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RETROFIT POTENTIAL AND COST EFFICACY OF GREEN ROOF

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Abstract :

Now a days there is a serious concern to introduce an effective and practical means to combat urbanization. Most of the people in developing countries are still ignorant of green roof and its various benefits associated with it. The west has successfully implemented this system but due to some reason developing and underdeveloped countries did not realize the importance of green roof due the high cost and technical know-how. Over the last decade, there has been a significant increase in research on green roofs. Green roofs have been proposed as the best long-term solution for mitigating the negative effects of urbanization. In this article it is discussed and analyzed that green roof has more advantages than the conventional roof. Various other aspects like retrofitting, building envelope, thermal comfortability etc. have been also discussed.

Keyword: Green roof, energy efficiency, sustainability, benefits, retrofitting

Introduction:

Due to the rapid increase in population and economic growth Pakistan's urbanization has been increasing. As a result of increased urban population, high-rise buildings, housing societies, and other new developments are being constructed at the expense of green spaces. Building construction always progresses in tandem with economic growth (Mtapuri et al., 2022). By 2030, the number of megacities with populations greater than 10 million is expected to rise to 43 (Wang et al., 2022). The construction industry's growth has been directly linked to a 3% increase in greenhouse gas emissions between 2000 and 2010 (Ke et al., 2022). The construction industry consumes roughly 40% of total global energy consumption, in addition to the increase in energy consumption caused by human activities (Chou et al., 2015). Most of the energy is absorbed by heating and cooling of the building. Thus, it seems reasonable that inter-alia architectural aspects, principals, building envelope are combined green technologies to save energy and environment. Much research indicates that green buildings is a power full tool which helps to mitigate the several environmental problems.

To achieve the energy efficiency in the building, basic factors that needs to be addressed are local context i.e., weather conditions, climate, building material, etc. (Ozarisoy, 2022). Out of all these Climate has the major effect on the building consumption and energy efficiency. Some of the environmental problems can be solved to some extent by focusing and modifying properties of building envelope. In building envelope roof is the main component which absorbs 80 percent of the heat from sun throughout the day (Sadineni et al., 2011). As a result, green roofs, green walls, vertical and rain gardens, and bio retention systems, among other urban development strategies, can help to mitigate the urban heat island effect.

Globally now a days to introduce plant and soil on the roof top is considered to be the best approach to make building sustainable and environmentally friendly (Fleck et al., 2022) . According to California Energy Commission traditional dark roof absorbs almost 80 % of the heat from sun (Arefin and Hossan, 2014). By installing green roof there is a reduction of 3-to-7-degree F (Jayasinghe, 2016). By this drop of temperature the need for air conditioning is reduced by 20 to 30 percent (Karachaliou et al., 2016). Big Challenge in Pakistan for people other than awareness is the cost to install the green roof system. So, it is required to in cooperate the cost-effective indigenous material green roof system.

Literature Review:

Plantation on top of a building's roof is an ancient approach. The Hanging Roof Gardens of Babylon were the oldest green roofs which were introduced about 500 BC (Pessoa et al., 2022). Green roof of modern day has developed their concept from ancient garden; though modern-day green roofs are much more effective, functional, and advantageous and practical. However, few studies on green roofs were conducted in the first half of the twentieth century because their use was limited at the time and continues to be in some places due to the fear of structural damage (Weldon, 2022). However, in the second half of the twentieth century, architects and scientists implemented green roofs with caution and deliberation. The main limitations had been financial. As well as a lack of knowledge and expertise. Green roofs are known as passive roofs, vegetative roofs, roof garden, living roofs, and cool roofs and due to its ecological benefits also described as eco roofs (Costanzo et al., 2016). Green roofs are roofs that have been planted with various types of flora/plants/vegetables. The idea was to improve the vegetation on top of the structure to gain social, ecological, economic, and environmental benefits. This eco sustainable roof is made up of several parts, including vegetation, a substrate, a filter layer, drainage material, insulation, a root barrier, and water proofing membranes (Cascone, 2019). . For the best results from the green roof, the best possible selection of each component of the green roof system is required. Each section is equally important and plays an important role in the green roof's performance. Green roofs are being installed in many developed countries for a variety of reasons. Further research is being conducted on the performance, benefits, and limitations of green roofs in various parts of the world. Fig. 1 Fig 2 and Fig 3 shows Building with green roof 2020 Awards of Excellence Winners.

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Fig 1: McDonald's Headquarters, Chicago, IL, Omni Ecosystems

Source: https://greenroofs.org/awards-of-excellence

Fig 2: Sandyland Cove, Lake Toxaway, NC, Living Roofs Inc

Fig 3: Plan of Sandyland Cove, Lake Toxaway, NC

Source: https://greenroofs.org/awards-of-excellence

Green roofs have gained widespread recognition as a sustainable method in recent years. Green roofs have numerous social, environmental, and economic benefits, according to several studies. Green roofs have also been shown to have several benefits, including reduced urban heat island effect, storm water management, biodiversity, roof life, improved air and water quality, quality of life, decreased energy consumption, reduced noise pollution, increased leisure activities, and increased aesthetics of urban environments. As a result of the benefits listed above, many countries began to install green roofs on existing structures as well as new and is becoming increasingly popular around the world (Calheiros et al., 2022). .

