Quality Festival 2019
ISSN 2620-2832

Jasna Radulović [1]
Danijela Nikolić
Jasmina Skerlić
Mina Vasković Jovanović
Ljubiša Bojić

BUILDING INTEGRATED PHOTOVOLTAICS - POTENTIAL AND APPLICATION

Abstract: *Global environmental concerns and rapidly increase demands for energy, coupled with permanent progress in renewable energy technologies, are creating new opportunities to utilize renewable energy resources. Solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources. Photovoltaics generate electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Building integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelopes, such as the roofs, skylights or facades. There are several advantages of integrated photovoltaics over more common non-integrated systems which make BIPV one of the fastest growing segments of the photovoltaic industry. Building integrated photovoltaic (BIPV) systems may represent a powerful tool for achieving the ever increasing demand for zero energy and zero emission buildings of the near future.*
Keywords: *Solar energy, Photovoltaics, Building integration*

1. Introduction

One of the most prominent renewable energy technologie, where the sunlight is converted into electricity without interference of any heat engine, is solar Photovoltaic technology (PV).

The industry of photovoltaic technology conversion of solar irradiation shows constant economical expansion. Since 1990. the annual growth was over 20%, and from 1997. over 33%. In year 2000. total installed capacities worldwide have exceded 1000 MW, and in developing countries number of house-holds which use electrical energy generated by means of PV was more than a million. Over the last five years the global Photovoltaic systems industry has grown more than 40% annually. According to predictions, PV will deliver about 345 GW by 2020. and 1081 GW by 2030 (Tyagi et al., 2013).

Leading technology in making solar cells is silicon, even though many researchers are trying to find new technology to reduce the material costs for production of solar cells, due to high cost of silicone. Thin film technology seems like suitable substitution, but the efficiency of this technology is still low, and researchers are making effort to enhance it. Commercial matherials commonly used for PV systems, besides ilicon (Si), include solar cells of cadmium-telluride (CdTe), coper-indium-diselenide

[1] Corresponding author: Jasna Radulovic
Email: jasna@kg.ac.rs

(CIS) and solar cells made of other thin layer materials (Razykov et al., 2011).

Flexible modules used in new thin film PV technology give important perspective to PV systems, as these have possibility of simple integration in roofs and building facades. In applications where the weight is important flexible modules are very suitable and offer much faster payback than other conventional photovoltaics, which makes expectation that they will play an important role in the global PV market in the near future (Kessler et al., 2004).

This paper points out potentials and application of the building integrated photovoltaic systems which contains PV modules placed on building roof, or on building envelopes.

2. Zero-net energy buildings with BIPV

Since 1970s net energy concept has been applied in many fields, including renewable energy. Technique used as the net energy analysis compares energy delivered to society provided by technology with the total energy used to produce it in an adequate form. Net energy concept used in buildings refers to amount of energy produced in renewable system and optimization of energy consumption in buildings, thus making balance between these two (Radulovic et al., 2013).

Zero-net energy buildings (ZNEBs) refer to buildings that are connected to the energy infrastructure, and by definition, they produces all the energy that they consume over the year. They form balance between energy taken from and supplied to the energy grid over the year. The “positive-net”concept means that the electrical energy supplied to the energy grid is higher than the amount received during one year (Positive-net energy buildings – PNEBs). Thus the recommendations for better economy are to go from ZNEBs to PNEBs.

Figure 1 shows ZNEB designed with PV panels installed on the roof. Size of PV array limits the amount of generated electricity. If PV system does not satisfy the building needs for electrical energy, the remaining energy is taken from enegy network, but if PV system satisfies the building needs for electricity, then the rest of producted energy is fed into the energy grid (Nikolic et al., 2012).

The system containing PV modules placed on building roof, as well as on building envelopes, is named building integrated PV (BIPV). Nowadays semi-transparent BIPV modules are often used to permit entrance of sunlight to interior of building, maintaining the function of electricity generation. BIPV integrated in building converts from purely electrical device to a construction product. As a construction product, it generates electricity, besides other features, thus replacing commonly used elements like roof, windows, blinds, fac, etc. (Ferrara et al., 2017).

