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Dynamic Simulation Approach for Estimating Solar Energy Potential of the Building Environment in the Macedonian Context

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A b s t r a c t

This research develops an integrated methodological framework for assessing solar energy potential within the built environment through dynamic simulation. The approach combines LiDAR-derived spatial data, GIS-based analysis, and time-dependent solar radiation modelling to evaluate both geometric and energy-related characteristics of roof surfaces. The methodology incorporates detailed roof documentation alongside dynamic solar simulation to quantify spatial parameters and corresponding solar energy capacity at building level. The results demonstrate that solar potential is strongly influenced by roof geometry, orientation, and local climatic conditions, and that dynamic simulation provides a reliable basis for identifying suitable surfaces for photovoltaic (PV) integration. The study further highlights the role of geospatial data in enabling precise energy assessments and supporting data-driven decision-making. By linking spatial analysis with energy modelling, this research contributes to the development of a solar cadastre applicable to urban and national scales. The findings underline the importance of dynamic, GIS-based approaches in advancing renewable energy strategies and facilitating the transition toward sustainable and decentralized energy systems within the built environment.

K e y w o r d s : built environment; solar potential; GIS; LiDAR; dynamic simulation; photovoltaics (PV); solar cadastre; renewable energy

1. Introduction

Energy consumption in the social context is in direct relation to the built environment. Within the European framework, the building contributes 40% of the energy consumption. This indicator places the energy and built environment as the key role in the process of energy transition. For that reason, in this research, besides the spatial aspect, the built environment is required to be analyzed from an energy aspect.

The proposed research analyzes the roof surfaces as a segment of the building envelope that is a critical point between the built environment and solar radiation. The geometry of the roofs in Macedonia varies in different contexts, but the main characteristics are defined by slope and aspect that vary from the georeferenced location. These two features determine the capacity for solar radiation absorption. Therefore, the roof surfaces are a significant spatial category for energy production in the process of integrating PV within the built envelope.

The process of energy production within the built envelope is placed in a legislative framework. It occurs from the wider context of the energy transition discourse and the theory of the built environment within the discipline of architecture. For that reason, in this research, the energy production is analyzed from the wider context of the built environment and the narrower context of the roof surfaces. To estimate the energy capacity of the roof surfaces, this research incorporates the dynamic simulation approach, which is a time-dependent quantification of the solar energy (monthly and yearly) from the roof surfaces.

The process of dynamic simulation is dependent on the process of determining the geometric and spatial characteristics of the roof. Therefore, the methodological framework of this research incorporates documenting the built roofs. For the purpose of the documentation method, this research incorporates spatial data in point cloud format that is obtained from the national cadastral agency in Macedonia. Those data are processed in the following steps: classification, interpolation, vectorization, and extrapolation. The methodological steps are part of the methods for defining geometrical characteristics that are relevant for extracting the spatial parameters of the built roofs in the analyzed case study in Gevgelija, Macedonia. Besides the documentation method, this research incorporates the method of dynamic simulation for quantification of the influence of the solar radiation within the analyzed built roofs. The process of quantification of the energy is analyzed within two time-dependent variables: month and year. The year-time analysis is performed within the computer software ArcGIS. The results of the yearly simulation indicate the relevant segments of the roof surfaces for integrating PV systems. The monthly analysis incorporates the proportional parameters of the city of Gevgelija, depending on the monthly differences from the PVGIS tool.

1.1 Subject and problem statement

This research investigates the solar energy potential from the built environment with emphasizing of the roof elements. Given the context of the built environment in Europe, where buildings contribute 40% of the energy consumption, there is a need for research that investigates energy analysis of the building skin from the solar radiation. The recognized problem from the research occurs from the lack of a methodological approach for estimating dynamic solar energy simulation in Macedonia.

1.2 Objectives

The main objective of this research is to develop a methodological approach for the documentation of the roofs and dynamic simulation of the solar radiation influences of the elements of the built environment. These objectives require data, tools, and models. While applying LiDAR data, documentation tools, and simulation tools, the study aims to contribute to developing a solar cadastre in the Macedonian context.

1.3 Hypothesis

The principal hypothesis of the research is that dynamic simulation of the solar radiation aligned with roof documentation enables accurate estimation of the solar potential from the built roofs in Macedonia. An additional hypothesis is that roof slope, orientation, and georeferenced positioning influence the solar absorption capacity of the roofs. Therefore, integrating spatial and solar energy analysis can contribute to identifying the suitable roof area for future integration of the PV.

