

Review article

A systematic review and multidimensional framework for solar farm site suitability

Mariam Kasradze^a, Mahyar Kamali Saraji^{a,*}, Dalia Streimikiene^a, Vishnu Suresh^b^a Kaunas Faculty, Vilnius University, Lithuania^b Faculty of Electrical Engineering, Wrocław University of Science and Technology, Poland

ARTICLE INFO

Keywords:

GIS-MCDM

Solar PV

MCDM

Site Suitability

Sustainability

Systematic Review

Renewable Energy Planning

ABSTRACT

The rapid expansion of solar photovoltaic energy requires efficient, multidimensional site-selection strategies to ensure long-term sustainability and investment efficiency. Selecting optimal locations for utility-scale solar PV farms is a critical part of energy system planning. However, existing reviews often focus on isolated dimensions, failing to provide a comprehensive synthesis of technical, economic, environmental, and social factors together. This study addresses this gap by conducting a systematic review integrating the SALSA framework with the PSALSAR methodology, screening 523 peer-reviewed publications, and synthesizing 103 high-impact studies from 2015 to 2025. The analysis identifies 11 key sub-factors across four pillars (technical, economic, environmental, and social) and introduces a three-phase decision logic (exclusionary screening, technical-economic optimization, and socio-climatic validation). Quantitative synthesis highlights a significant shift toward GIS-MCDM approaches and provides a frequency analysis of regional criteria. This integrated model provides a structured roadmap for developers and policymakers to align localized site selection with grid stability and national renewable energy targets.

1. Introduction

Following technological progress and growing electricity demand, energy consumption has increased substantially over the past few decades. Fossil fuel-based energy production is considered one of the main causes of CO₂ emissions (Giamalaki and Tsoutsos, 2019). Consequently, the need for a transition toward renewable energy is one of the biggest global challenges of the 21st century. According to the International Energy Agency (IEA), fossil fuel-based energy accounted for 60% globally, while renewable energy accounted for 30% (IEA, I. E. A., 2024). International organizations, various countries, and agencies are focusing on developing renewable energy technologies to reduce environmental impact (Abdel-Basset et al., 2021). Furthermore, the transition to solar energy varies significantly across regions and their challenges. For instance, Japan and the Philippines are characterized by land scarcity and are high-density nations; therefore, they require sophisticated spatial planning to address energy demand while dealing with diverse socio-environmental constraints (Pojudas and Abundo, 2022; Tao et al., 2025). Similarly, countries such as Vietnam and Thailand, located in the tropical developing region, require a unique approach to solar PV farm

development due to land-use and policy-driven challenges that often impede sustainable energy deployment (Ali et al., 2019; Wang et al., 2022). To this end, solar energy has become one of the most common and important sources globally, due to its abundance, affordability, and contribution to energy production decarbonization (Finn and McKenzie, 2020).

In the broader context, for solar energy applications, technologies such as Concentrated Solar Power (CSP) use mirrors or lenses to concentrate sunlight, generating heat that drives steam turbines to produce electricity (Wu et al., 2025). One advantage of CSP is energy storage via thermal systems. However, due to its modular capabilities, lower water consumption requirements, and low installation costs, the use of utility-scale Photovoltaic (PV) technology has been growing rapidly (Hossain et al., 2024). Moreover, CSP is highly dependent on specific Direct Normal Irradiance (DNI) levels and needs complex infrastructure, while PV systems convert sunlight directly into electricity, which makes PV systems more versatile for different geographical regions (Ukoba et al., 2024).

Moreover, due to technological improvements and large-scale manufacturing, the cost of photovoltaic modules has steadily declined,

* Corresponding author.

E-mail addresses: mariam.kasradze@knf.vu.lt (M. Kasradze), Mahyar.Kamali@knf.vu.lt (M.K. Saraji), Dalia.Streimikiene@knf.vu.lt (D. Streimikiene), vishnu.suresh@pwr.edu.pl (V. Suresh).<https://doi.org/10.1016/j.egy.2026.109613>

Received 26 October 2025; Received in revised form 22 June 2026; Accepted 13 August 2026

