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# PHOTOVOLTAICS ROLE IN BUILDING GREENER SOCIETY IN SOUTHEASTERN PART OF EUROPE

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**Abstract**

*Southeastern Europe is heavily dependent on coal and other fossil fuels for electricity generation, which contributes significantly to greenhouse gas emissions and air pollution. Electricity produced from renewable energy sources (RES) in Europe is still mostly originating from hydropower. In 2022 hydropower share in RES production was 41.6% in Europe, and specifically 51.6% in Bulgaria and 90.6% in Serbia. Although the Southeastern part of Europe has great potential for other RES generated electricity such as photovoltaics (PV), it is still not sufficiently exploited. In the year 2022, share of PV generated electricity among the other (non-combustible) renewables was 28.2% in Bulgaria, and only 0.1% in Serbia. Photovoltaic systems generate electricity in accordance with the environment, reducing air pollution and enabling creation of a greener society. This kind of system can be small residential, but also utility-scale power generation installations. PV utilization has to be supported on various levels (environmental, social, economic, legislative) to contribute to energy security, and consequently to achieve the Net Zero Emissions by 2050 Scenario. It is expected that photovoltaics will play a crucial role in enabling citizens' access to green and affordable electricity.*

**Keywords:** renewable energy sources (RES), photovoltaic (PV) systems, Southeastern Europe, green society.

## INTRODUCTION

Climate change and environmental degradation represent borderless serious threats for the whole planet. Societies and their representatives became more aware of this kind of problem appearing all over the world. Therefore, many countries have woken up to slow down climate changes and their negative effects. In 2015, the Paris Agreement was adopted, followed by the European Green Deal, adopted by the European Union (EU) in 2020 with the purpose of no net greenhouse gas emissions by 2050 and speeding up economic growth decoupled from resource use. The effects of climate policies are directed to mitigating the negative consequences of climate change with the transition of economies towards low-carbon standards. Many areas of southern Europe and old industrial regions are stagnating and lagging behind in the green transition of Europe, whereby discrepancy between big cities and rural parts is also present in many countries. Green transition is more vulnerable in less developed, peri-urban and rural regions in Southern and Eastern Europe [1].

In many countries of Southeastern Europe, electricity is still mostly produced from fossil fuels, not complying with the Paris Agreement and other regulations that should lead to the increased utilization of renewable energy sources (RES) and greener society. Having in mind that in Serbia 67% of electricity is produced from coal, followed by Bosnia and Herzegovina (65%), North Macedonia (51%) and Montenegro (41%), accomplishing the EU's long-term goal of carbon neutrality by 2050 demands the decarbonization of the




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energy systems. For countries that are still not EU members, reliance on coal for electricity production is also causing delays in EU accession negotiations. Most of the planned projects for transitioning away from coal rely on gas that is also fossil fuel and unsuitable for achieving the Green Agenda aims. Transition to renewable energy sources has to be performed, although it sometimes faces legislative and political obstacles. In many Southeastern European countries, state-owned enterprises dominate electricity markets. Grids have to be modernized and expanded, mainly because of regional interconnectivity and absorption of newly generated electricity from RES. Regional electricity market should be integrated and linked in order to make long-term sustainability. Serbia is going to finish building the Trans-Balkan Electricity Transmission Corridor that should create the basis for distributing electricity in the region and also to the EU [2].

Electricity generated in photovoltaic (PV) systems is widespread and frequently utilized as a type of renewable energy since its source is abundant and environmentally sustainable. Also, PV systems achieved technical maturity and cost-competitiveness [3].

In this paper, the current status and the role of PV systems deployment in the Southeastern part of Europe is analyzed, along with the appearing challenges and recommendations given. This paper is organized as follows. After the Introduction, the second chapter provides an overview of the RES electricity utilization, and the third chapter of the PV electricity utilization in the Southeastern part of Europe. The fourth chapter gives recommendations and solutions for increased and more efficient application of photovoltaics in the Southeastern part of Europe with the purpose of creating a greener society. Finally, there is a conclusion of the paper.

## ELECTRICITY GENERATED FROM RES IN THE SOUTHEASTERN PART OF EUROPE

The Southeastern part of Europe has generous renewable energy sources, but unexploited RES potential is still significant. When considering RES, electricity is mostly produced in large hydropower plants, whereby Southeastern Europe also has the greatest unexploited hydropower potential in Europe [4].

