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ROOFTOP PHOTOVOLTAIC (PV) SYSTEMS AS A TOOL FOR LOCAL ENERGY TRANSITION IN COAL-DEPENDENT MUNICIPALITIES

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Abstract

The Pelagonia region, represented by the municipalities of Bitola, Mogila, and Novaci, is the energy core of the Republic of North Macedonia, yet also one of its most polluted areas due to the long-standing dependence on the Bitola lignite-fired power plant. In the context of the European energy transition and the need for economy-wide decarbonization, local communities play a key role in the shift towards sustainable energy sources.

This paper presents results from a project-based assessment evaluating the potential for installing photovoltaic (PV) systems on public and municipal buildings in Bitola, Mogila, and Novaci. Using PV*SOL premium simulation software, optimal installed power, expected annual electricity generation, and associated CO_2 emission savings were calculated for each building.

The results obtained enable an assessment of the realistic contribution of these systems to reducing coal dependency, while enhancing the energy autonomy of local public institutions such as schools, kindergartens, health centers and other state facilities. Based on the simulation data, the Center for Climate Change performed the mapping of the analyzed buildings and their PV potential in QGIS Cloud, providing a public and transparent visualization of the results.

The study highlights both the technical and social dimensions of the local energy transition and demonstrates that small-scale, decentralized PV systems can represent an important first step toward a post-coal future for Bitola and the wider Pelagonia region, contributing simultaneously to CO_2 reduction and improved air quality.

Key words: *decarbonization, photovoltaic systems, PV potential, CO_2 reduction, improved air quality.*

INTRODUCTION

North Macedonia's electricity sector remains largely dependent on fossil fuels, with lignite historically playing a central role, particularly through the Bitola lignite-fired power plant. The municipalities of Bitola, Mogila, and Novaci are among the most directly affected by this dependency, both economically and environmentally [1].

As energy transition policies accelerate across Europe and as decarbonization becomes a cross-sector priority, local governments and local public services (schools, kindergartens, health centers and administrative buildings) become important actors: they represent a stable electricity demand, they control significant building stock, and they can implement distributed renewable generation with relatively low land-use conflict [2]. In this context, rooftop PV systems on public buildings are a practical and immediately deployable measure—using existing public infrastructure to produce clean electricity and reduce CO_2 emissions [3,4].

This paper therefore focuses on assessing the rooftop PV potential across selected public buildings in the three coal-dependent municipalities in the Pelagonia region. The intent is to quantify the technically feasible PV capacity, estimate annual electricity generation, and indicate the scale of CO_2 emission savings [5,6]. The analysis is positioned as an evidence base for local energy planning and as a contribution to a just-transition pathway for municipalities linked to coal-based generation [7,8].

MATERIAL AND METHODS

This paper is based on the analyses conducted within the framework of a project aimed at mapping public institutions in the municipalities of Bitola, Mogila, and Novaci where rooftop photovoltaic (PV) systems could realistically be installed. To support an evidence-based assessment grounded in real site conditions, field data was collected for the full set of identified public buildings in each municipality. For each building, the project team compiled a dataset including photographic documentation, measured roof heights, roof tilt, and rooftop geometry/dimensions, enabling both an evaluation of the physical condition of the roof surface and an accurate determination of usable rooftop area for PV deployment. On the basis of these building-specific measurements and assessments, individual PV projects were developed in PV*SOL premium. Within PV*SOL premium, each rooftop PV system was technically configured (i.e., system layout and component configuration), and the software outputs provided visualizations of the designed systems together with quantitative indicators, including expected annual electricity generation, utilized rooftop area, and avoided CO_2 emissions associated with replacing coal-based electricity with PV generation. After completing the building-level designs and simulations, results were aggregated at the municipal level and across the entire study area to enable direct comparison among Bitola, Mogila, and Novaci. Finally, using the consolidated simulation dataset, the Center for Climate Change mapped the analyzed buildings and their PV potential in QGIS Cloud, providing a public and transparent visualization of the spatial distribution of assessed public institutions and their estimated contribution to local energy transition.

Current energy situation in North Macedonia

The national energy context presented in the materials indicates a continued increase in renewable energy development in 2024. Renewables account for 55.72% of the total installed capacity and 41.03% of electricity production (compared with 29.22% in 2020) [9]. Domestic generation covers 88.97% of consumption, while 11.03% is supplied through imports [9]. Photovoltaic generation increased by 186% compared with 2023, and the share of thermal power plants in installed capacity decreased from 49% in 2020 to 34.65% in 2024 [9]. These trends confirm the direction of the transition but also emphasize the need for locally implementable measures in coal-dependent regions, where rooftop PV on public buildings can serve as an immediate and visible decarbonization step.

Rooftop PV potential assessment and study objectives in coal-dependent municipalities

The purpose of this study is to evaluate how PV rooftops on public buildings can support local energy transition in coal-dependent municipalities. The work focuses on public institutions because they combine stable electricity demand with available rooftop space and can be implemented through municipal decision-making. By quantifying rooftop PV capacity, expected annual electricity generation, and CO_2 emission savings for public buildings, the study provides a practical evidence base for local planning and for prioritizing early energy transition measures. In addition to technical impacts, the study emphasizes the social and governance relevance of public-sector PV deployment as a demonstrative step toward a just transition in the Pelagonia region.

