the three types of green roofs the newest to the market is extensive green roofs which are often non-accessible to the public and are characterized by low weight, low capital costs, low plant diversity, and minimal maintenance requirements (Peck 26, Oberndorfer *et al.* 824, Green Roofs Specifications, What is a Green Roof?). To add to this definition, the International Green Roof Association (IGRA) states that extensive green roofs are "well suited to roofs with little load bearing capacity and sites which are not meant to be used as roof gardens... [and also] the mineral substrate layer, contain[s] little nutrients, is not very deep but [is] suitable for less demanding and low growing plant communities" (Green Roof Types). Extensive green roofs often resemble a colorful lawn built overtop a roof, however, "the plant materials for extensive green roofs are perennials, usually of limited height, selected for their hardiness and adaptability to the climatic conditions..." (Cantor 15). Likewise, these plants are often drought-tolerant, resistant to winds, and excessive sun and are "visibly adapted to the natural extremes of the local conditions" and are often composed of one or two plant species (Green Roof Types, Wark and Wark 2).

Despite being the newest to the market, extensive green roofs are the most commonly adopted type of the three due to their low maintenance requirements and the lessened economic cost in comparison to the other two. However, extensive green roofs provide the least environmental benefits because they have the smallest type of vegetation (*sedum* and grasses) compared to, for example, trees and shrubs that are capable of sequestering more carbon dioxide than grasses. Extensive green roofs are designed to carry weight loads that are mostly composed of sedum, grasses, and mosses with a growing medium layer of about "1-6 inches or 2.5-15.2 centimeters," and have an approximate "wet roof load rang[ing] from less than 49 kg/m^2 (10lb/ft^2) to approximately

98 kg/m^2 (20lb/ft^2)" and a total weight of approximate weight of 60 - 150 kg/m^2 (Cantor 14, More than Meets the Eye, Wark and Wark). Unlike intensive roof, which are often described as elevated parks, extensive green roofs "are commonly designed for maximum thermal and hydrological performance and minimum weight load while being aesthetically pleasing" (Wark and Wark 2).

Figure 1.5: This image (taken from the www.greenroofs.org) is of an extensive green roof. The vegetation on this roof is composed of a mix of 13 sedum varieties and is of a high-profile roof (Ford Motor Company Dearborn truck plant), which has more than 454,000ft^2 of roof area.

1.4.2 Intensive Green Roofs

Intensive green roofs frequently resemble elevated parks or rooftop gardens, and often include walkways, benches, trees, and other additional large features, which sometimes requires "substantial structural reinforcement" (Wark and Wark 3, Speck 27). In comparison to extensive green roofs, intensive green roofs have a much deeper growing medium layer, which gives them a greater choice in type of vegetation. However, the trade-off associated with intensive green roofs is that the greater depth makes them much heavier thereby making them less common on existing buildings. When completed intensive green roofs resemble rooftop gardens due to the amount of larger plants and trees, but unlike rooftop gardens, which have all the vegetation contained in flower pots and, intensive green roofs can be distinguished by their "continuous underlying greenroofing layer system" (Introduction to Green Roofs). Another advantage to intensive green roofs is that they are fully accessible by the people who are using the building and not just for maintenance like extensive green roofs.

The accessibility factor is what makes intensive green roofs a popular choice in many urban cities, due to the minimal amount of green spaces available around the city and the ability to turn a rooftop into a recreational space (More than Meets the Eye). However, intensive green roofs require the most work, maintenance, and have the highest costs for construction of the three types (Speck 27). Generally, an intensive green roof's weight can range between 180 - 500 kg/m^2 and can have a built up height of up to 400 mm although sources disagree on the soil dept. The most conservative estimate was made by Cantor who expressed that there can be anywhere between 4 to 50 inches or more (10.2 – 127 cm) in comparison to 6 – 24 inches (15.3 – 61cm) (Cantor 16, More than Meets the Eye). Although most other sources do not give a range for the growing medium's thickness, they agree that an intensive green roof should have a minimum of 6 inches and should be built on relatively flat roof-tops and have a slope greater than 3% (Speck 27, Ward and Ward 3More than Meets the Eye, Introduction to Green Roofs). None-the-less, in addition to having the highest of everything, intensive green roofs are also capable of providing the greatest environmental benefits and ultimately only have two limiting factors, the building's structural load capacity and the client's budget. Below (Figure 1.4) is an example of a well-known intensive green roof: Chicago City Hall. In the image, larger trees and walkways can be observed, therefore making the roof type fall under intensive.

