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# MINI-REVIEW: GREEN ROOF AS A GREENERY SOLUTION IN DENSELY POPULATED AREAS AND ENERGY SAVING IN BUILDINGS

**Rustam Efendi**
Faculty of Engineering, Department of Mechanical Engineering
Universitas Sulawesi Tenggara
Email: rustamefenditm@un-sultra.ac.id

**Yohanna Anisa Indriyani**
Faculty of Agriculture
IPB University
Email: y_anisa@apps.ipb.ac.id

## ABSTRAK

Kepadatan penduduk dan keterbatasan lahan untuk penghijauan merupakan permasalahan besar di wilayah perkotaan. Pencemaran udara dan tidak sejuknya suatu ruangan juga menjadi permasalahan tersendiri. Penggunaan AC untuk menyejukkan ruangan pada faktanya membutuhkan energi yang besar dan juga memicu masalah lingkungan lainnya, misalnya pemanasan global. Salah satu upaya yang dapat dilakukan adalah penghijauan di atas atap, atau disebut dengan *green roof*. *Green roof* merupakan metode menamam di atas atap, berfungsi untuk mengisolasi panas dan membantu mempertahankan keanekaragaman hayati. Tanaman yang umumnya ditanam adalah tanaman hias maupun tanaman yang memiliki akar besar. Pemilihan tanaman harus mendapat pertimbangan karena disesuaikan dengan kemampuan atap pada setiap gedung. *Green roof* juga merupakan langkah menuju *green energy*, untuk mengurangi pemakaian energi yang berlebih dan meminimalkan permasalahan lingkungan. Tulisan ini mengulas perkembangan *green roof*, di mana *green roof* dipandang sebagai solusi atas permasalahan lingkungan dan problem energi.

**Kata kunci:** AC, *green energy*, *green roof*, kepadatan penduduk, penghijauan

## *ABSTRACT*

*A dense population and limited land for greenery are major problems in urban areas. Air pollutions and uncomfortable temperatures of rooms are also problems in urban areas.The utilization of air conditioning for cooling the room requires a lot of energy and also triggers other environmental problems, such as global warming. One of the efforts that can be done is to green the roof, called the green roof. A green roof is a method of planting on the roof, that serves to isolate the heat and help maintain plant biodiversity. Plants generally grown on the green roof are ornamental plants and some species of plants that have large roots. The selection of plants must receive great consideration because they are adjusted to the ability of the roof on each building. Green roofs are also a step toward green energy, to reduce excessive use of energy and minimize environmental problems. This paper reviews the development of green roofs, where green roofs have been considered a solution to environmental and energy problems.*

***Keywords:*** *air conditioning, dense population, green energy, greenering, green roof*

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## 1. INTRODUCTION

The development of green roofs to restore green areas in big cities has been becoming a popular topic [1]. Green roofs, also known as an ecosystem on the roof (eco-roof) and life on the roof (living roof), are roofs covered by a layer of soil for plants to grow. Green roofs are built for greenery, especially in narrow areas. There have been many studies that mention green roofs to be used as heat insulation in buildings against environmental temperatures [2]. Green roofs in sub-tropical countries are used as a way to increase more comfortable room temperature. A green roof reduces heat in the building so that the temperature inside the building decrease. Thus, it provides comfortable air conditioning for the occupants [2]. Green roofs have been widely applied and studied in all types of climates and have been shown to provide many benefits for building temperature insulation and also for maintaining biodiversity [3]. Lisa and Zuraihan [4] stated that green roofs have been proven to naturally reduce the solar radiation in buildings. Green roof implemented in air conditioning-installed rooms set at 18-26°C showed a significant decrease of the cooling load up to 40%.

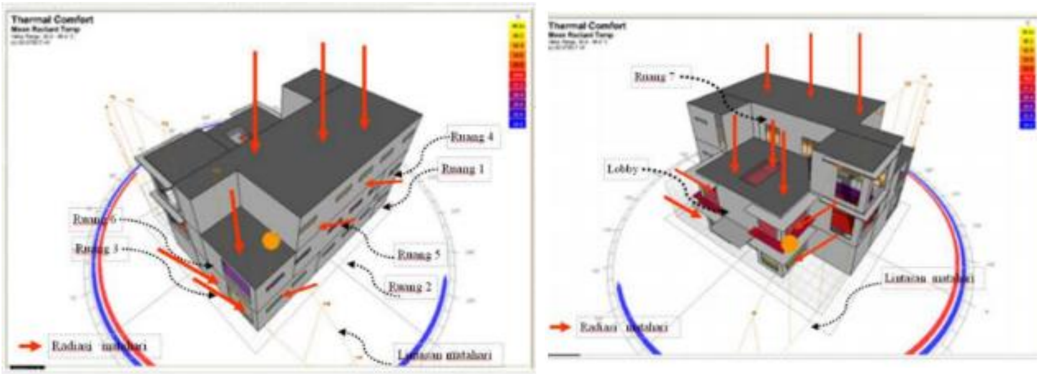


**Figure 1.** ***Green roof simulation can reduce solar radiation*** **[4]**

Green roofs are often planted with various plants for aesthetic value and a better ecosystem. Biologically, various types of vegetation replanted will grow at the same height and that biodiversity can improve ecosystem supplies [5]. Increasing the benefits of the ecosystem can also be added by some diverse faunas, supplied with additional water storage from natural processes such as rainwater and water storm, installed with temperature conditioning, and pollution reduction [6]. Heim and Lundholm's [5] added that diversity of plant species must be considered when designing a green roof, since the growing time of each plant may be different.