Green roofs are generally divided into two types. These are extensive and intensive. The substrate thickness of intensive green roofs is typically greater than 12 inches. It has more water storage capacity due to the substantial soil depth, and the plant selection can be more diverse as small trees, plants, and shrubs (Scolaro and Ghisi, 2022). However, more attention must be paid to the building structure's ability to support heavy loads. As a result, high and consistent maintenance is required for this type of roof to perform well. Extensive roofs, on the other hand, are based on a substrate thickness of 3-4 in. Sedum is commonly used as the vegetation layer on large roofs and does not require much watering. In comparison to an intensive green roof, it requires less investment and maintenance (Robbiati et al., 2022). This type of green roof is lightweight and ideal for retrofit applications. Because of this extensive green rooftop are most common all over the world.

Methodology:

This paper conducts a comprehensive review of the literature from various sources, such as journals, case studies, books, design strategies, and so on. The purpose of this research is to help the general public understand green roof systems. In addition, each component of the green roof and its benefits are described in this study. This paper discusses the various social, environmental, and economic benefits of green roofs in urban areas. Furthermore, the research gap, challenges, limitations, and technical obstacles of green roofs are all discussed.

Green Roof Development:

A green roof on top of a building is an ancient method. People used to build green roofs on rooftops as roof gardens for insulation and to mitigate the negative effects of urban development. The Hanging Gardens of Babylon, built around 500 BCE, was one of the most famous antiquated green roofs. During severe weather, many European countries, including Denmark, Finland, and Sweden, cover their rooftops with turf (Pearl mutter et al., 2022). Modern green roofs, on the other hand, are more effective and efficient due to proper design and techniques. When the energy crisis became a major phenomenon in the 1960s, Germany began installing green roofs on their building structures in order to reduce energy consumption. Globally, Germany is now recognized as the leader in green roofs, as large-scale green roofs are being created, designed, and installed (Cascone,

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2019). Countries such as the United States, Canada, Australia, China, Japan, and South Korea are currently working hard to incorporate green roofs into new and existing buildings in order to obtain the greatest benefits. In developed countries such as Canada, Japan, and the United States, it is mandatory to cover 20 to 70 percent of total roof area with green roof (Alim et al., 2022). The government is encouraging citizens and investors to use green roofs to make cities more secure, sustainable, and environmentally friendly.

In order to benefit from green roof, more research is being done today on low-cost green roofs with new design technology. Following the successful implementation of green roofs in developed countries such as the United States and Europe, green roofs have gained more attention in the rest of the world.

Green Roof Retrofitting:

All natural and agricultural areas have been transformed into concrete jungles due to urbanization, such as roads and buildings. Roofs are important because they transfer 80 percent of the heat energy from the roof top into the building, and conventional roofs can be replaced with green roofs (Zheng et al.,2022).There are various types of roofs used globally, accordingly primary research is required and then choose the best suited type of green roof to gain the maximum advantages. Green roofs can also be retrofitted onto existing structures, reducing the negative effects of urbanization. It will contribute to the improvement of the surroundings (Wong and Lau, 2013).

Green roofs are the best solution not only for brand new building structures, but also for existing structures. Castleton studied retrofit green roofs and walls, according to his study, when a green roof is retrofitted onto a conventional roof, energy loads are reduced and heat transfer into the building is reduced (Castleton et al., 2010). Lightweight retrofit roofs have a positive environmental impact. It is also being investigated whether the construction type and colors used influence the effectiveness of green roofs. Wooden structures are not strong heat conductors, they are employed in some buildings in Australia to provide better insulation and cooling than concrete block construction. Recent studies have shown that thermal insulation has a substantial impact on building internal comfort. Building insulation plays an important role in reducing the urban heat island effect. This study recommends that green roofs are the best choice for new as well as retrofitting in hot and humid climates (La Roche and Berardi, 2014).

A retrofit green roof, according to Detommaso, can reduce the temperature of the surrounding air by up to 0.4 °C during the day and 0.8 °C at night (Detommaso et al., 2021). The increase in additional loads and structural failure is the most difficult challenge in retrofitting green roofs. As a result, because of their light weight, extensive green roofs are suitable for retrofitting. Green roofs are recommended as an appropriate retrofitting technology for existing buildings to improve insulation. It is also discussed that retrofit green roofs on existing structures are more cost effective than new buildings because old structures did not have proper insulation systems. Green roofs installed on existing buildings can improve insulation and provide several environmental and economic benefits (Teotónio et al., 2018).

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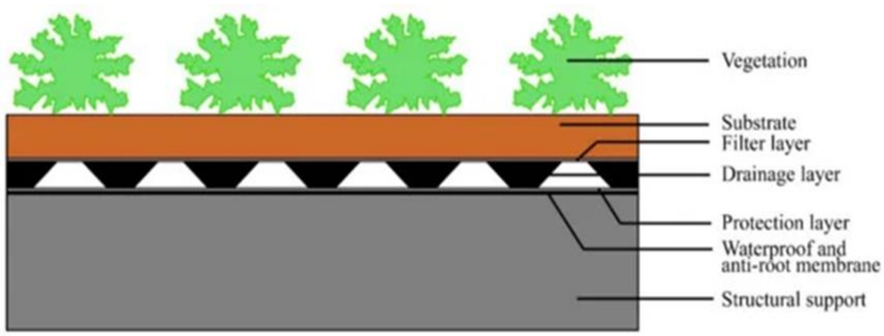
Green Roof Components:

As In comparison to ancient roof gardens, green roofs with new advancements are structurally planned and designed to combat urbanization. Green roofs are typically made up of several components that vary depending on location and conditions. To gain the utmost benefits from a green roof system and to meet the long-term expectations of the client, the best locally available efficient green roof components must be chosen. Green roofs are made up of the five components shown in Figure 4.