Figure 1.6: This image (taken from www.asla.org) is an example of an intensive green roof, and one that is extremely well known, Chicago City Hall. The image shows pathways and taller trees in what appears to be a park-like setting; a common look for intensive green roofs.

Summarizing the differences between extensive green roofs and intensive green roofs is the following table, which was created in the study by Oberndorfer *et al.* The table highlights the following major categories: purpose, structural requirements, substrate type and depth, irrigation, maintenance, cost, and accessibility (most of which is discussed in the paper).

Table 1.3: This table (taken from the paper written by Oberndorfer *et al.*) summarizes the differences between extensive and intensive roofs.

Characteristic	Extensive Roof	Intensive
Purpose	Functional; storm-water management, thermal insulation, fireproofing	Functional and aesthetics; increased living space
Structural requirements	Typically within standard roof weight-bearing parameters; additional 70 to 170 kg per m^2 (Dunnett and Kinsbury 2004)	Planning required in design phase or structural improvements necessary; additional 290 to 970 kg per m^2
Structural type	Lightweight; high porosity, low organic matter	Lightweight to heavy; high porosity, low organic matter
Average substrate depth	2 - 20 cm	20 or more cm
Plant communities	Low-growing communities of plants and mosses selected for stress-tolerance qualities (e.g., *Sedum* spp., *Sempervivum* spp.)	No restrictions other than those imposed by substrate depth, climate, building height and exposure, and irrigation facilities
Irrigation	Most require little or no irrigation	Often require irrigation
Maintenance	Little or no maintenance required, some weeding or mowing as necessary	Same maintenance requirements as similar garden at ground level
Cost (above waterproofing membrane)	\$10 to \$30 per ft^2 (\$100 to \$300 per m^2)	\$20 or more per ft^2 (\$200 per m^2)
Accessibility	Generally functional rather than accessible; will need basic accessibility for maintenance	Typically accessible; bylaw considerations

1.4.3 Semi-Intensive Green Roofs

The third and final category of green roofs, which many sources do not include, is semi-intensive green roofs (or hybrids). Semi-Intensive green roofs fall between extensive and intensive green roofs in all the different characteristics, meaning that it shares similar features with both types or is a cross between the two. Semi-intensive green roofs require more maintenance, work, and are more expensive than extensive green roofs, but overall require (in all categories) less than intensive roofs (Cantor 16, Green Roof Types). Semi-intensive roofs do require "a deeper substrate level [to] allow more possibilities for the design; various grasses, herbaceous perennials and shrubs such as lavender can be planted while tall growing bushes and trees are still missing" (Green Roof Types). Cantor describes the growing medium depth for semi-intensive green roofs as being 25 percent of 6-inches, meaning that it falls anywhere between 6 to 7.5-inches (16). Other features of semi-intensive green roofs that fall between the two other types are: its weight, which is approximately 120 - 200 kg/m^2, its accessibility to the public, and its environmental benefits (Green Roof Types).

Figure 1.7: This image (taken from www.greenroofs.com) demonstrates an example of a semi-intensive green roof. The image shows a variety of grasses, larger shrubs, and herbs, which together make up a semi-intensive green roof. This roof also demonstrates that they can be constructed on an inclined slope and still manage to retains

The following table summarizes the major categories that help distinguish between the different types of roofs (Green Roof Types). The major categories they detail

are: maintenance, irrigation, plant communities, system built-up height, weight, costs, and use.

Table 1.4: This table (taken from www.igra-world.com) is a simplified version of the information provided in the text above and details 7 different categories that help to distinguish between the different roof types.

	Extensive	Semi-Intensive	Intensive
Maintenance	Low	Periodically	High
Irrigation	No	Periodically	Regularly
Plant Communities	Moss, Sedum, Herbs, and Grasses	Grass, Herbs, and Shrubs	Lawn or Perennials, Shrubs, and Trees
System Built-up height	60 – 200 mm	120 – 150 mm	150 – 400 mm on underground garages > 1,000 mm
Weight	60 - 150 kg/m^2	120 - 200 kg/m^2	180 - 500 kg/m^2
Costs	Low	Middle	High
Use	Ecological Protection Layer	Designed Green Roof	Park -like Garden

1.5 Green Roof Benefits

Due to the vegetation, green roofs are capable of providing a variety of ecological and economic benefits including, mitigating storm-water runoff, air purification, providing a habitat for wildlife, mitigating the heat island effect, noise reduction, energy conservation, and increasing the longevity of the roofing membrane (Cantor 30, Peck 22, Banting *et al.* 7, Getter and Rowe 1276, Liu and Baskaran 1, Oberndorfer *et al.* 1, Green Roofs, More than Meets the Eye, Green Roof Types). These benefits are detailed below.

