Case Study: An Effective Model for Green Roofs in San Diego County

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Green roofs provide a myriad of environmental and financial benefits to a building and its owner. They can provide a pleasing outdoor aesthetic in an urban environment, as well as provide stormwater management and energy savings in an arid climate. California State University San Marcos completed a new University Student Union in 2014 that included a 2,540 square foot Live Roof system on its upper terrace. Supplier, contractor, and facilities team members were interviewed to analyze the success of the project from several viewpoints. The green roof was found to meet the University's goals on aesthetic design, energy, and stormwater management through its selection of material and local flora. Challenges for the implementation of the green roof included design coordination and installation logistics. A net present value of $946 was calculated based on figures provided by the University, representing a cost-benefit over a standard white roof. This project demonstrates a successful implementation of a green roof in an arid climate.

Key Words: Green Roof, Sustainability, Stormwater Management, Energy Efficiency

Introduction

Green roofs, often-called living or vegetated roofs, are roofs that are at least partially covered by vegetation. The vegetation is supported by a growing medium and the structure is protected by a complex system of waterproofing and other protection. Green roofs have been found to provide a myriad of environmental benefits such as a reduction in urban heat island effect, an increase in onsite rainwater retainage, and increased insulation values. Green roofs also have an increased cost that is primarily due to their material-intensive nature and the consequent need for a stronger structure to bear their weight. Roof gardens and green roofs are often considered synonymous, but there are a few significant differences. Primarily, roof gardens are used as a "programmed" space, or an area where people can occupy, whereas a green roof is typically not able to support the live load of people.

Early green roofs were developed in Scandinavia centuries ago where rural citizens placed sod on their roofs for insulation from the cold climate as well as to structurally hold together the layers of birch bark underneath. However, the first recorded instance of a roof garden was in the Ancient Roman Empire on the Mausoleums of Augustus and Hadrian (Magill 2011). Modern green roofs started being developed in the 1960's in Switzerland and Germany. Further researched was done in the 1970's that increased the effectiveness of green roof technology and government subsidies in some European countries proliferated the market. By 2005, an estimated 14% of Germany's flat roofs are green (Getter 2006). The United States has been slow to adopt green roofs and this is typically because their increased cost is seen as prohibitive.

Green Roof Assembly

A green roof is a complex multilayer system that supports the design intent of the roof. This section will focus on flat, commercial roof applications but the basic makeup of a green roof is mostly coherent through different building applications. The typical layers of a roof are as follows:

- Waterproofing Membrane
- Root Barrier
- Drainage and Flashing
- Filter
- Growing Medium
- Vegetation

Additionally, insulation can be included between the root barrier and the drainage layer but typically green roof contractors want to exclude it from their scope of work. More often than not, the insulation is installed below the roof deck (see Figure 1).

The waterproofing membrane layer is an important aspect in a green roof application as it prevents water from seeping into the building. It consists of material that is able to withstand hydrostatic pressure and facilitate diverting the water off of the roof. Typical materials include built-up bitumen, thermoplastic PVC, or elastomeric membrane. The root barrier layer prevents plant roots from disrupting the integrity of the waterproofing membrane. If the waterproofing ruptures, water can seep into the building, compromising its structural integrity. Root barriers are typically made of high-density polyethylene, impervious concrete, PVC, or TPO. The drainage layer takes excess water out of the system, preventing build up on the waterproofing layer. Yet, it leaves enough moisture to sustain the vegetation. It is made of a network of perimeter boards and pipes or alternatively a granular media. Filter fabric sits below the growing medium and prevents any debris or plant material from clogging the drainage layer.

The most critical and obvious parts of any green roof system are the growing medium and vegetation. The growing medium, or soil, is comprised of inorganic and organic matters, air, and water comprise the growing medium, or soil. It must be specifically fashioned to meet the needs of the vegetation it supports. It anchors the vegetation to the roof and provides nutrients for growth. The growing medium is often the heaviest aspect of a green roof and the depth of it determines if the roof is considered extensive or intensive. Extensive roofs have 6 inches or less of growing medium, are the cheaper of the two options and are suitable for smaller plants; intensive roofs are 6 inches or deeper, are more expensive, and allow for improved biodiversity. Intensive roofs are often used as a supplement to roof gardens. The vegetation is the defining characteristic of the green roof and should be carefully considered to meet the project goals and thrive within environmental parameters.

