The Effectiveness of Green Roof in Mitigating Urban Heat and the Prospect in Australia

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DOI: 10.32629/aes.v5i2.2275

Abstract: The effectiveness of green roofs in alleviating urban heat and their future development prospects in Australia are explored. As an ecologically sustainable building method, green roofs can not only effectively reduce urban temperatures but also improve environmental quality. Specifically, photovoltaic green roofs combine the advantages of photovoltaic power generation and green roofs, improving energy utilization efficiency and increasing ecological value. Although Australia started relatively late in the development of green roofs, their application in cities has become increasingly widespread in recent years, demonstrating enormous potential. To ensure the sustainable development of green roof technology, in-depth research is still needed on plant selection in specific regions.
***Keywords*:** green roof, photovoltaic green roof, urban heat

1. Introduction

"Urban" is defined as a spatial concentration of people whose lives are organized around nonagricultural activities[1], including well-build structure, high building density and high human density. With the urbanization, the density of buildings and population is also growing. Through the statistic of United Nation, the number of people living in urban areas worldwide increased rapidly from 751 million in 1950 to 4.2 billion in 2018. In 2018, 55% of the world's population resides in metropolitan regions, by 2050, that number is projected to rise to 68%[2]. Urban issues also arise when living standards rise, the relation between social, economy, and environment need to be balanced.

One of the environmental issues with urbanisation is the urban heat island effect. In comparison to the nearby rural region, the temperature in the metropolitan area is higher. There is less plant cover and a higher construction density. The ground and buildings' hard surfaces absorb heat and raise the temperature. Additionally, vegetation's ability to regulate temperature is losing efficacy. The increase of ecological problems in cities has led to the development of the concept of urban ecology. As a sub-discipline of ecology, it focuses on the human impact on urban landscape, aiming to promote environmental sustainability[3].

Another factor contributing to urban heat is excessive energy usage for electricity and transportation. Energy is converted to glasshouse gases, which are released into the atmosphere and raise local temperatures[4]. Carbon emissions is an environmental issue globally which is the main reason cause climate change. Several nations have signed the Paris Agreement to control climate change and keep the rise in the global average temperature to under two degrees[5]. By 2030, the emissions need to be reduced by 45% and by 2050, it need to reach net zero[6]. The demand for the development and promotion of clean energy is an important measure to alleviate environmental problems.

This essay will concentrate on the effectiveness of green infrastructure in resolving urban issues, particularly the use of green roofs and PV (Photovoltaic)-green roof. Additionally, the future development of green roof in Australia will be discussed.

2. The effectiveness of green roof in mitigating urban heat

With the process of urbanization, the number and density of buildings have increased, which corresponds to the compression of the area of urban green space. Roofs account for 40% - 50% of the impervious urban surface area in most cities in developed regions[7]. The roof will receive direct sunlight, absorb heat during the day and release it at night which cause urban heat. The building's thermal insulation is negatively impacted by the exposed roof. In the summer, the hard surface will absorb heat and raise the temperature inside. In winter, the indoor heat will be lost. As a result, the comfort is decreased, especially on the top floor, and the need of air conditioning will be noticeably increased, affecting energy consumption. The surrounded temperatures also increase through the solar and infrared radiation absorption by urban materials[8].

Green roof is one of the green infrastructures that applies the ecological concept to urban planning and increases urban resilience. Green roof refers to the transformation of the traditional roof structure, aiming to support vegetation planting and

regular irrigation, to enhance the social, economic, and environmental sustainability.

Under the cover of vegetation, the absorption of heat on the roof surface is reduced, which improves the thermal insulation effect of the building and saves energy. Compared with the urban hard surface, the rainwater on the roof surface with plants can infiltrate into the growth medium and be collected and reused through the stormwater management system. The functions of green roof also include purifying air, reducing environmental noise, and protecting the roof. As part of the ecosystem, green roofs provide habitats for birds, insects, fungi, and other organisms. The green roof that allows people to enter has social value, providing activity space for building users and promoting social exchanges[9].