1.5.1 Storm-Water Runoff

The ecological benefit most often cited by many authors is the ability for green roofs to cut down storm-water runoff. In accordance to how they are designed, the plant material, and the growing medium, green roofs are able of "absorb[ing] significant quantities of rainfall and storm water runoff," thereby delaying or reducing the amount of water that will flow into the sewers (Cantor 30, Oberndorfer *et al.* 823, The Value of Green Infrastructure 4, More than Meets the Eye). According to the IGRA, immediate

water run-off can be reduced by 50-90% with most of the water being returned back into the water cycle through transpiration/evaporation directly off of the roof (Green Roof Types, Green Roofs: More than Meet the Eye, Introduction to Green Roofs). Liu and Baskaran found that the delay of storm water can be anywhere between 95 minutes and 4 hours and "that when initial rainfall was 2.8mm/h, runoff from the green roof was reduced to 0.5mm/h (1278). In their research they then describe how a North Carolina research found a 57% - 87% reduction in flow rate (similar to what was found by the IGRA) and that by slowing down the rate of runoff and "turning it out over a longer period of time, green roofs can help mitigate the erosional power of runoff that does enter streams, either through direct runoff or storm sewers" (Liu and Baskaran 1278). If the designer wishes to increase the reduction in flow rate, green roofs can be build in "combination with other forms of modern rain water management (for example, storage tanks or retaining trench-soaking hole systems)" in order to fully divert the water from infiltrating the storm water drainage system (Green Roof Types). Ultimately though, the Sierra Club website stated it best "green roofs reduce the amount of water that is wasted when it ends up in drainage systems" (More than Meets the Eye).

1.5.2 Heat Island Effect

Another major advantage listed by many of the authors is the ability to mitigate the heat island effect. The Environmental Protection Agency (EPA) describes the heat island effect as "built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings" and a high estimate provided by the IGRA is up to 10°C (approximately 50°F) during the summer months (Heat Island Effect, Green Roof Types). Cantor adds how the temperatures are elevated through the process of dark-colored pavements and constructions that absorb heat during the day and then slowly releasing it throughout the night (30). This phenomenon can increase summertime peak energy consumption demands, air conditioning prices, greenhouse gas emissions and air pollution in general, heat-related illness and mortality, water quality, and smog formation (Heat Island Effect, Cantor 30). Therefore, the fragmentation of monotonous black (or dark colored) tar rooftop and the "evaporative cooling [effects] provided by green roofs"

is capable of reducing elevated temperature in urban areas (The Value of Green Infrastructure, Green Roof Types). Likewise, as global temperatures rise, the decrease in heat-absorbing surfaces can only be an advantage since the effects of higher temperatures are known to reduce the quality of life (Green Roof Types). Therefore, more green spaces should be built; regardless of whether or not they are green roofs or parks because they are capable of absorbing up to 80% of the energy input (Green Roof Types).

1.5.3 Air Purification

Another major ecological effect that green roofs have is the ability to enhance air quality. Although the effects are not astronomical, green roofs are capable of lessening the smog formation in urban cities by taking up air pollutions and particulates, directly sequestering carbon, and reducing (indirectly) the air pollution and carbon dioxide emissions caused from electricity generation through the reduction of energy use (The Value of Green Infrastructure 5, Green Roofs: More than Meet the Eye). This ability to purify the air has proven beneficial because many studies now support that rising health problems can be attributed to levels of nitrogen oxide, carbon monoxide, volatile organic compounds (VOCs), and exhaust fumes that can be found in the environment (Green Roof Types). Other pollutants that get absorbed by the vegetation are NO_2, SO_2, O_3, N_2O, and CH (The Value of Green Infrastructure). Therefore the ability for green roofs, especially intensive green roofs that can have a greater effect on the air, to trap airborne particulates is an indirect impact that could make a significant difference if more rooftops were to adopt this technology. According to the IGRA, one square meter of green roof is capable of filtering approximately 0.2kg aerosol dust and smog particles per year with the addition of nitrates and other harmful materials that get deposited on the vegetation after rainfall (Green Roof Types).

