THE USE OF PV IN NET-ZERO ENERGY BUILDINGS: CHALLENGES AND PERSPECTIVES

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Summary: *From 31 December 2020, all new buildings shall be nearly zero-net-energy consumption buildings (ZNEBs), according to the recast of the European Directive 2010/31/EU. In a Zero-net-energy buildings scenario, Photovoltaics (PV) is very suitable for generating energy, 'on site' and 'at site'. This fact enlarges the perspective of use of PV from the architectural scale to a wider scale, including the space close to the building or even to the urban and landscape scale. The authors of this paper consider opportunities and challenges for the use of PV in ZNEBs and also perspectives for investigating the relationship between PV and ZNEBs.*
Keywords: *Photovoltaics, zero-net-energy buildings*

1. INTRODUCTION

It is generally believed that our climate is changing, and there is a growing concern about the increase in energy use and its adverse effects on the environment. Today, the renewable energy systems have a significant impact on the environment, so the development of renewable energy resources and the use of renewable energy are essential. One of the most promising renewable energy technologies is photovoltaic (PV) energy conversion. PV energy conversion represents the direct conversion of sunlight into electricity. Commercial PV materials commonly used for PV systems include solar cells of silicium (Si), cadmium-telluride (CdTe), coper-indium-diselenide (CIS) and solar cells made of other thin layer materials. PV systems are still an expensive option for producing electricity compared to other energy sources, but many countries support this technology. Over the last five years, the global PV industry has grown more than 40% each year [1]. A radical approach for the mitigation of the energy demand is the concept of the ZNEB [2]. By definition, Zero-Net Energy Building (ZNEB) produces all energy it consumes during year, and yearly electrical energy supplied to the electricity grid balances the amount received from the electricity grid.

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The topic of zero energy buildings (ZNEBs) has received increasing attention in recent years, until becoming part of the energy policy in several countries. In the recast of the EU Directive on Energy Perfor-mance of Buildings (EPBD) it is specified that by the end of 2020 all new buildings shall be “nearly zero energy buildings” [3].

From renewable energy, the building may usually produce electrical energy by the PV array on its roof. If the building is also connected to the national electricity grid, the building may consume electrical energy either from the PV array or from the electricity grid. The generated electrical energy may feed either the building or the electricity grid. The building supplies the electricity grid with electrical energy when there is the electrical energy surplus in the building. When there is electrical energy shortage in the building, the electricity grid supplies the building with electrical energy [4]. All the ZNEBs use some sort of PV technology. Photovoltaics can be used exactly where the energy is consumed (‘on-site’ energy generation). PV modules are often placed on roof tops of buildings. It can be easily integrated anywhere into the building envelope. Such system is termed BIPV (building-integrated photovoltaic), and it helps to increase the power generated per unit floor area of the building.

In a Zero-net-energy buildings scenario, Photovoltaics (PV) is also very suitable for generating energy ‘at site’. The ‘at-site’ energy generation implies that the energy generation system is detached from the building, and it is placed within the building ‘site’s’ boundary. This fact enlarges the perspective of use of PV from the architectural scale to a wider scale, including the space close to the building or even to the urban and landscape scale [5].

In this paper, opportunities and perspectives for the use of PV in ZNEBs are analyzed.

2. ZERO-NET ENERGY BUILDINGS

There have been growing interests in net zero energy buildings in recent years. Since the 1970s, the net energy concept has been applied in many different fields, from the fossil fuel and nuclear power to renewable energy. Net energy analysis is a technique used to compare the amount of energy delivered to society by a technology to the total energy required to produce it in a useful form. In the building sector, net energy is often referred to a balance between the energy consumption in a building and the energy produced by its renewable energy systems [6].

ZNEBs can be used to refer to buildings that are connected to the energy infrastructure. In ZNEBs, there is a balance between energy taken from and supplied to the energy grid over a year. By definition, ZNEB produces all energy it consumes during year. The ‘‘zero-net’’ concept means that yearly the excess electrical energy supplied to the electricity grid balances the amount received from the electricity grid. Positive-net energy building (PNEB) produces more energy than it consumes during year. The ‘‘positive-net’’ concept means that yearly the excess electrical energy supplied to the electricity grid is higher than the amount received from the electricity grid For better economy, it may be recommended for ZNEB to go toward PNEB [4].

The ZNEB designed with PV panels installed on the roof [1] is shown at Fig. 1. Electricity generated by the PV array is limited with the size of PV array.

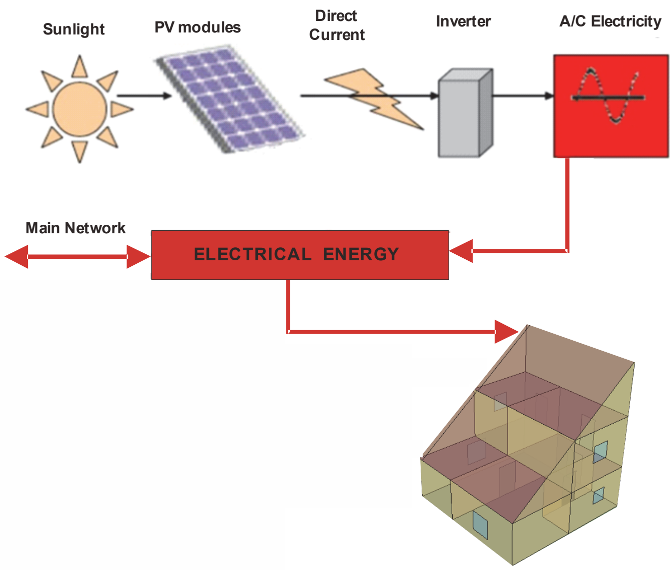

Fig. 1 *Zero-Net Energy Building with PV module*

When PV system would not directly satisfy the building needs for electrical energy, then the rest of electricity will be used from the electricity grid. When the PV system would satisfy the building needs for electrical energy, then the rest of PV generated electricity will be fed-in the electricity grid [1].

