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Building integrated photovoltaics- an overview.

Construcción de energía fotovoltaica integrada: una descripción general.

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ABSTRACT

From the older concept of photovoltaic installation, which includes the addition of solar panels to a building's roof, the construction technology has merged with the photovoltaics technology. The result is Building Integrated Photovoltaics (BIPV), in which integrating the architectural, structural and aesthetic component of photovoltaics into buildings. Building integration of photovoltaics (BIPVs) has been recognized worldwide as a pivotal technology enabling the exploitation of innovative renewable energy sources in buildings, acting as electric power generators within the new framework of smart cities. The standard semitransparent photovoltaic (PV) modules can largely replace architectural glass installed in the building envelopes such as roofs, skylights, and facade of a building. Their main features are power generation and transparency, as well as possessing a heat insulating effect. PV glass shows the same mechanical properties as a conventional, architectural glass used in construction. Additionally, it provides free and clean energy. Given these properties, PV Glass maximizes the performance of the building's envelope. The cost of the PV system and its implementation is still significantly high in comparison to solar thermal systems.
Keywords: Building Integrated Photovoltaics, renewable energy, power generation, heat insulating effect.

RESUMEN

Desde el concepto más antiguo de instalación fotovoltaica, que incluye la adición de paneles solares al techo de un edificio, la tecnología de construcción se ha fusionado con la tecnología fotovoltaica. El resultado es Building Integrated Photovoltaics (BIPV), en el que se integra el componente arquitectónico, estructural y estético de la energía fotovoltaica en los edificios. La integración de energía fotovoltaica en edificios (BIPV) ha

sido reconocida en todo el mundo como una tecnología fundamental que permite la explotación de fuentes innovadoras de energía renovable en los edificios, actuando como generadores de energía eléctrica dentro del nuevo marco de las ciudades inteligentes. Los módulos fotovoltaicos (PV) semitransparentes estándar pueden reemplazar en gran medida el vidrio arquitectónico instalado en las envolventes del edificio, como los techos, las claraboyas y la fachada de un edificio. Sus principales características son la generación de energía y la transparencia, además de poseer un efecto termoaislante. El vidrio fotovoltaico muestra las mismas propiedades mecánicas que un vidrio arquitectónico convencional utilizado en la construcción. Además, proporciona energía limpia y gratuita. Dadas estas propiedades, PV Glass maximiza el rendimiento de la envolvente del edificio. El costo del sistema fotovoltaico y su implementación sigue siendo significativamente alto en comparación con los sistemas solares térmicos.
Palabras clave: Construcción Fotovoltaica Integrada, energías renovables, generación de energía, efecto aislante térmico.

INTRODUCTION

Solar energy is the most abundant source of energy in the world. The demand for solar electric power system has grown steadily over the last decades. The need for reliable and low cost electric power in the world is the primary force driving the world-wide PV industry today. Traditionally, a PV module is installed in open areas that are exposed to direct sunlight in order to generate electricity. However, in an urban environment, there is limited space on a building's roof, and thus the walls or building curtains can be utilized effectively for this purpose. In order to become a zero energy or zero emission building, such a building needs to harvest energy from its surroundings, where energy from the sun is one of the obvious choices [Frost & Sullivan, 2008]. PV module can be combined with construction components, such as facades, walls, windows, or roof structures, to form an integrated design. This design is known as building-integrated photovoltaics (BIPV), and this technology shows great potential for the development of more effective solar modules. Solar PV technology is a promising way to harness solar power as it generates electrical power on-site directly from solar radiation through the photovoltaic effect of the employed solar cells. Recently, building-integrated photovoltaic (BIPV) technology has become a research hotspot of solar PV technology [Zhang et.al, 2018].

The main component of a BIPV system is the PV module,that is an array of interconnected PV cells together. Usually, PV cells are manufactured from silicon materials. Silicon-based PV technologies can be grouped into three types: monocrystalline silicon, polycrystalline silicon, and thin-film amorphous silicon. Si wafer technology and thin film technology are the main technologies used for manufacture of