Available online 20 August 2026

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with costs dropping by approximately 25% each time production volume doubles (Hooshangi et al., 2023). Therefore, the declining costs of solar energy have significantly improved its competitiveness in many regions, and it is expected to become economically viable in additional areas soon (Saraji et al., 2024). In this context, the expansion of solar photovoltaic (PV) farms is beneficial not only from an economic perspective but also in supporting and aligning with global transition goals (Islam et al., 2025). However, Solar farm site selection is a crucial step in the successful implementation of utility-scale photovoltaic projects (Ara et al., 2024). Solar farms that are not built in an appropriate place can lead to technical inefficiencies, socio-environmental conflicts, underutilization of investment, and long-term sustainability issues (Yavari et al., 2022). In contrast, well-sited solar farms can maximize energy output, minimize costs, ensure environmental compatibility, and gain stronger public support (Wati and Meukam, 2024). Therefore, the site selection process and its multidimensional assessment, including environmental, social, technical, and economic considerations, are crucial for maximizing both economic and environmental benefits (Onuoha et al., 2025).

Furthermore, the selection of solar PV sites has been a fundamental baseline of broader energy system planning. In modern energy systems, the site selection process has shifted from land acquisition to complex technical integration (Heo et al., 2021). While selecting an optimal location is critical to maintaining grid stability and reliability, a poor site-selection process can lead to voltage instability and significant energy losses. Therefore, recent literature emphasizes that site evaluation must be treated as an integrated system, in which local environmental factors are considered alongside the macro-level requirements of the power network (Sekeroglu and Erol, 2023). This systemic approach ensures that utility-scale projects are not only planned and adjusted geographically, but are also technically and economically resilient, aligning with the overall energy mix (Yildiz et al., 2025). To maintain analytical rigor, this study’s scope is limited to utility-scale, land-based solar PV farms, as these large-scale installations face distinct land-use, tenure, and justice challenges that require systematic operational decision-making to meet technical and social requirements. Although many studies have been conducted over the past decade, the majority of these studies either emphasize specific geographic contexts or prioritize specific factors without holistically integrating all key dimensions. For instance, while some studies stress the technical aspects, such as grid connectivity or solar radiation (Chen et al., 2014; Qian et al., 2024), others prioritize economic factors, such as infrastructure availability or social dimensions like community acceptance (Sward et al., 2021; Wang et al., 2023). Although many studies have explored various models and techniques for selecting solar PV farm locations, a comprehensive, integrative understanding of site selection criteria remains lacking in the literature. While recent studies (Bohra and Anvari-Moghaddam, 2022; Jong and Ahmed, 2024; Noorollahi et al., 2022) have provided comprehensive lists of suitability criteria, they often present these factors in regional and climatic contexts. This creates a gap in understanding the procedural flow of site selection. This study distinguishes itself by positioning these 11 sub-factors within a multi-decision process, integrating them into sequential phases from initial screening to final validation. This feature shifts the focus from selecting several factors to a multi-decision model that shows how all factors can be operationalized throughout the site selection lifecycle. Therefore, this research seeks to address this gap by systematically reviewing and analyzing peer-reviewed studies published in the last decade on solar PV farm site selection. The review synthesizes findings into a comprehensive integrated operational framework that presents four interlinked dimensions: environmental feasibility, economic viability, social acceptance, and technical Sustainability. Each dimension comprises a set of commonly identified sub-factors, as reported across the literature. To address the identified research gap and achieve the study’s objectives, this research makes the following key contributions:

- Developing a novel, multi-dimensional framework that presents 11 subfactors across 4 main economic, technical, environmental, and social pillars and operationalizes these factors for a three-phase decision logic (exclusion, optimization, validation). The framework provides a standardized implementation pathway for solar PV farm siting.
- Conducting a quantitative synthesis of 103 peer-reviewed studies to identify a significant shift from traditional geographical information systems (GIS)-multi-criteria decision making (MCDM) toward Hybrid-Machine Learning models, highlighting regional variations in methodological dominance.
- Developing a practical strategic guideline for researchers and practitioners, integrating modern socio-economic challenges into the solar PV farm site selection process, and filling the gap between the practical research and long-term sustainability and viability of solar PV projects.

2. Methodology

A Systematic Literature Review (SLR) is a rigorous method used to answer clearly defined scientific questions by collecting, synthesizing, and critically evaluating existing scholarly evidence (Mengist et al., 2020). This method enables researchers to identify key trends, combine methodological approaches, reveal research gaps, and suggest a further research agenda for a specific research subject. The current study employs the SLR approach to examine the site suitability assessment for solar PV farm development, focusing on specific factors addressed in peer-reviewed literature.