3. Rigid and Flexible BIPV modules

When BIVP module is created using available PV structures in combination with rigid substructures, like metal plates or sheets of glass, it is called rigid BIVP, and it replace conventional covering matherials for roofs, facs and ades (Figure 2). Flexible BIPVs can be constructed with organic PV (OPV), dye-sensitized solar cells (DSC), perovskite solar cells (PSC). Also, all thin-film technologies can be used, such as amorphous silicon (a-Si), microcrystalline silicon (μ-Si), a combination of a-Si/μ-Si, copper indium gallium selenide (CIGS) and cadmium telluride (CdTe), (Figure 3).

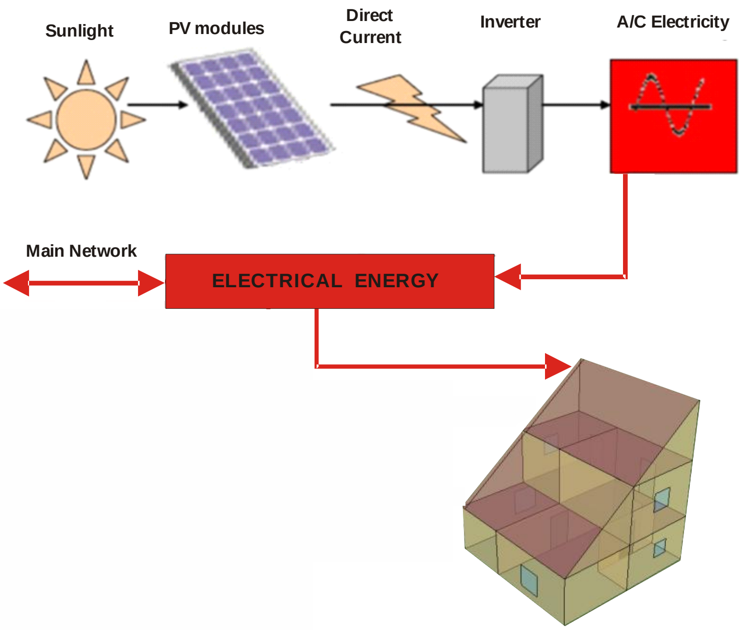

Figure1. Zero-Net Energy Building with BIPV module

Figure2. Rigid building integrated photovoltaic modules on a laboratory building of Fraunhofer ISE. The BIPV modules were developed and produced in a pilot production facility at the institute. © Fraunhofer ISE (Ferrara et al., 2017)

Figure3. Flexible thin film laminates. Global Solar – Roof with flexible CIGS laminat (Global Solar, 2015)

3.1. Potential of flexible solar cells for building integration

The Building integrated Photovoltaics (BIPV) market, which got increased political support during the last years is still one of the big hopes for TF technologies. In this context, these modules have many advantages compared to c-Si ones: strongly reduced weight for the application to the building stock, see through property, adjustable optical transmittance, excellent building appearance, potential capability for applying flexible substrates, and less sensitivity to the degradation of light intensity and increasing temperature of the module (Radulovic et al., 2014).

Flexible PV technologies in comparison with traditional Si-based photovoltaics offer a unique versatility that architects and engineers will harness to renew the facades of existing buildings, as well as in the construction of new buildings and in the development of power-generating products. Flexible solar cells provide building component manufacturers with thin and lightweight PV foils that allows integration with building materials of various architectural shapes. Combining PVs and architecture in this way is also cost-effective integration (Pagliaro et al., 2008). Flexible solar PV devices offer a convenient alternative energy source for indoor and outdoor applications. These flexible modules are suitable for applications where it is important that module weight is low, besides being flexible and easy integrated with elements of various shapes and sizes for the design of innovative energy-generating products. They offer a much faster payback than products based on conventional PVs (Pagliaro et al., 2008).

New material tehnologies, like OPV and DSC are also applicable for building integration module (Radulovic, 2014). Since OPV relies on carbon based semiconductors, low cost high volume manufacturing of flexible solar modules without any raw-material concern appears achievable. In combination with the feature that devices can be fabricated in a number of colors and levels of transparency, this makes DSC an attractive applicant for BIPV applications, making integration to building windows possible without loosing sunlight in the interior. Fortunately, cell efficiencies are stagnant at about 11% since more than 15 years and further optimization of any main component of DSC devices is not likely to yield significant efficiency improvements (Bojic et al, 2015).