Increasing attention toward environmental sustainability encourages construction developers to design more environmentally friendly buildings [7]. Starting in 2008, the slogans of go green, green energy, and greenhouse, have begun to develop. It is stated that at least 40% of the energy use in the world is related to the construction and maintenance of buildings, including the development of building design which is also required to have a green aspect [8]. Recently, many building professionals are promoting green roofs as a way to increase green space in urban areas. It is also stated that green roofs can lower the room temperature of the building by 3.4℃ from the temperature outside the building [9]. Medium-scale green roofs have been proven to create more comfortable and warmer temperature in winter. Research in Athens reported that there was an increase of 1.6℃ in temperature, from 21.9°C to 23.5℃ [10]. Yaghoobian and Srebric [11] also stated that the implementation of green roofs in buildings showed a balance in energy consumption.

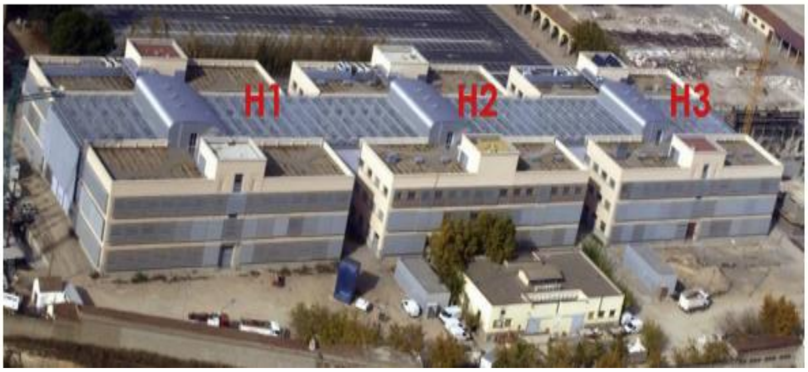


**Figure 2. *Green roofs on buildings* [13]**

Research on green roofs conducted in Malaysia reported that there were temperature changes for each condition (morning, afternoon, evening, and night). The green roof could decrease the temperature at 07.30 and 10.00 AM by 0.21℃ and 1.73℃, respectively, and at night (12.00 PM) by 1.2℃ [12]. Therefore, a green roof is an effort to provide a more comfortable condition for occupants (Figure 2) [13].

## 2. METHODOLOGY

### 2.1 *Layers Structure On Green Roof*

The structures of green roofs consist of some layers [14] as follows. In addition, the roof layering structure can be seen in Figure 3.

a) Membrane protection
The preferred approach for green roof construction is a protected membrane configuration (waterproofing membrane is adhered directly to the deck and covered by green roof components). The long-term performance of waterproofing membranes is significantly affected by exposure to ultraviolet, heat, and thermal cycles, which lead to a breakdown of the membrane's chemical composition. In the protected membrane configuration, overburdened components shield the waterproofing membrane from these elements as well as mechanical damages.

b) Waterproof membrane
Selecting or designing a high-quality waterproofing membrane is essential since the membrane will be buried underneath the layers of overburden that may easily be repaired or maintained. The waterproofing membrane can be a fully adhered, mechanically attached, or loose-laid system. It is suggested to use a waterproofing membrane fully adhered directly to the deck substrate, as it minimizes the potential for water migration if a leak takes place.

c) Additional system components
Green roof systems incorporate several layers in addition to the waterproofing membrane. Functional components include a root barrier, drainage layer, separation layer, moisture-resistant insulation, aeration layer, moisture retention layer, reservoir layer, filter fabric layer, and growth medium with plantings. Materials should have appropriate compressive strength for the desired green roof system.


**Figure 3.** ***The green roof layers structure*** **[15]**

### 2.2 *Vegetation*

Vegetation is one of the key factors of green roofs. According to Miller [15], vegetation on green roofs must be interrelated sub-systems consisting of:

a) Drainage or water drainage system
Drainage is very important in green roofs to control water for the growth of vegetation and to prevent waterlogging and erosion that may take place in green roof layers. The design of drainage is the most important thing to be considered at the beginning of the green roof design [16].

b) Plant nutrition in growing media
Sufficient nutrition is needed for the plants to grow. Unbalanced nutrition will cause a problem in the growing of the plants.

c) Waterproof protection system
A green roof must have waterproof protection system on the bottom layer attached to the roof of the building. This system serves to protect the human activities underneath, avoid biological hazards, and prevent the effects of heat.

d) Waterproof system
This system is very important to protect the construction of green roof layers from excessive water.

e) Heat insulation system
A heat insulation system is important to save energy. It can be made by deepening the soil medium. Vegetation that is planted deeper can be stronger and not easily damaged so that the heat insulation can be maximized [17].

