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SOLAR ENERGY IN THE REPUBLIC OF SERBIA: THE POTENTIAL AND LEGAL FRAMEWORK

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Abstract: This paper analyzes the potential of solar energy, the existing legal framework, and the state of installed capacities in the Republic of Serbia, in order to determine, through comparison with the European Union (EU) average, the degree of development and to identify opportunities for improving legislation. Solar energy is one of the fastest-growing renewable energy sources (RES) and a key element in achieving the European Union's climate neutrality goals. The study reviews the evolution of EU legislation, from RED I to RED III, together with the REPowerEU plan and the EU Solar Energy Strategy (2022). Serbia's solar potential exceeds the European average by approximately 30%, yet its utilization remains limited. The Law on the Use of Renewable Energy Sources (LURES) has largely transposed the RED II Directive, introducing measures such as the buyer-producer model, guarantees of origin, and market-based incentives. However, delays in adopting by-laws and incomplete harmonization with EU legislation hinder full implementation. The findings support the hypothesis that, despite favorable natural conditions and the existence of a partially harmonized legal framework, the share of solar energy in Serbia's total renewable energy capacity significantly lags behind the EU average, indicating the need for more intensive development of this sector and further alignment with EU legislation.

Key words: solar energy potential, legal framework

INTRODUCTION

Energy is one of the most important resources on our planet and is of limited availability, facing increasing global demand and sustainability challenges [1,2]. Due to rapid population growth, modern lifestyle, and technological advancement, the world's energy demand is expected to rise significantly in the coming decades [3]. According to United Nations (UN) projections, the world population will increase from an estimated 8.5 billion in 2030 to 9.7 billion in 2050 [4], which will require a substantial expansion of energy production to meet growing needs. The energy sector represents a key component of sustainable development [5], while ensuring sufficient access to clean and affordable energy sources is one of the fundamental commitments of contemporary policy [6]. Fluctuations in fossil fuel prices, climate change, and the instability of global energy markets have highlighted the need to accelerate the transition toward renewable energy sources (RES) [7]. Among them, solar energy stands out as one of the fastest-growing and most accessible forms of renewable energy, both within the European Union (EU) and globally [8,9]. It is affordable, clean, and plays a central role in the green transition toward climate neutrality. According to the International Renewable Energy Agency (IRENA), by the end of 2021 global solar capacity had reached 843 GW (gigawatts), representing a 19% increase compared to the previous year [7]. Based on IRENA data, this capacity more than doubled compared to 2017 levels. Furthermore, international reports emphasize that additional acceleration in the development of RES, and particularly solar energy, is necessary to achieve the targets of the Paris Agreement [6] [7]. Solar energy represents one of the most promising renewable energy sources, both globally and within the energy sector of the Republic of Serbia. Although the Republic of Serbia possesses significant solar potential and a legislative framework largely aligned with European standards, there are considerable differences in the level of utilization of this resource compared to the EU [10]. The aim of this paper is to analyze the potential of solar energy in the Republic of Serbia, the existing legal framework, and the state of installed capacities, and to determine, through

comparison with the EU average, the degree of development and to identify opportunities for improving legislation. The hypothesis of this research is that, despite favorable natural conditions and the existence of a harmonized legal framework, the share of solar energy in the total renewable energy capacity of the Republic of Serbia still significantly lags behind the EU average, indicating the need for more intensive development of this sector and for further harmonization of national with EU legislation. Although a harmonized and adequate legal framework is an important prerequisite, it represents only one of the elements necessary for the further development of this renewable energy source in Republic of Serbia.

The methodology encompasses an analysis of the domestic and EU legal framework, a review of relevant literature, and a comparative approach.