4. BIPV application

PV systems can be integrated in buildings in many ways. As it is possible to use the BIPVs as construction products, with a wide range of forms, colours, patterns and flexible dimensions, many forms of roofing material, facs, ades, windows, shadings, etc. can be derived and integrated in existing buildings and new constructions. Taking into consideration the combination of roof and facades elements with additional layers, new functionalities and application of BIPV modules can be made, leading to more effective solutions in this field. The goal is a return of invested capital by electricity gained from BIPV modules. Further develpoment and impolementation will be in the urban contexts, such as bus shelters and roofs for parking lots (Ferrara et al., 2017).

Important part of BIPV integration is price. Cost of BIPVs is usualy calculated in €/Wp, or €/kWh. This is not convinient for architects and planners, so the price will be conveted to €/m^2 in the future, approaching the construction industry practice. It is expexted that the price for standard PV modules will decrease for 40-55% from today to 2030. Nowadays, additional costs for implementation of BIPVs in new constructions can be approximated by 100 €/m^2 (Ferrara et al., 2017).

5. Conclusion

Research and development of both PV and BIPV are constantly improving and it will lead to beter solutions and designs in the future, offering the wide range of integration in buildings and urban contexts.

Continious enhancement of solutions regarding increased solar cell efficiency, reduced production costs and improved building integration will eventually reduce costs and increase the market share. In a Zero-net-energy buildings scenario, photovoltaic modules integrated on building roofs, or on building envelopes are also very suitable for generating energy.

Acknowledgment: This paper is a result of project TR33015 supported by the Ministry of Science and Technological Development of Republic of Serbia.

References:

Bojić, M., Radulović, J., Nikolić, D., Miletić, I. (2015). Flexible Thin-Film Photovoltaic Technologies: In Building Integration, *Proceedings of COST TU1205 Symposium Combined with EURO ELECS 2015 Conference*, Guimaraes, Portugal, 120-127, ISBN 978-9963-697-17-5.

Ferrara, C., Wilson, H.R., Sprenger, W. (2017). Building-integrated photovoltaics (BIPV). *The Performance of Photovoltaic (PV) Systems*, 235-250. doi: https://doi.org/10.1016/B978-1-78242-336-2.00008-2

Global Solar, (2015), http://www.globalsolar.com/

Kessler, F., Rudmann, D. (2004). Technological aspects of flexible CIGS solar cells and modules, *Solar Energy 77*, 685–695

Nikolic, D., Skerlic, J., Miletic, M., Radulovic, J., Bojic, M. (2012), Energy optimization of PV panels size at Serbian ZNEB and PNEB, *Conferinta nationala cu participare internationala instalatii pentru constructii si confortul ambiental*, Editia 22, *Timisoara, Romania*, 226-234, ISSN 1842 – 9491.

Pagliaro, M., Ciriminna, R., Palmisano, G., (2008), Flexible Solar Cells, *Chemistry and sustainability, energy and materials*, 1, 880 – 891.

Radulovic J., Bojic M., Nikolic D., Skerlic J. (2014), Thin film photovoltaic technologies: status and perspectives, *45. International Congress and Exhibition on Heating, Refrigerating and Air-Conditioning*, *Belgrade*.

Radulović, J., Bojić, M., Nikolić, D., Skerlić, J., Taranović, D. (2013). The use of PV in net-zero energy buildings: challenges and perspectives. *11th International Conference on Accomplishments in El. and Mechan. Engineering and Information Technology*, 797-802

Razykov, T.M., Ferekides, C.S., Morel, D., Stefanakos, E., Ullal, H.S. (2011). Solar photovoltaic electricity: Current status and future prospects. *Solar Energy 85*, 1580–1608

Tyagi, V.V., Nurul Rahim, A. A., Rahim, N.A., Jeyraj, A., Selvaraj, L. (2013). Progress in solar PV technology: Research and achievement. *Renewable and Sustainable Energy Reviews 20*, 443–61

Jasna Radulovic
Faculty of Engineering,
Kragujevac,
Serbia
jasna@kg.ac.rs

Danijela Nikolic
Faculty of Engineering,
Kragujevac,
Serbia
danijelan@kg.ac.rs

Jasmina Skerlic
Faculty of Engineering,
Kragujevac,
Serbia
jskerlic@kg.ac.rs

Mina Vaskovic Jovanovic
Faculty of Engineering,
Kragujevac,
Serbia
mina.vaskovic.jovanovic@kg.ac.rs

Ljubiša Bojić
Faculty of Engineering,
Kragujevac,
Serbia
ljubisa.bojic@gmail.com