### 2.3 *Vegetation for The Green Roof*

The kind of vegetation for the green roof is very diverse and must be considered based on the design of the green roof. For extensive green roofs, for instance, sedums, mosses, and perennials are good choices. Perennials, small shrubs, and lawns are good choices for semi-intensive green roofs. Meanwhile, for intensive green roofs (roof gardens), some plants like shrubs, trees, and lawns are good options. Vegetal [18] presented a comparison among extensive green roofs, semi-intensive green roofs, and intensive green roofs in some criteria (Figure 4).

| CRITERIA | Extensive green roofs | Semi-extensive green roofs | Intensive green roofs (roof garden) |
|---|---|---|---|
| Load-bearing component | CONCRETE WOOD TANBARK | CONCRETE | CONCRETE Maximum pitch 5% |
| Plant choice | Sedums, mosses, perennials | Perennials, smalll shrubs, lawns | Shrubs, trees, lawns |
| Thickness of growing medium | 4 to 15 cm | 12 to 30 cm | 30 and over cm |
| Weight of complete system (kg/m²) | 75 to 180 | 200 to 500 | 500 to 2000 |
| Irrigation | No* | ✓ | ✓ |
| Maintenance | | | |
| Cost of roofling | € | €€€ | €€€€ |
| Accesibility | No | Limited | ✓ |

*With the exception of southern areas and sloping roofs

**Figure 4.** ***Three types of green roofs*** **[18]**

## 3. RESULTS AND DISCUSSION

Vegetation planted for the green roofs can be very diverse (Figure 5) [18], from decorative plants to fruit trees. However, the kind of that vegetation should be considered, since in particular, the roots of fruit trees would damage the roof of the building. The climate should also be considered since some vegetation undergoes best growing in certain climates, and some other vegetation could be sensitive to certain climatic conditions. In tropical climate areas, like Malaysia for instance, the selection of green roof vegetation is more flexible because almost all plants can grow [19]. Vegetation for green roofs can be growing either in barely soil media or in the pot [19]. Planting media for green roofs can also be combined with rocks (Figure 6). Rocks serve to protect the soil from solar radiation and also reduce soil evaporation [20].

(a)

(b)

**Figure 5.** ***Comparison of the various green roofs: extensive green roof (a), semi-intensive green roof (b)*** **[18]**

**Figure 6.** ***Green roof planting media that combine with rocks*** **[20]**

Green roofs can be applied to various types of roofs (Figure 7). Ponni and Baskar have conducted a study to compare two different kinds of roofs: a roof made from concrete versus roofs made from lightweight materials. They concluded that buildings with roofs made from lightweight materials (such as fiber and asbestos) have low heat transfer than buildings with non-lightweight material roofs, with room temperature 5-6°C cooler [21].

(a) (b) (c)

**Figure 7.** ***Type of roofs as a medium for implementing green roofs: green roof Chicago's city hall building in the US (a), roof pond Chiang Mai University located in Chiang Mai province (b), reflective white roof (c)***

The basic framework in building a green roof is its layered system that involves various materials. Thus, making a green roof requires an extra cost and may face some difficulties in its installation. Some challenges faced in building green roofs are (1) the size and mass of green roof installation are too large, (2) installation of non-standard green roofs will cause the floor damage, and (3) green roofs could cause the roof to become heavier, potentially causing a roof collapse, (4) the roots of vegetation planted in the green roof could penetrate the roof floor. Therefore, establishing green roofs that are low-cost and easy installation is still a challenge today.

## 4. CONCLUSION

A green roof, as a method of planting on the roof of a house or a building, is very beneficial but challenging to be developed.

a) A green roof can provide a more comfortable condition for occupants in residential buildings. It decreases the room temperature of the buildings and lowers the cooling load of the air conditioner, meaning that a green roof can reduce the use of energy or improve energy savings.
b) A green roof can also be beneficial for densely populated areas by providing green space in narrow areas. For areas that still have large green spaces, a green roof can serve as more beneficial energy saving in buildings than providing additional green space.
c) Challenges that arise in building green roofs can be minimalized by selecting the types of planted vegetation. In addition, the layout of the plants on the roof should be paid much consideration. Moreover, the structure of the soil membrane layer should also be considered at the beginning stage of designing a green roof to minimize any potential damages. In densely populated areas, a green roof can be established with vegetation by using water media (hydroponic). This alternative planting media might be able to minimize the mass load on roofs than soil planting media. However, for the cooling function of the room, the utilization of hydroponic for a green roof system still needs some studies.

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