INVESTIGATING THE ROLE OF GREEN ROOFS IN IMPROVING PERFORMANCE OF BUILDINGS WITH GREEN ARCHITECTURE APPROACH

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ABSTRACT
Green roofs are ideal architectural combination of aesthetics, economy, and ecology. Green roofs that are named as roofs with vegetation are thin layers of live plants, which can place on top of the conventional roofs. If the designation is proper, they would be changed into some live and sustainable ecosystems, which can be context for many found interactions in the natural environment. Previous studies have indicated that gardens on the roofs can restrict and reduce negative effects resulted from the environment such as increase in energy costs; global warming; lack of green space; and air and water pollution. In addition to reduction of reflection and transmittance of the noise, they can increase useful life of the roof more than two times. In designing such roofs, one can consider specific climate; rainfall patterns; structure; visual and aesthetics aspects, architectural epistemology, and adjustment with other green systems such as solar panels. As forests, agricultural fields, and suburban and urban lands are replace with impervious surfaces resulting from development, the necessity to recover green spaces is becoming critical to maintain environmental quality. Vegetated or green roofs are one potential remedy for the mentioned problem. Therefore, the focus of this review is primarily on extensive green roofs.

Keywords: Green Architecture, Energy, Green Roof, Sustainable Architecture, Green Space

INTRODUCTION
The term “green roof” applied here refers to inside and outside decoration plants of roof gardens through planting based on natural principles or self-casted vegetation. Bervanley (1990) has described roof garden as follows: planting decorative vegetation with separated layer from the natural ground, which has been made by the hand of human at least in one floor. Ecoroof is a term that is applied usually for describing natural green roof. The term “urgent green roof” is considered for describing roof coverage with self-casted vegetation. When outside view or outside walls of the building are vegetated, the term of green view can be applied. Buildings may be decorated by lichens, mosses, grasses, and flowering plants, which may be grown naturally on rocks and cliffs.

Figure 1: Multipurpose urban design and using green roof, solar energy, and air flow (source: Studio Engleback)

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However, extensive green roofs cost 50-80% less than intensive green roofs, and are still effective with regards to sustainability efforts. Even though the construction of a green roof is slightly more expensive than constructing a conventional roof, the long-term benefits greatly outweigh the immediate drawbacks. In the construction of green roofs, we are inevitably helping restore the balance that is necessary to ensure that our earth will be able to sustain its inhabitants. The Carleton Green Roof plays an important role in sustainable development initiatives in that it is a local project with global considerations.

**Classification of Green Roofs**

Association of Green Roof Guideline of Germany (FLL) has considered 3 classes for green roof based on application cases, construction method, and maintenance regulations (FLL, 1990). The classification can’t always specify combined or intermediate species of the green roof. The three classes are as follows:

- Intensive
- Simple intensive
- Extensive

Intensive roofs refer usually to roof gardens. They are similar to gardens or parks on the ground’s surface. They may include grass planting, garden, woodland, and even water fountains. They are made mostly on top of the stable cement layer and are available. This type needs constant repairs like irrigation, reproduction, weeding with deep layers of soil, agriculture and establishments. This type of green roof has highest rate of demand for structures and high costs in terms of construction and renewal. In addition, the type would not indicate the cost that has been consumed.

Simple intensive green roofs would be covered by plants and grasses. This type of vegetation needs constant repairs such as irrigation, cultivation and cuttings. Demand for the structures is in average level and the price is lower than intensive roofs and is higher than extensive roofs. They are sometimes available and mostly are designed for landscapes.

Extensive green roofs need minimum repairs and need no irrigation (except for some cases while construction). Vegetation is usually moss, grass or shrub. The focus is usually on using local species and real vegetation. This type of roof has the lowest demand for buildings and the highest cost for renewal and construction. Extensive green roof indicates usually increase in initial costs and vegetation of the roof for expanding it in small scale. However, it has usually no important proportion in total price of industrial or commercial development. Generally, there is no woodland in buildings with green roof, because of sufficient depth of the soil.