To ensure transparency and consistency in the review process, the PSALSAR framework is applied, which includes six steps: protocol, search, appraisal, synthesis, analysis, and reporting (Mengist et al., 2020). This structured approach identifies the multidimensional factors underlying utility-scale solar PV site suitability. The overview of the SLR methodology applied to identify important factors for solar PV farm site suitability is displayed in Table 1:

2.1. Protocol development and scope justification

The PICOC framework (Population, Intervention, Comparison, Outcome, and Context) was used to justify the scope of the literature search. This framework helped to establish boundaries for the review and ensured the relevance of selected papers to the research topic. The scope justification using the PICOC framework is presented in Table 2.

The primary research questions guiding this review were:

- What methodological approaches are used to assess site suitability for solar PV farm installation?
- Which criteria are most frequently considered in the literature?

Table 1
SLR methodology.

Steps	Main tasks and approaches
protocol	Identifying and analyzing the most relevant factors influencing site suitability for solar PV farms across technical, economic, environmental, and social dimensions. Method: The PICOC framework was applied to justify the scope and refine the research questions.
Search	A systematic search was conducted using relevant keywords across Scopus and Web of Science databases.
Appraisal	The PRISMA approach was employed to ensure transparency in the selection of studies. Screening: Applied inclusion/exclusion criteria to identify only peer-reviewed articles relevant to solar PV farm siting.
Synthesis	Classification and extraction of relevant data from the selected studies
Analysis	Analysis of the extracted data to propose a integrated operational framework for solar PV farm site suitability
Report	Summarizing the research results

Table 2
Research Scope Justified by PICOC Framework.

Concept	Definition	Application
Population	Studies investigating solar farm site suitability across various sustainability factors	Peer-reviewed articles analyzing the siting of solar farms using multi-criteria MCDM, GIS, or hybrid frameworks.
Intervention	Existing frameworks and models for solar site selection	Synthesizing methodologies and factors used to determine optimal solar farm locations.
Comparison	Differences among identified siting criteria and methodological approaches	Comparing the variety of technical, environmental, economic, and social factors and how they are evaluated or weighted across studies.
Outcome	Identification and classification of key site suitability factors	Development of a novel qualitative conceptual model integrating identified criteria into four sustainability dimensions.
Context	Geographic, policy, and planning perspectives influencing solar site selection	Understanding challenges, gaps, and trends in site selection research across different regions, scales, and policy contexts.

- How do these criteria interact, and what gaps exist in the current research for integrated assessment?

2.2. Search strategy

Comprehensive research was conducted between February and March 2025 in two major academic databases, Web of Science and Scopus, using keywords such as:

"solar farm," "solar power plant," "solar energy site," "solar PV farm," "solar photovoltaic farm," "site selection," "location selection," "spatial

planning," "suitability analysis," "factors," "criteria." Only peer-reviewed journal articles published in English between 2005 and 2025 were considered.

2.3. Appraisal and screening

The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) approach is used to screen selected articles, ensuring a transparent and systematic process. Duplicate records, non-peer-reviewed publications, and articles lacking relevance to solar PV site suitability were excluded. The appraisal process involved a detailed examination of abstracts, keywords, and full texts as needed. The research flow, based on the PRISMA statement, is illustrated in Fig. 1.

2.4. Synthesis and analysis

The selected studies were synthesized, and key information, including publication year, geographic scope, method type, and criteria used, was extracted. This synthesis formed the foundation for a conceptual model of site suitability for solar PV farms.

2.5. Reporting and framework development

In the final stage, insights from the analysis were organized into a conceptual framework that synthesizes all identified site suitability factors into four interconnected dimensions: Technical Sustainability, Economic Viability, Social Acceptance, and Environmental Feasibility.

