Analysis II – Energy Considerations for Green Roofs

Background

As seen from the previous analysis, many of the credits for sustainability can be obtained through the materials and methods of construction, but in order to achieve a LEED rating the building must also operate conservatively and efficiently. Because of a green roof's insulating properties, installing one can contribute to the more efficient operation of the building's HVAC system which translates to lower energy costs.

In the warm months, green roofs prevent the building from heating up inside, and in the winter months they aide the building in retaining heat. However, the degree of heat loss varies upon the amount of saturation retained within the drainage system. An increased amount of water retained will result in a decreased amount of heat loss experienced. As mentioned before, a green roof can hold several inches of water at a time. For the calculations in this analysis, an average depth of 1 ¼" of water will be assumed to be retained on the roof.

In order to achieve the LEED Silver Rating, 3 additional credits from those stated in Analysis I must be earned. The best scenario would be to earn these credits through optimizing the building's energy performance; however, it is unlikely that the addition of a green roof will provide the required 17.5% efficiency rate as compared to ASHRAE 90.1. Green roofs have been known to only reduce the cooling load by 25-50% on the floor directly below as compared to a typical built-up roof. Despite not receiving the additional credits through a green roof, the building will experience an enhanced performance. The following analysis will quantify the savings that installing a green roof on 1099 New York Avenue can provide.

The proposed green roof is to be a typical extensive system. Prospect Waterproofing, the project's roofing contractor, installs Garden Roof Assemblies as designed by American Hydrotech, Inc. The system is comprised of a concrete substrate, waterproofing membrane, rigid board insulation, a composite garden drainage layer, 3" of growing medium, and a top layer consisting of small plants such as grasses and mosses. A sample section can be seen in **Figure 2.1** below.

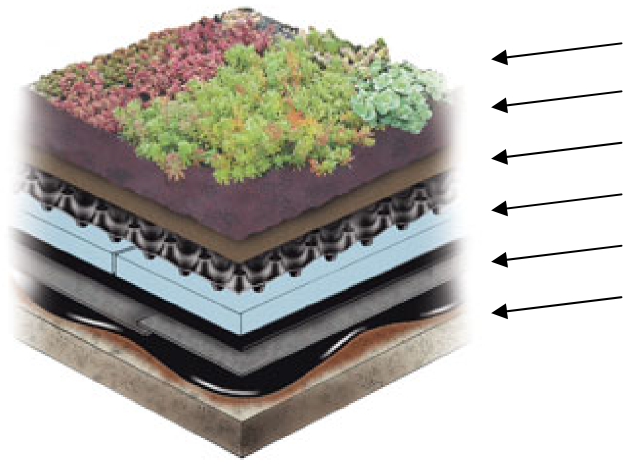


Figure 2.1 Typical extensive green roof assembly provided by American Hydrotech, Inc.

Problem

Green roofs can result in a significant increase in the cost of construction, but are often justified by the amount of energy savings they can provide. The enhancement of a building's performance from a green roof varies upon the composition of each layer of the roof system, the building's orientation, the area of coverage the green roof provides, and the ratio of that area to the area of occupied space inside the building. Considering that the thermal properties a green roof can provide vary from building to building, the realm of savings is not known until a building energy model can be constructed and compared against a baseline model.

The model is constructed through a series of equations using numbers from thermal properties of all the barriers between conditioned and non-conditioned inside areas, as well as the miscellaneous loads from lighting and office equipment. From these values the load demand and energy consumption can be calculated.

Objective

The objective of this analysis is to prove that the addition of over 8,000 sq ft of extensive green roof will contribute to the increase of the building's energy performance. To do this, an energy model of the existing project and a model of the project with the added green roof values will be constructed. The models will then be compared and a cost savings analysis will be performed. The expected outcome will be a reduced load on the eleventh floor of the building and a decrease in the overall energy consumption.

Analysis

The initial energy model was created using TRACE 700 energy modeling software by Trane in lieu of performing hand calculations. Below, **Table 2.1** shows the input values for the assumed office spaces and retail areas. The room sizes were predetermined by the project's Mechanical Engineer.