PV cells. Main thin-film (TF) solar cells, in particular, make use of amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium sulphide (CIS) and copper indium gallium diselenide (CIGS) and have the advantage that the semiconducting material is deposited on a substrate such as glass, steel or plastic, allowing for a wide range of architectural possibilities including the rigid or flexible nature of the modules [Frost & Sullivan, 2008].BIPV has dual purpose, as they serve as both the outer layer of a structure and generate electricity for on-site use or export to the grid. Being part of the building envelope and replacing some of its conventional components, a BIPV system will not relatively have a significant extra cost to the existing structure, and these components may also provide other functions to the building, such as shading, cladding, and insulation, in addition to being energy converters [Biyik&Araz, 2017]. The electricity produced can be partially or fully used to balance the electrical requirements of the indoor energy systems, thus, mitigating the power supply pressures of traditional power grids, and further reducing the fossil fuel consumption and greenhouse gas emissions. The prEN 50583:2012 "Photovoltaic in buildings" sets a definition of BIPV and defines a PV module to be building integrated if it provides at least one of the following functions: Mechanical rigidity, Weather protection, Energy economy, Fire protection and Noise protection [Pellegrino et.al, 2015]. The key opportunities for construction companies to embrace this emerging and exciting technology are clear enhanced economic value for their buildings deriving from far better energetic and functional performance and enhanced visual aspect [Pagliaro et.al, 2010].

PV INTEGRATION

Facades: Fig 1 represents integration of PV modules in facade. The facades provides more area for PV installation than roofs. Hence, nowadays the integration of PV on facades are more applicable for high rise buildings. The PV facades also act as shielding against harmful radiations. Thermal and noise insulation are other functions rendered by these facades. There are two types of constructive solutions for PV Multifunctional Façade: ventilated façade and double skin [Biyik&Araz, 2017].

Fig. 1. BIPV Façade

Source: (https://solarenergydesign.com)

Roofs: Photovoltaic roof tiles or shingles are usual roof tile with integrated solar cells, used for roof covering. They are tightly integrated into the roof. Many different forms are used like photovoltaic roof tiles, Photovoltaic roof shingles, and solar laminates. Fig 2 represents the BIPV roof tiles which is a part of PV integration in roofs.

Fig. 2. BIPV Roofs

Source: (https://encrypted-tbn0.gstatic.com/images)

Skylights: A PV Skylight ensures optimization of the photovoltaic generation providing at the same time bioclimatic properties of thermal comfort inside the building, as most of the UV and IR rays are absorbed by a silicon-based material that acts as a sunscreen [Biyik&Araz, 2017]. Fig 3 shows the BIPV skylights which combine the advantage of light diffusion in the building while providing an unobstructed surface for the installation of PV modules or laminates.

Fig. 3. BIPV Skylights

Source: (https://www.skycoskylights.com)

All these BIPV solutions provides an enormous future for the distributed energy approaches as an energy-efficient measurement for buildings designed under sustainable criteria. For PV integration purpose, products such as BIPV foil product, BIPV tile product, BIPV glazing product are nowadays available which act as multi- functional products.

ADVANTAGES & DISADVANTAGES

Advantages

- The PV module has a thermal insulation effect as it consists of several layers and heats up during the process of photovoltaic energy conversion. With the aid of semi-transparent PV modules it is possible to control the amount of incident daylight and thus the degree of thermal radiation [Lu & Law, 2013]
- Reduction in amount of carbon emissions due to utilisation of renewable resources [Attoye et.al, 2018]
- Providing a great opportunity for innovative architectural design and making future buildings more aesthetically appealing
- Helps to attain energy self-sufficiency in buildings, thereby providing a way to sustainable future
- Multi-layered PV modules can be used in facades to achieve higher noise insulation levels

Disadvantages

- Influenced by climate
- High initial cost
- Maintenance is difficult

RESULTS

The construction sector has been continuously undergoing drastic changes due to the rapid development. There are several types of integration but we can generally classify them in two categories: roof integration, and facade integration. The PV integration in the building facade should be promoted particularly because of the available exposed area to the solar radiations which is usually larger than the roof. The analysis of different research papers indicates that, the BIPV systems are meeting the energy demand. The high rise buildings get satisfied with the façade integration, whereas other buildings which contain large roof area matches with roof integration of PV modules.

Table 1.The potential electricity generation capacity of building-integrated photovoltaics (BIPVs) for different [(Zhang et.al, 2018), www.pvdatabase.org]

Project/Location	Integration mode	PV surface area (m^2)	Energy generated
BP Solar Skin, Norway	Façade integration	192	16 (kWh/day)
Beijing South Railway Station, China	Roof integration	7000	223.6 (MWh/year)
SetiaEcopark, Draco	Roof integration (Flat roof)	27.1	17 (kWh/day)
Bukit Jelutong	Roof integration (inclined roof)	23.3	11.2 (kWh/day)
Solar power die delfgaauwseweye, Netherland	Façade and roof integration (façade+ flat roof)	-	33 (kWh/day)

The electricity generation capacities of the BIPV projects illustrated in the table 1 shows a great diversity that is dependent on their building scale and active area. There is a wide range of BIPV electric generation capacity reported, ranging from a few kWh/year to more than 100 MWh/year.