- Waterproof and a root barrier membrane
- Water Retention Layer
- Drainage layer
- Filter membrane
- Growing medium
- Plants

Fig 4: Sections of a green roof



(Source: Cascone, S. (2019). Green roof design: State of the art on technology and materials. Sustainability, 11(11), 3020.)

To maximize benefits, it is essential to choose the type of green roof based on the context and location. Each layer of green roofs is important and should be chosen carefully to achieve the best results.

Waterproof membrane / Root Barrier Membrane:

This membrane is installed on top of the roof to prevent water leakage, because soil moisture and moisture content increase the probability of water penetration and seepage, this water membrane layer will not allow moisture to enter the building. As a result, a waterproofing membrane is critical for green roofs and must be chosen carefully. Bitumen sheets or liquid layers, as well as thermoplastic membranes, can be used depending on our local conditions. This layer extends the lifespan of green roofs.

A root barrier is essential in an intensive green roof system. It protects the structure from root invasion. If this layer is not included in the green roof system, the root will grow

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through and ruin the entire structure of the green roof. Root barriers can be made from polyethylene sheets.

Water Retention Layer:

This layer, as the name implies, is located on the root barrier layer and serves to retain water. It keeps the roots moist and prevents water runoff.

Water Drainage Layer:

The drainage layer is on top of the retention layer and serves to drain excess water. It keeps excess water from accumulating on the roof and causing leaks. Polymer-based layers and pebbles can be used for drainage. It reduces the structure's load. It also protects the waterproof membrane and increases the building's energy efficiency.

The following drainage layer materials are commonly used:

1) Polyethylene or polystyrene prefabricated drainage panels are used to store more water during the drainage process.
2) Lightweight expanded clay aggregates, crushed brick, coarse gravel, and stone chips are also used to store more water.

The selection of drainage layer based on context and location is also important because drainage layers can improve building energy efficiency. For small-scale projects, coarse materials are usually sufficient. As a result, additional research is required to select the best cost-effective and environmentally friendly drainage layer.

Filter Membrane:

A filter layer's primary function is to separate plants and soil from the drainage layer, preventing small fragments of plant and soil from entering and clogging the drainage layer. It secures the vegetation and medium in place. Polymeric fibers are most commonly used.

Growing medium/ Soil:

The plants get their nutrition from this layer. Typically, soil is used as a growing medium. Appropriate selection of this layer is critical because it has a direct influence on plant growth. The selection of soil based on location and context is critical for achieving the best results from a green roof. The most of green roof benefits, such as improved water quality, runoff reduction, peak flow reduction, and thermal benefits, are directly related to the soil of green roofs.

A high-water holding capacity in the growing medium reduces peak runoff flow and helps plants survive in drought conditions. Increased soil volume and depth can increase water holding capacity. According to some studies, adding an additive to the substrate can increase its water holding capacity. To control the flow of water, soil with a high air-filled porosity should be used during the rainy season and prevents a green roof from leaking. To achieve the best results from a green roof, it should be properly designed.

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Necessary Soil Properties for green roofs:

- Maximum strength and stability under varying conditions
- Regional and capable of supporting a wide range of plants
- Budget friendly
- Organic content should be at a minimum.
- Should have a large capacity for holding water
- Light in weight
- Less seeping and high absorption capacity
- Excellent aeration and flow properties
- Contribute to improving water quality

A substrate with all of the above properties is extremely rare. However, the best substrate should be chosen in light of the local context and environment.

Plant:

It is the most attractive and mesmerizing part of the green roof. The plant layer should be chosen with care because it extends the life of the green roof. The success of a green roof is determined by healthy plants. The geographical location, intensity of rainfall, humidity, wind, and sun exposure should all be considered when selecting a plant (Arabi et al., 2015). Growing medium depth can also limit the plant types that can be used on green roofs. Plants improve runoff water quality, air quality, and reduce heat waves in an area. The rooftop, on the other hand, is not the ideal natural environment for plant growth. Water and soil depth are always limited on rooftops. The soil requires nutrients to keep plants performing well (Rapisarda et al., 2022). The following characteristics are required for plant selection during plant selection:

- Ability to withstand extreme climate situations
- Drought resistant
- Cost efficient
- Rapid multiplications
- Soft and delicate roots
- Requires less maintenance
- Capability to thrive in low-nutrient environments
- Can reduce heat island effect

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It is extremely difficult for plants to possess all of the aforementioned characteristics. Sedums are the most chosen plant for extensive green roofs because they perform well in a variety of climates. Recent studies have shown that sedum can function well all over the world and can go without water for longer periods of time. According to Di Miceli sedums lived and even after 4 months without water, according to some studies, while a few types of sedums survived two years without water. Sedums are used all over the world because of these characteristics. Sedums have also proven effective on shallow extensive green roofs and have numerous benefits (Di Miceli et al., 2022).

Cost Effectiveness of the Green Roof:

Cost is one of the most significant barriers to green roof implementation in developing countries. Extensive roofs are lighter in weight than intensive roofs. Parts of the extensive green roof are lightweight, and the depth of the growing medium is also reduced. As a result, an extensive green roof costs less than an intensive green roof (Durdyev et al., 2022).

