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# Spatial Opportunities and Challenges in Solar Energy Infrastructure in Durrës Region: A Post-Communist Industrial City

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## Abstract

*Albania is undergoing a profound energy transition, moving from a hydropower-dominated electricity system towards a more diversified renewable mix in line with European Union climate and energy objectives (EUKI/GIZ, 2024). The coastal city of Durrës Albania's second largest urban centre and a key industrial and transport hub represents a strategic testbed for scaling up solar photovoltaic (PV) infrastructure in a dense, post-communist urban fabric. Drawing on geographic information systems (GIS) and remote sensing (RS), this article assesses the spatial suitability of roofs, industrial zones and brownfield sites in the Durrës region for the deployment of solar energy infrastructure. Annual solar irradiation in much of Albania ranges between 1,500 and 1,700 kWh/m², with particularly favourable potential along the western coastal belt, creating favourable conditions for PV deployment. (Ministry of Infrastructure and Energy, 2016) This study argues that a GIS-based, spatially explicit approach can support evidence-based decision-making for solar infrastructure in post-communist cities, helping local governments and national authorities to prioritise investments, align with emerging building-energy standards, and design pilot "solar districts" that combine decarbonisation with urban regeneration.*

**Keywords:**
*solar energy, GIS, remote sensing, urban planning, post-communist city, Durrës, Albania*

## 1. Introduction

Across Europe, the low carbon transition is increasingly recognized as a spatial process that reshapes infrastructures, land use patterns and urban regional development trajectories. (Bridge, 2013)

In Central and Eastern Europe and the Western Balkans, this transition unfolds within specific post communist legacies of industrialization, central planning and uneven infrastructural investment. (Andrew Barry, 2024).

Albania is emblematic in this regard: while its electricity mix has historically relied on hydropower, recurrent droughts and rising demand have exposed the vulnerability of a mono resource system and pushed policymakers to diversify towards solar and wind energy. (Europian Agency, 2025)

Albania's solar resource is comparatively favorable. National assessments estimate average annual global horizontal irradiation between approximately 1,500 and 1,700 kWh/m², with higher values in parts of the western lowlands. (NREAP & OeEB, 2024)

Recent strategic documents such as the National Renewable Energy Action Plan (NREAP), the National Energy and Climate Plan (NECP) and the 2030 Renewable Energy Sources Development Strategy highlight solar PV as a priority for enhancing energy security and meeting 2030 targets for renewable energy and greenhouse gas reduction. (EUKI/GIZ, 2024) At the same time, the legal framework has been updated to introduce competitive auctions, investor protections and specific rules for self consumption and prosumers, while new building energy requirements are set to make rooftop renewables obligatory for new and renovated constructions from 2026 onwards. (Global, 2025)

Within this national context, Durrës Albania's second largest city and main maritime gateway plays a pivotal role. Durrës combines dense residential neighbourhoods, an extensive industrial belt (including port-related activities in Shkozet), coastal tourism, and a rapidly transforming peri-urban fringe. This complex urban industrial landscape concentrates both vulnerabilities (exposure to coastal flooding, heatwaves and ageing infrastructure) and opportunities for decarbonization through distributed solar generation and building-integrated photovoltaics (BIPV). Yet, despite high solar potential and emerging policy incentives, the spatial planning of solar energy infrastructure at city-region scale remains weakly institutionalized.

The main objective of this study is to argue for the use of geospatial data in assessing the spatial opportunities and constraints for solar energy infrastructure in the Durrës Region by evaluating a GIS- and RS-based framework. The study addresses three core questions:

- How can geospatial data and GIS tools be used to map the technical suitability of rooftops, industrial areas, and brownfield sites for solar energy?
- What are the main spatial patterns used to assess spatial opportunities

and identify priority zones for solar investment?

- Which socio-institutional challenges and planning constraints hinder the realization of this technical potential in a post-communist urban context?