1.4 Structure of research

The research is structured in seven main sections. It begins with the introduction, with the segments of the context, problem, and objectives. Then this research includes a section of previous research related to the subject, materials, and methods, followed by the results, a discussion of the theoretical and empirical findings in the conclusion.

2. Section of previous research

Previous research in estimating solar potential from the built environment incorporates various approaches for dynamic simulation of solar energy (Aburmalah & Üzümcüoğlu, 2025), (Sohaimi et al., 2025), (Ilter, 2018), (Amin & Muhy Al-Din, 2019), (Gün, 2023).

The authors determine solar and PV potentials through the analysis of the roof slope, orientation, and shading (Idrovo-Macancela et al., 2025). This research differentiates between the roof surfaces and segmented surfaces that are suitable for integrating PV. The results of the analysis indicate that 68% of the roof surface is suitable for integrating PV. Similar research investigates the application of the BISE model for the simulation of solar energy, where the results indicate that 60% of the roof surfaces are suitable for the installation of PV (Molnár et al., 2022). In a similar direction, (Soha et al., 2024) incorporate a methodology for the simulation of the solar radiation in the software ArcMap within the tool “Area solar radiation”. The adapted methodology integrates the shading of the surrounding buildings. The process of simulation places high criteria for solar radiation on an annual basis, higher than 900 kWh/m². Another example integrates multi-parameter analysis of the effective solar radiation while incorporating orientation, shadows, optimal slope, and suitable roofs (Lambarki et al., 2025). This approach differentiates between roof surfaces and suitable roof surface and identifies that 61% is relevant for integrating PV. Next example applies web tools for Solar Resources Maps and GIS data for the calculation of the solar radiation through the parameters: DNI, DIF, and GHI (Soto Calvo & Lee, 2025). This research is covered at the national level in Cuba with the average daily radiation of 5,4 kWh/m². In the section on previous research, are analyzed dynamic simulation of the solar radiation within the tool CityJSON (Alfouly et al., 2025. The results of this study are placed in the optimization direction of the built form for improving the energy performance. In the direction of GRASS GIS algorithms and QGIS software, the influence of the solar radiation is analyzed on the sloped roofs, incorporating four components: direct, diffuse, reflective, and global radiation (Chiabrando et al., 2017). The analytical process is based on the DSM model with raster-based graphics and excludes the cloud patterns. The method of estimating solar radiation is a process that depends on data. The data are relevant for the documentation process, for example, by applying a drone for creating a DSM model that is base for solar radiation analysis (Mohammadzadeh Bina et al., 2025). The research analyzes this potential based on the roof type and orientation, as well as the monthly variation of the solar energy. The position of the PV on the vertical surfaces of the building envelope is the subject of the research through point-cloud and SOL algorithm (Brito et al., 2017). The vertical surfaces are analyzed through hyper points in the calculation of the hourly energy gains during the winter and summer days. The method of the solar radiation of the roof surfaces requires analysis of the roof slope and the parameters related to the orientation and georeferenced positioning (Rodríguez-Gómez et al., 2022). The research on solar simulation is analyzed in the URSUS-PV software.

The estimation of solar potential is dependent on the shadow layout of the PV systems, which is the subject of the research for mapping solar radiation (Goss et al., 2014). The algorithms applied in this research assist in the precise calculation of the PV performances. The methodology for solar analysis is based on the software PVsyst for analysis of the solar radiation as part of the sustainable energy strategies (Mewes et al., 2017). The study of the solar influences in the built environment incorporates GIS tools and climate data for the calculation of the PV integration (Massano et al., 2023). The simulation of this research is demonstrated through yearly analysis in the households in Torino.

The previous research for solar radiation includes multimodal approaches: program languages (JavaScript and HTML), ArcGIS, and QGIS (Ramafikeng et al., 2025). The results of such an approach indicate that annual solar radiation of 1499 kWh/m² has significant potential for integrating PV for energy production. Another research incorporates tools for analysis of PV integration: ArcGIS, Geo-Model, and orthophotography data from Google Earth (Aboushal, 2018). These results are applied to the process of urban planning in Alexandria.