If a suitable local plant and local growing medium are used for the extensive roof, the cost can be reduced even further (Ma'bdeh et al., 2022). As a result, there is a critical need for the development of low-cost green roofs that can provide multiple benefits in urban areas. There is a need to educate the general public on the fact that going green has far more long-term benefits. When we compare the cost of running an air conditioner to the cost of maintaining a green roof, the maintenance of a green roof is far less expensive.

Benefits of Green Roof:

There are numerous direct and indirect benefits to installing a green roof in an urban area. Green roofs are intended not only to restore nature to the urban environment. However, critical issues such as urban heat island effect and stormwater management must also be addressed. Green roof benefits are classified into three categories:

- Environmental
- Economic
- Social

1. Environmental benefits of green roofs:

Reduction in Urban Heat Island Effect:

The most efficient way to reduce the ambient air temperature in urban areas is to install green roofs on buildings. Summer temperatures in urban areas are 5-7 0C higher than in rural areas due to concrete heat absorption, which raises the local air temperature (Lundgren and Kjellstrom 2013).

Green roofs not only contribute to the reduction of urban heat islands by covering conventional roofs with heat-absorbing plants, but they also use solar energy to evaporate water from the substrate and transpire moisture from the plants. The temperature on the roof drops as a result of this evapotranspiration process (Juras, 2022). .

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Rainwater management:

One of the most significant advantages of green roofs is that they help to reduce the load on sewer systems by 70-95% during the summer. Green roofs are permeable surfaces that aid in storm water management. Flooding can be reduced by collecting rainwater and delaying peak flow. The substrate will absorb rainwater and hold it in the pore. Rainwater can also be stored in plants before being released back into the environment through transpiration. The remainder of the water passes through the filter fabric and into the drainage layer (Liu et al, 2022).

Rainwater purification:

A natural bio-filtration process keeps pollutants and contaminants out of streams and watercourses. According to Kaiser 95% of the lead, copper, and cadmium sulfide and 19% of the zinc from rainwater remain in the soil, helping to improve local water quality (Kaiser et al., 2019).

Carbon Dioxide Reduction:

Green roofs help to reduce the amount of carbon dioxide in the atmosphere, which is one of the primary causes of global warming. Photosynthesis in plants consumes CO2 emissions and releases oxygen; this reduces CO2 dioxide emissions and keeps the air clean. According to studies, 1 m^2 of green roof can absorb 5 kg of CO2 per year. Furthermore, reduced energy consumption reduces carbon dioxide emissions by 3.2kg per year (Tams et al., 2022).

Reduction in Air pollution:

Plants and vegetation absorb airborne elements from the atmosphere, such as smog, heavy metals, and hazardous composites, improving air quality and human health. Green roofs help to reduce environmental air pollution. Pollutant levels in the urban environment are dangerous to human health and the environment. The ability of plants to clean the air is considered to be the most effective mitigation strategy. According to research, one square meter of green roof can absorb 0.2kg of airborne particles per year (De Lange et al., 2016).

Natural habitat/ Biodiversity:

Green roofs promote natural habitat in urban settings (Williams et al., 2014). It also benefits biodiversity by attracting wildlife. To increase the ecological impact of the roof, structures such as bird baths and beehives can be added.

2. Economic Benefits:

Insulates the Building:

A dark roof absorbs heat due to which there is an increase in usage of mechanical system to make a building cool, however a green roof lowers the temperature of the roof and the

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building itself. The green roof also serves as insulation (Yuan et al., 2022). This reduces the amount of heat entering the building, decrease the cooling loads, and to some extent it provides some insulation during the summers, although, it does not replace the need for additional thermal insulation.

Improves Effectiveness of HVAC System:

Roof temperature is cooled by a green roof which helps to increase the efficacy of rooftop mechanical system by making the air on the roof cooler. HVAC system on cooling mode needs to get pre-cool the outside air to get the required temperature (Yuan et al., 2022). HVAC If the roof top air is already made cooler by green roof system, the mechanical system will use less energy as it will be operating at a lower ambient temperature.

Extends Roof Life:

A green roof extends the life of a roof by shielding the roof materials from direct UV rays, acidic rain, and extreme temperatures, resulting in less maintenance and lower renovation costs.

Energy efficiency:

Energy consumptions are reduced by 30 to 40% with the help of green roof. The green roof offers an annual energy saving of 1% to 6% in cooling and 0.5% in heating. The efficiency of green roof also depends on several aspects including climate conditions, type of construction, thickness of insulation etc. (Zinzi and Agnoli 2012).

Noise reduction:

A commercial building is surrounded by a lot of noise. Employees don't want to hear the rumble of heavy traffic outside their office, and if you're at home, you probably don't want to hear the rumble of jets flying overhead late at night. A green roof system absorbs up to 30% of environmental noise pollution and provides good sound insulation (Suszanowicz and Kolasa 2019). It contributes to a calmer living environment and more friendly surroundings in urban areas. It reduces noise near industrial areas and airports in major metropolitan areas.

3. Social benefits of green roofs:

Aesthetics:

A green roof is visually attractive and, in the case of a building in public and commercial areas, it assures the public attention (HUI et al., 2022). Studies have shown that green areas and plants have a relaxing psychological effect and helps to reduce stress, anger, and blood pressure.

Enhance Urban Comfort:

Green roofs increase urban green space while also increasing the comfort and satisfaction of building occupants by providing an appealingly pleasant and attractive environment for recreation. Some green roofs promote urban farming and kitchen

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gardening by including harvestable herbs and vegetables. Insects and birds that have lost their natural habitat due to urbanization can also find refuge on a green roof.