By combining spatial analysis with an interpretive discussion of planning and governance issues, this study contributes to three strands of literature: (i) GIS-based solar potential assessment and site selection, (Y. Choi, 2019)(ii) research on urban energy transitions and post-socialist infrastructures, (Tuvikene, 2019) and (iii) policy debates on Albania's renewable-energy diversification and urban sustainability. (EUKI/GIZ, 2024).

While the empirical focus is on Durrës, the conceptual and methodological insights are relevant for other coastal, post-communist cities in South-East Europe seeking to integrate solar energy into urban development strategies.

## 2. Conceptual framework: Solar energy and post-communist urban transitions

The energy transition literature has increasingly emphasized the importance of space, place, and scale in understanding how low-carbon systems are built, contested and governed. (Bridge, 2024) From this perspective, energy transitions are not purely technological shifts but involve the reconfiguration of infrastructures, landscapes, and socio-political relations. In post-communist contexts, this reconfiguration is shaped by the legacies of central planning, deferred maintenance, fragmented ownership after privatisation, and often limited local fiscal capacity. (Tuvikene, 2024)

Post-socialist urban infrastructures water systems, district heating networks, transport corridors, and industrial zones have been characterized by path-dependent lock-ins, uneven modernisation and socio-spatial inequalities. (Tuvikene T. , 2019) At the same time, they offer "infrastructural leverage points" where targeted investments in renewable energy and efficiency can yield disproportionate benefits in terms of emissions reduction and service quality. Rooftops of public buildings, former industrial sites, logistics hubs, and large retail complexes are such leverage points for solar energy, especially in medium-sized cities with constrained land resources.

Recent work on local energy transitions in post-socialist settings shows that ambitious renewable-energy projects emerge where supportive policy streams, local coalitions and strategic visions converge. (Toplišek, 2020). However, the realization of such projects often encounters barriers: complex land-tenure structures, outdated land-use plans, lack of granular data on buildings and networks, and limited inclusion of energy considerations into master plans and zoning regulations. The adoption of GIS-based tools for mapping solar potential is thus not merely a technical exercise; it is part of a broader shift towards evidence-based, spatially explicit planning that can empower municipalities and regional actors.

In this article, the Durrës Region is conceptualized as a post-communist urban–industrial landscape where solar energy infrastructure intersects with multiple planning agendas: port expansion, coastal risk management, industrial restructuring, housing rehabilitation, and heritage conservation.

## 3. Urban and environmental context of Durrës

Durrësi is one of the most important nodes of transport in the country. Through this city cross and develop themost important national and international road axes and maritime links as: East-West Corridor (262 km), part of the pan-European Corridor VIII, North-South Corridor, 405 km (Hani i Hoti-Tirana-Durres, Vlora, Saranda- Greece / Durres-Gjirokastra-Kakavija / Durres-Greece), and Durres-Kukes-Morine (180 km). (Sonila Xhafa, 2013)

Durrës lies along the central Adriatic coast of Albania and forms part of the country's most urbanised and economically dynamic corridor connecting Tirana, Durrës and the surrounding municipalities.

With a population of several hundred thousand residents in the wider urban area, the city combines:

- A dense historic core with mixed residential and commercial uses;
- Extensive post-war housing districts with mid-rise apartment blocks;
- A major seaport and logistics platform;
- Industrial and warehousing zones, notably in Shkozet and adjacent areas;
- Rapid suburbanisation and coastal tourism development along the littoral.

The city of Durrës is located in the southwest of Durrës County and is bordered by the waters of the Adriatic Sea. The main economic activities include tourism, maritime transport, trade, manufacturing industries, and services.

The natural conditions of the city strongly support economic and urban development. The advantages offered by its coastal–hilly relief, Mediterranean climate, water resources, vegetation and fauna, as well as its coastline with beaches and bays, have facilitated the use of urban space for diverse economic and human activities.

The rapid population growth during the transition period was accompanied by increasing human pressure on nature and biodiversity, leading to degradation and in some cases, loss of important natural resources and habitats. Under these circumstances, the conservation and sound management of natural resources hold particular importance for achieving the sustainable development objectives of the region.

