Commentary │ Received 2 December 2022; Accepted 7 February 2023; Published 1 March 2023
https://doi.org/10.55092/rse20230003

Green Facade and Photovoltaic: a Multifunctional System

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Abstract: Cities are growing all over the world and the increasing number of inhabitants requires ever more dense development. As a result, more and more green spaces had disappeared. Not only does climate change, but also the increased Urban Heat Island Effect leads to ever higher temperatures in urban areas. This affects the quality of life and living, as well as the environment and economy. In addition to this, the world is in an ever-growing need for renewable energy. Photovoltaic Systems (PV) and Green Facades (GF) are well-known systems that are used as strategies to increase building efficiency, thermal performance, noise reduction, and quality of life. In this paper, the focus is on a review of the combination of PV and GF, the so-called Multifunctional System (MFS), and its impact and influence on the building facade (BF) temperatures. Furthermore, several options for integrating these systems and their possible future outcomes are discussed.

Keywords: Green Facade; Vertical Greening; Building Greening; Photovoltaics; Greening and PV

1. Introduction

An "urban heat island" (UHI) effect, brought on by sealed surfaces and highly populated areas, is progressively a concern for cities. The UHI mitigation strategies among others are de-sealing of surfaces (for greater water retention and active cooling via transpiration), the use of reflecting surfaces (to reduce heat storage in materials), and the reduction of CO_2 emissions [1]. Both Photovoltaic Systems (PV) and Green Facades (GF) are well-known systems that are used as strategies to increase building efficiency, thermal performance, noise reduction, and quality of life (air quality, noise damping, and aesthetics). Numerous scientific studies have examined these system characteristics as well as the viability of implementing them in real-world settings [2–9]. However, one of the downsides of the photovoltaic is that its efficiency is affected negatively by temperature increases, and due to that, researchers have been trying to find a way to help this cause by introducing new methods. The key point to remember is that since photovoltaic energy production and building greenery both take place on the exterior of buildings (such as the roof or façade), they have always been in direct competition for surface use. Until a few years ago, both systems were used separately, and have not been brought to work together.

The basic assumption was that the plants receive only limited amounts of indirect sunlight (filtered through the PV-module), which limits their potential for growth [10] In [11], the authors demonstrated that this assumption was false. Different studies have since been established in which various combinations of photovoltaic panels and Building Greening (BG) systems were examined with the aim of designing solutions with a combined usage of these technologies for building exteriors [4,5,11,12]. The purpose of this paper is to provide an overview of options for integrating PV panels and BG systems, their current assessment, as well as the possible future outcomes.

2. Multifunctional System: description and use

The MFS developed as a part of a long-term project and presented in [10,11] was conceived in order to develop a system solution in which the synergies of PV and GF work together to bring an optimal, long-lasting, cost-effective, and energy effective solution that can be replicated in advanced future constructions and used for the renovation of older buildings. Figure 1 shows the schematic of the MFS.

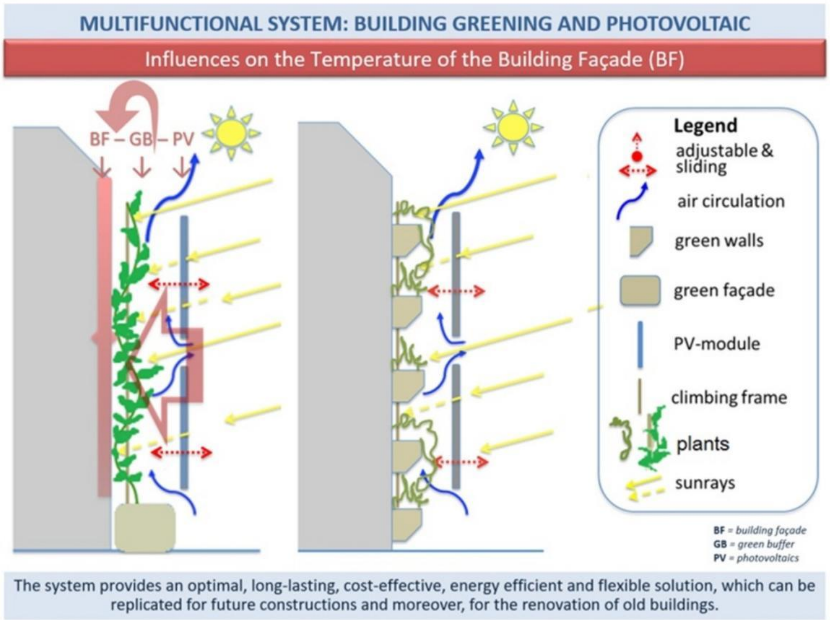

Figure 1. Schematic of the Multifunctional System: Building Greening and Photovoltaic for Green Facades [10].