Improve Human Health and Comfort:

Green roofs reduce heat entering the building through roof. Due to this indoor comfort is improved and helps in the reduction of heat stress associated with heat waves.

Improve Quality of Life:

Green roofs provide natural habitat for plant and animal species which is lost due to in in urbanization. Also, the interaction between human and nature is also enhanced by introducing green areas into the built environment. Green spaces have been shown in studies to improve human physical and mental health, productivity, and to reduce blood pressure and hospital stays (Aguilar Fajardo et al., 2022)

Limitations/Constraints of Green Roofs:

According to the public and legislators, green roofs have some limitations. Although research, studies, and environmentalists are working hard to highlight the benefits of green roofs, there are several impediments to their growth. The limitations are more visible in developing countries, where policymakers are still unable to recognize the benefits of installing green roofs. It is a time-consuming process if government support or regulations are not involved in the green roof awareness campaign.

In the majority of counties, various factors limit the growth of green roofs. The first and most significant barrier is the cost of installing a green roof. The cost of installing a green roof varies depending on the type of green roof, location, labor, and equipment. The cost varies depending on the location and context. There has been little research into the costs of green roof systems for urban usage. As a result, the return on cost is unknown and difficult to comprehend. Green roofs are 27% more expensive to install than conventional roofs, according to Niu et el research in Washington DC. However, over a 40-year period, the net present value of a green roof is approximately 25% lower than that of a conventional roof.

Another barrier that confuses users is the maintenance of green roofs, and research on this topic is limited. It has been discovered that industrial developers made unrealistic promises such as green roofs that do not require irrigation, pollination, or the prevention of wild plant growth, among other things. Specifically, green roofs require continuous watering during drought conditions, and irregular fertilization promotes weed growth, necessitating regular maintenance.

Conclusion:

It is concluded that green roofs improve urban life and social activities. The installation of plants and grass on building roofs and walls is regarded as a mitigation method for lowering summer temperatures or insulate building envelopes in winter. The green roof indicated the social status of the home's owners in some cultures. Green roofs are used

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for socializing or relaxing in the terrace garden. Thatched roofs were found in permanent and temporary structures from prehistory to the beginning of the twentieth century, for whatever reason, whether to symbolize a social status or to mitigate climatic conditions. Since the early twentieth century, futurists have been looking for a way to improve the lives of city dwellers. Regardless of their approach or social beliefs, vegetation remains an important component of the inhabitants' well-being. At the turn of the twentieth century, people and society were more concerned than the environment itself.

The assessment of green roofs, which start with the definition, system components, historical advancement, and impact on green roof performance. The paper is exploration on the green roof technology in the building envelope. It demonstrates an understanding of the effectiveness of these systems as insulation materials in a hot, humid climate, as well as passive techniques that aid in reducing energy consumption and increasing thermal envelope performance.

Green roof research has been an important challenge, but it also provides a great opportunity for upcoming research this paper discusses the research on green roof characteristics, ecologic, social, and economic benefits, challenges, and possible applications. The limitations of green roof technology, such as installation costs, are also debated in this paper. There is a need to develop cost-effective green roof methods in order to achieve the best results and maximize benefits such as environmental, social, and economic. However, more in-depth real-world investigational work on each component of the green roof is required.

References:

Aguilar Fajardo, A. C., Bacchi, G., Cusicanqui Lopez, J. A., Gilardi, G., Maggetti, D., & Tommasi, L. (2022). Green Roof Benefits and Technology Assessment. A Literature Review. In INTERNATIONAL SYMPOSIUM: New Metropolitan Perspectives (pp. 1937-1946). Springer, Cham.

Alim, M. A., Rahman, A., Tao, Z., Garner, B., Griffith, R., & Liebman, M. (2022). Green roof as an effective tool for sustainable urban development: An Australian perspective in relation to stormwater and building energy management. Journal of Cleaner Production, 132561.

Arabi, R., Shahidan, M. F., Kamal, M., Ja'afar, M. F. Z. B., & Rakhshandehroo, M. (2015). Considerations for plant selection in green roofs. Universiti Putra Malaysia. Alam Cipta, 8(3), 10-17.

Arefin, A., & Hossan, M. A. (2014). Solar Power as Renewable Energy for Home Systems in Bangladesh. Dhaka, Bangladesh.

Calheiros, C. S. C., Castiglione, B., & Palha, P. (2022). Nature-based solutions for socially and environmentally responsible new cities: The contribution of green roofs. In Circular Economy and Sustainability (pp. 235-255). Elsevier.

Cascone, S. (2019). Green roof design: State of the art on technology and materials. Sustainability, 11(11), 3020.

Castleton, H. F., Stovin, V., Beck, S. B., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. Energy and buildings, 42(10), 1582-1591.

Chou, J. S., & Yeh, K. C. (2015). Life cycle carbon dioxide emissions simulation and environmental cost analysis for building construction. Journal of Cleaner production, 101, 137-147.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 65 Issue 09 | 2022
DOI 10.17605/OSF.IO/PJ9NF

Costanzo, V., Evola, G., & Marletta, L. (2016). Energy savings in buildings or UHI mitigation? Comparison between green roofs and cool roofs. Energy and buildings, 114, 247-255.

De Lange, G., Van Meerten, H., Lelieveld, C., De Vries, B., Van Zomeren, A., Rover, V., ... & De Vos, S. (2016). Climate Resilience and Circularity in Construction assignments. Part of report in work package, 4.