Numerous research on green roofs have acknowledged their role in energy efficiency. In modern urban and architectural planning, green roofs are widely used all over the world under the government support. In Toronto, the green roof regulation requires all new development projects with a total construction area ≥ 2000 m2 to include green roofs on 20-60% of the roof area[10]. The Tokyo green plan offered tax incentives in 2012 and required that the roofs of private buildings larger than 1000 m2 and public buildings larger than 250 m2 be covered in vegetation[11].

In a warm climate, green roofs are generally thought to be effective in decreasing indoor temperature changes and building energy consumption through reduce the direct impact of solar radiation and the shading of the roof layer. A study on the performance of traditional roofs and green roofs in Catania, southern Italy, shows that the well-insulated traditional roofs have a minimum exterior surface temperature of approximately 54 ° C, while non-insulated green roofs is about 36 ° C[12]. Based on the improvement of heat absorption, the demand for air conditioning in buildings decreases which reduce energy consumption. Research from Greece found that installing green roof on well-insulated buildings cans save 2% of energy, while 37%-48% on non-insulated building[13]. A study in New York found that the energy savings of about 40%-110% can be achieved by installing a green roof as opposed to a white one[14]. To summarize, the green roof has the ability to lower the amount of heat entering a building during the day, which helps to maintain a high level of thermal comfort inside, as well as lower the temperature of the building's exterior, lower the energy needed to heat and cool it, and effectively reduce the heat island effect.

3. The use of PV-green roof in mitigating urban heat

The use of fossil fuels is one of the important causes of climate change. It is a global consensus to promote the use of clean energy. Compare with wind energy and water energy, solar energy is more efficiency in urban region. The rooftops in urban region receive strong direct sunlight which have great potential for solar power generation. Photovoltaic panels have been widely employed in architecture design as a sustainable feature, especially in nations with strong solar radiation because of its simplicity of installation and stability of benefits[15]. PV (Photovoltaic)-green roof is also called biosolar roof. It is a new direction which combine PV panels on the green roof, aiming to organise urban space, improve the efficiency of solar panels and increase the ecological benefits of green roofs at the same time.

As a green infrastructure that produces energy efficiency, PV panels on the green roof can fully receive sunlight and produce clean energy. However, the efficiency of its energy generation is related to the surrounding environment, including panel temperature, surface dust etc. According to the statistics of Fouad, Shihata and Morgan[16], there is a 0.38% to 0.45% power loss for every 1°C increase in temperature. Building solar panels on green roofs can reduce the ambient temperature and improve the efficiency of power generation by using the cooling effect of plants on the air and roof surface. The experiment at the University of Hong Kong shows that the PV green roof system provides 4.3% more power than the PV on the bare roof[17]. In the Mediterranean climate, the energy production efficiency of a PV-green roof with gazania is 1.29% higher than the one with gravel, and the power generation of a green roof with Sedum is 3.33% higher than the one with grave[18].

Since sunlight is dispersed throughout the surface of the solar panel, some sunlight may be blocked from reaching the PV module by the presence of dirt or dust, which results in power generation losses[16]. However, small dust particles can be captured by plants on green roof systems, filtering and cleaning the surrounding air[15]. One research shows that the work efficiency of PV panels decreased by 33.5% after one month of exposure, and 65.8% after six months without cleaning[16]. Another research investigated the impacts of dust on PV panels in the UAE and discovered that five weeks of exposure to the elements outside caused a 10% reduction in power output[19].

PV panels will also provide shadows for roof plants while working, creating a cool habitat. The study of PV green roof in London Olympic Park[20] found that PV modules act as shelters for plants during drought. The proportion of invertebrate species under PV is larger than that other green roofs in the same city, and black redstart and linnet birds are frequently spotted. This demonstrates that the PV-green roof is valuable as the feeding ground for both rare (protected) and ordinary birds.