Room	Total Area (ft^2)	Roof (0.2135 Btu/h·ft^2·°F)	Wall 1 (0.0616 Btu/h·ft^2·°F)	Wall 2 (0.0616 Btu/h·ft^2·°F)	Wall 3 (0.0616 Btu/h·ft^2·°F)	Glass (0.29 Btu/h·ft^2·°F)	Floor (0.0908 Btu/h·ft^2·°F)
11th Floor							
Office 01	340	340	336			189	
Office 02	220	220	174	174		272	
Office 03	600	600	463			463	
Office 04	790	790	637			637	
Office 05	220	220	174	174		348	
Office 06	1,860	1,860	1,447			1,447	
Office 07	220	220	347	174	174	521	
Office 08	880	880	730			410	
Office 09	210	210	174	174		196	
Office 10	800	800	614			98	
Office 11	7,390	5,230					
Floors 02-10							
Office 01	340		336			189	
Office 02	220		174	174		272	
Office 03	600		463			463	
Office 04	790		637			637	
Office 05	220		174	174		348	
Office 06	1,860		1,447			1,447	
Office 07	450		174	347	174	521	
Office 08	880		730			410	
Office 09	210		174	174		196	
Office 10	800		614			98	
Office 11	7390						
Retail							
Retail 1	220		292			292	
Retail 2	220		240	258		498	
Retail 3	567		687			687	
Retail 4	230		283			283	
Retail 5	1,550						740
Retail 6	420		481			481	420
Retail 7	3,530						3,530
Retail 8	1,300		1,271			1,271	1,100

Table 2.1 displays the values entered into TRACE 700 for office area and thermal conductivity. Wall orientation was also entered into the calculations, but is not included in this table.

The following data output displayed in **Table 2.2** is the energy consumption summary for 1099 New York Avenue as intended in the original design.

Description	Electric Consumption (kWh)	Water Consumption (1000 gal)	Total Source Energy (kBtu/yr)
Primary Heating	101,605.4		10,404.4
Primary Cooling			
Cooling Compressor	278,840.5		28,553.3
Tower/Condenser	89,797	1,904.7	9,195.2
Cooling Accessories	8,760		897
Totals	**479,002.9**	**1,904.7**	**49,049.9**

Table 2.2 Energy Consumption Summary as designed for 1099 New York Avenue.

One average, the building was estimated to consume **479,002.9 kWh** and **1.9 million gallons** of water, totaling to **49,049.9 kBtu/yr**. Since green roofs are most efficient during the warm season, a monthly consumption breakdown from April through September has been provided in **Table 2.3** below.

Equipment	Apr	May	June	July	Aug	Sept	Total
Water-Cooled Chiller							
Electric (kWh)	21,106.3	26,409.8	29,487.3	32,811.9	30,499.3	26,128.0	166,443.0
Peak (kW)	46.0	57.4	65.7	68.8	65.1	58.3	361.3
Cooling Tower							
Electric (kWh)	7,669.0	9,507.3	9,200.6	9,507.2	9,507.3	9,200.6	54,592.0
Peak (kW)	12.8	12.8	12.8	12.8	12.8	12.8	76.8
Cooling Tower							
Make Up Water (1000 gal)	143.7	188.5	212.1	235.2	218.4	185.8	1,183.7
Peak (1000 gal/hr)	0.4	0.4	0.5	0.5	0.5	0.4	2.7
Control Panel							
Electric (kWh)	720.0	744.0	720.0	744.0	744.0	720.0	4,392.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	6.0
Heating							
Electric (kWh)	5,299.1	1,338.8	386.5	235.1	652.4	1,527.6	9,439.5
Peak (kW)	26.6	11.9	8.1	5.9	10.8	12.1	75.4

Table 2.3 Monthly Energy Consumption for April through September.

After the initial energy model was created, a second model was developed including the enhanced thermal properties of a green roof. To do this, a U factor had to be calculated for the extensive system assembly. The construction of the green roof consists of a 10" concrete slab with 2% reinforcement, neoprene flashing, 2" of rigid board insulation, a polyethylene drainage mat, 3" of growing medium, and a saturation level of 1.25". The measures of the materials' thermal resistance as stated in ASHRAE 90.1 are listed in the following table.

Material	Thickness (in)	R-Value ($h\cdot ft^2\cdot °F/Btu$)	U-Value $Btu/h\cdot ft^2\cdot °F$
Medium Density Concrete	10	5.68	0.18
Neoprene Flashing	0.25	0.06	16.7
Rigid Board Insulation	2	9.77	0.10
Polyethylene Drainage Mat	0.25	0.68	1.47
Growing Medium	3	9.144	0.12
Saturation	1.25	0.284	3.52
	Total	**25.6**	**0.04**

Table 2.4 R-Value Calculations for Extensive Green Roof System.