Detommaso, M., Gagliano, A., Marletta, L., & Nocera, F. (2021). Sustainable urban greening and cooling strategies for thermal comfort at pedestrian level. Sustainability, 13(6), 3138.s

Di Miceli, G., Iacuzzi, N., Licata, M., La Bella, S., Tuttolomondo, T., & Aprile, S. (2022). Growth and development of succulent mixtures for extensive green roofs in a Mediterranean climate. PloS one, 17(6), e0269446.

Durdyev, S., Koc, K., Karaca, F., & Gurgun, A. P. (2022). Strategies for implementation of green roofs in developing countries. Engineering, Construction and Architectural Management.

Fleck, R., Gill, R. L., Saadeh, S., Pettit, T., Wooster, E., Torpy, F., & Irga, P. (2022). Urban green roofs to manage rooftop microclimates: A case study from Sydney, Australia. Building and Environment, 209, 108673.

HUI, L. C., JIM, C. Y., & Yuhong, T. I. A. N. (2022). Public views on green roofs and green walls in two major Asian cities and implications for promotion policy. Urban Forestry & Urban Greening, 70, 127546.

Jayasinghe, B. T. D. (2016). Energy saving methods in hot water supply for hospitality industry.

Juras, P. (2022). Positive Aspects of Green Roof Reducing Energy Consumption in winter. Energies, 15(4), 1493.

Kaiser, D., Köhler, M., Schmidt, M., & Wolff, F. (2019). Increasing evapotranspiration on extensive green roofs by changing substrate depths, construction, and additional irrigation. Buildings, 9(7), 173.

Karachaliou, P., Santamouris, M., & Pangalou, H. (2016). Experimental and numerical analysis of the energy performance of a large scale intensive green roof system installed on an office building in Athens. Energy and Buildings, 114, 256-264.

Ke, Y., Xia, L., Huang, Y., Li, S., Zhang, Y., Liang, S., & Yang, Z. (2022). The carbon emissions related to the land-use changes from 2000 to 2015 in Shenzhen, China: Implication for exploring low-carbon development in megacities. Journal of Environmental Management, 319, 115660.

La Roche, P., & Berardi, U. (2014). Comfort and energy savings with active green roofs. Energy and buildings, 82, 492-504.

Liu, W., Qian, Y., Yao, L., Feng, Q., Engel, B. A., Chen, W., & Yu, T. (2022). Identifying city-scale potential and priority areas for retrofitting green roofs and assessing their runoff reduction effectiveness in urban functional zones. Journal of Cleaner Production, 332, 130064.

Lundgren, K., & Kjellstrom, T. (2013). Sustainability challenges from climate change and air conditioning use in urban areas. Sustainability, 5(7), 3116-3128.

Ma'bdeh, S. N., Ali, H. H., & Rabab'ah, I. O. (2022). Sustainable assessment of using green roofs in hot-arid areas–Residential buildings in Jordan. Journal of Building Engineering, 45, 103559.

Mtapuri, O., Camilleri, M. A., & Dłużewska, A. (2022). Advancing community-based tourism approaches for the sustainable development of destinations. Sustainable Development, 30(3), 423-432.

Ozarisoy, B. (2022). Energy effectiveness of passive cooling design strategies to reduce the impact of long-term heatwaves on occupants' thermal comfort in Europe: Climate change and mitigation. Journal of Cleaner Production, 330, 129675.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 65 Issue 09 | 2022
DOI 10.17605/OSF.IO/PJ9NF

Pearlmutter, D., Pucher, B., Calheiros, C. S., Hoffmann, K. A., Aicher, A., Pinho, P. ... & Nehls, T. (2021). Closing water cycles in the built environment through nature-based solutions: The contribution of vertical greening systems and green roofs. Water, 13(16), 2165.

Pessoa, V. G., Guiselini, C., de Souza, H. H., & Pandorfi, H. (2022). Green roofs: environmental contributions with an emphasis on carbon sequestration. Revista Brasileira de Geografia Física, 15(03), 1229-1238.

Rapisarda, R., Nocera, F., Costanzo, V., Sciuto, G., & Caponetto, R. (2022). Hydroponic Green Roof Systems as an Alternative to Traditional Pond and Green Roofs: A Literature Review. Energies, 15(6), 2190.

Robbiati, F. O., Cáceres, N., Hick, E. C., Suarez, M., Soto, S., Barea, G. ... & Imhof, L. (2022). Vegetative and thermal performance of an extensive vegetated roof located in the urban heat island of a semiarid region. Building and Environment, 212, 108791.

Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. Renewable and sustainable energy reviews, 15(8), 3617-3631.

Scolaro, T. P., & Ghisi, E. (2022). Life cycle assessment of green roofs: A literature review of layers materials and purposes. Science of the Total Environment, 154650.

Suszanowicz, D., & Kolasa Więcek, A. (2019). The Impact of Green Roofs on the Parameters of the Environment in Urban Areas. Atmosphere, 10(12), 792.

Tams, L., Nehls, T., & Calheiros, C. S. C. (2022). Rethinking green roofs-natural and recycled materials improve their carbon footprint. Building and Environment, 219, 109122.

Teotónio, I., Silva, C. M., & Cruz, C. O. (2018). Eco-solutions for urban environments regeneration: The economic value of green roofs. Journal of Cleaner Production, 199, 121-135.

Wang, Z., Yang, Z., Zhang, B., Li, H., & He, W. (2022). How does urbanization affect energy consumption for central heating: Historical analysis and future prospects? Energy and Buildings, 255, 111631.