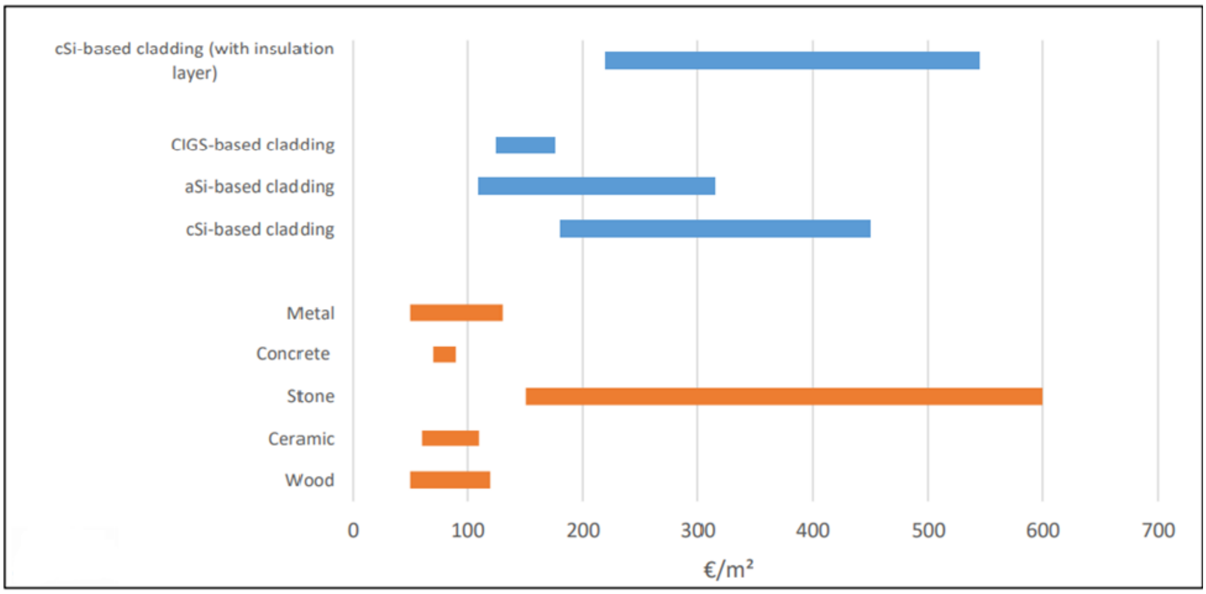

Fig. 4. Comparison of the cost of various ventilated façade cladding elements [Competitiveness status of BIPV solutions in Europe, BIPV boost]

In Fig 4, costs of different façade cladding materials are compared. BIPV elements considered here are based on three different PV technologies, namely amorphous silicon, crystalline silicon and CIGS (including semi-transparent or opaque glazing). Except for the stone as façade cladding, all the regular cladding materials have the advantage in terms of cost when put in regards of active materials. BIPV solutions based on thin-film, i.e. amorphous silicon as well as CIGS, can potentially compete with higher range bricks or wood cladding [Competitiveness status of BIPV solutions in Europe, BIPV boost].compared to glass, steel or other more conventional cladding materials, installing BIPV adds only a marginal extra cost (2%–5%) to the overall construction costs of a commercial building, in case of CIGS [Eiffert, 2003].

DISCUSSION

There are important factors such as shadowing effect, ambient temperature, the direction of the building and the slope of the PV to get higher power output and high efficiency in experimental applications. The efficiency of PV cells, area covered by PV cells influence the energy generation rate. In BIPV systems, the shading effect of PV modules can significantly reduce the heat gain through external envelopes, thus greatly affecting the heating or cooling load and further reducing the energy requirements of indoor air conditioning systems [Zhang et.al, 2018].

The BIPV systems, although have a higher investment cost compared to conventional materials, came out to be more cost-effective after payback period. Energy produced by BIPV in a year per square meter is in the range 117.98 - 161.72 kWh, slight changes may occur depending on PV cell efficiency and area covered by PV cells [Kirk Shanks, 2019].

CONCLUSION

Basic BIPV technology and applications have been extensively studied in the literature. In recent years, research efforts focus on novel designs to increase the efficiency. Through this literature review, the multiple benefits of BIPV can be identified and the prospect of the development of this technology can be demonstrated.

The majority of the BIPV performance assessment efforts focus on energetic aspects. In addition, both façade and rooftop BIPV applications are equally common in the literature. New technologies and products with a higher efficiency and lower cost are important for energy and economic payback time reduction for BIPV applications. Development of sustainable buildings can be attained with the help of available BIPV solutions and thin film technology. High efficiency with low cost BIPV products are the need of the hour, which helps in bringing energy self -sufficiency in buildings.

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