The city is exposed to a combination of climate and environmental risks, including coastal flooding and sea-level rise, heat stress in dense built-up areas, and seismic vulnerabilities in older building stock. These risks heighten the need for resilient and sustainable urban planning, where renewable energy is integrated with adaptation and regeneration strategies.

National-level assessments show that Albania's coastal belt, including the Durrës region, benefits from relatively high solar irradiation, typically in the range of 1,500–1,700 kWh/m² per year. (Ministry of Infrastructure and Energy, 2016)More recent investment promotion documents emphasise that certain areas may reach or exceed 1,700 kWh/m² annually, underscoring the economic viability of PV installations on non-arable land and degraded sites. (AIDA, 2024)

Policy-wise, Albania's 2030 energy and climate framework aims to increase the share of renewables in final energy consumption and to expand non-hydro capacity, including at least several hundred megawatts of solar PV. (EUKI/GIZ, 2024) The legal framework for renewable energy has been updated to align with EU rules, introduce auctions and guarantee grid access for qualifying projects. (Global, 2025) In parallel, new draft regulations on building performance foresee that from 2026 onwards, new and substantially renovated buildings will need to include on-site renewable energy systems most often rooftop solar thus directly linking urban development with solar deployment. (News, 2024)

These national commitments create a favourable, though still evolving, enabling environment for municipal and regional solar initiatives in Durrës. However, the translation of targets into concrete projects depends on planning instruments, data availability and local governance capacity, which remain uneven.

## 4. The role of geospatial data and GIS- and RS-based solar suitability assessment  opportunities for solar energy development

Spatial planning and regulatory studies are considered essential development instruments and an urgent necessity, particularly in urban centers affected by the spontaneous and informal developments of the transition period, unplanned demographic growth, mismanagement of land, and lack of control over urbanisation processes. The rapid increase in population during the transition was accompanied by growing human pressure on nature and biodiversity, leading to degradation—and in some cases loss—of important natural resources and habitats. Under these conditions, the protection and sound management of natural resources are crucial for fulfilling the sustainable development objectives of the region. Likewise, assessing the opportunities for the use of renewable resources is of great importance, and in this regard, geospatial methods play a key role.

GIS methodology represents one of the most important tools and instruments for organising, integrating, and processing spatial information (cartographic, imagery, planimetric), statistical data (databases, statistical reports), graphic outputs, and analytical products. It supports the execution of integrated geographic, management, and spatial planning analyses; the identification of optimal development alternatives for different areas; and the determination of the most suitable ways to manage and use natural resources efficiently, in support of the sustainable use and development of the urban territory.

This city lies within the subtropical belt (with mild, wet winters and hot, dry summers), in the lowland Mediterranean climatic zone, and specifically in the central Mediterranean lowland sub-zone.

The city of Durrës belongs to the medium-warmth belt. Each cm² of horizontal surface receives approximately 133.3 k/cal, and consequently, Durrës experiences about 2,786 hours of solar sunshine per year. (NASA, 2023)