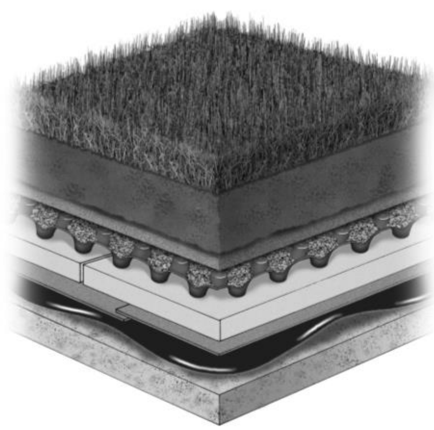

Figure 1: Section of a typical green roof. The insulation layer is optional.
Source: American Hydrotech, Inc.

Environmental Benefits of Green Roofs

The benefits of implementing a green roof on a building include reduced energy consumption, reduced urban heat island effect, mitigation of air pollution, noise reduction, and rain water runoff management. The extents of these effects are dependent upon the design of the green roof and can vary widely. Some benefits are also more significant in arid climates like San Diego and each will be discussed further with such environmental conditions in mind.

Green roofs have the capacity to reduce the energy consumption in warm climates by preventing direct solar radiation onto the building. The vegetation provides a layer of protection above the roof that blocks this radiation and the soil acts as further insulation from heat transfer. This keeps the indoor air temperature from varying excessively, thus reducing spikes that cause the need for cooling. Cooling systems are usually the highest energy drain in commercial buildings, so implementing a green roof can reduce the need to cool the interior space. In fact, green roofs can reduce energy need by up to 48%; however, this number can vary widely depending on environmental conditions (Berardi, 2014). The absorption of solar radiation has a second benefit in reducing the urban heat island effect. The urban heat island effect occurs in urban environments where buildings and other human developments, like asphalt pavements, absorb more solar radiation than its surrounding area. The heat "island" name is derived from what a temperature graph of an urban environment and its surrounding would look like where higher temperature readings would spike around urbanization (see Figure 2). However, despite the reduce energy consumption associated with green roofs, white roofs have a higher potential to reduce the heat island effect because of their higher solar reflectance index (SR). The SR of a roof denotes the percentage of solar radiation that is reflected off of a roof; white roofs have an SR of 0.55 and green roofs, 0.20 (Sproul, 2014).

Green roofs also diminish air pollution in condense urban environments when widely utilized. There have been several studies confirming this effect as vegetation on green roofs absorbs CO2 and other air pollutants. Singapore, Washington D.C., Detroit, and Chicago have all seen major reduction in air pollution from green roofs. Singapore, one of the most sustainable cities in the world, was able to reduce air pollution by 37% (Berardi, 2014). While all of these cities are quite different climatically, Singapore is closest to San Diego and could prove to be an effective precedent for extensive use of green roofs.

Due to the insulating nature of green roofs, they also provide a moderate amount of noise reduction, which can be helpful in an urban environment like San Diego. A report in 2008 by two sound engineers, Connelly and Hodgson, revealed that green roofs could increase transmission loss of sound by "…5 to 13 dB at low and mid frequencies, and from 2 dB to 8 dB at high frequencies" (Berardi, 2014, p. 422).

Rainwater runoff management has become an important aspect in building projects. Rainwater, or stormwater, that falls on a roof travels along the building and/or site and proceeds into the local drainage system. There has been concern that rainwater is being polluted from the built environment and thus pollutes the water cycle, endangering many natural and anthropogenic systems. Green roofs have been shown to help rainwater management significantly as they can reduce runoff by up to 100% in intensive roofs and provide a natural filter to otherwise harmful pollutants (Berardi, 2014).

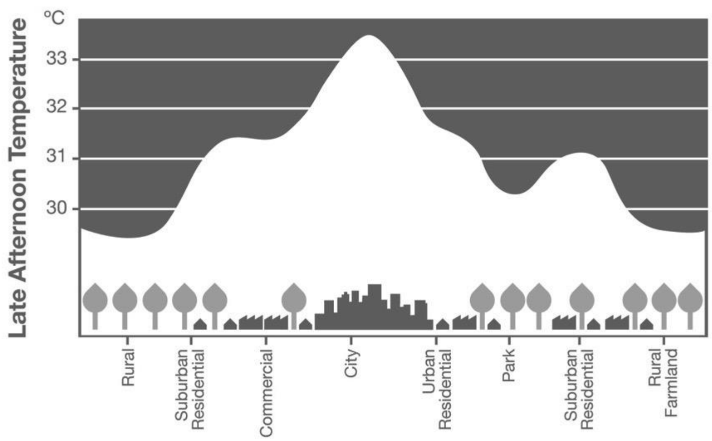

Figure 2: Graphic example of urban heat island effect
Source: healthyurbanhabitat.com