It can be observed that there is a layer called green buffer (GB) between the PV and the BF. The PV layer serves not only as a support for the growth of climbing plants but also as protection from extreme temperatures in summer and winter, as well as from other extreme weather events, such as cold winds and hails. At the same time, thanks to the transpiration of plants, GB provides a cooling effect for PV and building fa çade (BF). On the other hand, PV semi-encloses the GB and protects it. This way the synergies of both PV and BG benefit the BF. This being said, it can be concluded that the system as a whole enhances the benefits of its components. The benefits of the MFS are, as a consequence of these synergies, enhanced and prolonged beyond the summer throughout the year.

The GB space, which has its own hygrometric characteristics (HC), is created by the use of both PV and Gf simultaneously. The GB acts as an insulation tool in its interaction with the other two layers. Throughout the year, it regulates the temperature on the BF as well as the operating temperatures of the PV-modules. A detailed analysis of the influences of the GB on the PV was presented in [11]. According to the results, it can be observed that the PV operating temperatures in increasing ranges are reduced by the GB, up to 4 °C. By outdoor temperatures above 20 °C, the temperature differences increase. The paper also addressed the validation of the assumptions on the development of plants behind a PV on a facade.

Figure 2 shows the test area used in [10,11], which has been operable since July 2015 and was a part of a long-term project.

Figure 2. Test area mounted on the Eco-Testing- Station ("Öko-Prüfstand") – Test Area of the Research Center of the Building Physics and Sound Protection.

The Eco-Testing Station it was mounted to is a construction that is used as a test site for the analysis of ecological and natural materials.

The building facade has been divided into four fields (F1-F4), as shown in Figure 3, where each field corresponds to one system variation. This has been done in such a manner, in order to achieve a better comparison and evaluation of the effects and impacts of a system with and without a GB. Monitoring devices to control and save the data of the hygrometric parameters (temperature and humidity) were used for a posterior analysis on all testing surfaces. During the analysis and validation, system variations were created –systems with the same characteristics but one with a GF and one without GF- and compared to a bare wall (reference field. This enabled the separate analysis of all the synergies and influences of each component on other components, as well as on the system as a whole. The analyzed data was filtered using the time intervals depending on the objectives of the analysis and its variables. The regular and unusual behaviors and patterns under typical and unusual component's influences and external parameters were identifiable this way.

Figure 3. Test area distribution [10].

3. Key findings

The results presented in [10,11], regarding the influences of the MFS on the BF, as well as the influences of the MFS on the PV prevail the performance of the system and its components throughout the year.

The key findings reached after the extensive measurements and analysis are following:

- Plants can grow behind PV systems on façade, meaning it is possible to use GF and PV at the same time, causing the competition between the two to subside.
- The GB has a positive influence on the module temperature of the PV throughout the year. It lowers the maximum temperature values by up to 4 °C and the average temperature by up to 2 °C.
- The MFS protects itself and its components (PV and BF) from extreme temperatures, as well as from sharp fluctuations. F3 and F4 maintained temperatures similar to air temperatures, both during the summer and winter. Almost no abrupter changes in the temperature were noticed by the systems with a GB. The systems behavior showed a steady reaction and demonstrated a good thermal insulation to the BF against temperature changes.
- The benefits of MFS can be observed not only during the summer, but throughout the whole year.
- The system showed a positive insulation effect on the BF. The average reduction of 21.4 °C up to 30 °C for the maximum temperatures was observed during the summer. In winter, the system inhibited heat loss on the wall up to 3 °C on average in comparison to the other systems, when the air temperature dropped below 0 °C.

4. Concluding remarks and future perspectives

According to the measurements and analysis, it can be stated that the MFS allows better use of the BF surface while being simple, ecological, affordable, and easy to replace. This simple system can be used for small applications without any major modifications or increased costs, as the green facades are the most simple, affordable, and well-known system. In addition to this, the required maintenance of MFS is no more than usually required by any of the individual systems.

Considering the encouraging results obtained in previous research, wide future perspectives are emerging and more work in this field is required. One of the potential improvements on the system that is yet to be developed and assessed is developing an optimal fastening system (sliding system), that could solve some of the maintenance difficulties, be free of thermal bridges, etc. The rising popularity and awareness of the practical use of MFS systems in the future will hopefully motivate more researchers and engineers to work on its improvement and develop the optimized solutions for any encountered obstacles.

Acknowledgments

The author received no special funding for this work.

Conflicts of Interests

The author declares no conflicts of interest.

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