The process of solar radiation is a data-dependent process. The data from satellite images are applied to the method of deep learning for the identification of suitable roof surfaces for the installation of the PV and energy production (Jiang et al., 2022). In the direction of deep learning and machine learning, previous research incorporates a spatial-time approach based on CNN models for remote sensing of the data for estimating energy potentials of the roof surfaces (Žalik et al., 2024). Another algorithm-based approach develops a zero-shot deep learning framework for analysis of the building skin while integrating AIoT and GIS parameters for spatial and meteorological data (Dong et al., 2025). These parameters enable a spatial and time frame for estimating solar potential in the process of integrating PV. Previous research involved a combination of machine learning, GIS data, and models for hourly estimation of the solar radiation (Walch et al., 2020). This research from the three directional approaches analyzes that 55% of the roof surfaces are relevant for integrating PV in the national context of Switzerland.

3. Materials

The proposed research is based on three pillars that are defined as the materials of the research. Within the proposed study is included the legislative framework of the built environment and the estimation of the solar potential of the built roofs. The legal and legislative framework in this research is related to the national and European context in the direction of sustainability and energy production from renewable sources. For that reason, this research incorporates the legislative framework in which directives and laws about the built environment and renewable energy are established. Besides the legal framework, this research incorporates data from spatial and climatic characteristics. The spatial data are a point-cloud model from LiDAR technology as a basis for the documentation process of the built roofs. In this part of the research, tools are applied for working with data and the simulation of solar radiation.

3.1. Legislative framework

The European legislation has numerous documents directly related to solar energy and renewable sources within the built environment. For example, the EPBD directive relates to the performance of buildings. Part of this directive is integrating PV systems in the existing and new buildings, where the actual process is dependent on the geometry and the technology of the building and the systems. In a similar direction, the European Green Deal includes the aspects of the built environment through the objectives of climate neutrality by 2050. The interrelation of the architecture and energy defines the necessity for integrating solar technology within the buildings. Another initiative is NEB, where sustainability is directly addressed. Within the initiative are included: energy, architecture, aesthetics, and technology inclusion. Part of the NEB is decentralized production of energy that is related to the sustainable communities, and recognizes energy potentials within the built environment.

Besides the European context, this research addresses the Macedonian legislative framework. The main characteristics of the national legislation are that some laws incorporate European directives related to energy efficiency. For example, the law of energy efficiency integrated the European directive 2012/27/EU on energy efficiency and Directive 2010/31/EC on the energy performance of buildings. Within this law, two documents are included: the long-term building renovation strategy and the energy performance certificate of the buildings, and the statement of compliance of the project documentation. The objectives of this law are defined from various perspectives of sustainability and renewable energy sources. In addition to the law on energy efficiency, the law on construction includes a chapter about the use of Highly Efficient Alternative Systems. This law provides specific guidelines about the installation of PV systems for energy production within the built environment. Furthermore, besides the law on construction, other laws that directly regulate objectives related to the energy production from renewable sources include the law on energy and the law on renewable energy sources. These laws define a framework for addressing solar energy within the built environment in the legislative context in Macedonia.

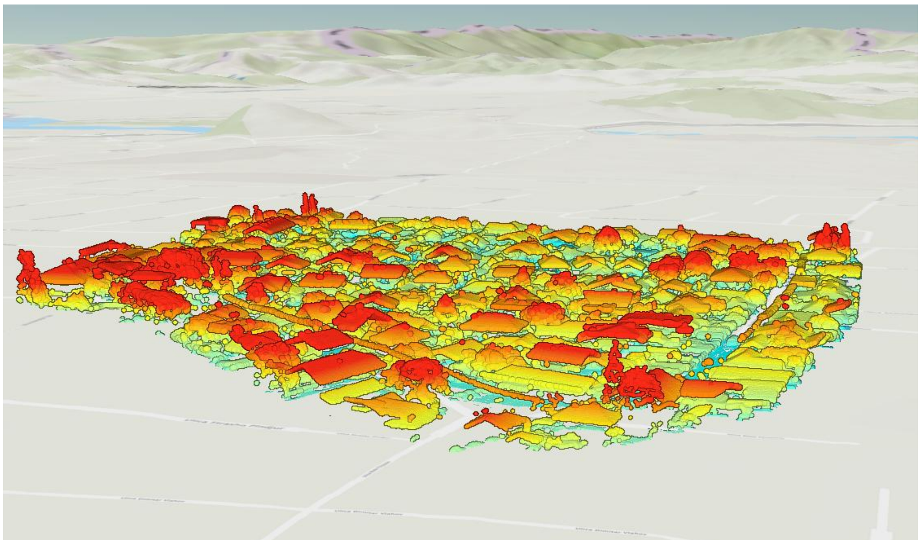

Figure 1. Point cloud data for the city of Gevgelija.