3. The status quo of solar PV site selection

This section highlights the increasing scholarly interest in this field, particularly since 2015, in response to the global push toward renewable energy and sustainability targets, such as the SDGs. Moreover, the increased interest in renewable energy, particularly solar PV farms, can

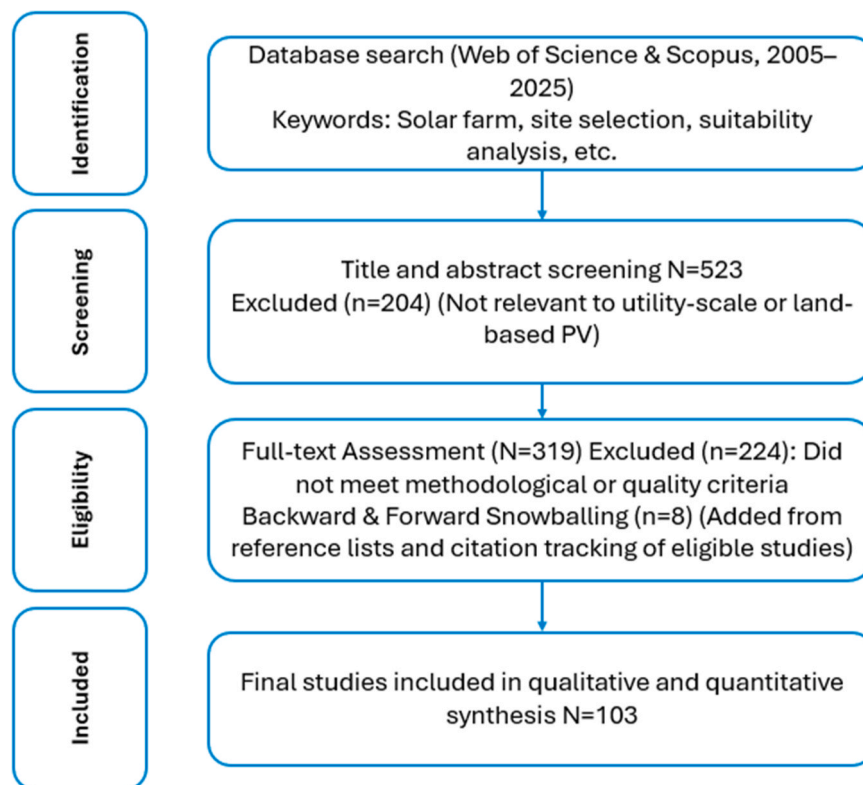


Fig. 1. Research Information Flow illustrating the systematic search (2005–2025), screening phases, and the integration of snowballing techniques to reach the final N = 103 included studies.

be linked to the initiation of the Paris Agreement, which spurred research into the development of sustainable energy systems and the energy transition.

3.1. Publications between 2015 and 2019

During the period from 2015 to 2019, solar PV farm site selection studies primarily focused on environmental and geographic factors using GIS-based and MCDM methods. As shown in Table S1 in the supplementary material, most studies emphasized topography, solar irradiance, and exclusion zones, with limited attention to economic and social dimensions. Several models, including AHP and fuzzy logic, were applied to optimize site assessment, though integration across all four sustainability pillars remained rare.

3.2. Publications between 2020 and 2023

Between 2020 and 2023, as shown in Table S2, there was a noticeable increase in the methodological sophistication of site selection studies, including the use of hybrid models such as AHP-TOPSIS and simulation-based approaches. The studies reviewed in this period began to incorporate economic and social considerations more frequently, though technical and environmental factors still dominated. Different case studies were analyzed over this period, showing how solar energy became an important topic.

3.3. Publications from 2024 to present

Recent studies from 2024 show a shift toward more integrated and stakeholder-driven approaches to site selection. As indicated in Table S3, many recent publications adopted multi-objective optimization and GIS-based composite indices, incorporating regulatory, infrastructural, and socio-political factors. There is also a growing focus on aligning site selection with long-term sustainability goals and smart grid compatibility, particularly in the context of climate adaptation and land use planning.

3.4. Quantitative synthesis: frequency and methodological dominance

A quantitative synthesis has been conducted to reveal the hierarchy of factors used in solar PV site suitability research. The synthesis (Table 3) showed that environmental and technical factors, specifically solar radiation and topography, are the most included factors across 103 reviewed papers. Their high frequency indicates that these factors are non-negotiable thresholds for solar project viability. On the contrary, social and economic factors (present in fewer than 40% of included studies) represent a significant research gap, suggesting that academic models often prioritize environmental potential rather than social acceptance or land-cost realities, which are crucial for solar PV site developers.