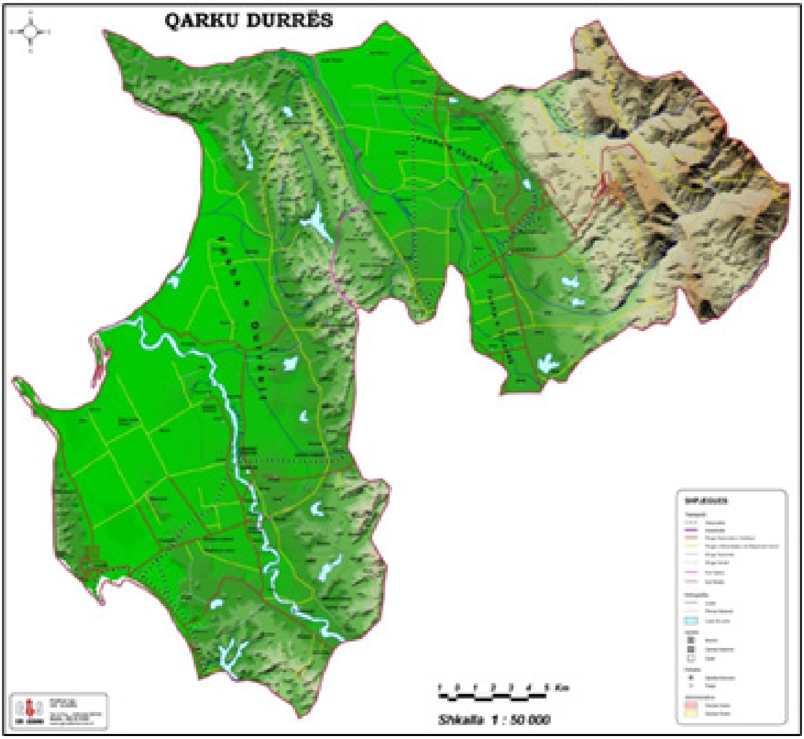
From the second week of April to the end of November, when cyclonic air masses prevail, the ten-day average cloudiness is around 5 oktas, with 7–8 overcast days and 210–220 days with sunshine. In July–August, cloudiness drops to about 2 oktas, with only 1–2 overcast days and approximately 335–350 days with sunshine. (NASA, 2023)

Durrës is characterized by a high number of sunshine hours. Over the course of a year, the city receives 2,026 hours of sunlight. The month with the most sunshine is July, with 356 hours, while the lowest number of sunshine hours occurs in December, with 108.7 hours. (Hidrometeorologjik, 1985)

The high number of sunshine hours in the urban areas of the Durrës district is important to consider as a significant source of alternative energy through solar panels.

The use of geospatial data has become a fundamental component in assessing spatial opportunities for solar energy development, particularly in urban and regional contexts where competition for land use is high. GIS- and Remote Sensing–based analyses enable the identification, classification, and evaluation of factors that directly influence the technical and spatial suitability of photovoltaic (PV) installations. By integrating diverse data sources topographic, environmental, infrastructural, and building-related—robust analytical models are generated that support strategic planning and informed decision-making in the energy sector. In this context, some of geospatial data the can be used in this case are:

- Digital Elevation Model (DEM) used to derive slope and aspect, resampled to an appropriate resolution for urban-scale analysis (e.g., 10–30 m); The Digital Elevation Model (DEM) is used to extract essential parameters such as slope and aspect, which directly influence the capture of solar energy. Solar radiation data, generated through the Solar Analyst tool in ArcGIS, provide accurate annual or seasonal estimates of solar exposure by integrating topographic and atmospheric characteristics. Using the DEM, slope and aspect layers are derived through standard GIS functions. For ground-mounted PV installations and large rooftops, slopes below 10° are generally preferred to reduce shading, ease mounting and lower construction costs. (Puusepp, 2019). In this study, slope is reclassified into three ordinal classes: 0–5°: very favorable (score 1.0); 5–10°: moderately favorable (score 0.7); 10°: unfavorable (score 0.2). Aspect is similarly reclassified, with south-facing slopes (S, SE, SW) receiving higher scores due to better annual solar exposure in the Northern Hemisphere, while north-facing slopes are penalised. Flat rooftops are treated as having optimal or adjustable orientation, depending on structural conditions.




**Map 2:** Physical–geographical characteristics of Durrës County  (Xhafa, 2015)

-Land-use and land-cover (LULC) data, derived from high-resolution satellite imagery such as Sentinel-2, enable the identification of suitable areas and the exclusion of conflict-prone zones, including forests, high-value agricultural land, or protected habitats. Land-use classes are used to filter out areas that are not appropriate for solar deployment (e.g., dense forests, wetlands, high-value agricultural land, strictly protected zones) and to highlight preferred categories:

a.Rooftops of public, commercial and multi-family residential buildings;

b.Industrial and logistics land (including warehouses and port-related facilities);

c.Brownfield and under-utilised land within the urban area;

d.Degraded or low-productivity land on the urban periphery.