3.2. Research data

The data, especially the source of the data, is the main category for defining the spatial characteristics of the roof surfaces. From the section of the previous research, various approaches for estimating solar potential are relevant for the nature of the data and the research on the built environment. The proposed research for documentation purposes applies single-source data in the format of a point cloud from the national agency for cadastre in Macedonia. Based on the point-cloud data in combination with the research tools, various methods for documentation of the built roofs are defined. Every segment of data in this process is a result of previous documentation steps that have particularities and specifics.

Within the proposed research, the source of the data comes from the aerial laser scanning within the built environment. As a result of the aerial scanning process, spatial data is in point cloud format. These processes are usually covered in wider regional and national level of scanning and often are organized within the national institutions. In Macedonia, between 2017 and 2021, aerial laser scanning was organized by the agency of cadastre. For the purposes of this research, the authors submitted a request for the point cloud data, which was later approved by the agency. These data sets are spatial models in the format point-cloud. The quality of the data on the national level is at least 2-5 points per m². Every point of the data is in .LAZ/.LAS format and is referenced in the GIS systems.

3.3. Research tools

Based on the subject of the research, the research tools stem from the wider approaches of dynamic simulation within the built environment. The research data from its sources, complemented by the function of the research tools, are in line with the research objectives of quantifying solar energy. In this process, the source of the data is the basis for the research tools for documentation of the built roofs. The wider process of documentation requires tools for working with the actual data. These tools are part of the GIS and LiDAR technology and the wider approaches of remote sensing of spatial data. These tools are integrated into the simulation process in the software ArcGIS, which enables work with data, transformation, and analysis. The actual data are key aspects in determining the spatial characteristics of the built roofs, and their type depends on the accuracy of the parameters. Within the process of documentation of the roofs, four types of tools are applied: classification, interpolation, vectorization, and extrapolation, with the definition of roof aspect and roof slope. In addition to the documentation tools, this research integrates tools for determining the solar potential of the documented roofs. The process of solar radiation is a simulation-based approach that incorporates two main tools: quantification of solar energy and reduction of the roof parameters (orientation, slope, and solar radiation absorption). The tools for documentation and simulation within this research are applied in line with the GIS systems for georeferenced coordination. Besides the tools for annual simulation, this research incorporates PVGIS as a tool for a monthly simulation of the solar radiation.

4. Methods

Research materials in the previous section are based on two methods: documentation of the roofs and simulation of solar radiation to quantify the absorption of solar radiation.

4.1. Documentation of the roofs

The methods for documentation of the roofs are a key segment of the research because they enable the precise determination of the geometric characteristics of the built roofs. The process of documentation is related to the quantification of the spatial parameters of the built environment. The pillars of the documentation process are grounded on the data from the aerial laser scanning (LiDAR technology) and later on processed in the format of georeferenced point-cloud data. This source of data enables high spatial accuracy and a high level of detail that is a precondition for defining various levels of detail within the documentation of the built environments. The process of documentation is part of the wider approach of remote sensing and GIS, with the application of the research tools for processing, analysis, and transformation of the spatial data. The actual process of documentation from the methodological aspect is organized in the following steps: classification of the point cloud, interpolation of the classified data in raster-based models (DEM and DSM), vectorization of the roofs, and extrapolation of the geometric characteristics. The process of classification enables distinguishing the points from the ground, roof, and other elements of the built environment, while the process of interpolation enables the transformation of the point cloud into continuous spatial models. The final stage of the documentation involves the determination of the slope and aspect of the roofs within the segmentation of DSM models. These parameters are key indicators for the estimation of suitable roof surfaces for integrating the PV systems. In that direction, the methods for documentation of the roofs define the relation between spatial analysis of the roofs and the energy potential of the built environment.

