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Green vertical systems for buildings as passive systems for energy savings

Gabriel Pérez [a], Lídia Rincón [a], Anna Vila [a], Josep M. González [b], Luisa F. Cabeza [a,*]

[a] GREA Innovació Concurrent, Edifici CREA, Universitat de Lleida, Pere de Cabrera s/n, 25001 Lleida, Spain
[b] Dept. Construccions Arquitectòniques I, Universitat Politècnica de Catalunya, Avinguda Diagonal 649, 3ª planta, 08028 Barcelona, Spain

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ABSTRACT

This paper presents a classification of green vertical systems for buildings. The aim of this classification is to facilitate the identification and differentiation between systems. This classification is also essential to compare future research results relating to their operation. In addition, the mechanisms by which green facades can be used as passive energy savings systems are reviewed: shadow produced by the vegetation, insulation provided by vegetation and substrate, evaporative cooling by evapotranspiration, and the barrier effect to the wind. Finally, the paper describes the first results about the behaviour of a double-skin green facade or green curtain in Dry Mediterranean Continental conditions. It is verified that a microclimate between the wall of the building and the green curtain is created, and it is characterized by slightly lower temperatures and higher relative humidity. This means that the green screen acts as a wind barrier and confirms the evapotranspiration effect of the plants.

1. Introduction

In recent years the mechanisms that influence the use of green roofs as passive system for energy savings in buildings have been studied. However, there are very few studies on the use of green facades with this purpose. In addition, while building systems of green roofs are quite normalized, in the case of green facades there are too many differences between systems. This hinders the comparison of previous experimental results. Therefore it is necessary to establish a classification of green facades to distinguish different types and to compare in the future their behaviour as passive system for energy savings.

On the other hand, since plants are living organisms and their development depends on the weather, the final results may greatly differ from one climating area to another, spoiling the expectations of energy savings that had been planned according to theoretical calculations for a given system. So it is essential to know the behaviour of the different plant species in local weather conditions for the efficient operation of green facades.

Most of the published work on this topic originates from German studies, thus there is a great need for more research into all aspects of this technology and its applications in other parts of the world [1].

Given the extreme climatic conditions in the area of Lleida (continental part of the region of Catalonia, Spain), it is even more necessary to have more knowledge about the development of these species in this local weather conditions. *Lleida* has a climate classified as Dry Mediterranean Continental, characterized by its great seasonal variations. It has low rainfall, divided in two seasons, spring and autumn. It also has a thermometric regime with large differences between a long winter (between the spring and the last frost may take more than 160 days) and a very hot summer. The average annual rainfall falls between 350 and 550 mm, and the mean annual temperatures oscillates between 12 and 14 °C, with thermal amplitudes of 17–20 °C. A special mention must be made to the fog, typical of the region in the months of November, December and January that can give a period of up to 55 days in the absence of sunlight. This is a very similar climate to that of the area of Madrid, although it has annual rainfall and fewer days of fog per year (Table 1).

This paper is divided in three parts. First it proposes a classification of green vertical systems. This classification considers both traditional systems and newly developed systems. Second, it summarizes an overview of the mechanisms in order to use the green vertical systems as a passive system for energy savings. Finally, it describes one of the started actions in order to collect data about the real behaviour of green verticals systems of buildings as passive system for energy savings. Specifically it is a double-skin green facade or green curtain in a real building in Dry Mediterranean Continental conditions.

2. Typologies of green verticals systems of buildings. Proposal for classification

Traditional green facades are considered those made by climbing plants that develop directly in the building wall without any subjection system. This practice of landscaping has been typically

* Corresponding author. Tel.: +34 973 003576; fax: +34 973 003575.
E-mail address: lcabeza@diei.udl.cat (L.F. Cabeza).

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Table 1
Normal climatic values for Lleida/Station 2. Period: 1971–2000 – Altitude (m): 192 – Latitude: 41°37′33″N – Longitude: 00°35′42″E State Meteorological Agency. Spanish Ministry of Environment http://www.aemet.es/es/portada.