Rooftop PV potential in Bitola, Mogila, and Novaci

The rooftop photovoltaic potential was assessed for public and municipal buildings in the three coal-dependent municipalities of Bitola, Mogila, and Novaci. The results show clear differences among the municipalities, mainly due to the number of buildings analyzed and the available rooftop area. Bitola represents the largest part of the building stock analyzed and therefore has the highest estimated PV potential. Mogila and Novaci have a smaller number of analyzed public buildings and lower total rooftop areas compared with Bitola; however, their results remain important at the local level, especially considering the role of public institutions in demonstrating practical decarbonization measures. The comparative results for Bitola, Mogila, Novaci and the total analyzed area are summarized in Table 1.

Table 1. Comparative summary of rooftop PV potential in Bitola, Mogila and Novaci

Indicator	Bitola	Mogila	Novaci	Total
Number of analyzed buildings	86	20	17	123
Total rooftop area (m²)	114 859	3 958	5 974	124 791
Maximum PV capacity (kWp)	9 465	656	502	10 623
Expected annual generation (kWh/year)	12 752 357	878 171	687 502	14 318 030
Avoided CO_2 emissions (kg/year)	4 962 561	358 080	261 117	5 581 758

The aggregated results indicate that public-building rooftop PV systems can make a relevant contribution to local energy transition in the Pelagonia region. Decentralized PV generation on public institutions can reduce dependence on coal-based electricity, improve the predictability of municipal energy expenditures, and provide environmental co-benefits through reduced CO_2 emissions. Beyond the technical indicators, the results underline the importance of public-sector PV systems as a visible and socially legitimate first step in a broader just-transition process.

Figure 1 presents a representative example of a rooftop PV system design developed in PV*SOL premium for one of the analyzed public buildings in Bitola. Similar building-level PV*SOL premium simulations were performed for all analyzed public and municipal buildings in Bitola, Mogila, and Novaci, and the obtained outputs were used for the municipal-level aggregation presented in Table 1.

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Figure 1. Example of a designed rooftop PV system in Bitola (PV*SOL premium visualization)

Mapping of public institutions

The analyzed public institutions and their estimated PV potential were mapped in QGIS Cloud by the Center for Climate Change using the complete PV*SOL premium simulation dataset, in order to support transparent planning, coordination, and public communication. For each assessed building, the map includes a structured attribute set that can be accessed directly through the interactive layer, such as the municipality where the object is located, the building name, the building type (public-institution category), the maximum feasible installed PV capacity, the expected annual electricity generation from the designed PV system and the rooftop area/dimensions used in the assessment [10]. By linking these technical indicators to a geographic location, the spatial visualization allows users to understand not only the overall potential but also how it is distributed within and across municipalities. This enables municipalities to plan phased implementation more effectively (e.g., prioritizing higher-potential rooftops or clusters of institutions), to coordinate procurement and budgeting across institutions, and to communicate planned rooftop PV investments in a clear and verifiable way. In this paper, the mapping outputs presented and discussed focus on the three municipalities in the vicinity of REK Bitola—Bitola Municipality, Mogila Municipality, and Novaci Municipality.