When it comes to methodological dominance, comparing the studies in Table S1 (2015–2019) with those in Tables S2 and S3 (2020–2025) reveals a clear technological transition. While the Analytic Hierarchy Process (AHP) combined with GIS remains the most common method, there is a growing use of hybrid MCDM approaches and machine learning techniques. Therefore, this trend shows that site suitability analysis is shifting from static suitability maps to more complex dynamic models that can handle non-linear variables and various uncertainties associated with different factors. This evolution is a response to the increased complexity of the site selection process, as researchers need to model complex interactions between climate viability, grid hosting capacity, and multi-stakeholder preferences. The recent growth in machine learning usage highlights a shift from expert-driven to data-driven decision-making. The evolution, frequency, and current tendencies of the methodological approaches revealed in the selected papers are summarized in Table 4.

Table 3
Frequency and dominance analysis of site selection criteria.

Category	Factor	Frequency (%)	Dominance Level	Scientific Rationale in Literature
Environmental	Solar Radiation: GHI (Global Horizontal Irradiance) and DNI	~92%	Primary	Most critical for energy yield.
	Slope/Topography	~85%	Primary	Essential for construction and drainage. Used to filter agricultural and protected lands.
	Land Use / Land Cover	~78%	High	Minimizes infrastructure costs. Crucial for logistics and maintenance traffic.
Technical	Grid Proximity/Capacity	~72%	High	Focuses on NIMBY issues and demand proximity.
	Road Proximity	~68%	High	The least included factor within chosen literature.
Social	Urban/Residential Distance	~42%	Moderate	
Economic	Land Acquisition Cost	~28%	Low	

Table 4
Dominance and evolution of methodological approaches between 2015 and 2025.

Methodological Category	Frequency (%)	Primary Applications	Trends & Insights
Traditional GIS-AHP	58%	Basic suitability mapping; regional planning.	Declining: Moving from standalone use to being a component of hybrid models.
Hybrid MCDM	35%	Complex trade-offs; ranking of alternative sites.	Stable: Used to reduce the subjectivity inherent in standard AHP.
Machine Learning	12%	Predictive modeling; handling non-linear environmental data.	Rising: Significant growth in 2023–2025 studies for high-precision mapping.
Fuzzy Logic Integrations	22%	Addressing uncertainty in expert opinions and spatial data.	Dominant after 2020: Essential for handling uncertain social and economic criteria.

Moreover, recent developments in methods for tropical and land-scarce regions demonstrate the advancement of these methodologies over traditional GIS-MCDM models. For instance, machine learning is commonly used in Japan to account for non-linear effects alongside regulatory constraints in spatial planning (Tao et al., 2025), and matching algorithms are being used to develop technical specifications based on local communities' socio-environmental preferences (Irie et al., 2022). Similarly, a four-stage framework has been developed in the Philippines to identify areas for policymakers that include economic externalities, considered together with land constraints (Pojudas and Abundo, 2022). Additionally, in tropical region countries such as Vietnam and Thailand, the usage of high-resolution GHI mapping with qualitative policy-driven factors, including government support, land acquisition, etc., has become the most effective tool to address the challenges for solar PV technology development in different land-use and climatic conditions (Ali et al., 2019; Nguyen et al., 2022; Wang

et al., 2022).

Furthermore, the geographic dominance analysis shows that over 50% of the global literature on GIS-MCDM methods is concentrated in the Middle East and North Africa (MENA) and Mediterranean regions. This can be linked to high GHI in these areas. However, while MENA region studies focus more on technical/environmental optimization, research from Asia-Pacific and Europe increasingly focuses on social acceptance and land-use challenges, reflecting the high population density of these areas and competing land interests. The regional comparison presented in Table 5 suggests that site selection criteria are not universal and depend heavily on the local socio-economic context.

4. The framework of factors of the solar PV site suitability

After conducting a systematic literature review on solar farm site selection, the identified factors were grouped into four interrelated categories: technical sustainability, economic viability, social acceptance, and environmental feasibility. Each group reflects a core dimension influencing the successful development of solar farms and includes specific sub-criteria that are frequently used in siting analyses. While the proposed framework includes all identified dimensions for solar PV farm site selection, it is important to note that specific parameter thresholds (e.g., slope limits, distances, temperatures) are highly context-dependent. Therefore, it is important for researchers and practitioners to use the studies listed in Tables 3–5 to determine local criterion values for specific regions and environmental constraints.