This new U-Value for the green roof of **0.04 $Btu/h\cdot ft^2\cdot °F$** should be compared to **0.2135 $Btu/h\cdot ft^2\cdot °F$** for the existing roof structure. **Tables 2.5 and 2.6** contain the energy consumption data for the building with the proposed green roof included.

Description	Electric Consumption (kWh)	Water Consumption (1000 gal)	Total Source Energy (kBtu/yr)
Primary Heating	95,785.6		9,808.5
Primary Cooling			
Cooling Compressor	274,133.8		28,071.4
Tower/Condenser	83,382.0	1,927.2	8,538.3
Cooling Accessories	8,760.0		897.0
Totals	**462,061.0**	**1,927.2**	**47,315.2**

Table 2.5 Energy Consumption Summary for building with the proposed green roof.

The addition of the green roof proved to reduce electricity consumption by **16,041.9 kWh** and although water consumption increased by **22,500 gallons**, the total source energy was reduced by **1,734.7 kBtu/yr**.

Equipment	Apr	May	June	July	Aug	Sept	Total
Water-Cooled Chiller							
Electric (kWh)	20,730.9	25,372.6	28,114.0	31,252.2	29,240.2	25,309.3	160,019.0
Peak (kW)	42.0	51.7	59.1	62.1	59.1	53.5	327.5
Cooling Tower							
Electric (kWh)	7,167.0	8,697.0	8,416.4	8,697.0	8,697.0	8,416.4	50,090.8
Peak (kW)	11.7	11.7	11.7	11.7	11.7	11.7	70.2
Cooling Tower							
Make Up Water (1000 gal)	145.5	184.3	204.8	226.5	212.3	183.5	1156.9
Peak (1000 gal/hr)	0.3	0.4	0.4	0.5	0.4	0.4	2.4
Control Panel							
Electric (kWh)	145.5	184.3	204.8	226.5	212.3	183.5	1,156.9
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	6.0
Heating							
Electric (kWh)	5,006.8	1,288.4	368.1	216.4	621.9	1,482.3	8,983.9
Peak (kW)	24.4	11.6	5.8	5.7	7.5	12.1	67.1

Table 2.6 Monthly Energy Consumption for May through September with proposed green roof.

A comparison of the source energy consumption and the observed savings can be seen in **Table 2.7** below.

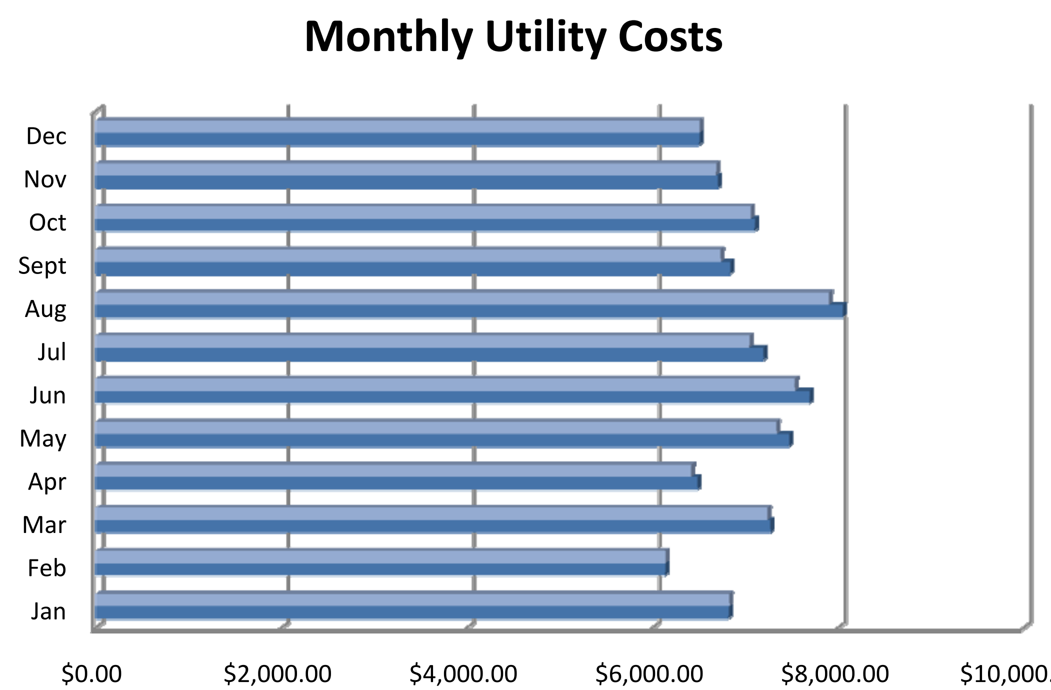
Total Source Energy as Designed (kBtu/yr)	Total Source Energy w/ Green Roof (kBtu/yr)	Estimated Savings
49,049.9	47,315.2	3.54%