4.2. Dynamic solar simulation

The methods for quantification of the solar energy from the built environment are a category that complements the spatial parameters in order to analyze the solar radiation distribution. The main direction is the analysis of the solar influences in the quantification process for estimating the possibilities for energy production while integrating PV systems within the roof surfaces in urban areas in Macedonia. That process includes three main parameters: spatial, energy, and technologically linked in one context to define the potential for energy production.

The spatial aspects are related to the geometric characteristics of the built roofs: slope, orientation, and geo-spatial positioning. The energy aspects are related to the solar radiation from the influences of the direct, diffusive, and reflective components of the solar influences in dependance of the climate and seasonal variation. The technological differences are related to the typology, efficiency, and the boundary parameters of the PV systems.

The methodological approach for dynamic solar radiation is based on an analysis that involves: defining boundary parameters of the solar radiation, quantifying the solar energy in GIS tools, and defining suitable roof surfaces for integrating PV for energy production. The process of simulation is based on raster models that are segmented into slope, orientation, shading, and dynamic aspects related to time intervals.

The results of the methodological steps for estimating solar radiation are extracting a suitable roof surface for integrating a PV system as part of the rationalization and reduction of the segments of the roof with non-relevant geometric and energy characteristics. This approach combines spatial analysis, solar potential, and possibilities for energy production from the solar influences.

4.3. Defining parameters

The applied methodology for documentation of the roof surface and dynamic simulation of solar energy defines three parameters. The nature of the parameters links the spatial characteristics of the built environment with solar energy potentials: roof plan surfaces, roof slope surfaces for integrating PV and solar energy.

The surface of the roof is the first parameter in the research and occurs from the methods for documentation of the built roofs within the analyzed urban segment. This parameter demonstrates the orthogonal projection of the entire roof. The results of the roof surface parameter are presented in raster-based models and in numerical quantities. These quantities are additionally analyzed in a chord diagram in order to estimate the categories, intervals, and the percentage distribution of the similar group values. These indicators have two main functions: on one side, understanding the urban morphology with roof size, and on the other side, a basis for the solar energy parameters.

The second parameter of the applied methodology is the segment of the roof surfaces for integrating the PV system. This indicator is the reduced area from the total roof surface because occur from the combined geometrical and solar analysis. Therefore, besides the roof surface, in this research, values for suitable roof surfaces are incorporated. While the roof surfaces show the orthogonal projection of the roof plan, the value of the suitable roof surfaces demonstrates the sloped segments of the roof that have technical criteria for integrating PV based on three conditions: a lower slope than 45°, excluding north orientation, and annual solar radiation higher than 800 kWh/m². The graphic presentation of the results is in three types: raster-based models, tables, and visual diagrams that enable spatial and statistical interpretation of the solar area distribution.

Figure 2. Capacity for solar radiation absorption.

The parameters for solar energy are related to the dynamic simulation of the influences of the solar radiation on the suitable roof surface for integrating PV. This parameter demonstrates the ability for solar radiation absorption and defines the solar energy capacity. The process of quantification of solar energy is based on the raster model and considers the slope, orientation, and absorption capacity. The results in solar energy are analyzed on the annual level in the unit MWh. The results are presented in three ways: raster model, table, and analytical diagram. The analysis of solar energy is directly related to the roof morphology, built density, and the orientation of the surface segments for absorption of the solar radiation.

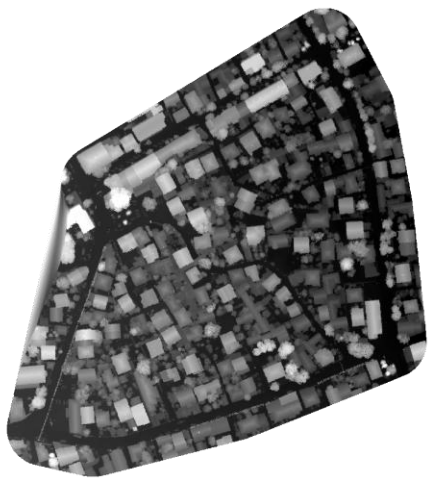

Figure 3. Integrated raster model.

5. Results

The results of the research respond to the applied methodology for the documentation of roof surfaces and the dynamic simulation of the solar influences. Applied materials and methods resulted in two time-dependent results on an annual and a monthly basis.