A green roof is typically defined as a roof of a building, which is partially or completely covered with plants. It may be a tended roof garden or a more self-maintaining ecology like a green wall or breathing wall. Green roofs are primarily described in terms of being either “extensive” or “intensive”. Extensive green roofs are made of foliage averaging 6 inches or shallower and are frequently designed to satisfy specific engineering and performance goals. Intensive green roofs in contrast, contain much deeper or larger foliage, which may then be extended to landscapes including lawns and trees. An example of an extensive green roof is Carleton’s green roof, located above the Olin Hall of Science Building. Carleton’s green roof is an instance of a local project that contributes to the global effort of environmental sustainability.

**Construction**

A traditional green roof is typically comprised of four parts: a seal, a layer of drainage and filtration, a substrate of growth, and a vegetable layer. The seal is usually composed of rubber, while the drainage and filtration components are made of gravel and stones. The substrate of growth layer is made of compost and the vegetable layer which is made up of the foliage that will eventually make the green roof “green”. The bottom layer is designed to be more prone to water absorption, while the top later was mixed in with 2” of pure compost to create a heavier surface which prevents loss of soil and seeds to the wind. Beneath the soil level, the drainage and filtration component of Carleton’s green roof is made of a DBR-50 Rootbloc product, which is designed to enhance better draining through a grid system of small plastic cups; used to retain water while any excess overflow drains away.
Another important benefit of green roof is its ability to contribute to overall energy conservation. Even though the results of investigating energy conservation and the Carleton green roof suggested that the results are not significant in winter; other studies have suggested that the energy conserving benefits are most evident in the summer. However, energy-related benefits are less important in multi-story buildings, due to the low ratio of roof area to the total of exposed building mass.

In March 2007, the Minnesota Green Roofs Council reported the existence of 80 green roofs located within the City of Minneapolis. This is two times more than the number it was five years ago, and they expected this number to continue growing as the benefits of green roofs becomes more evident in urban area. The council also noted that “The City of Minneapolis is considered one of the more progressive cities supporting green roofs and can be favorably compared to cities like Portland, Seattle, and Boston in promoting green roofs”. In North America, Chicago leads the way in promoting green roofs. In 2006, Chicago boasted 2 million square feet of green roofs either installed or underway. On a global scale, Germany is considered as a world leader in implementing green roofs. One in twenty German buildings features a green roof, and one in eight new buildings feature a green roof. This amounts to billions of square feet of green rooftops installed over the past 50 years.

**Vegetation**

While intensive roof garden generally uses plants and vegetation associated with landscaping works, extensive garden on the other hand uses very selective types of plants which are dry-resistant or succulent types.

![Dry resistant plants for lightweight extensive roof gardens](image)

**Components of Green Roofs**

Essentially roof gardens are build-up through the installation of a few key components to form the finished system.

The components generally include the following layers:

- Waterproofing / root barrier layer
- Drainage / water storage layer
- Filter layer
- Planting medium
- Vegetation

**Improvement of Air Quality**

Roof vegetation can improve the air quality by acting as a filter to trap airborne dust particles. In a study carried out in Frankfurt, Germany, streets without trees were noted to have an air pollutant count of 10,000 to 20,000 dirt particles per liter of air, compared to one with trees in the same neighborhood where only 3,000 particles per liter of air were noted A higher temperature at roof level tends to create a thermal draft drawing up dust particles from street level. Roof greening has been found to be effective in
moderating the thermal draft by reducing the temperature differences between rooftop and street level. The higher the temperature is, the greater the concentration of smog would be. In a field test conducted in Los Angeles, it was noted that the concentration of smog measured as low atmospheric ozone is below national standard at temperatures below 21°C. However at temperatures of about 35°C, all days are smoggy. Cooling the city by about 5°C would have a dramatic impact on smog concentration.