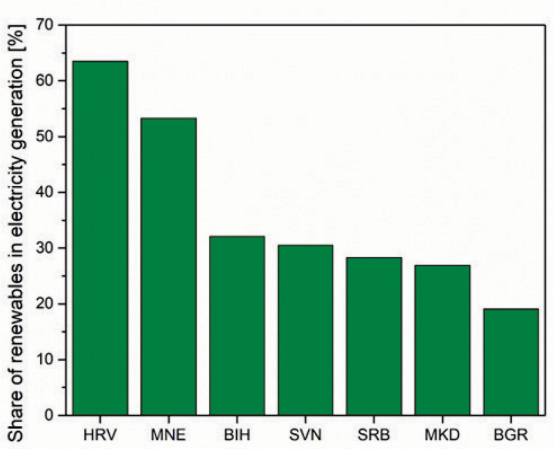


***Fig. 1.*** *Share of renewables in electricity generation in 2022 [5]*

Share of renewable electricity sources in electricity generation in 2022 was the highest in Croatia, and the lowest in Bulgaria (Fig. 1). In all countries represented in Fig. 1, renewable energy is still mostly produced in hydropower plants. Considering non-combustible renewables, in 2022, in Bulgaria the share of electricity produced from hydropower was the lowest (51.6%), and in Serbia it was the highest (90.6%) [5].

Non-EU members from the region usually receive lower financial support from the EU for speeding up the green transition. For example, Croatia and Bulgaria are going to receive 6.3 billion EUR and 6.27 billion EUR, respectively each from the Recovery and Resilience Facility funds designated for the EU members states. Western Balkan countries got for the identical aim only 1 billion EUR from the EU's Energy Support Package [2].

## PV SYSTEMS UTILIZATION FOR ELECTRICITY PRODUCTION IN THE SOUTHEASTERN PART OF EUROPE

From 2011 to 2021, the electricity capacity of installed photovoltaics increased more than 480 times [6]. In Europe, utilization of PV systems has been enlarging mostly due to higher social awareness and RES aims set to be achieved by various regulations [7].

PV power potential in Europe is presented in Fig. 2. with the estimated power output per month (Photovoltaic Power Output Potential - PVOUT) produced by unit installed capacity (1 kWp) of PV system. This variable, measured in kWh/kWp, quantifies the efficiency of selected PV technology and the influence of the air temperature because the PV conversion efficiency decreases at higher temperatures. The practical PV power potential is also limited by various operational conditions (MPP tracking, shading, PV panel soiling, grid status, local consumption, etc.) and regulatory land-use constraints. It can be seen that PV potential of the Southeastern part of Europe is greater than the average.

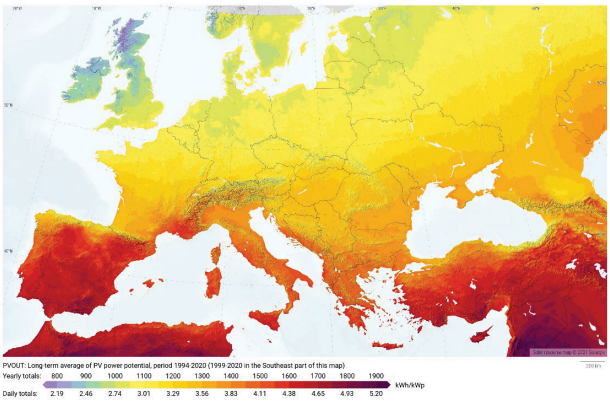


***Fig. 2.*** *Long-term average of PV power potential in Europe [8]*

When it is up to the electricity generated in PV systems, compared to other non-combustible renewable energy sources (Fig. 3), the highest share in 2022 was recorded in Bulgaria (28.2%), and the lowest in Serbia (0.1%).