This logic draws on “brownfields to brightfields” approaches that prioritise the reuse of contaminated and post-industrial land for renewable energy, thereby coupling decarbonisation with regeneration and land recycling. (Esri, 2021)

-Building footprints, represented as vector polygons for public, commercial, and residential structures, enable the assessment of rooftop potential for PV installations by analyzing their surface area, shape, and spatial positioning within the urban landscape.

-Infrastructure data, medium- and high-voltage electricity network, substations, as well as major roads, rail lines and port facilities; Distance to the existing electricity grid is a critical determinant of economic feasibility, as connection costs can significantly affect project viability. A buffer analysis is performed to classify locations within 300 m, 300–1,000 m, and beyond 1,000 m from medium- or high-voltage lines and substations, assigning decreasing suitability scores with distance. (Puusepp, 2019). Proximity to major roads and port infrastructure is also considered beneficial, as it facilitates construction, operation and maintenance of PV facilities. Buffers around main roads and the port area are thus included as secondary criteria.

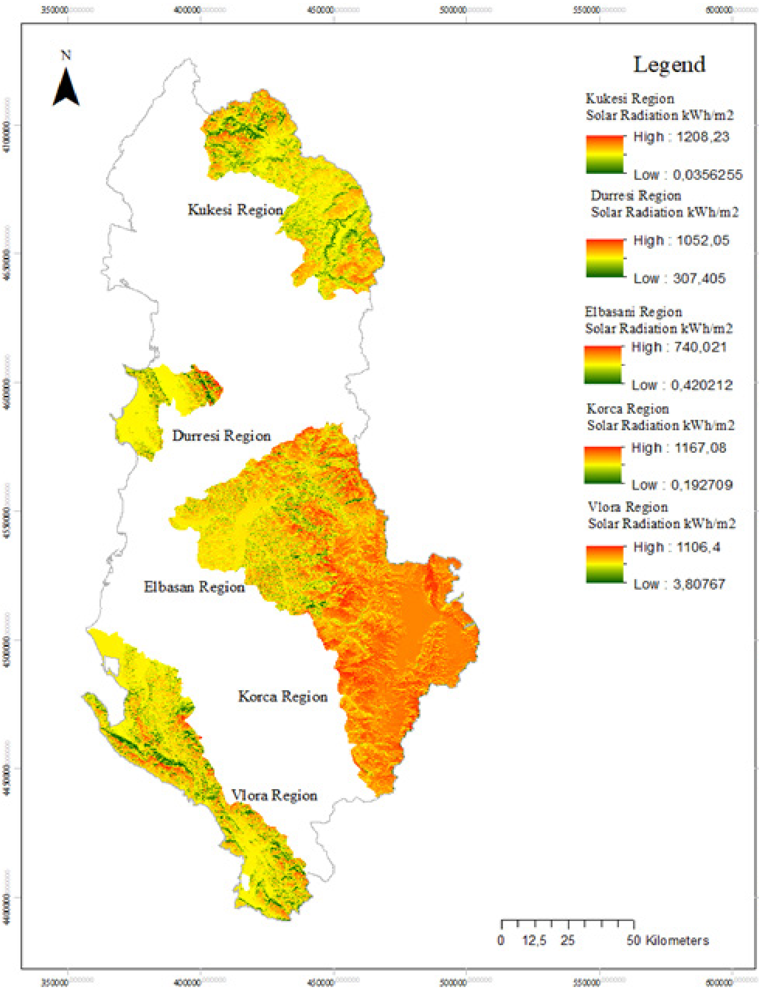
-Protected-area data such as environmental protection zones, cultural heritage sites, and coastal setback lines etc. These data play a critical role in the final outputs of geospatial analyses for solar energy. These data are used to filter and constrain suitable areas, ensuring that the final suitability maps, solar potential models, and decision-making recommendations comply with legal and environmental standards.