Plants through the photosynthesis process can absorb carbon dioxide and release oxygen into the atmosphere in order to improve the air quality. About 155 m² of planted surface area will produce enough oxygen for one person for 24 hours (Kuhn, 1996). Power generation and air-conditioning collectively can contribute to the emission of about 20 tons of carbon dioxide emissions on per year in a highly urbanized city state like Singapore (WWF, 1999). With roof gardens reducing the surface and air temperature thereby lowering the air conditioning load, the emission of carbon dioxide can be cut back by as much as 2% (Akbari et al., 1990).

**Improvement of Water Quality**

Depending on the thickness of the various layers of the roof garden, a green roof is able to filter out heavy metals and nutrients present in rainwater (Johnston & Newton, 1996). This advantage would be beneficial in urban areas where precipitation is collected for domestic usage in addition to treated potable water supply from the utility provider.

**Improvement of Stormwater Management**

Roof gardens retain rainwater on the roof through the various layers and significantly reduce the peak discharge flow rate into the stormwater drainage system. The ability to absorb and retain up to 75% of rainfall thereby reducing the immediate discharge to 25% (Kohler, 1989) effectively ensures that the risks of flash flooding is reduced.

![Image of Total peak runoff rates with and without green roofs](https://example.com/figure3.png)

**Figure 3:** Total peak runoff rates are lowered through the use of roof gardens limiting the risk and occurrence of flash floods (Source: NParks & NUS, Handbook on sky rise greening in Singapore)

In Portland, Oregon, USA, green roofs were implemented successfully to prevent storm water from overwhelming the city’s sewer system which tends to flood over during heavy storms and allowing untreated sewage to flow into the Willamette River.

**Higher Energy Savings**

In Tokyo, Japan, it was noted that a reduction of air temperature of between 0.11 to 0.84°C could be achieved if 50% of its rooftops were planted with roof gardens. Translated into real dollar value, the energy saving is estimated to be about S$1.6 million per day in electricity bill (Hitosh, 2000).

**Conclusion**

Green roofs play an important role in sustainable development efforts. The implementation of green roofs helps decrease the negative effects of storm water runoffs, mitigate urban heat island effects, contributes to improving our air quality, extends the life of roofing systems and also serves aesthetic purposes. However, green roofs also have some drawbacks: the most prevalent being the cost. Different benefits of green roofs are discussed by some scholars including Bravenley (1990), Johnston (1955), Johnston and Newtonian (1993), and Osmand (1999), and Welsh (2001) and their results have been summarized as follows:
Research Article

- Environment
  - Reduction of waste waters resulted from surface rainfalls
  - Reduction of waste waters can reduce overflow of it
  - Cleanness and recycle of polluted waters
  - Absorbing air pollutions and dust
  - Reduction of urban temperature
  - Increasing humidity
  - Air absorption
  - Absorption of electromagnetic radiation
  - Helping absorption of greenhouse gases, especially Co2 and excretion of oxygen

Figure 4: Thermal behavior of flat roof, comparing to green roof (flat roof is hotter than the green roof because of less vegetation)

- Ecology and Plant Diversity
  - Providing new habitant for wild life
  - Replacing destroyed habitants
  - Creating quiet shelters

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Creating stone stairs in green space networks
- At reach green space in internal core of the city

- **Adaptation**
  - Freedom for designers
  - Gray membranes and uniform materials for building roofs
  - Cinema equipment
  - Interesting landscapes of vegetation
  - Development of park system
  - Gardens can provide broad space for people

- **Health**
  - Psychological benefits in relations with the natural environment
  - Improving air quality- helping reduction of lung cancer
  - Improving water quality

- **Building Context**
  - Protecting roof from ultraviolet ray
  - Protecting the roof from mechanical losses
  - Reducing daily changes of temperature on roof
  - Improving thermal insulation

- **Economic**
  - Enhancing roof’s lifetime
  - Attracting customers
  - Reducing water and wastewater costs
  - Reducing heating and air conditioning costs
  - Using recyclable materials that can decrease material costs

- **Academic**
  - Green roofs can cause holding classes in open space at the internal environment of the city.

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