THE POTENTIAL OF SOLAR ENERGY IN THE REPUBLIC OF SERBIA

Solar photovoltaic (PV) energy is a widely available, environmentally friendly, and economically viable alternative to conventional energy sources [11]. According to the International Renewable Energy Agency (IRENA), in only 71 minutes the Earth receives enough solar energy to meet humanity's annual energy demand [12]. The Republic of Serbia possesses excellent potential for solar energy utilization [13]. Solar power accounts for approximately 16.7% of the country's technically usable renewable energy potential, while the energy potential of solar radiation is about 30% higher than in Central Europe, with radiation intensity among the highest in Europe [14]. Nevertheless, the utilization of solar energy in Republic of Serbia remains in its early stages [15]. According to Lambić [14], the average daily global solar radiation for a flat surface in Republic of Serbia during winter ranges from 1.1 kWh/m² in the north to 1.7 kWh/m² in the south, while during summer it ranges from 5.4 kWh/m² in the north to 6.9 kWh/m² in the south. For comparison, the average annual value in Germany is around 1,000 kWh/m², whereas in Serbia it is approximately 1,400 kWh/m². Stamenić [16] further noted that the most favorable areas in the Republic of Serbia record a high number of sunshine hours, with the annual ratio of actual irradiance to total possible irradiance being approximately 50%. According to Lambić [14], most of the Republic of Serbia records between 1,500 and 2,200 sunshine hours annually, with an average annual solar irradiation ranging from 1,200 to 1,550 kWh/m². The most favorable areas include Vojvodina and southeastern Serbia, where the potential for PV conversion is particularly high. Stamenić [16] further emphasized that, with the technology available at the time, PV conversion efficiencies between 14% and 20% were achievable, indicating significant opportunities for expanding solar installations in the country. Although the Republic of Serbia has real potential for the production and application of solar energy, these potentials are still not sufficiently utilized, despite the existence of a harmonized legal framework [13]. In order to assess the position of the Republic of Serbia in relation to the EU, a comparison of installed renewable energy capacities was carried out based on Eurostat data for 2024 [17].

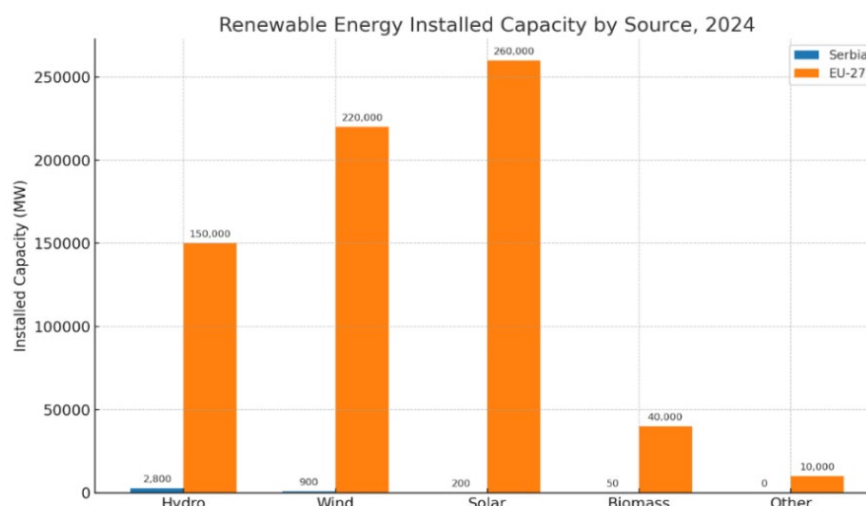


Fig. 1. Installed renewable energy capacity by source in 2024: comparison between the Republic of Serbia and the EU.

According to Eurostat [17], Serbia has a dominant share of hydropower within its total renewable energy capacities, while solar energy accounts for only a small fraction. The comparative chart of Serbia and the EU-27 clearly shows that the share of solar power plants in Serbia is several times smaller than in the EU. This outcome supports the initial hypothesis of underdeveloped solar energy deployment in Serbia, despite the existence of a harmonized legal framework.