Local Environment of San Diego

The County of San Diego is considered a dry Mediterranean climate, characterized by its mostly sunny weather and mild to warm temperatures. The monthly average high temperatures range from 65ºF in December to 77ºF in August. San Diego averages 146 sunny days and 10.34 in of precipitation per year (. The city is considered semi-arid but varies from region to region due to microclimates that manifest from its diverse terrain. Moderate temperatures and precipitation in the winter also fosters a nearly yearlong growing season for local plant species (Perry 2010). There are two local weather phenomena that are worth noting, "June Gloom" and the Santa Ana Winds. June Gloom is a period during May and June where a thick marine layer will linger over coastal and some inland communities longer than usual. Typically, this layer "burns off" during morning hours but can last the entire day in some cases. The Santa Ana's are warm, easterly winds that significantly drop the humidity in San Diego for 7-10 days out of the year. Wind speeds can reach 40 mph and can increase the danger of wildfires by creating dry conditions and rapidly dispersing flames.

Methodology

The objectives of the case study are as follows:

- To determine effective compositions of green roofs in San Diego, CA
- To highlight environmental benefits of green roofs
- To highlight financial aspects
- To provide a example for developers on how to successfully implement green roofs

The hypothesis for this paper is that a green roof can be a beneficial addition to a project in comparison to a standard white roof. This paper's methodology was both qualitative and quantitative and was based on a case study. Interviews were conducted with individuals that had a direct connection with the green roof on the project. The interviewees were Tom Hawkins, the President of Florasource, Harold Oakley, a Superintendent for PCL Construction, and Scott Kirby, a Facilities Manager for CSU San Marcos. These three individuals provided different views on the project that when analyzed by the researcher allowed for a more objective view of the green roof's advantages and disadvantages. The key issues of the green roof were then broken down into the following: goals, challenges, and benefits. These issues were then used as a basis for a general recommendation for developers on how to best implement green roofs in San Diego County. Quantitative data was taken from these interviews and analyzed to determine the net present value and payback period of the green roof when compared to a standard white roof.

Case Study

California State University San Marcos (CSUSM) has provided comprehensive educational studies to San Diego County since 1989. The university lies in San Marcos, CA and is part of the system of 23 CSU campuses. In 2014, CSUSM completed construction on a new 89,000 SF University Union to serve their student population. The UU is part of the 2014 CSU Sustainability Policy to further integrate sustainable practices into CSU campuses. Included in its expansive outdoor space is a 2,540 SF Live Roof ® system. Live Roof is a prefabricated, modular green roof system that is installed by Florasource Ltd in Southern California. PCL Construction Inc. was the design-builder for the entire University Union project. The green roof also contributed to the University Union's success of becoming LEED Gold certified because of its benefits to a multitude of criteria.

Project Specifics

The following are additional key details of the green roof that pertain to this case study:

- Green roof area: 2,540 SF
- Green roof cost: $66,040
    - Square foot cost: $26/SF
- Live Roof models: Standard and Deep
    - 4.25"-6" of growing medium
    - 27-50 lbs./SF of vegetated weight (range includes Standard and Deep systems)
- 16 species of indigenous plants and grasses

Results

The following sections were compiled from the interviews of Harold Oakley and Tom Hawkins that took place two years after the completion of the project. This time period allowed for a retroactive look at methods of design and implementation that worked well and ones that did not. Subsequent analysis of qualitative data is as objective as possible. Quantitative data is only as accurate as sources claim and should not be used as a cost model; these numbers are specific to this project and do not reflect a quote from any party.

Green Roof Goals

The University's overarching goal for the green roof was to aid in their adherence of the 2014 CSU Sustainability policy. This policy dictates that CSU campuses must meet certain objective sustainability goals such as increased energy and water management on buildings. The following are the three specific goals for the green roof on CSU San Marcos' University Students Union.

1. Provide Outdoors Aesthetics: The green roof is part of the 10,000 SF of architecturally programmable spaces for the University Union. It is located adjacent to a large rooftop terrace that contains seating for students and offers panoramic views of the surrounding hillsides. The green roof was meant to provide a close interaction with nature and with its local flora, extend this interaction beyond the roof and into the local environment.