1.5.4 Wildlife Habitat

Another beneficial way that green roofs help the environment is by increasing available habitat for wildlife. As many authors claim, green roofs, especially in urban areas, can provide “eco-restorative habitats for displaced creatures” and also provide “food, shelter, nesting opportunities and a safe resting place for spiders, beetles, butterflies, birds and other invertebrates (Banting *et al.* 24, Getter and Rowe 1279, Green

Roof Types). Green roofs are able to compensate for the land areas that are lost in the creation of sealed surfaces as "they create lively and vigorous places and connect isolated refuges for flora and fauna within the sterile city centers" (Green Roof Types). By taking it a step further and planting native species to the regions, green roof are able to preserve biodiversity and provide a unique environment to even rare and protected species, such as an example in Getter and Rowe's article provide (1279, Green Roof Types). Similar to the air purification category, providing a habitat for wildlife is an advantage that comes with the creation of the green roof and does not require any sort of further modification.

1.5.5 Noise Reduction

Another advantage provided by green roof is not ecologically geared, but is focused on improving the quality of life of the client. Green roofs have the ability of reducing noise "due to the thickness of the entire installment, from waterproofing membrane, growing media and plant materials" (Cantor 30). Since "hard surfaces in urban areas are more likely to reflect sound" green roofs act like "acoustical barrier, [as] they reduce the volume of sound from traffic, airplanes, and other sources that penetrates the building" (Getter and Rowe 1280, Cantor 30). Because of the vegetation that is grown overtop the roof sound waves (up to 40dB for green roofs up to 12 cm thick) are absorbed thereby reducing the client's noise exposure levels (Getter and Rowe 1280). However, in general, "green roofs reduces sound reflection by up to 3dB and improve insulation by up to 8dB" (Green Roof Types).

1.5.6 Energy Conservation

Perhaps one of the most important factors related to why people get green roofs is because of energy conservation or economic savings they can receive from their implementation. As mentioned before, green roofs are capable of saving energy by reducing the HVAC energy output due to the additional layers of insulation that are created when construction the green roof (Banting *et al.* 8). They are capable of "reduc[ing] the penetration of summer heat and the escape of interior heat in winter…[yet] there is possibly an even greater benefit in the summer due to the cooling created by the evapotranspiration effect from plants and the evaporation retained moisture from the soil" (Banting *et al.* 8, The Value of Green Infrastructure). Getter and

Rowe also describe how the most energy saving will occur during the summer months “because the insulation properties of the substrate are greater when air space exists in the pores as oppose to when they are saturated, which is normally the case during winter” (1279). A study quoted by Getter and Rowe estimate that Chicago City Hall (Figure 1.7) saves approximately $4,000 annually in heating and cooling cost combined and that if the whole city of Chicago had green roofs, then they could save $100,000,000 annually (1279).

These savings come from the increased shade and insulation provided through the growing medium, vegetation, and the other layers of the green roof that reduce the “amount of solar radiation reaching the roof’s surface [therefore] decreasing the roof surface temperature and heat influx” (The Value of Green Infrastructure, Getter and Rowe 1279). Getter and Rowe estimated savings to be around 15% annually from reduced energy consumption (1279). However, Cantor believes that it is hard to predict the annual savings, but states that “in many cases, the green roof eventually pays for itself” due to the savings and the extended roof life expectancy (33). Yet, according to the Sierra Club GreenHome there was a study done in 2006 by the University of Michigan that compared expected costs of conventional and green roofs and found the following:

> On average, installing a green roof costs about $22.10/ft^2 versus $15.95/ft^2 for a conventional roof. In its life, however, the green roof saves over $200,000 with two-thirds of that coming from reduced energy needs. Taking into consideration the added savings, the average cost of this topnotch turf would be about $12.57/ft^2 – meaning you could save $3.38/ ft^2 by choosing a green roof (More than Meets the Eye).

With that, it becomes evident that savings are inevitable, but the amount will vary on the roof size, green roof type, location, and months of the year.