Weldon, K. (2022). Green Roofs in Cities: An Assessment of the Benefits and Review of Policy.

Williams, N. S., Lundholm, J., & Scott MacIvor, J. (2014). Do green roofs help urban biodiversity conservation? Journal of applied ecology, 51(6), 1643-1649.

Wong, J. K. W., & Lau, L. S. K. (2013). From the 'urban heat island'to the 'green island'? A preliminary investigation into the potential of retrofitting green roofs in Mongkok district of Hong Kong. Habitat International, 39, 25-35.

Yuan, J., Patra, I., Majdi, A., Dwijendra, N. K. A., Opulencia, M. J. C., & Chetthamrongchai, P. (2022). Fundamental green roof performance of residential building in desert climate: In terms of sustainability and decrease in energy consumption. Sustainable Energy Technologies and Assessments, 53, 102574.

Zheng, X., Yang, Z., Yang, J., Tang, M., & Feng, C. (2022). An experimental study on the thermal and energy performance of self-sustaining green roofs under severe drought conditions in summer. Energy and Buildings, 261, 111953.

Zinzi, M., & Agnoli, S. (2012). Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy and Buildings, 55, 66-76.

Mtapuri, O., Camilleri, M. A., & Dłużewska, A. (2022). Advancing community-based tourism approaches for the sustainable development of destinations. Sustainable Development, 30(3), 423-432.

Wang, Z., Yang, Z., Zhang, B., Li, H., & He, W. (2022). How does urbanization affect energy consumption for central heating: Historical analysis and future prospects? Energy and Buildings, 255, 111631.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 65 Issue 09 | 2022
DOI 10.17605/OSF.IO/PJ9NF

Ke, Y., Xia, L., Huang, Y., Li, S., Zhang, Y., Liang, S., & Yang, Z. (2022). The carbon emissions related to the land-use changes from 2000 to 2015 in Shenzhen, China: Implication for exploring low-carbon development in megacities. Journal of Environmental Management, 319, 115660.

Chou, J. S., & Yeh, K. C. (2015). Life cycle carbon dioxide emissions simulation and environmental cost analysis for building construction. Journal of Cleaner production, 101, 137-147.

Ozarisoy, B. (2022). Energy effectiveness of passive cooling design strategies to reduce the impact of long-term heatwaves on occupants' thermal comfort in Europe: Climate change and mitigation. Journal of Cleaner Production, 330, 129675.

Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. Renewable and sustainable energy reviews, 15(8), 3617-3631.

Fleck, R., Gill, R. L., Saadeh, S., Pettit, T., Wooster, E., Torpy, F., & Irga, P. (2022). Urban green roofs to manage rooftop microclimates: A case study from Sydney, Australia. Building and Environment, 209, 108673.

Arefin, A., & Hossan, M. A. (2014). Solar Power as Renewable Energy for Home Systems in Bangladesh. Dhaka, Bangladesh.

Jayasinghe, B. T. D. (2016). Energy saving methods in hot water supply for hospitality industry.

Karachaliou, P., Santamouris, M., & Pangalou, H. (2016). Experimental and numerical analysis of the energy performance of a large scale intensive green roof system installed on an office building in Athens. Energy and Buildings, 114, 256-264.

Pessoa, V. G., Guiselini, C., de Souza, H. H., & Pandorfi, H. (2022). Green roofs: environmental contributions with an emphasis on carbon sequestration. Revista Brasileira de Geografia Física, 15(03), 1229-1238.

Weldon, K. (2022). Green Roofs in Cities: An Assessment of the Benefits and Review of Policy.

Costanzo, V., Evola, G., & Marletta, L. (2016). Energy savings in buildings or UHI mitigation? Comparison between green roofs and cool roofs. Energy and buildings, 114, 247-255.

Cascone, S. (2019). Green roof design: State of the art on technology and materials. Sustainability, 11(11), 3020.

Calheiros, C. S. C., Castiglione, B., & Palha, P. (2022). Nature-based solutions for socially and environmentally responsible new cities: The contribution of green roofs. In Circular Economy and Sustainability (pp. 235-255). Elsevier.

Scolaro, T. P., & Ghisi, E. (2022). Life cycle assessment of green roofs: A literature review of layers materials and purposes. Science of the Total Environment, 154650.

Robbiati, F. O., Cáceres, N., Hick, E. C., Suarez, M., Soto, S., Barea, G. ... & Imhof, L. (2022). Vegetative and thermal performance of an extensive vegetated roof located in the urban heat island of a semiarid region. Building and Environment, 212, 108791.

Pearlmutter, D., Pucher, B., Calheiros, C. S., Hoffmann, K. A., Aicher, A., Pinho, P. ... & Nehls, T. (2021). Closing water cycles in the built environment through nature-based solutions: The contribution of vertical greening systems and green roofs. Water, 13(16), 2165.

Cascone, S. (2019). Green roof design: State of the art on technology and materials. Sustainability, 11(11), 3020.

Alim, M. A., Rahman, A., Tao, Z., Garner, B., Griffith, R., & Liebman, M. (2022). Green roof as an effective tool for sustainable urban development: An Australian perspective in relation to stormwater and building energy management. Journal of Cleaner Production, 132561.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 65 Issue 09 | 2022
DOI 10.17605/OSF.IO/PJ9NF

Zheng, X., Yang, Z., Yang, J., Tang, M., & Feng, C. (2022). An experimental study on the thermal and energy performance of self-sustaining green roofs under severe drought conditions in summer. Energy and Buildings, 261, 111953.