Month	T	TM	Tm	R	H	DR	DN	DT	DF	DH	DD	I
January	5.3	9.6	1.0	26	81	4	1	0	12	13	5	116
February	7.9	13.7	2.2	14	70	3	0	0	5	8	7	167
March	10.8	17.5	4.2	27	61	4	0	0	3	3	8	226
April	13.2	19.8	6.5	37	58	5	0	1	1	0	6	248
May	17.3	24.0	10.5	49	58	6	0	3	1	0	5	279
June	21.4	28.5	14.4	34	54	4	0	3	0	0	9	313
July	24.7	32.2	17.2	12	51	2	0	2	0	0	14	348
August	24.5	31.6	17.4	21	56	3	0	4	0	0	12	313
September	20.7	27.3	14.1	39	63	4	0	2	1	0	8	250
October	15.3	21.2	9.4	39	71	4	0	1	4	0	6	200
November	9.3	14.2	4.4	28	79	4	0	0	11	5	5	137
December	6.0	9.8	2.1	28	83	4	0	0	14	10	5	96
Year	14.7	20.8	8.6	369	66	46	1	18	53	37	91	2685

T – Monthly/annual temperature average (°C).
TM – Monthly/yearly maximum daily temperatures average (°C).
Tm – Monthly/annual minimum daily temperatures average (°C).
R – Monthly/annual precipitation average (mm).
H – Relative humidity average (%).
DR – Monthly/annual days of precipitation greater than or equal to 1 mm average.
DN – Monthly/annual snow days average.
DT – Monthly/annual storm days average.
DF – Monthly/annual fog days average.
DH – Monthly/annual frost days average.
DD – Monthly/annual clear days average.
I – Monthly/annual sunshine hours average.

associated with damage to the facade materials, animal attraction, and high maintenance costs. However, recently, different building systems are being developed. These new systems allow greening the facades of buildings, which have evolved technically and conceptually with respect to the traditional ones.

We can encompass all the systems available on the market under the common name of *green vertical systems of buildings* (Table 2).

A first division is the differentiation between *green facades* and *living walls*.

Green facades are facade systems in which climbing plants or hanging port shrubs are developed using special support structures, mainly in a directed way, to cover the desired area. The plants can be planted directly in the ground at the base of the structure, or in pots at different heights of the facade.

Green facades can subsequently be divided into three different systems. *Traditional green facades*, where climber plants use the facade material as a support; *double-skin green facade* or *green curtain*, with the aim of creating a double-skin or green curtain separated from the wall; and *perimeter flowerpots*, when as a part of the composition of the facade hanging port shrubs are planted around the building to constitute a green curtain.

In the case of double skin green facades, the systems used are *modular trellises*, *wired*, and *mesh structures*. *Modular trellises* are very light trellis metal modules mounted on the building wall or on independent structures, which become the support for climbing plants. Application examples of commercial systems are the Green Screen system [2], and the G-SKY Green Wall Container [3]. The *wired structures* use a system of steel cables, anchorages, separators, and other items which constitute a light structure that serves as support for climbing plants. Application examples of commercial systems are the Façade Scape system I-SYS Stainless Cables and Rods by Carl Stahl Décorcable [4], and the Jakob inox line [5]. The *mesh structure* is a very light structure that provides support for the climbers, made with steel mesh anchored to the building wall or to the building structure. One application example of commercial systems is the FacadeScape system X-Tend Stainless Steel Flexible Mesh Fabric by Carl Stahl Décorcable [4].

Table 2
Classification of *green vertical systems* for buildings.

	Extensive systems		Intensive systems
Green facades	Traditional green facades		
	Double-skin green facade or green curtain	Modular trellis	
		Wired	
		Mesh	
			Perimeter flowerpots
Living walls			Panels
			Geotextile felt

Living walls are made of *panels* and/or *geotextile felts*, sometimes pre-cultivate, which are fixed to a vertical support or on the wall structure. The panels and geotextile felts provide support to the vegetation formed by upholstering plants, ferns, small shrubs, and perennial flower, among others.

Panels of varying sizes and types, with holes in which the substrate and plants are located, are fixed to the wall. Application examples of commercial systems are the G–SKY Green Wall Panels [3], the ELT Easy Green Living Wall Panel – Elevated Landscape Technologies [6], the Parabienta "green wall" [7], the Paramento vegetal vertical – Intemper [8], and the Green Wall System – Marie Clarke [9].

The geotextile felt systems use geotextile felt as support for the plants or mosses, anchored directly to the wall. Application examples of commercial systems are the Mur végétaux – Patrick Blanc [10], and the BRYOTEC Technology – MCK Environment – BRYOTEC [11].

This classification considers the different construction systems, the different types of plant used, as well as future maintenance necessary. As vegetated roofs, green vertical systems can be differentiated as extensive and intensive systems. Extensive systems are easy to build and it have minimum future maintenance, and intensive systems have more complex implantation and require a high level of subsequent maintenance.