-Other data . When official datasets were incomplete, they were complemented by open-source data, remote-sensing interpretation and local expert knowledge.

The use of GIS and geospatial data enables the generation of a range of analytical products that support planning and decision-making in solar energy development, such as solar radiation maps that identify high-exposure areas; PV suitability maps that integrate topographic, environmental, and infrastructural factors; and rooftop solar potential models that assess installation capacity on buildings. Additionally, grid proximity models and energy planning scenarios help minimize spatial conflicts and optimize implementation costs.

The methodological framework follows established GIS-based approaches for solar radiation mapping, site evaluation and potential assessment. (Y. Choi, 2019)It combines terrain analysis, solar radiation modelling, land-use filtering and proximity analysis into a composite suitability index between 0 (unsuitable) and 1 (highly suitable).

Solar Analyst in ArcGIS is used to model annual global solar radiation on the DEM surface, accounting for topographic shading, latitude and generic atmos-




**Map 2:** A workflow example. Solar Radiation in different Regions in Albania. (Sinjari Sonila, Sallja Endrit, Kosovrasti Albana, 2023)

pheric parameters. (Esri, 2025) The resulting raster (e.g., kWh/m²/year) is then reclassified into quintiles or threshold-based classes. Cells exceeding a defined radiation threshold (e.g., 1,500 kWh/m²/year) are assigned higher suitability scores, reflecting the national average and investment benchmarks reported for Albania.

Where roof-scale analysis is performed, radiation values are sampled on building footprints or derived using rooftop-specific tools that estimate panel area and potential output (AIDA, 2024)

The yearly average  of solar irradiation in the country various to Western Part like Durres with 148 kwh/m², Vlora with 147 kwh/m²,etc to small amounts in Southern Highlands provinces of Korca

By translating complex spatial information into interpretable maps and suitability classes, GIS can help:

•Prioritise zones for detailed feasibility studies and investment promotion;

•Inform revisions of local general plans and zoning regulations;

•Support the design of targeted financial incentives (e.g., higher support levels for brownfield-based projects);

•Coordinate energy, land-use, transport and environmental policies at city-regional scale.

Combaining the reclassified layers slope, aspect, radiation, land-use and distance to grid into a composite solar suitability index using raster overlay.

**5.Governance challenges and planning implications  of installing PV**

The Albanian government is actively working to implement strategies aimed at managing urbanization effectively, but the effectiveness of these measures depends on addressing underlying issues such as informal settlements and inadequate public services. (Nikolli, P., Gashi, F., & Sinjari, S., 2025).

This methodological study supports the use of geospatial technologies and data in solar energy decision-making for municipalities and national agencies.

A cluster of opportunity is found on the rooftops of public, educational, health and administrative buildings in the urban core. Many of these structures feature flat or gently sloping roofs, which are technically suitable for PV arrays. Their institutional ownership can also simplify decision-making, especially when combined with national programmes for public-sector decarbonisation and energy-efficiency retrofits.

The same applies to large commercial and service buildings shopping centres, hotels, office complexes where rooftop PV can significantly reduce electricity costs and contribute to corporate sustainability goals. The emerging legal requirement for on-site renewables in new and renovated buildings from 2026 will further increase the relevance of building-integrated PV in Durrës. (News, 2024)

However, the realisation of this potential faces challenges such as:

-Incomplete or outdated digital records on building stock and structural capacity;

-Fragmented property rights and co-ownership arrangements in residential blocks;

-Limited incentives for public entities to invest in PV under current budget rules;

-Lack of systematic integration of rooftop assessments into urban planning processes.