Table 2.7 Estimated source energy savings.

After both calculations were performed, a total source energy savings on an annual basis of **3.54%** was observed. This is largely due to the decrease in electricity consumption. Assuming an average cost of $0.1214 per kilowatt-hour and $2.14 per 1000 gallons of water for commercial buildings in the District of Columbia, a cost comparison chart was formulated to analyze the annual savings in utility costs. (See **Chart 2.1** below.)

The total estimated cost for the annual electricity and water consumption as designed is **$84,217** whereas the estimated cost with the green roof is **$83,372**. The result is a savings of **$845** or **1%** per year.

The savings in energy consumption is a direct effect from the green roof reducing heat loss and building envelope cooling loads. The enhanced insulation from the green roof transmits 10,000 Btu less per hour than the conventional roofing system. Additionally, on the eleventh floor return airflow was decreased by 1,000 cfm and the plenum sensible load was reduced by 150,000 Btu/h.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Green Roof	$6,825.	$6,132.	$7,237.	$6,414.	$7,333.	$7,530.	$7,039.	$7,899.	$6,730.	$7,050.	$6,680.	$6,500.
Existing	$6,815.	$6,131.	$7,268.	$6,482.	$7,465.	$7,685.	$7,194.	$8,050.	$6,830.	$7,096.	$6,703.	$6,499.

Chart 2.1 visualizes the comparison of monthly utility costs between the two roof systems.

Cost Impact

The built-up roof as designed for the project costs an estimated $275,000. Prospect Waterproofing has estimated that the proposed green roof system will cost an additional $10 per sq ft resulting in a total increase of $82,700 (30%) to $357,700 overall for the roof. The energy cost savings experienced by the addition of a green roof only amounts to $845 per year.

The total savings over the life-cycle for the mechanical equipment (20 years) and the roof (50 years) is equal to $16,900 and $42,250 respectively. The costs savings summary can be seen in **Table 2.8** below. It would therefore take nearly 100 years for the initial cost of the green roof to be paid back from an energy standpoint. (Please note that this analysis is solely an investigation into the cost associated with energy savings at their present rate; therefore, neither the change in cost of the mechanical equipment nor the escalations in energy prices were measured for this analysis.)

Initial Cost Increase	Energy Savings (1 yr)	Energy Savings 20 yr (Life of Mechanical Equip.)	Energy Savings 50 yr (Life of Green Roof)
$82,700	$845	$16,900	$42,250

Table 2.8 Summary of the savings in cost of utilities for green roof installation

Conclusion & Recommendations

In other studies of green roofs, it has been found that the lower the ratio of roof area to building area, the less effective the installation of a green roof will be. In other words, green roofs do not work well on tall buildings. This is largely due the increased amount of area energy has to escape in other spaces in the building. The primary composition of the walls in this building is glass, a material with poor thermal properties. The majority of the energy savings from a green roof are generally experienced on the floor directly below the assembly. On 1099 New York Avenue, the 11th floor is only 9.1% of the total building area. That means that installing a green roof on this project is only able to optimize energy performance in 9.1% of the total building. As mentioned before in Analysis I, a green roof can only reduce 20-50% of energy consumption in this space.

The goal of this analysis was to evaluate the energy savings as the result of installing a green roof on the existing project at 1099 New York Avenue. It was found that a green roof could provide 3.54% efficiency, however the cost associated with savings was valued at only 1%. Despite the small measure of increased energy performance, a green roof system can still provide many other benefits as seen in Analysis I and it is therefore still recommended as a corrective course of action that should be taken for this project.