3. USE OF PHOTOVOLTAICS ON ZNEBs

PV is one of the most promising renewable energy technologies in achieving sustainable development. There have also been a number of case studies worldwide demonstrating the potential of ZNEBs to help alleviate the depletion of energy resources and the deterioration of our environment [4,7-9]. All the ZNEBs case studies shown in Table 1 adopted some sorts of PV technology.

In urban and suburban areas, PV modules are often mounted on roof tops of houses and also of non-residential buildings (e.g. offices, hotels, schools). To maximize the number of PV modules installed and hence the electrical power generated, other facades of the building envelope are sometimes utilized. Such system is termed BIPV (building-integrated photovoltaic). BIPV helps to increase the power generated per unit floor area of the building, making solar energy more viable as an alternative and/or supple-ment to the electricity grid. In recent studies semi-transparent PV modules for the building envelope are used, and it has been shown that the dual function of electricity generation and allowing daylight to enter theinterior spaces to facilitate daylighting designs is practicable [6].

Another way to increase the energy efficiency of PV is the hybrid photovoltaic thermal system (HPVT). A solar cell has a 9-18% solar-to-electric conversion efficiency, i.e. more than 80% of the solar radiation received is not converted into electricity, but either reflected or dissipated as thermal energy.

Table 1 *Summary of recent ZNEBs case studies* [6]

Region /country/ city	Ref.	Building	Renewable energy and other technologies
Hong Kong	[7]	Residential	PV, BIPV, solar hot water, wind turbines.
Las Vegas	[8]	Residential	PV tiles, solar water heater.
Madrid and Shanghai	[9]	Residential	Solar thermal hybrid HP, PV-powered reversible HP.
Serbia	[4]	Residential	PV with water-to-water HP, GSHP (ground-source heat pumps

An HPVT system makes use of thermoelectric cooling modules to reduce the solar cell temperature and takes advantage of the hot water produced by the waste heat generation. HPVT generates both electrical and thermal energy. Also, some recent studies on large-scale integration of PVs in towns have estimated that PV systems can cater for 35% of the total electricity consumption. This alleviates the burden on fossil fuels and helps to reduce the associated CO_2 emissions. However, the wide diffusion of PV generation may cause power instability and compromise the quality of existing power grid structure. More work on “smart grids” is required. Furthermore, ZNEBs should ideally be designed to function in synergy with the local utility grid and not putting extra stress on the existing power infrastructure [6].

4. CHALLENGES AND PERSPECTIVES OF PV USE

In a ZNEB scenario, PV is very suitable for generating energy, ‘on site’ and ‘at site’. This enlarges the perspective of use of PV from the architectural scale to a wider scale, including the space close to the building or even to the urban and landscape scale [5]. The energy generation is considered ‘on-site’ if the energy generation system is within the boundary of the building, namely the building’s footprint. The ‘at-site’ energy generation implies that the energy generation system is detached from the building, and it is placed within the building ‘site’s’ boundary.

As an example of ‘at-site landscape PV design’ the Solar Strand, designed by the Californian landscape architect Walter Hood, built in 2012 at the Buffalo University (USA) is given. In 2010, the University of Buffalo launched a competition for the design of a 1.1 MWp PV (5500 PV modules) system to be placed in the campus area for powering the dormitories [5,10].

The design challenge was transforming a large PV system from a mere technical system into an element of the campus landscape, which could make people more confident with the place they live in. Hood conceived an array of PV modules, whose pattern was designed as if the modules were the elements of a DNA molecule (Fig. 2).

The ground where PV is located obviously has a double function: for the student’s enjoinment, as well as for the landscape equipment.

The example we gave just imply some of possibilities for using PV in Net ZNEBs. This kind of research in future, which take into account the possibility of considering PV as a ‘Landscape-integrated PV’, will certainly be a wide field of investigation.

Fig. 2 *The Solar Strand, Buffalo University Campus, Buffalo (US), 2011. Design: Walter Hood, Hood Design. Pictures by courtesy of the architect ©W. Hood.*

5. CONCLUSION

In this paper the possibilities of PV use in ZNEBs are considered. It is shown that the 'at-site' energy generation should be approached from the Landscape Ecology perspective. The exact example of the use of PV 'at-site', considered in this study, can be appreciable at the landscape level. This gives the possibility to think about Landscape Integrated Photovoltaics (LIPV) as the next area for the PV investigation from the design point of view. It can be concluded, by looking at the ZNEB as an artificial landscape, that the traditional forms for buildings and cities will completely change in future.

Acknowledgement

This investigation is a part of the project TR 33015 of Technological Development of the Republic of Serbia and the project III 42006 of Integral and Interdisciplinary investigations of the Republic of Serbia. We would like to thank to the Ministry of Education and Science of Republic of Serbia for the financial support during this investigation.

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