LEGAL FRAMEWORK IN THE EUROPEAN UNION

The European Union (EU) has developed a comprehensive legal framework for RES, including solar energy, aimed at achieving climate neutrality and ensuring energy security. This framework has evolved significantly over the past fifteen years, reflecting both the EU's environmental commitments and the need to reduce dependence on fossil fuels. In the EU, solar energy has significant potential to rapidly become an indispensable part of the EU electricity and heating system and a major driver for achieving the European Green Deal objectives, while gradually eliminating the EU's dependence on Russian fossil fuels. By the end of 2020, the EU had reached 136 GW of installed photovoltaic (PV) capacity, with more than 18 GW added in that year alone. PV systems accounted for around 5% of total EU electricity generation [18]. To meet the 2030 renewable energy target proposed by the European Commission and the objectives of the REPowerEU plan, the deployment of solar energy must be significantly accelerated, requiring the installation of approximately 45 GW per year during this decade [10]. In the last decade and a half, the EU has gradually strengthened its legislation in the field of RES, adapting it to more ambitious climate and energy objectives. As a complement to the Renewable Energy Directives (RED I–III), the massive and rapid deployment of RES is central to the REPowerEU plan and the EU Solar Energy Strategy, which position solar energy as a simple and abundant resource and a key driver for reducing the EU's reliance on fossil fuels across all economic sectors [10]. In 2019, the regulatory framework known as the Clean Energy for All Europeans package was adopted, comprising eight legislative acts in the field of climate and energy. Among these are Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, which sets renewable energy targets for 2030 [19], and Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, which, among other provisions, requires that future measures and targets in the field of RES be included in the Integrated National Energy and Climate Plans (NECP) [20].

The principal legislative framework in this field is the Renewable Energy Directive (RED). Directive 2009/28/EC, adopted in 2009, established a binding target of a 20% share of energy

from RES in gross final energy consumption by 2020 [21]. This was subsequently updated by Directive (EU) 2018/2001 (RED II), which set a target of at least 32% by 2030 and required transposition into national law by 30 June 2021 [19]. Following the adoption of the European Green Deal [8], the EU adopted more ambitious climate objectives through the European Climate Law, which establishes a binding target of a net domestic reduction of greenhouse gas (GHG) emissions of at least 55% by 2030 compared to 1990 levels, and climate neutrality by 2050 [22]. Further revisions were proposed under the Fit for 55 package in July 2021, where increasing the share of renewable energy, particularly solar, was identified as a key measure to achieve these goals. The revised Renewable Energy Directive (RED III) establishes that the share of renewable energy in the Union's gross final consumption shall be at least 42.5% by 2030, with a collective aim to reach 45% [23]. RED III forms part of the Fit for 55 legislative package, which seeks to ensure that the Union reduces its net GHG emissions by at least 55% by the end of the decade.

LEGAL FRAMEWORK IN THE REPUBLIC OF SERBIA

Following the entry into force of the Stabilisation and Association Agreement (SAA) on 1 September 2013 [24], the Republic of Serbia obtained the status of an EU-associated country. By adopting the Law on the Ratification of the Treaty on the Establishment of the Energy Community [25], Serbia became a member of the Energy Community and undertook the obligation to implement European directives in the field of RES. With the adoption of the Law on the Use of Renewable Energy Sources (LURES), [26] most provisions of Directive (EU) 2018/2001 – RED II were “for the most part transferred” into the Serbian legal system (Government of the Republic of Serbia, 2021). As a *lex specialis* in the field of RES, LURES introduced a number of key innovations aimed at stimulating investment and aligning national legislation with the EU's decarbonization commitments. Among the most important innovations are new incentive mechanisms for RES-based electricity generation and provisions defining the balancing responsibility of guaranteed suppliers, in line with the EU Guidelines on State Aid for Environmental Protection. One of the most significant novelties introduced by LURES was the expansion of the prosumer concept, allowing final consumers to install their own RES facilities under simplified procedures and offset their consumption through net metering or net billing (Arts. 51–54 LURES). Another novelty was the possibility of directly concluding commercial power purchase agreements (PPAs) between RES producers and buyers (Art. 46 LURES). Studies show that the introduction of prosumers and PPAs increases market competitiveness and accelerates the integration of distributed RES generation [27]. Despite these reforms, certain regulatory gaps remained. The feed-in tariff framework was incomplete, as no model contracts or quotas were adopted, and the three-year incentive plan required by law was not implemented (Art. 14 LURES). This regulatory uncertainty discouraged investors and contributed to delays in project realization, confirming findings from comparative studies that incomplete support schemes reduce investment security and long-term RES development [28]. The market premium system, although market-oriented, required a liquid electricity market. According to the USEA study on large-scale RES integration in Serbia (2022) [29], linking the Serbian power exchange (SEEPEX) with neighboring EU markets would significantly improve liquidity and facilitate RES integration. Furthermore, studies analyzing SEEPEX and European market coupling indicate that connecting SEEPEX with day-ahead and intraday EU markets can enhance price stability, liquidity, and long-term RES integration [30][31]. Persistent delays in adopting by-laws created overlaps and inconsistencies with the Law on Energy (LE), underscoring the need for urgent regulatory harmonization. Another key innovation of LURES was the introduction of a regulated system of guarantees of origin (Arts. 49–51 LURES). A guarantee of origin (GO) is an electronic document certifying that a specific quantity of electricity has been produced from RES, in line with Article 19 of Directive (EU) 2018/2001 (RED II). In Serbia, guarantees of origin are issued by the transmission system operator (EMS), and they can be transferred,

