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A review of energy characteristic of vertical greenery systems

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ABSTRACT

Rapidly growing cities and human activities change the environment and are accompanied by some drawbacks. Sustainable remedies are needed to protect the environment and the earth against warming environment, pollution, natural resource use and other negative aspects of human activities. Applying vertical greenery systems not only reduce temperature, but also have many economic, environmental and social benefits. This review is about vertical greenery systems description, division and benefits with a focus on energy related topics. The paper describes different experiments on vertical greenery systems by attention to their energy characteristic from recent years. Scan research and studies have determined positive aspects of these sustainable systems as well as a few negative aspects. Moreover, different parameters which are involved in thermal performance of vertical greenery systems are highlighted. Based on various scan research some recommendations for future studies are proposed.

Contents

1. Introduction

Urbanization and rapidly growing population change city features and convert them to concrete jungles [1]. Migration into urban areas and growing population lead to some problems like

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Table 1
Reviews on vertical greenery systems.

Name	Type of Manuscript	Objective
Kohler, 2008	Review	Vertical greenery systems technology with a focus on Germany
Yu, 2009	Review	Greenery in urban areas based on both systematic and thermal benefits
Hunter, 2014	Review	Thermal performance of green facades/quantify study
Jaafar, 2011	Literatures	Vertical greenery systems heat reduction
Perini, 2011	Literatures	General information
Loh, 2008	Literatures	General information
Bennett, 2012	Literatures	General information
Nafici, 2012	Literatures	General information
Shiah, 2011	Report	Potential feasibility and significant factors of installing vertical greenery systems

air, noise, and water pollution, increase concrete buildings and hard surfaces, lack of vegetation, increasing urban heat island, global warming etc. [1–8]. Increased air temperature leads to growing discomfort in indoor environments [9,10]. Applying sustainable methods in the form of greenery systems and applying these systems to buildings is an intelligent way to mitigate some of these drawbacks, and can mitigate depletion of resources [11].

Using renewable energy is a practice toward sustainability and is suitable for developing countries without clean energy [12] although this is applicable for developed nations as well. Some important renewable energy systems are ground source-based systems, day-lighting systems, and solar-based energy systems [13]. Solar energy is a powerful source to mitigate energy problems [14], and there are some ways to utilize solar energy like solar panels [15], solar walls [16], trump walls [17] etc. Although the sun is the main source of natural energy in the world, its radiation heats the environments and leads to increased temperatures. Therefore, solar energy should be controlled, because if it is not controlled correctly it has a negative warming effect. Using plants and greenery is an ecological solution to control solar radiation and reduce temperature. Moreover, the use of plants offers natural advantages as plants are a clean source [1,6].

Plants and greenery have numerous benefits for urban areas and environment [18–24]. To illustrate, in external spaces, plants are natural tools for controlling microclimatic condition by their shading effects, absorption and reflection abilities [25,26]. It is proved that small green areas spaced at appropriate intervals help to cool surroundings [27], and an experiment confirms this claim and reveals direct connection between temperature and green areas [21]. Applying greenery on unused building surfaces is a way to integrate urban areas and plants [28]. It is an answer to heavy population and high cost of land that prevent city habitants from having enough public green spaces on the ground [6,29]. Moreover, the greenery benefits buildings and structures, because all buildings and its surrounding areas act as closed working systems [30]. Applying green roofs and vertical greenery systems are appropriate ways to use greenery systems in buildings. Controlling temperature by green roofs is becoming common and valuable research have been done [6,31–34], but using vertical greenery systems to control temperature is a new idea and requires more consideration [35]. Specifically, vertical greenery systems require special techniques and systems in implementing on buildings, where these techniques and systems will have different influences on building performance.

Attention to vertical greenery systems is drawing attention from different points of views. Kohler [36] reviewed research activities on green walls and green facades technology with a focus on Germany. Yu [37] provided a comprehensive review on greenery in urban areas based on both systematic and thermal benefits and divided these greeneries into public green areas, rooftop gardens and vertical landscaping. Moreover, there is a peer-review on thermal performance of green facades in quantify point [38]. It compared related studies and experiments and found some research design problems and missed issues in the studies such as lack of microclimatic information, plants properties, or green facade design components. Jaafar [39] conducted a literature review on vertical greenery systems with a focus on vertical greenery system heat reduction. In addition to these reviews, there are some literatures about vertical greenery systems [40–42]. Moreover, Bennett [43] has provided an overview on green facade, and there is also a general writing about the impact of green roof and green facade on urban agriculture [7]. Apart from that, there is a report written by researchers at the University of British Columbia about the potential feasibility and significant factors of installing vertical greenery systems [44]. Table 1 compares the objectives of reviews and writings on vertical greenery systems.

These writings show that studies about vertical greenery systems are developing and attempts are underway to find ways for improving these system performances to control urban as well as environmental problems. Energy aspects and temperature reduction ability of vertical greenery systems are significant points, and study about them are important to optimize vertical greenery systems thermal performances.

Current review is focused on the energy aspects of vertical greenery systems. Observing and tracing recent studies and experiments on temperature and energy characteristics of vertical greenery systems is the main objective of this article. The focus is on the effects of different parameters that are involved in the vertical greenery system performances, and also applying new methods to improve their efficiency. For this aim, definitions, terminology and division of vertical greenery systems are offered. Afterwards, the benefits of these systems are described, and then different research about plants properties and growth are presented. Studies into vertical greenery systems energy reduction are then presented and the studies on different parameters that are effective in vertical greenery systems thermal performances are described. The summary emphasizes current state of research gaps and possible future research areas on vertical greenery system.

2. Materials and method

In the first step, this article presents a comprehensive literature review on vertical greenery systems definitions, terminology, classifications, and benefits. The study resources was formed from different source types such as journals, conference papers, theses, books as well as one standard, one report, and one serial. Most of them are up to date manuscripts and they are related to recent years. To evaluate thermal performance and energy characteristic of vertical greenery systems 22 peer-reviewed papers were scanned from 2005 to 2014 to ensure the most updated data on vertical greenery systems. They consist of 18 journals, 3 master theses, and one conference paper (Table 2). Several papers consisted of more