1.5.7 Expanded Life Span Expectancy

Roof life expectancy is another advantage that often gets mentioned, usually tied in with economic savings since an increased life expectancy means not replacing the roof as often and therefore savings. Currently, the expected “lifetime of a conventional roof is about 20 years, whereas a green roof should last 40 years or longer,” meaning that green roofs are predicted to last about twice as long while saving annually on energy costs (Getter and Rowe 1282). The expanded life span expectancy is attributed to the growing

medium and the vegetation that protect the roofing membrane from exposure that generally damage conventional roofs (such as ultraviolet radiation and ozone) (Getter and Rowe 1278, Oberndorfer *et al* 828, Green Roof Types). Another form of exposure that has a tendency to damage rooftops is temperature fluctuations, which green roofs protect from, not only seasonal temperature variations, but also day and night changes (Getter and Rowe 1278, Oberndorfer *et al* 828).

Benefit	Reduces Stormwater Runoff											Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes   Maybe   No

Figure 1.8: This figure (taken from The Value of Green Infrastructure) highlights different form of 'green infrastructure' including green roofs. It is included in this paper to demonstrate how green roofs compare to other technologies in the above categories.

APPLICATION TO UNION COLLEGE

2.1 Union College Background Information

Located in downtown Schenectady, New York, Union College was founded in 1795 as the first planned campus in the United States. Since its founding, the college has grown tremendously, both in size and population. Currently there are approximately 2,100 undergraduate students and over 200 Faculty on about one-hundred acres including 8 acres of gardens and woodlands known as Jackson's Garden (Union at a Glance). According to Union's website, the college has been "defining—and continually redefining—liberal arts education… Since 1795, we've been challenging convention, blurring boundaries and shaking up traditional thinking," however this 'shaking up of traditional thinking' has yet to expand to green roof technology (Union at a Glance). As the college strives to go greener through the work of clubs and organizations such as Environmental Club and U-Sustain, the potential to receive Green Grants for projects around campus, and through the new LEED Gold certified Peter Irving Wold Center (Wold Center), there is no reason that green roof technology should not be considered on this campus.

As a progressive environmentally minded campus, Union College utilizes a variety of different green technologies around campus. These different technologies include motion-sensing and LED light fixtures; gathering renewable energy from photovoltaic, wind turbines, and geothermal systems; efficiently using thermal resistance and high-albedo coverings for rooftops; controlled temperature systems based on occupancy; and low VOC containing materials. With the list of materials growing longer every year, the College continually demonstrates its commitment to becoming more sustainable. Implementing a green roof on one of the buildings would only further advance the College's achievements as an environmentally friendly campus. With that in mind, I propose that the ideal building to construct a green roof on would be College Park Hall (CPH), located just off of Nott St and Erie Blvd (Figure 2.1 shows where the major dormitories are, including CPH in the upper left hand corner) (Residence Halls).

Figure 2.1: Aerial map (taken from www.union.edu) of the major dormitories of Union College. College Park Hall (CPH) is located in the upper left hand corner at the intersection of Nott St. and Eerie Blvd.

Of the buildings that are located around the campus with flat roofs, the 5,500 ft^2 flat roof of CPH would be a great choice because the building was recently renovated. In 2004, when the college began the remodeling of CPH from what used to be a hotel to student dormitories, the structural engineer (Steve Sopko) greatly overcompensated for the load carrying capacity that the building would be able to handle. With the New York State standard having just dropped from 45lb/ft^2 to 35 lb/ft^2, CPH far exceeds the standard with 65lb/ft^2 (McKinney). Although, within the past year, the Union College Facilities Department pursued plans to build a green roof on the roof of the columns near the Schaeffer Library on the main campus, these plans feel through since the building would not have been able to support the additional weight. However, with CPH being able to support an additional 30lb/ft^2 (since the standard has changed), that is enough for the additional 10-15 lb/ft^2 allocated to a green roof and the additional weight of snow during the winter.

2.2 Case Studies

This section will look at relevant case studies of a high profile green roof (Ford Company) as well as a few colleges and universities that have successfully implemented green roofs on one or more of their buildings. Especially among Colleges and

University, within the last decade, the list of locations that have installed green roof technologies has grown longer and longer.

