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Green wall systems: A review of their characteristics

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ABSTRACT

Current systems for greening the buildings envelope are not just surfaces covered with vegetation. Greening systems, as green roofs and green walls, are frequently used as an aesthetical feature in buildings. However, the current technology involved in these systems can maximize the functional benefits of plants to buildings performance and make part of a sustainable strategy of urban rehabilitation and buildings retrofitting.

During the last decades several researches were conducted proving that green walls can contribute to enhance and restore the urban environment and improve buildings performance.

The aim of this paper is to review all types of green wall systems in order to identify and systematize their main characteristics and technologies involved. So, it is important to understand the main differences between systems in terms of composition and construction methods.

Most recent developments in green walls are mainly focused in systems design in order to achieve more efficient technical solutions and a better performance in all building phases. Yet, green wall systems must evolve to become more sustainable solutions. In fact, continuing to evaluate the contribution of recent green wall systems to improve buildings performance and comparing the environmental impact of these systems with other construction solutions can lead to an increase of their application in buildings and therefore result in a reduction on these systems cost.

The decision of which green wall system is more appropriate to a certain project must depend not only on the construction and climatic restrictions but also on the environmental impact of its components and associated costs during its entire lifecycle.

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1. Introduction

Current systems for greening the buildings envelope are not just surfaces covered with vegetation. There are several greening systems in the market, like green roofs and green walls, which technology involved is being developed to increase their performance and longevity.

Greening systems, as green roofs and green walls, are frequently used as an aesthetical feature in buildings. However, the current technology involved in these systems can maximize the functional benefits of plants to buildings performance [1]. Greening systems can also make part of a sustainable strategy [2–4] of urban rehabilitation and building retrofitting [5–7].

At a city scale, green roofs and green walls contribute to the insertion of vegetation in the urban context without occupying any space at street level [8]. In fact, covering buildings with vegetation, when applied in a significant urban scale, can improve the urban environment by contributing to urban biodiversity [1,9], stormwater management [10], air quality [11–13], temperature reduction [14] and mitigation of the heat island effect [15,16]. At the same time, the application of greening systems can have, besides the environmental aspects, social and economic benefits. These systems encourage the fruition of urban areas [17], have a therapeutic effect by inducing a psychological wellbeing through the presence of vegetation, improve cities image [7], increase property value [18] and function as a complementary thermal [19] and acoustic protection [20,21].

Green walls have a greater potential than green roofs considering that in urban centers the extent of facade greening can be double the ground footprint of buildings [22].

At a building scale, green wall systems can be used as a passive design solution [23] contributing to buildings sustainability performance [24]. Vegetation has the potential to improve the microclimate both in winter [25], functioning as a complementary insulation layer, and in summer [26], providing shade [27–29] and an evaporative cooling effect [30]. Vegetation absorbs large amounts of solar radiation [31] while the effect of evapotranspiration of plants can further reduce the impact of solar radiation, showing increased humidity levels and surface temperatures lower than hard surfaces [32,33]. Recent studies show that green wall systems have the ability to control heat gains and losses, contributing to improve indoor thermal comfort and reduce energy demands for heating or cooling [15,34–36].

Green wall is the common term to refer to all forms of vegetated wall surfaces. Traditional green wall methods are historically known, since the Hanging Gardens of Babylon and the Roman and Greek Empires. In Mediterranean climates, vines were commonly used to cover pergolas, shading the building envelope, or on building walls, cooling the envelope during summer [37]. Since the seventeenth and eighteenth centuries, mostly in UK and Central Europe, the use of climbing plants to cover building walls proliferated [38]. In the 19th century woody climbers were commonly used as ornamental elements of buildings envelope in European and North American cities [39].

First investigations on green facades were based on botanical aspects [22]. However, since the 1980s a new idea occurred of green facades as contributors to cities ecological enhancement. The garden city movement from the end of the 19th century marked the integration of greening in urban planning. The German Jugendstil movement (Art Nouveau) from the early 20th century encouraged the integration of the house with the garden. During this period emerged some incentive programs for the installation of green facades. In fact, Berlin is an important example, from 1983 to 1997, where around 245.584 square meters of green facades were installed [22].

This paper aims to review the main green wall systems available, systematizing their main characteristics and technology involved. A search of green walls, available internationally on the market or in invention databases (e.g., Esp@cenet, Free Patents Online, Fresh Patents, Google Patents, Lusopat, Wipo – Patentscope), allowed the identification and characterization of most of the existing green wall systems. It must be noticed that this is a field in constant actualization. However, the analyzed solutions constitute a representative universe to identify the main features of green walls in terms of configuration, composition and materials used.

This paper is divided in two main sections. First, a classification of green wall systems, including a definition for different systems according to their characteristics is proposed. Second, the main requirements of different green wall systems in terms of composition, processes of installation and maintenance and their environmental impact and cost are systematized.

In order to compare the several green wall systems and their features, an analysis of their composition is made according to the following items: supporting elements, growing media, vegetation, drainage and irrigation. Additionally, given the importance of these subjects, two subsections were added to focus, first on the different phases of the systems lifecycle, namely on the differences on their installation and maintenance, and second on the environmental performance and cost of green wall systems.

2. Classification and definition

Considering the recent developments in green walls technology it is important to identify and classify all existing green wall systems, according to their construction techniques and main characteristics.

Authors use several nomenclatures when referring to all types of green wall systems. Some use the term “vertical garden” [40,41] others call them “vertical greening systems” [42], “green vertical systems” [23] or “vertical greenery systems (VGSs)” [43]. When referring to direct or indirect green facades, Ottelé et al. and Perini et al. [44,45] used the terms direct greening systems and indirect greening systems, respectively.

Another concept called “Biowalls” was mentioned by Francis et al. regarding the application of green walls in indoor spaces in order to enhance the environment [9].

This concept includes the technology involved in living walls; therefore it can be inserted in this category.

In fact, the concept of green walls refers to all systems which enable greening a vertical surface (e.g., facades, walls, blind walls, partition walls, etc.) with a selection of plant species, including all the solutions with the purpose of growing plants on, up or within the wall of a building [38]. In this paper a classification of green walls according to the different existing systems and their construction characteristics is proposed (see Fig. 1).

Green walls can be subdivided in two main systems: green facades and living walls [22,39]. There is an evident distinction between green facades, where usually climbing plants grow along the wall covering it, and the most recent concepts of living walls, which include materials and technology to support a wider variety of plants, creating a uniform growth along the surface.

2.1. Green facades

Green facades are based on the application of climbing or hanging plants along the wall. Plants can grow upwards the vertical surface, like traditional examples, or grow downward the vertical surface, in case they are hanged at a certain height [39].

Green facades can be classified as direct or indirect. Direct green facades are the ones in which plants are attached directly to