2. Increase Water Conservation: The USU's green roof was designed to optimize function with limited water usage. As San Marcos has a semi-arid climate and the project was being constructed during California's driest years, there was a severely limited supply of water for outdoor irrigation. The University's hope was that the green roof would require little to no watering and make a significant impact on the buildings stormwater management.

3. Increase Energy Efficiency: As part of the CSU system's continuing goal of reducing greenhouse gas emissions, the University requested a 21% higher efficiency than California Title 24, the state energy code and building standard. To help achieve that, the green roof was designed to increase insulation values and reduce the need to cool interior spaces.

Green Roof Challenges

The green roof on the University Student Union provided several design and logistical challenges to the project team. Tom Hawkins stated that green roofs are more successfully implemented when pertinent members of the project team are brought on early in the design process. While overall more beneficial, this provided coordination challenges early on in the project in regards to the green roof. The most important conversation was between Florasource and the project's structural engineering team, DCI Structural Engineering, to determine the maximum dead load the green roof could exhibit. Florasource also worked with LandLAB, a landscape architecture firm, and Native Sons Wholesale Nursery to select the plants and growing medium that would be used on the green roof. Further design coordination was also done with project's architect of record, Hornberger and Worstell. It is important to note that correct installation by the contractor is paramount as any significant change in distributed weight could compromise the structure of the roof, especially during a seismic event.

Another challenge for implementing the green roof was installation logistics. Coordination between Florasource and PCL was important for the prefabrication of the Live Roof modules as fabrication and delivery of the custom units took 4 weeks. The two parties needed frequent communication during the weeks leading up to scheduled delivery to ensure success. There were also several specific installation requirements that an inexperienced contractor could neglect, compromising the green roof. The waterproofing membrane needed to be sealed and flood tested, edging needs to be installed, and a pre-installation checklist was completed. Site logistics needed to be explained to Florasource as well to prevent any delays.

Future maintenance is also a concern for the University despite Live Roof's mitigation of major maintenance concerns; this mitigation will be explored further in the section below. Leaking in the waterproof membrane, while not a major threat unless it reaches the extent of compromising structure, can prove disruptive if water reaches any low-voltage systems. Unfortunately, green roofs in general hinder a maintenance teams ability to repair the underlying layers of a roof when compared to a standard white roof. The team must also take care to not disrupt too much of the surrounding vegetation during repairs to avoid any permanent damage during upheaval. Overall, maintenance costs for the system are expected to be about $0.24/SF when annualized over its life span. This is significantly higher than the $0.02/SF of a white roof (Sproul 2014). In addition, the increased replacement cost of the Live Roof system over a traditional white roof amounts to $1.25.

Green Roof Benefits

The Live Roof system is an exceptional example of green roof technology as it neutralizes some problems with more traditional systems. Part of this success is due to its modular nature as installation time is significantly shorter than others. Each 12"x24" module was assembled offsite by Native Sons Wholesale Nursery for the University's custom design. Installation on the roof took place over the course of two days. The modules edges are not seen as soil extends 1" above the box when finished thus creating a more natural and uniform aesthetic. This also prevents photodegradation from detrimental UV rays and allows for soil nutrients to naturally transfer amongst the entire space. This unique feature is what allows Live Roof's 50-year life span, which is 2.5 times longer than a standard white roof. Due to their prefabricated nature, the plants are able to mature before installation allowing for increased resiliency during that process.

The green roof on the University Students Union exhibits significant performance in stormwater management as the Live Roof system can absorb and filter 95% of the first inch of rain that falls on it, meeting the University's goal. Because of the green roofs ability to absorb so much water, the University was able to downsize stormwater retention equipment. Cisterns and bioswale sizes were drastically reduced and represented a savings of about $10,000. The university also did not need to install an extensive irrigation system either as the vegetation incorporated into the design are able to thrive off of the local rainfall. The 16 species of plants were mostly local varieties of the genus *sedum*, specifically succulents, and native western U.S. grasses but there were a number of Mediterranean species as well that are well suited for the similar climate of San Marcos.

When compared to a standard white roof, Scott Kirby estimates that the green roof on the USU saves $2,500 per year in cooling costs. This is due to the evapotranspiration property of the vegetation that provides a cooling effect as well as the increased insulation value gained from the thick growing medium. The greater thermal mass of the green roof also creates a "thermal lag" when compared to a regular white roof. This means that the time it takes for the entirety of the roof to heat is increased, thereby reducing rapid temperature swings and increasing the life of the roof.

