# Energy Cost Analysis of a Green Roof and Photovoltaics System on WPI's Future Recreation Center

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## Abstract

Green roofs are new roofing technology that use vegetation to cleanse the environment, and photovoltaics directly produce electricity from absorbed sunlight. This study determined the economic feasibility of installing photovoltaic and green roof technologies on the roof of the new recreation center at WPI and found an economic balance between the two technologies. Due to the cost benefit and pay back period analyses, the green roof system would be the more beneficial technology for the future recreation center at WPI.

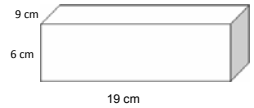
## The Recreation Center

We measured the football field in the model and since, a football field is supposed to be 100 yards long, we set 28 cm to 100 yards. The main rectangular building had additions like the rectangular pyramid and a smaller rectangular prism. All the dimensions of the building were then approximated and the total volume as shown above was calculated.

**Roof Calculations**

Area of the roof:
19cm*(100yards/28cm)*9cm*(100 yards/28cm)
=1900yards/28*(3ft/1yard) * 900yards/28*(3ft/1yard)
= 19630 $ft^2$ ≈ 19000 $ft^2$

Scale: 100 yards ≡ 28 cm
Conversion factor: 1 yard ≡ 3 feet




## Background

### Green Roofs

Modern green roofs are roofs with innovated designs that incorporate vegetation into the roof in order to improve the surrounding environment and lower energy costs. There are two classes of green roofs: intensive and extensive.

**Extensive Green Roof**

- Lower Scale Green Roof
- Vegetation: small plants and grasses
- Requires less growing medium
- Are built on small homes and buildings
- Little roof reconstruction

**Intensive Green Roof**

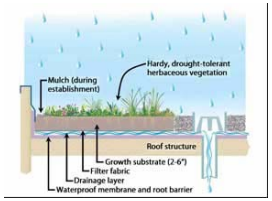
- Nicknamed "Roof Top Gardens"
- For large city buildings
- Resemble parks
- Vegetation: short grasses to trees
- Structural requirements: demanding
- Normally built on new roofs

## Background cont.

Green Roofs cont.


**Layers**

- Structural Support -> the roof
- Roofing Membrane-> vapor control
- Membrane Protection and Root Barrier-> protects the roof from the plants and the environment which extends the life of the roof.
- Insulation-> keeps heat inside the building
- Drainage System-> controls rain water

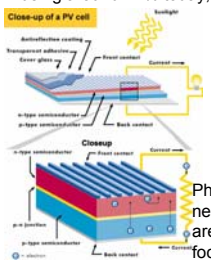



**Drainage**

- All storm water passes through the roots
- Precipitation is filtered for better water quality
- Cuts down the pollutants: carbon dioxide, nitric oxides, and CFC's
- Roofing membrane is protected by the plants

### Photovaltaics

Photovoltaic panels convert the energy absorbed from sunlight into electricity. This energy can be connected to the electric grid and directly used on site or sent elsewhere to where it is needed. This is a useful application of otherwise unused solar energy that would just be absorbed by the roof. This technology has a relatively high initial cost, but there is no fuel cost and very low maintenance costs. The efficiency of the panels is also relatively low, being around 22% today, but rapidly improving.




**How PV Panels Work**

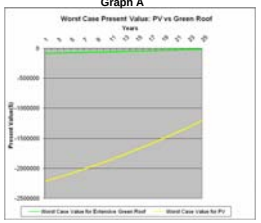
- Photons of light hit a valence band of electrons
- The electron s are excited -> work in the form of electrical power
- Sunlight ->the only reactant necessary to produce power
- Free source of energy

Photovoltaic Systems (PV) are gaining popularity as the need for renewable technologies is increasing. PV systems are being improved everyday with new technology, focusing more on nanotechnology, which minimizes all the electrical circuits and wiring. With these new methods of production, the cost is falling to appealing prices to consumers and larger corporations. With these low prices, and the idea of acquiring an image that shows that the consumers and corporations are helping the environment

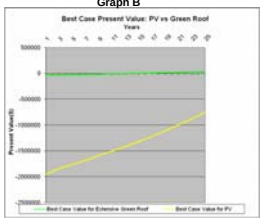
The cost of PV paneling per square foot is approximately $10 per watt production capability. The average payback is anywhere from 5 to 15 years depending on the size and the total cost. This is not including the many tax incentives and other factors that promote consumers to purchase this technology. For instance, California is pro-green and will cover half of the costs of purchasing and installing a PV system (Incentives in CA). So the average payback time would be cut in half.

## Calculations

**Graph A**




**Graph B**




Graph A depicts the calculation: -(installation cost + maintenance * inflation rate)+(energy produced or saved * cost of energy * inflation rate). Also, Graph A considers degradation of the PV panels and does not include any grants or subsidies. Graph B depicts the same calculation, but it includes all grants and subsidies the systems were eligible for and does not include degradation of the PV panels. The payback period is the time between installation and when the curves intersect the x-axis. For Graph A the payback period is not achieved in the 25 year study period. It is actually between 28 and 29 years for the extensive green roof, and between 47 and 48 years for PV. For Graph B, the payback period is between 13 and 14 years for the green roof and 36 and 37 years for the PV. PV has a high installation cost and high annual energy production, as shown by the yellow lines. Extensive green roofs have a relatively low installation cost but only reduce energy costs slightly, as shown by the green lines.

## Conclusions/Recommendations

Though there are advantages and disadvantages to both Green Roofs and Photovoltaics, Green Roofs provide more savings for WPI. PV systems have high installation costs, around $2.25 million, but very low maintenance fees with a pay back period of at least 36 years. A PV system generates electricity from a free and environmentally friendly source, the sun, which cuts back on the dependence of fossil fuels. PV produces more energy per year than green roofs, but because of the high installation cost it would not be as beneficial to WPI.

An extensive green roof system for the recreation center roof would have a low installation cost of about $80,000. This system would have a higher maintenance cost per year, but still cuts the energy costs for the building by reducing the energy used per year for heating and cooling. If the roof of the future recreation center is a conventional roof, there would be a large repair and replacement fee every 20 years due to the low life span of these roofs. A green roof would extend the life of the roof and the roof would need major repairs once about every 40 years. Another advantage of green roofs is the ability to cleanse the environment. A green roof would filter pollutants, including $CO_2$, $NO_X$ and $SO_X$ from precipitation and supply another green space for WPI.

Our calculations did not completely follow our expected results. First we believed the pay back period for a PV system would be less than 30 years, but it is at least 36 years. It turns out that the maintenance fees for extensive green roofs are at least $400. Due to the increased life span of an installed green roof, an extensive green roof saves money each year.

For many years new technologies have been developed to combat the increasing dependancy on fossil fuels. Both PV and Green Roof systems save energy, thus reduce the dependence on fossil fuels and environmental effects from fossil fuels.

Due to the advantages and disadvantages of both systems we propose merging the systems and construct a photovoltaic-extensive green roof system on the roof of the future recreation center. By implementing both technologies, WPI could produce energy for the new building, save energy, and provide an environmental scrubber. Installing these two systems would provide WPI with many research opportunities across the departments that could be used in determining the optimal balance between the two systems. WPI could become a leader in Green Roof and PV technologies.

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