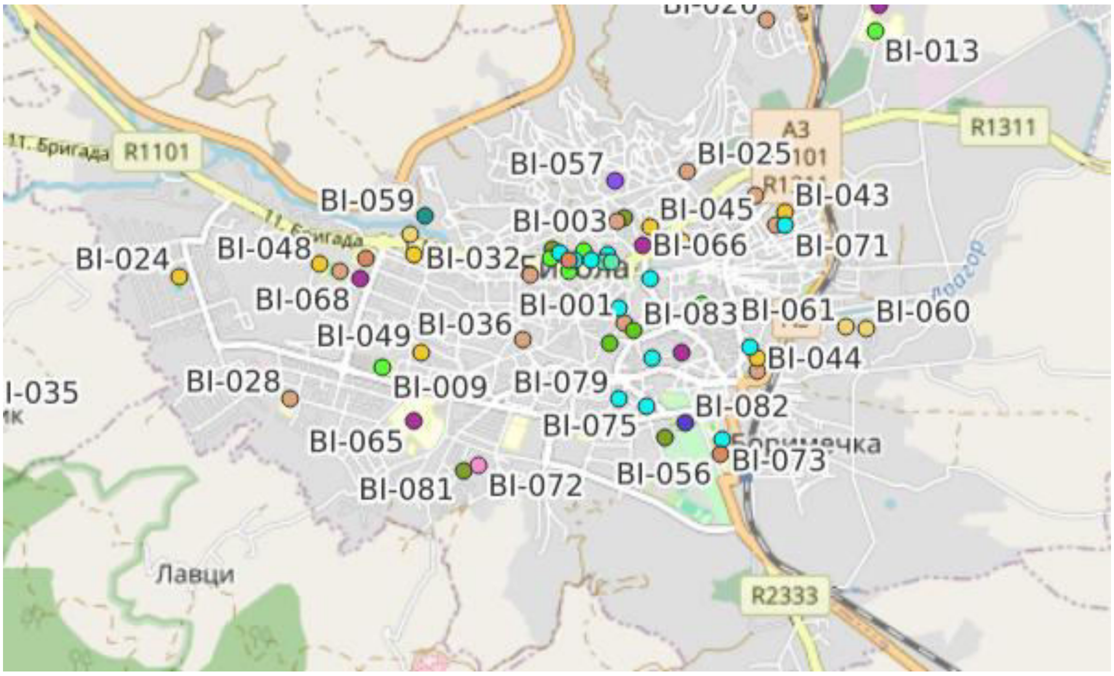

Figure 2. Close-up view of the QGIS Cloud map showing the spatial distribution of mapped public institutions within Bitola[1]

RESULTS AND DISCUSSION

The results of the assessment confirm that rooftop photovoltaic (PV) systems on public buildings can represent a meaningful and immediately applicable measure for supporting local energy transition in coal-dependent municipalities. The analysis of public institutions in Bitola, Mogila, and Novaci shows that existing rooftop surfaces can accommodate distributed renewable generation, while contributing to reduced dependence on coal-based electricity and lower CO_2 emissions.

Among the three analyzed municipalities, Bitola shows the largest rooftop PV potential, mainly due to its larger public-building stock and greater available rooftop area. This confirms that the scale of municipal infrastructure strongly influences the overall technical potential for rooftop PV deployment. However, the results also show that smaller municipalities, such as Mogila and Novaci, can still achieve meaningful energy and environmental benefits through public-sector PV systems.

Although the contribution of Mogila and Novaci is smaller in absolute terms, their role remains important in the context of local energy transition. In smaller municipalities, rooftop PV systems on schools, kindergartens, health centers, and administrative buildings can have a strong demonstrative effect. Such projects can reduce electricity costs for public institutions, increase awareness of renewable energy technologies, and support the gradual transition away from coal-based electricity.

At the aggregated level, public-building rooftops in Bitola, Mogila, and Novaci represent a significant opportunity for decentralized renewable electricity generation in the Pelagonia region. Since these systems are installed on existing buildings, they do not require additional land occupation, which is particularly relevant for coal-dependent areas where land-use planning, environmental degradation and future land repurposing are sensitive issues. Therefore, rooftop PV should be viewed not only as a technical solution, but also as one of the most accessible and lowest-conflict entry points for local renewable energy deployment.

[1] Interactive map available at: https://qgiscloud.com/imincev/solarni_krovovi_CKP_qgiscloud/

The mapping of the public institutions analyzed in QGIS Cloud further strengthens the applicability of the results. By spatially presenting each building together with its estimated PV capacity, annual electricity generation and rooftop characteristics, the mapping platform supports planning, prioritization and communication. Municipalities can use this spatial overview to identify priority buildings, group projects by location or institution type, and communicate planned investments more transparently to stakeholders and the wider public.

At the same time, the full value of rooftop PV deployment will depend on the institutional models used for implementation and management. In municipalities with multiple public institutions, coordinated planning may improve procurement efficiency, financing options, and electricity management. Therefore, the identified technical potential should be viewed not as an isolated engineering result, but as a foundation for broader municipal energy planning, including possible future models for joint coordination of public-sector electricity production and consumption [11].

Overall, the findings demonstrate that rooftop PV systems on public institutions can serve as a practical, scalable and socially visible tool for local energy transition in Bitola, Mogila, and Novaci. While the magnitude of potential differs among municipalities, all three cases show that decentralized PV generation can contribute to lower emissions, greater use of local renewable resources, and stronger institutional engagement in the transition away from coal.

CONCLUSION

This study demonstrates that rooftop photovoltaic (PV) systems on public buildings can serve as a practical and effective tool for local energy transition in coal-dependent municipalities. Through the assessment of public institutions in Bitola, Mogila, and Novaci, the research confirmed that existing rooftop surfaces provide significant opportunities for decentralized renewable electricity generation without requiring additional land use.

The results obtained show that the three municipalities together hold a considerable technical potential for PV deployment, with clear benefits in terms of annual electricity production and CO_2 emission reduction. Among them, Bitola has the largest identified potential, while Mogila and Novaci also show that even smaller municipalities can achieve meaningful energy and environmental benefits through the use of rooftop PV systems on public institutions.

Beyond the technical findings, the study highlights the broader strategic importance of public-sector PV deployment. Rooftop systems on schools, kindergartens, health centers, and administrative buildings can support municipal energy planning, reduce dependence on fossil-based electricity, and serve as visible examples of local commitment to sustainable development. In this context, the spatial mapping of suitable buildings further strengthens the practical applicability of the results by supporting prioritization and future planning [12].

Overall, the findings confirm that rooftop PV systems represent a realistic, scalable and locally applicable pathway for supporting the transition of coal-dependent municipalities toward cleaner and more sustainable energy systems.

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