Net Present Value

To determine if the green roof on the USU was financially beneficial, a net present value calculation was performed based on expense information gained from the interviews of Scott Kirby of CSUSM and Harold Oakley of PCL Construction. A net present value calculation the current worth of a future sum of money and in this case, an annual stream of money as well, dependent upon a predetermined discount rate. For context, a sum of money today is worth more than a sum of money one year from now and the difference in that worth is based on a given rate of return that that money could produce if invested.

The calculation for this green roof is not for the green roof itself, but for a comparison to a standard white roof. For this purpose, premium is used to describe that increase in cost of a green roof in comparison to a white roof. The cost of the green roof on CSUSM's University Student Union was $66,040 while a standard white roof of the same size (2540 square feet) will cost an estimated $34,036 based on a national estimate of $13.40 per SF (GSA, 2011). The maintenance costs premiums of the green roof are $0.22 per SF as the estimated costs of the green roof are $0.24 per SF and $0.02 per SF for a white roof. The replacement premium for a green roof was also considered and was based on the estimate of $3.25 per SF for a green roof (Sproul 2014), was calculated to occur at the end of its 50-year lifespan. The stormwater savings, given directly by the facilities manager of the building, were $10,000 and represent a current savings premium. The energy savings of the green roof amounted to a reported $2,500 per year for the green roof and were converted down to a present value. The given discount rate was 8.00% based on an industry low rate of return of 5.00% plus the average annual inflation rate of 3.00%. These figures were thus used in the net present value calculation below (See Table 1).

Table 1 ***Net Present Value of Green Roof Premiums***	
Initial Premium	**-$32,004**
Green Roof	-$66,040
White Roof	-$34,036
NPV of Maintenance Premium	**-$7,012**
Annual Maintenance Premium	-$559
NPV of Replacement Cost	-$176
NPV of Stormwater Savings	**$10,000**
NPV of Energy Savings	**$30,584**
Annual Energy Savings	$2,500
Internal Rate of Return	8.00%
Net Present Value	**$1,568**
Payback Period	12.5 Years

Conclusion and Recommendations

California State University of San Marcos installed the green roof on their new University Student Union to accomplish three goals: provide an aesthetically pleasing experience, provide stormwater management best practices, and increase energy efficiency. Their green roof achieved all three of these goals as the green roof is an interactive part of their rooftop terrace, absorbs almost all of the rain that falls on its area, and saves the university $2,500 in cooling costs every year. Additionally, as shown by the net present value calculation, the green roof will pay for itself within the first 12.5 years of service and represents a total savings of $1,568 over its lifetime.

This case study provides accomplished the goal of this paper by providing an example of a green roof in the arid San Diego County climate that can provide both environmental benefits as well as benefits to the green roof's owner. With proper design and installation coordination, green roofs can provide a net benefit to society. Their ability to conserve water and energy, reduce air and noise pollution, and provide an enjoyable space in which people can exist. Additionally, the savings associated with these environmental benefits outweigh their increased costs.

That is not to say that every building will be able to successfully implement a green roof; that is not the hypothesis set forth by this paper. This paper has achieved the small goal of demonstrating the effectiveness of a green roof in an arid climate. Any further research on the subject that uses this paper should mind this parameter. Arid climates are notoriously difficult to cultivate vegetation and so this paper is used to prove green roofs are possible, continuing research should thus focus on both refining my techniques as well as applying them to different climates and case studies. I would also recommend that CSUSM continuously monitor their green roof to see how the *sedums* fair overtime in their environment as well as the endurance of the Live Roof materials. Should the lifespan or maintenance costs of the roof differ from my calculations, a second set should be run to either confirm or deny my results.

References

Berardi, U., Ghaffarianhoseini, A.H., & Ghaffarianhoseini, A. (2014). State-of-the-Art Analysis of the Environmental Benefits of Green Roofs. *Applied Energy 115,* 411-428.

Getter, K.L., & Rowe D.B. (2006). The Role of Extensive Green Roofs in Sustainable Development. *Hortiscience, 41(5)*, 1276-1285.

General Services Administration, United States. (2011). The Benefits and Challenges of Green Roofs Public and Commercial Building.

Magill, J.D., Midden, K., Groniger, J., & Therrell, M. (2011). A History and Definition of Green Roof Technology with Recommendations for Future Research. *OpenSIUC.*

Perry, R. (2010). *Landscape Plants for California Gardens.* Pomona: Land Design Publishing.

Sproul, J., Wan, M.P., Mandel, B.H., & Rosenfeld, A.H. (2014) Economic Comparison of White, Green, and Black Flat Roofs in the United States. *Energy and Buildings, 71*, 20-27.