2.2.1 Ford Dearborn Truck Plant

Covering 454,000ft^2 (10.4 acres) of Ford's truck plant is the largest extensive green roof in North America (Peck 133). After having bought a 1,100-acre brownfield property in 1999, Bill Ford, Jr. pledged to convert the area into a "model of a sustainable manufacturing center" doing so by "'reestablishing habitat, greening the site, preserving buildings with historic importance, cleaning impacted soil using phytoremediation and managing storm water discharge'" (Cantor 193). Initially, a green roof was not in the plans since the building covers such a large area of space, but since so much of the site is completely paved, the idea of building a green roof was proposed by the engineers to help manage storm water runoff. Having been completed in the fall of 2002 by a variety of designers, consultants, and architects, this extensive green roof was grown on a one-inch thick growing medium, demonstrating the extreme of how little growing medium is needed for vegetation to grow.

In addition to the growing mat, three layers of materials were. Unlike most other green roofs, the Ford truck plant is an exception because it utilized vegetation mats that were grown nearby, then cut into 1-meter pieces, and along with geotextiles were lifted to the roof for installation. The three layers of the roof consist of the original roof installation of a modified bitumen moisture-resistant membrane, a root-impermeable membrane, and then a drainage layer (Xero Flor) followed by a layer of water absorbing fleece (Cantor 196). The design objectives for this green roof were: to reduce the quality of storm water runoff; ecological restoration; educational opportunities; waste diversion; and ecological sensitivity maintenance (Peck 132). Since its establishment it has been part of many studies including one that "identified and recorded twenty-nine insect species, seven spider species, and two bird species in a 2-acre area" thus showing the it is also a habitat for wildlife (Cantor 196).

2.2.2 University of Pennsylvania

Another green roof example that is more applicable to Union College is the green roof that was dedicated to the graduates of the Nursing program at the University of

Pennsylvania. Located on top of Fagin Hall, the building that houses the School of Nursing, at the University of Pennsylvania is one of their many green roofs. Roofmeadows, a company that specializes in green roof construction, was also responsible for building the other green roofs that can be found at the University of Pennsylvania. The other buildings that also have green roofs, include the Radian apartment complex, Steinberg Hall – Dietrich Hall Café, Erdman Center, and the Perelman Center for Advanced Medicine (Roofmeadows). Although the college has a few green roofs, Roofmeadows describes this particular roof on the School of Nursing as the "jewel box green roof" because it was constructed on a section of the roof that is surrounded by windows on all four sides, making the roof visible from the office spaces that look onto the courtyard. By placing the green roof at that very location, the building increases its aesthetic value and provides benefits to employees from the increased green space. Although the roof in non-accessible, it is located overtop what use to be a concrete courtyard to what is now a beautiful garden that allows the employees to gain benefits that green spaces provide to people, such as reduced stressed.

Along with the benefits that this provides to the people who work in the building, this particular green roof was built with the intent of reducing the city's storm water runoff to slow down the rate of water entering the West Philadelphia sewer system. This helps mitigate the Combined Sewer Overflows (CSO) issue that is prevalent in Philadelphia. CSO occurs when the city's pipes capacities are exceeded due to heavy rain or sudden snow melt, therefore mixing wastewater and sewer together in the main pipes. In order to prevent flooding of homes and streets, the wastewater combination is diverted from the treatment facility to being dumped directly into nearby stream or river from any or all of the 164 permitted sewer outfall sites (City of Philadelphia). However, when the system is not being inundated by heavy rain or snow melt, the sewer and wastewater collection municipalities are capable of handling the normal load through the single-pipe system. So by increasing the number of green roofs in the greater Philadelphia area they would be able to drastically reduce the amount of storm water that enters the sewer system during a heavy rainstorm.

Along with providing that benefit to the city, the University of Pennsylvania's green roof will increase the longevity of the waterproofing membrane by protecting it

from UV radiation and will create a habitat for wildlife within the urban setting. All of these benefits, which are provided by its extensive green roof design that "including a variety of perennials supported by a thin extensive green roof profile," will increase the longevity of the roof and the urban environment around the University (Roofmeadows). By simply replacing the concrete atrium on the fourth floor of a five-floor building with a thin layer of extensive roof and only 6-inches of growing medium, the University can benefit the environment, the city, and itself for the savings it will gain. The image below (Figure 1:10) shows a partial view of the green roof that was installed at the University and the surrounding window of the fifth floor offices.

Figure 2.2: Image (taken from www.roofmeadows.com) of the extensive green roof built on Fagin Hall at the University of Philadelphia.