A set of opportunities lies in brownfield sites, former industrial plots and under-utilised land within the urban area or along the periphery. In line with international experience, such sites can be converted into "brightfields" PV parks that generate renewable energy while avoiding conflicts with agriculture and natural habitats. (Esri, 2021)

In Durrës, candidate locations include:

•Decommissioned industrial parcels with low redevelopment prospects;

•Degraded land near transport corridors;

•Under-used spaces in the urban fringe where land-use conflicts are limited.

These areas often score high on solar radiation and slope criteria, but may be constrained by contamination, unclear land titles or absence of detailed site assessments. Addressing these constraints requires coordinated action between central government, municipal authorities, environmental agencies and potential investors.

Strengthening the capacity of municipal planning departments, improving data governance, and establishing formal procedures for using GIS evidence in plan-making are therefore essential. Despite recent improvements in Albania's renewable-energy legislation, investors in urban solar projects still face regulatory and financial uncertainties. These include:

-Evolving rules on prosumers, net metering and surplus electricity sales;

-Complex permitting procedures for projects near protected or coastal zones;

-Grid-connection constraints in areas where distribution networks are weak;

-Limited access to affordable finance for small and medium-sized enterprises and households.

Recent policy developments such as competitive auctions for utility-scale PV and updated laws harmonised with EU acquis aim to address some of these barriers. (Global, 2025) Additional initiatives, supported by the EU and international financial institutions, focus on strengthening Albania's energy security and financing new solar power plants. (EU, 2025)Yet, these instruments have so far been more oriented towards greenfield utility-scale projects than towards distributed urban PV. For cities like Durrës, tailoring financial mechanisms (e.g., credit lines, guarantees, on-bill financing) to urban rooftop and brownfield projects is crucial.

## 6. Post-communist legacies and opportunities

The Durrës case also illustrates how post-communist legacies shape both obstacles and opportunities for solar infrastructure. On the one hand, fragmented property rights after privatisation, informality in the housing sector and delayed infrastructure modernisation complicate project development and risk management. On the other hand, the presence of extensive public and semi-public building stock, large industrial platforms and strategic port infrastructure creates focal points for coordinated interventions.

Comparative experiences from Central and Eastern Europe show that successful local energy transitions in post-socialist settings are often driven by coalitions of municipal leaders, utilities, businesses and civil society actors that mobilise EU funds and national programmes to transform post-industrial areas. (CLG, 2025). For Durrës, the combination of port-related redevelopment, coastal resilience planning and the broader Albanian–European energy integration (including cross-border renewable energy interconnections) offers a window of opportunity to embed solar infrastructure into a wider vision of urban and regional transformation. (Reuters, 2025).

## 7.Conclusions and avenues for further research

This paper has explored the spatial opportunities and challenges associated with deploying solar energy infrastructure in the Durrës Region of Albania, treated as a representative post-communist industrial city in South-East Europe.

Legal and regulatory frameworks, property regimes, grid constraints, financing mechanisms and planning cultures all mediate whether and how solar projects are realised. In this respect, Durrës exemplifies the broader tensions of post-communist energy transitions: high renewable potential co-exists with institutional inertia and infrastructural lock-ins, but also with emerging opportunities created by national strategies, EU alignment and international partnerships.

Future research could extend this work in several directions:

-Incorporating more detailed building-level information (height, structural capacity, roof obstacles) to refine rooftop potential estimates;

-Integrating socio-economic indicators (income, energy poverty, land values) to design socially just and economically viable solar programs;

-Applying multi-criteria decision-making methods (such as AHP or fuzzy logic) in combination with GIS to explore alternative weighting schemes;

-Examining governance arrangements and actor coalitions that enable or impede the implementation of identified priority projects.

For policymakers and planners, the key message is that spatially explicit, GIS-based analysis should become an integral part of urban energy and climate planning. In Durrës, this implies embedding solar suitability maps into local plans, using them to guide incentives and regulations, and designing pilot "solar districts" that leverage port, industrial and public-building clusters. Doing so would not only advance Albania's energy and climate objectives but also contribute to a more resilient, inclusive and sustainable urban future for one of the country's most important coastal cities.

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