4.1. Technical sustainability

Technical sustainability focuses on grid connectivity, land suitability, and energy efficiency for solar power generation. Proximity to substations and infrastructure lowers costs and energy losses. Moreover, for an optimal modern site selection process, grid hosting capacity and curtailment risks need to be evaluated. As PV penetration increases, the technical ability of the local grid to absorb power without stability issues, as well as the risk of forced output reductions during peak production (Zambrano-Asanza et al., 2021). These risks are primary constraints for project feasibility (Madavan et al., 2023). Additionally, factors such as solar irradiance, slope, and temperature affect energy output.

4.1.1. Grid connectivity

Grid connectivity is one of the most important factors considered when evaluating the technical sustainability of solar PV farm sites, as it influences energy transmission efficiency, installation costs, and long-term operational reliability (Saraji et al., 2024). Connecting a solar farm to the national or regional energy networks depends on existing

energy infrastructure, specifically transmission lines, substations, and grid capacity(Chen et al., 2014).

Many studies use the distance to transmission lines as a crucial criterion for selecting a solar PV farm site, as it significantly affects the cost and energy losses. They identified that sites located closer to high-voltage transmission lines reduce the need for additional infrastructure investment and minimize transmission losses (Yilmaz et al., 2024). Conversely, the farther a solar PV farm is from the energy grid, the more capital-intensive the connections required are, particularly in remote or rugged natural conditions (Kocabaldır and Yücel, 2023).

Another factor that falls under technical sustainability for site selection for solar PV farms is proximity to substations, which serve as a connection point between the solar power plant and the main energy grid (Halder et al., 2022). Substations are crucial for regulating voltages and ensuring grid system stability (Sreenath et al., 2020). Therefore, sites located nearer to substations have technical advantages, including reduced connection delays, improved grid synchronization, and lower costs.(Ünsal et al., 2024). A distance of 1–5 km to substations is considered the optimal distance for an area's technical feasibility.

Furthermore, another key factor related to sustainable grid connectivity is the capacity of the existing grid infrastructure to absorb and distribute additional renewable energy from new areas (Hassan et al., 2023). If the existing infrastructure already operates near its technical limits, the site's physical proximity to the grid would no longer be a significant factor in site selection (Lindberg et al., 2021). Some studies incorporate grid capacity constraints as a tool to exclude areas where integration would be cost-intensive and compromise grid stability (Kocabaldır and Yücel, 2023).

Additionally, distance to roads is commonly considered within the context of grid connectivity due to its relevance to transporting PV modules, construction equipment, and maintenance staff, among other factors (Kırcah and Selim, 2021). Well-connected road infrastructure is crucial for long-term development plans and the maintenance of solar PV farms, particularly in locations where large-scale installations need to be transported, as logistical efficiency is essential (Ara et al., 2024).

Moreover, another integrative tool, such as the Construction Suitability Index (CSI), is used for optimal solar PV farm site selection (Chai et al., 2024). CSI integrates various spatial, technical, and logistical variables, including elevation characteristics, distance to roads, and distance to transmission infrastructure, to generate a score that ranks areas according to construction feasibility (Chai et al., 2024). Together with connectivity infrastructure indicators and physical terrain, CSI allows an efficient planning process for suitable locations. For instance, areas scoring high according to CSI tend to align with low-cost installation zones and minimal topographic constraints, which allows planners to reduce environmental and financial development costs (Chai et al., 2024).

Moreover, if the site selection process includes areas from different countries or zones near restricted or militarized areas, proximity to borders is a particularly important criterion for grid-related planning (Ibrahim et al., 2021). Additionally, farm sites near national or administrative borders may face more regulatory or security issues and might be excluded from national grid plans (Bedewy and Al-Timimy, 2023). Thus, proximity to borders, even less frequently included in site selection studies, can be quite critical in specific geopolitical aspects (Doorga et al., 2019; Kahatapitiya et al., 2023).

4.1.2. Energy efficiency

Energy efficiency plays a critical role in the successful conversion of solar radiation into usable electricity while developing solar PV farms. Energy efficiency incorporates both environmental conditions and technical performance parameters of PV systems (Yavari et al., 2022). Several studies have identified various spatial and climatic factors that influence energy efficiency evaluation during the solar PV site selection process((Wati and Meukam, 2024), (Yilmaz et al., 2024))

One of the commonly acknowledged determinants is solar radiation,

Table 5
Regional distribution and geographic dominance of research.