5.1. Annual results

In the central urban area of the city of Gevgelija, an analysis segment with surfaces 57575,73 m². Within the segment are recognized 71 buildings that are systematically presented in the table labeled with GE and then the number of the building itself.

5.2. Roof area

The results of the roof area are obtained by applying point-cloud data and the methodology for documenting the roofs. The roof area of the analyzed buildings within the segment has a value of 24683,98 m². Within the analyzed example, the values are distributed in 7 categories. The values have the following intervals: 37 buildings with roof surface from the interval 100-300m², 17 buildings 300-600m², 8 buildings below 100m², 4 buildings 600-900m², 2 buildings 1200-1500m², and 1 building 900-1200m². The distribution of the categories suggests that one interval has the highest number of buildings, which characterizes a one-modal pattern.

5.3. Suitable roof area for integrating PV

The results of the suitable roof area for integrating PV are a consequence of the method for rationalization of the roof surfaces and excluding the following areas of the roof: a slope greater than 45°, north orientation, and annual solar radiation lower than 800 kWh/m². The suitable roof area of the analyzed buildings within the urban segment of Gevgelija has a value of 15478,63 m². The values in the individual buildings are distributed in categories: 34 buildings 50-150m², 18 buildings 150-300m², and the other categories have lower than 10% in comparison with these two intervals. The results of the suitable roof surfaces indicate that the distribution value has a two-modal pattern with a high concentration of the two intervals.

Figure 4. Suitable roof surfaces for integrating PV.

5.4. Solar energy

Besides the geometric parameters of the roof surface, the results of this research include the values of the solar energy. These values are the result of the materials for climatic data and methods for solar simulation. The solar energy capacity of the suitable roofs within the analyzed urban segment of Gevgelija has the value of 16826,50 MWh. The values of the results are distributed in 6 categories. The highest interval of 26 buildings has a value of 100-200MWh, then 200-400MWh, and 50-100MWh. These results of the solar energy indicate that two categories have the highest number of buildings. The distribution shows that solar energy has a two-modal pattern of values for solar energy from suitable roof surfaces.

5.5. Monthly results

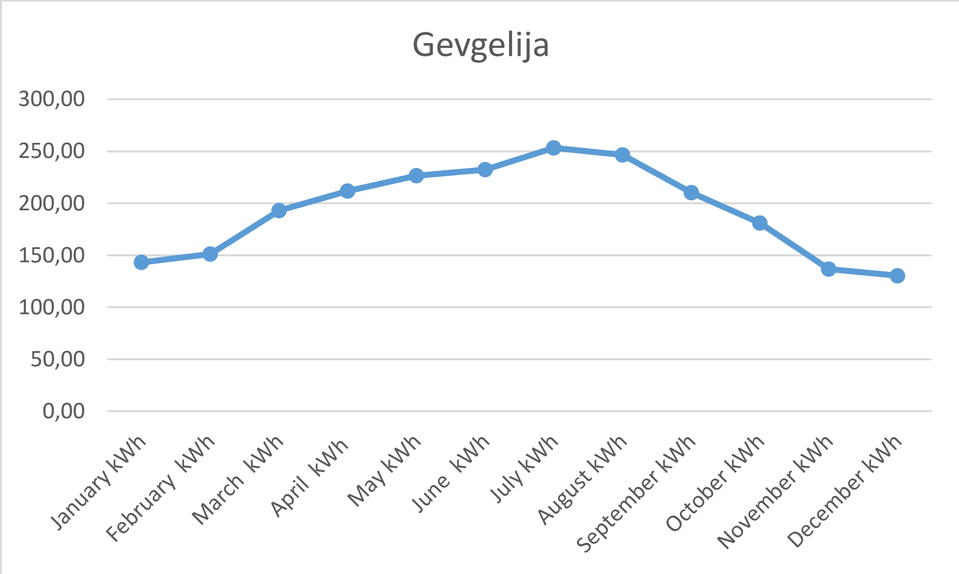

Figure 5. Monthly dynamics of solar energy potential.

The process of dynamic simulation in this research is analyzed in annual and monthly time-dependent intervals. In the previous section, the annual indicators were analyzed, but in this section, the monthly results are presented. The method for estimating the monthly differences is based on the PVGIS platform. This method indicates that annual energy capacity has differences based on the monthly solar radiation pattern. Therefore, the results show that depending on the microclimate and the georeferenced positioning of every building, the solar energy values are calculated for each month separately. These results for the energy capacity on a monthly basis show the difference in solar energy between time intervals that define the dynamic simulation process.