traded, or canceled once the corresponding electricity is consumed. However, the Serbian GO system is not yet fully integrated with the European Energy Certificate System (EECS), coordinated by the Association of Issuing Bodies (AIB). Without international recognition, the tradability of Serbian GOs is limited, which reduces investment security and weakens the competitiveness of RES projects [32]. Although LURES set a six-month deadline for the adoption of all relevant by-laws, this deadline was not fully met, which led to inconsistencies with the Law on Energy (LE). Amendments to the LE were adopted in 2021 to resolve part of these issues, particularly concerning incentive mechanisms and balancing responsibility. [33] Serbia continues to harmonize its energy sector regulations with the EU acquis, and further amendments to the LE were adopted at the end of 2024 [34], introducing certification for RES system installers, new conditions for issuing energy permits in line with strategic documents, the concept of active customers and aggregators, as well as changes to the methodology for determining electricity prices for guaranteed supply. The results of the analysis show that the Republic of Serbia has a dominant share of hydropower in its total renewable energy capacity, while solar energy accounts for only a minor share. A comparison with the EU average clearly reveals that the share of solar power plants in Serbia is several times lower, which confirms the initial hypothesis of underdeveloped deployment in this sector.

Although the legislative framework in the field of renewable energy is largely harmonized with European directives and represents a key incentive for development, the achieved capacities demonstrate that normative harmonization alone is not sufficient. It is necessary to ensure additional investments, develop market mechanisms, while transparent regulation and integration into European energy markets remain essential to unlock Serbia's solar potential and enable convergence with the European average.

CONCLUSION

Solar energy plays a key role in the global transition to clean energy and in achieving net-zero emissions. It is cost-effective, clean, and adaptable, making it the fastest-growing source of energy in the EU. In this context, the REPowerEU plan, adopted and revised in 2023, aims to reduce the EU's dependence on Russian fossil fuels. As part of this plan, the European Commission presented the EU Solar Energy Strategy (2022), a comprehensive roadmap for the accelerated deployment of solar capacity. The fundamental legislative act in this field is Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II), which has since undergone three revisions. In the Republic of Serbia, the LURES is designed to support a significant increase in the capacity of facilities generating electricity from RES. The law includes numerous innovations aimed at aligning national legislation with the EU acquis while taking market realities into account. Although the law has largely transposed the RED II Directive, the provisions of the most recent RED III Directive have not yet been implemented. Key reforms include the buyer–producer model, the issuance of guarantees of origin (GO), the prosumer schemes (net metering and net billing), the possibility of concluding commercial power purchase agreements (PPAs), and the shift to market-based incentive schemes such as the market premium. A necessary step also highlighted in recent studies is the integration of the Serbian electricity exchange (SEPEX) with EU markets in order to improve liquidity and facilitate long-term RES integration. The 2024 Amendments to the Law on Energy further introduced certification of RES system installers, active customers and aggregators, as well as new conditions for issuing energy permits. Serbia's solar potential, which exceeds the European average, combined with a progressively developing legal framework, provides a strong foundation for accelerating solar energy deployment. To fully realize this potential, strategic priorities should include completing regulatory harmonization, establishing stable and transparent investment conditions, and enabling integration into the European electricity market. The findings of this research confirm the initial hypothesis: despite favorable natural conditions and the existence of a harmonized legal framework, the share of solar energy in Serbia's total RES capacity significantly lags behind the EU average.

Therefore, additional investments, the development of market mechanisms (such as commercial PPA contracts), and the accelerated implementation of secondary legislation are necessary for Serbia's solar potential to be realized at a level that would bring the country closer to the European average.

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