Wong, J. K. W., & Lau, L. S. K. (2013). From the ‘urban heat island’to the ‘green island’? A preliminary investigation into the potential of retrofitting green roofs in Mongkok district of Hong Kong. Habitat International, 39, 25-35.

Castleton, H. F., Stovin, V., Beck, S. B., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. Energy and buildings, 42(10), 1582-1591.

La Roche, P., & Berardi, U. (2014). Comfort and energy savings with active green roofs. Energy and buildings, 82, 492-504.

Detommaso, M., Gagliano, A., Marletta, L., & Nocera, F. (2021). Sustainable urban greening and cooling strategies for thermal comfort at pedestrian level. Sustainability, 13(6), 3138.

Teotónio, I., Silva, C. M., & Cruz, C. O. (2018). Eco-solutions for urban environments regeneration: The economic value of green roofs. Journal of Cleaner Production, 199, 121-135.

Arabi, R., Shahidan, M. F., Kamal, M., Ja’afar, M. F. Z. B., & Rakhshandehroo, M. (2015). Considerations for plant selection in green roofs. Universiti Putra Malaysia. Alam Cipta, 8(3), 10-17.

Rapisarda, R., Nocera, F., Costanzo, V., Sciuto, G., & Caponetto, R. (2022). Hydroponic Green Roof Systems as an Alternative to Traditional Pond and Green Roofs: A Literature Review. Energies, 15(6), 2190.

Di Miceli, G., Iacuzzi, N., Licata, M., La Bella, S., Tuttolomondo, T., & Aprile, S. (2022). Growth and development of succulent mixtures for extensive green roofs in a Mediterranean climate. PloS one, 17(6), e0269446.

Di Miceli, G., Iacuzzi, N., Licata, M., La Bella, S., Tuttolomondo, T., & Aprile, S. (2022). Growth and development of succulent mixtures for extensive green roofs in a Mediterranean climate. PloS one, 17(6), e0269446.

Durdyev, S., Koc, K., Karaca, F., & Gurgun, A. P. (2022). Strategies for implementation of green roofs in developing countries. Engineering, Construction and Architectural Management.

Ma'bdeh, S. N., Ali, H. H., & Rabab'ah, I. O. (2022). Sustainable assessment of using green roofs in hot-arid areas–Residential buildings in Jordan. Journal of Building Engineering, 45, 103559.

Lundgren, K., & Kjellstrom, T. (2013). Sustainability challenges from climate change and air conditioning use in urban areas. Sustainability, 5(7), 3116-3128.

Juras, P. (2022). Positive Aspects of Green Roof Reducing Energy Consumption in winter. Energies, 15(4), 1493.

Liu, W., Qian, Y., Yao, L., Feng, Q., Engel, B. A., Chen, W., & Yu, T. (2022). Identifying city-scale potential and priority areas for retrofitting green roofs and assessing their runoff reduction effectiveness in urban functional zones. Journal of Cleaner Production, 332, 130064.

Kaiser, D., Köhler, M., Schmidt, M., & Wolff, F. (2019). Increasing evapotranspiration on extensive green roofs by changing substrate depths, construction, and additional irrigation. Buildings, 9(7), 173.

Tams, L., Nehls, T., & Calheiros, C. S. C. (2022). Rethinking green roofs-natural and recycled materials improve their carbon footprint. Building and Environment, 219, 109122.

De Lange, G., Van Meerten, H., Lelieveld, C., De Vries, B., Van Zomeren, A., Rover, V., ... & De Vos, S. (2016). Climate Resilience and Circularity in Construction assignments. Part of report in work package, 4.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 65 Issue 09 | 2022
DOI 10.17605/OSF.IO/PJ9NF

Williams, N. S., Lundholm, J., & Scott MacIvor, J. (2014). Do green roofs help urban biodiversity conservation? Journal of applied ecology, 51(6), 1643-1649.

Yuan, J., Patra, I., Majdi, A., Dwijendra, N. K. A., Opulencia, M. J. C., & Chetthamrongchai, P. (2022). Fundamental green roof performance of residential building in desert climate: In terms of sustainability and decrease in energy consumption. Sustainable Energy Technologies and Assessments, 53, 102574.

Zinzi, M., & Agnoli, S. (2012). Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy and Buildings, 55, 66-76.

Suszanowicz, D., & Kolasa Więcek, A. (2019). The Impact of Green Roofs on the Parameters of the Environment in Urban Areas. Atmosphere, 10(12), 792.

HUI, L. C., JIM, C. Y., & Yuhong, T. I. A. N. (2022). Public views on green roofs and green walls in two major Asian cities and implications for promotion policy. Urban Forestry & Urban Greening, 70, 127546.

Yuan, J., Patra, I., Majdi, A., Dwijendra, N. K. A., Opulencia, M. J. C., & Chetthamrongchai, P. (2022). Fundamental green roof performance of residential building in desert climate: In terms of sustainability and decrease in energy consumption. Sustainable Energy Technologies and Assessments, 53, 102574.

45. Aguilar Fajardo, A. C., Bacchi, G., Cusicanqui Lopez, J. A., Gilardi, G., Maggetti, D., & Tommasi, L. (2022). Green Roof Benefits and Technology Assessment. A Literature Review. In INTERNATIONAL SYMPOSIUM: New Metropolitan Perspectives (pp. 1937-1946). Springer, Cham.