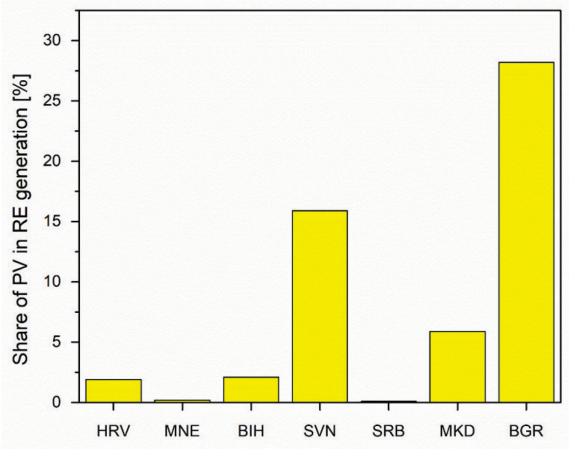


***Fig. 3.*** *Share of PV in non-combustible renewable energy (RE) generation in 2022 [5]*

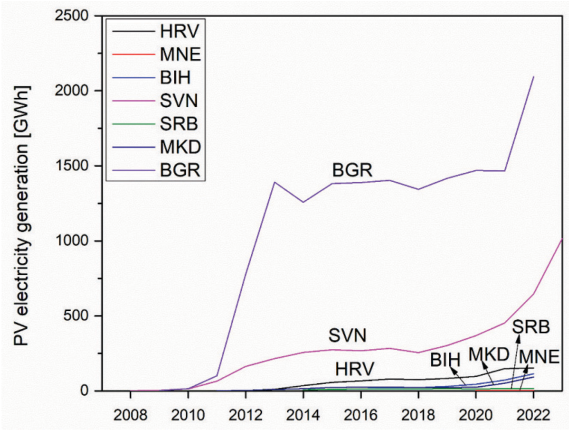


***Fig. 4.*** *PV electricity generation in the region [5]*

According to the [5], in the region, higher PV electricity generation has started firstly in Slovenia in 2008, and Bulgaria in 2009 (Fig. 4). It can be seen that PV electricity generation is the highest in these two countries. IEA has recorded the first PV utilization for electricity generation in Montenegro in 2020, thus in this country only 3 GWh was generated in 2022 [5].

The utility-scale solar technical potential of certain countries in the Southeastern part of Europe is evaluated to be approximately 114 PJ. PV solar potential for electricity production is higher in the southern part of the region. Although PV potential is more modest in northern part, it is still equal or better than in other European countries (e.g. Germany) [4].

***Tab. 1.*** *Technical potential for utility-scale solar PV in the power sector (TJ), electricity production in 2022, and calculated potential PV share for certain countries in the Southeastern part of Europe [4], [9]*

| Country | Technical utility-scale PV potential (TJ) | Electricity production in 2022 (TJ) | Calculated potential PV share (%) |
|---|---|---|---|
| HRV | 15682 | 51192 | 30.6 |
| MNE | 3874 | 11959 | 32.4 |
| BIH | 14886 | 58972 | 25.2 |
| SVN | 1613 | 49014 | 3.3 |
| SRB | 33509 | 127836 | 26.2 |
| MKD | 8014 | 21359 | 37.5 |
| BGR | 36468 | 181796 | 20.1 |

According to Table 1, it can be seen that if all the PV potential were used to the full extent, it would not be enough for the produced electricity to be dominant from this source, which indicates that smaller PV systems could be a solution for better utilization of the solar PV potential in the Southeastern part of Europe.

## DISCUSSION

Increased penetration of PV electricity into the grid in the Southeastern part of Europe requires a complex approach that deals with technical, regulatory, economic and social aspects of photovoltaics. The most important technical aspects are grid infrastructure upgrades, development of energy storage and demand response solutions technologies, as well as technologies that will improve real-time management and forecasting of production and consumption. Most of the activities are not only technical, but also require parallel actions in the legislative and political interstate field. Economic measures play a crucial role in driving PV integration into the European power grid by making solar investments more attractive and accessible.

Generation of PV electricity is not ideal and faces some challenges. It is well known that solar radiation has an intermittent nature on a daily, seasonal and interannual basis. Green transition foresees increased utilization of PV systems that can jeopardize the steady operation of the electricity systems in the cases of extended periods of decreased availability of solar radiation. On the basis of eight regional climate models, Kapica et al. analyzed the performance of solar PV, wind and solar-wind hybrid systems in Europe considering two possible climate change projections. Most models envisage an increase in the total duration of periods when solar radiation is not going to be sufficient for PV electricity generation in most parts of Europe (especially during the winter and autumn) except in its southern areas [10]. Obtained results are in line with the Intergovernmental Panel on Climate Change (IPCC) reports that predict warmer and wetter future climate with more storms, leading to more cloudy sky and consequently to lower solar radiation intensities, indicating shorter periods for PV systems peak operation [10], [11].

Analyzing PV potential should not only involve meteorological and technical aspects, but also economic, social, aesthetic or political constraints via suitability factors. Only the exclusions of technically ineligible areas are restrictive when considering PV potential. Adding economic, social, aesthetic or political constraints to technical PV potential are taking to various, but more realistic results, that in some cases can limit development objectives of photovoltaics, but more frequently make them unhindered. Social willingness and politics should not be included explicitly [12].