2.2.3 The Evergreen State College

Located in Olympia, Washington is The Evergreen State College. The Evergreen State College Seminar II building is what the college refers to as a step towards becoming more sustainable. In 2004, they completed 20,443 ft^2 of green roof on top of their new building that houses a majority of their classes. According to the school's website, "special attention was taken during the design and construction phase to create a sustainable and economical building that could provide an example for the rest of the community" (Evergreen). Similar to the Wold Building (here at Union College) this building was certified Gold LEED certification, but for a variety of different reasons (Evergreen). The building, which is approximately 159,900 ft^2, was designed with the

considerations of building ecology, energy efficiency, building format, the materials being used, and overall good design (Evergreen). About 10% of the building was made of recyclable material and 40% of the roof is covered with a green roof (Evergreen). Although Union College will most likely not allow for a green roof to be built on the Wold Building, the Seminar II building is a good example to look at because similarly, the college is dedicated to sustainable action and being an example for the local community. The image below is of a side view of what the building looks like in its completed state (Figure 2.3).

Figure 2.3: This image (taken from www. aiatopten.org) is of a side view of the Seminar ii building at The Evergreen State College in Washington.

Rather than having just one green roof, there are thirteen in total that were originally going to be built for food production. Upon discovering that food production would not be possible, the college was still highly interested in constructing the green roofs because of the storm water drainage advantages it would provide (Peck 96). Therefore, after developing a $20,000 computer model that "demonstrated the additional storm water performance benefits of the green roofs" they were convinced that building a green roof would have many advantages for the college. This green roof also embraces the use of "water retention vaults [that are] designed to release water back to the environment slowly" (Peck 96). Along with the water retention benefits that the building provides "the combined benefits of the reduced roof top temperature and the high R-value insulation provide the owner with a very energy efficient roof system… that helps reduce the energy needs of the building which was designed with no cooling system"

(Peck 96). Although there are areas of the building that could not be covered with one of the 33 low growing or perennial species, they are still efficiently covered with Energy Star approved white coatings over the waterproofing membrane to reduce energy consumption (Peck 96).

RECOMMENDATIONS

As green roofs begin to gain popularity throughout the United States and especially on college campuses, as demonstrated by the case studies, Union College should be considering whether or not to implement a green roof to further their commitment to the environment. Although Green roofs are capable of providing energy savings as one of their main economic benefits, whether or not Union's CPH would benefit from these savings would be unknown without further detailed engineering analysis or until the green roof were actually constructed on and savings were calculated. Currently though the building is sufficiently insulated with a batt insulation of 3/12-inches stud cavity and 2-inches of rigid board as part of the EFIS system. The batt insulation has an approximate R-value of 11 and 7-8 for the EFIS board for a total R-value between 17-18 without including the insulation value that the GWB and air films would provide. Therefore the exterior walls could easily have an approximate value of R-19 for walls. Similar to that, the roof is highly insulated with an approximate value of R-24. This insulation comes from the 4-inches of isocyanurate insulation that are spread out in 4x8 sheets to fully cover the roof. As previously mentioned, the building was renovated in 2004 from a hotel to a dormitory. During this renovation, the contractors, architects, and engineers designed the building for energy efficiency; therefore the savings that would come from a green roof would be minimal if existent at all.

However, that does that mean that the other benefits that green roofs are capable of providing should be overlook when considering whether or not to implement a green roof on CPH. Schenectady and the City of Philadelphia have a very similar sewer system. Since the Schenectady system was built a while back, most the city still operates on a one-pipe system that drains all of the water either to the river or to the treatment facility. Therefore, during heavy rains (as we have seen quite a few of this year already) and during snow melt, the system gets inundated and much of the sewer and waste water flush directly into the river, which is bad for the environment. However, like the

University of Pennsylvania, by building a green roof, the college would be able to reduce its storm water runoff, thereby placing less stress on the City of Schenectady's treatment facilities. Likewise, the other benefits that were listed in the benefits section of the paper would be applicable to Union College. The green roof would still be able to provide a habitat for the wildlife, act as a noise barrier for the area it would be constructed overtop, increase the lifespan of the roof due to the additional covering from the green roof, and purify the air and reduce our overall carbon emissions.

Therefore considering all of the advantages that a green roof is capable of providing to the environment and that the college has made a commitment to become more sustainable, it is my formal recommendation that a green roof should be highly considered for Union College's College Park Hall. Although the initial investment in the roof would probably not provide the return on investment that it could in other buildings around the United States, it would act as a educational facility for the students that attend Union, it would demonstrate that the college really intends on keeping its commitments, and it would provide some benefits to the environment that the current roofing system is not providing

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