6. Discussion

This research involved a methodological approach for estimating the solar potential of the built roofs by the example of the segmented urban fragment in Macedonia. The research framework integrated LiDAR data, GIS tools, and the process of dynamic simulation to analyze solar potentials of the built environment. The spatial results of the research demonstrated that geometric parameters of the slope and orientation have key influences in determining the solar potential. In a similar direction, the results from the methodology of the solar simulation demonstrated rationalization of the roof surfaces through segmentation of the suitable roof surface that contributes to the research foundations in energy discourse. The applied methodology of this research is analyzed within the segmented urban area, but the results can be implemented at the wider urban and national levels.

The results demonstrated that the urban areas with Mediterranean climatic influences, according to the example of Gevgelija, have a roof-built density of 4287,22 m²/ha. Besides the roof density, the results demonstrated that a suitable roof for integrating PV for the analyzed location has a value of 2688,39 m²/ha. According to the defined spatial and climatic circumstances, the capacity for absorption of solar radiation on the annual level has a value of 2922,50 MWh/ha. In this research, a comparative analysis is conducted for dynamic simulation at the annual and monthly levels. This process indicated that solar energy depends on the time framework. Therefore, the time-dependent processes are a crucial segment in the research discourse of the energy and built environment. Besides the positive characteristics, this research has limitations that are related to the data source and the method of documentation and simulation. Applied data has a single source; likewise, the applied methodology is a single software for documentation and simulation. These limitations need to be considered in future research where data and the way of documentation and simulation would be analyzed by multiple sources and multiple software.

In addition, future research suggests analysis of the PV cells in order to determine the final electrical energy that can be generated based on the elements of the built environment. The future research also suggests an analysis of the energy consumption patterns in order to compare the capacity of production and consumption.

7. Conclusions

This research developed and validated an integrated methodological framework for the documentation and dynamic simulation of solar potential within the built environment in Macedonia. By combining LiDAR-based spatial data, GIS tools, and time-dependent solar radiation modelling, the study confirms the central hypothesis that dynamic simulation, when aligned with precise roof documentation, enables reliable estimation of solar energy potential at the level of individual roof segments.

The methodological approach proved effective for extracting detailed geometric characteristics of roof surfaces through classification, interpolation, vectorization, and extrapolation of point cloud data. These processes established a high-resolution spatial basis for analysis, demonstrating that accurate determination of slope, orientation, and georeferenced positioning is a critical precondition for assessing solar energy potential in complex urban morphologies.

The results highlight that only a portion of total roof surfaces is suitable for photovoltaic (PV) integration, with suitability primarily determined by slope, orientation, and solar radiation thresholds. The study further demonstrates a clear relationship between urban form, particularly building density and typology of the distribution of solar energy capacity. This confirms that solar potential is analyzed beyond the climatic parameter together with spatial-architectural one, shaped by the morphology of the built environment.

A key contribution of this research lies in its applicability to the development of a solar cadastre in Macedonia. The proposed framework supports multi-scalar implementation from various scales. Such an approach from the individual building to the national level supports practical tool for spatial planning, energy strategy development, and policy alignment. In this context, the methodology enables scenario-based evaluation of PV integration, energy production, storage, and potential distribution within decentralized energy systems, consistent with European and national sustainability objectives.

Despite its contributions, the research is subject to limitations related to the reliance on a single data source and a single software environment for both documentation and simulation. Future studies should explore the integration of multi-source datasets, alternative modelling platforms, and higher-resolution climatic inputs to improve robustness and comparability of results.

Further research directions include the incorporation of PV system performance parameters to estimate actual electricity generation, as well as the analysis of energy consumption patterns to evaluate the balance between production and demand. Expanding the methodology to other components of the building envelope, such as façades, and integrating cross-scale energy modelling could enhance its relevance for achieving long-term energy independence and supporting the transition toward low-carbon built environments by 2030s and 2050s.

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Conflicts of Interest
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Institutional Review Board Statement
Not applicable.

CRediT Author Statement
All authors have read and approved the final version of the manuscript.

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