Improved cross-border interconnections between the countries would help balance supply and demand, making it easier to integrate high levels of PV generation across different regions. To increase RES utilization, regional collaboration is very significant, energy infrastructure has to be modernized, international partners should adjust their access to countries in the region, helping them to streamline energy policies established on local needs [2]. The development of renewable energy zones, especially in regions with high solar radiation, can provide a structured approach for increasing the production of

photovoltaic power plants in Europe, and also in the Southeastern region. This can be particularly stimulating since certain countries, such as Slovenia and Bulgaria, have a high percentage of basic electricity production from nuclear power plants. Through cooperation with surrounding countries, a great advantage for balancing energy with intermittent production from PV sources can be achieved.

For creating electricity markets greener, regional power trading is required. Liberalization of the electricity market should be performed. Because of that, an adequate regulatory framework has to be established in the region in order to create appropriate conditions for citizens and SMEs (small and medium-sized companies) to become prosumers of renewable electricity and consequently to create energy communities. For this purpose, in urban conditions, PV systems on roofs and facades are the most promising solutions. For example, in a multi-family object with a PV system mounted on the joint roof, a group of households can become collective prosumers. Successful prosumer initiatives in the EU can be examples of good practice to follow (Compile project in the Slovenian municipality of Luče, Green energy cooperative in the Croatian town of Križevci, etc.). Countries from the region that are still not EU members have to adjust their legal and regulatory frameworks that would result in more RES projects. For example, policies for reducing import duties for RES technology should be implemented. A database of the installed PV systems (and other RES systems) should be created for analysis, planning and forecasting purposes. Electricity infrastructure has to be modernized and developed to be capable of efficient utilization of new RESs. Non-EU members from the region should get greater financial support from the EU for creating a green society [2].

Policies and economic incentives that support the consumption of energy generated by on-site PV (such as net metering and peer-to-peer energy trading) can increase the share of PV while reducing the need for long-distance transmission. Self-consumption concept has become an important aim for PV electricity production since it enables electricity utilization in the place of its generation (locally generated electricity) and energy independence. Consequently, the self-consumption concept induced a special interest with industry stakeholders and citizens, making them prosumers [7]. Encouraging community photovoltaic projects is an effective way to expand solar adoption, especially in urban and suburban areas where individual rooftop space may be limited, or residents lack property rights to install PV panels. Also, incentivizing municipalities to install community PV projects on public buildings, schools, parking facilities or unused land, is helping to reduce costs and making solar energy more accessible to local residents. Distributed battery storage in homes and companies can help to stabilize the grid and store excess solar energy for use during times of low solar radiation. Some of the solutions used in other parts of Europe such as dynamic pricing to shift demand to peak hours of PV generation may contribute to a wider allocation of PV sources. These measures, with the participation of citizens, and with direct and indirect incentives from the states of the region, make community PV projects more feasible, fair and attractive, empowering people to contribute to the energy transition and benefit directly from renewable energy.

## CONCLUSION

Electricity in the Southeastern part of Europe is still mostly produced from fossil fuels. In order to create a greener society, there is a lot to do in the electricity sector, especially to increase utilization of RESs. Considering various aspects, one of the most suitable types of renewable energy systems to achieve this goal are PV systems.

Photovoltaics are not ideal and are facing some challenges, whereby the main one is an intermittent nature of solar radiation. With planned increased application of photovoltaics in the Southeastern part of Europe, technical, regulatory, economic and social aspects have to be considered. Especially significant technical aspects include grid infrastructure upgrades, development of energy storage, demand response solutions technologies, and technologies that will improve real-time management and forecasting of production and consumption.

This paper aims to point out the extremely large disproportions in the participation of renewable sources in the total balance of electricity in the Southeastern part of Europe. This disproportion is particularly pronounced in the area of photovoltaic energy sources, where certain countries, e.g. Serbia, have a very small percentage of participation in the total RES portfolio, unlike Bulgaria and Slovenia, with a significant PV participation. Also, this paper wants to point out the need for regional connectivity, bearing in mind that a different energy mix of energy sources can enable better utilization of the PV potential of the entire region. With better connectivity through electric transport corridors, this goal and other Green Agenda goals are achievable, while simultaneously initiating other measures such as normative and market changes and adjustments.

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