4. The Future Development of Green Roofs in Australia

Although the effectiveness of green roofs in mitigating the urban heat island effect has been confirmed worldwide, the installation and evaluation of green roofs need to be more tailored to Australia's conditions, including climate, local materials, and local policies. The history of green roof in Australia is relatively short. Since 2010, green roof projects in Australian cities have expanded significantly, particularly in the area with high population density, limited open space and progressive local governments such as inner suburbs and CBD of major Australian cities[21]. Businesses, educational institutions, and new high-density residential structures often have green roofs.

At present, green roof has developed to a certain extent in Australia, but the practice and evaluation of PV green roof are relatively scarce. One of the literatures is about the evaluation of the benefits of Barangaroo's PV green roof. Barangaroo is a commercial area in Inner Sydney with high rise and high-density office buildings. Research compares two roofs on commercial buildings at Barangaroo. One is a green roof covered with vegetation and equipped with solar panels; the other is a traditional roof. Through the data comparison, the effectiveness of PV-green roof in Sydney is proved including adjusts the indoor temperature, absorb the heat generated by direct sunlight, and use solar energy to generate electricity[22].

However, the development of green roof in Australia still faces many challenges. Through searching the relevant research of roof greening in Australia, it is found that choosing plants suitable for the local climate and formulating more effective policies are the two gaps and require further development in the future.

The difference of plant survival rate under different climatic conditions cannot be ignored. Most of the research on the green roof plants selection take place in the northern hemisphere. As a country in the southern hemisphere, Australia has different climates and unique biological communities. In the selection of plants for green roofs in the northern hemisphere, temperature, sunlight, wind, drought degree, and occasional root water inflow are usually considered. This can also be used as a reference when choosing plants for green roofs in Australia, but the drought needs to be attention[21].

Australia has a large latitude span, which leads to different climates in different cities. More specific research is needed in plant selection. Brisbane located in the subtropical zone, has a humid and hot climate. A study in Brisbane showed that forbs such as H. scandens (snake vine), H. violacea and D. brevipedunculata have a high survival rate under local climatic conditions. On the contrary, several succulent plants widely used in the world do not survive well. In addition, the mixed planting of succulent plants and weeds can improve the survival rate and coverage rate of plants[23]. However, Melbourne in southern Australia has a dry climate, succulent plants perform better in drought tolerance than many native plants[24].

Although Sedum is a well-known green roof plant worldwide, it is not native to Australia. To avoid the uncontrolled spread of exotic plants, biosecurity issues need be considered while choosing species. Australian native plants are more adaptable to the local climate and have great potential to become green roof plants. Native herbaceous perennials that can withstand drought has great potential. In southern Australia, when summer droughts last for extended periods, these plants dominate in native grassland and grassy woodland[21].

Due to high installation costs and professional technical needs, government policies are essential to support green roof. In recent years, Australian policies on green roofs have been gradually standardized, and many incentive policies and subsidies for the construction of green roofs have been introduced. The Green Roofs and Walls Policy[25] approved by City of Sydney Council aiming to leaders are encouraged to install green roof and green wall. The overall covering of green roof and green wall in Sydney has risen by 23% since the policy was implemented. There are similar incentive policies in Melbourne, Adelaide, and Brisbane, to guide and subsidize the construction of green roof and green wall[26].

Compared with the policies of other countries, it is found that the policies of European countries are mainly incentives and subsidies. In some cities in Asia and North America, green roofs are forced to be installed under certain conditions[26]. Instead of regulating or requiring its inclusion in new projects, Australia's green roof laws all place a greater emphasis on disseminating knowledge and encouragement installation. With the process of urbanization and the development of green roof in Australia, mandatory policies are essential to effectively achieve the sustainable development goals of cities through standardization and universality.

5. Conclusion

In conclusion, green roofs have high benefits in mitigating urban heat and realizing ecological sustainability. As an advanced approach, PV-green roof creates ecological value for green roof while improving the efficiency of PV panels. For Australia, the development of green roof started late, but green roof is used more and more widely in cities. For the future development, more research is needed on the plant selection of green roofs in specific areas. Government policies and evaluation methods also help promote the construction and popularization of green roofs.

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