Region	Frequency (%)	Leading Countries	Research Focus
MENA	32%	Iran, Saudi Arabia, Egypt, Morocco	Maximizing GHI; desert-specific constraints (dust/heat).
Mediterranean Europe	23%	Turkey, Greece, Spain, Portugal	Balancing tourism, agriculture, and high solar potential.
Asia-Pacific	18%	China, India, Vietnam, Indonesia	Grid integration and land-scarcity issues (floating PV/rooftop).
Sub-Saharan Africa	12%	Nigeria, Ethiopia, South Africa	Rural electrification and off-grid suitability.
North America & South America	15%	USA, Brazil, Chile	Policy-driven site selection and major infrastructure zones.

typically measured as GHI and DNI (Abdel-Basset et al., 2021). Areas with higher annual solar radiation are preferable for solar PV farms, as they have greater potential to generate more energy (Rediske et al., 2019). Moreover, in addition to solar radiation, other climate conditions and temperatures also significantly impact solar farm performance (Finn and McKenzie, 2020). Although solar panels require sunlight to generate electricity, extreme heat can significantly reduce their efficiency (Al Garni and Awasthi, 2017). Excessively high temperatures pose a risk to panel materials over time, reducing their conversion efficiency, particularly in regions where cooling mechanisms are lacking (Jathar et al., 2023). Therefore, for long-term energy efficiency, it is crucial to select sites with high solar radiation and moderate temperatures that balance the yield and support the long-term health of systems (Al Garni and Awasthi, 2017).

Another important factor in achieving energy efficiency is considering the topography (Mehrian et al., 2024). Specifically, slope and elevation directly affect sunlight reception and panel installation (Yilmaz et al., 2024). Flat or slightly sloped terrain ensures optimal panel orientation for sun exposure throughout the day, whereas steep slopes or highly variable elevations may complicate construction, reducing the efficiency of solar systems due to shadows and uneven radiation (Jbahi et al., 2024). Therefore, slope analysis is a crucial factor in solar PV farm site selection and is commonly incorporated into GIS-based research models to support informed decision-making.

Another factor contributing to efficient energy capture is land cover and the albedo effect (Qian et al., 2024). The reflective properties of a surface influence how much radiation is absorbed and how much is reflected away from the surface. Surfaces with high albedo, such as sand, snow, and light-colored areas, tend to reflect a significant amount of sunlight, thereby reducing the radiation that can be absorbed by solar panels (Gul et al., 2018). On the contrary, darker surfaces with lower albedo absorb more solar radiation, thereby increasing the energy efficiency of solar panels (Aziz et al., 2021). Therefore, the correlation between surface reflectivity and the potential of solar systems is essential while selecting sites.

Also, land cover classification is used to identify the type of surfaces not only for higher energy generation but also to align with ecological constraints, ensuring both energy efficiency and environmental sustainability (Chai et al., 2024; Noorollahi et al., 2022). Lastly, some studies have found that air pollution and dust levels can significantly affect the effectiveness of solar systems (Qian et al., 2024). In areas such as deserts or industrial regions, dust accumulation on the panels can reduce sunlight absorption and overall energy generation (Mehrian et al., 2024). Several studies highlight the importance of frequent cleaning and maintenance of systems in high-dust zones to avoid increased operational costs and energy inefficiency (Qian et al., 2024).

4.1.3. Future expansion

Future expansion is a critical sub-factor within technical sustainability, as it reflects the potential for continued solar project growth and the ability to meet future energy demands (Al Garni and Awasthi, 2017). In terms of meeting sustainability goals, the site should not only meet technical criteria but also have the potential to accommodate growth, both spatially and infrastructurally (Sun et al., 2021). One of the most important factors for a solar PV farm site's future expansion is land availability. To evaluate site suitability in terms of sustainability and future development potential, it should not only meet current spatial requirements but also provide nearby land that can be repurposed or expanded if additional capacity is required (Sicuaio et al., 2024). Many studies highlight that even highly suitable, technically isolated areas may lack scalability due to differences in ownership, land use, or topographic limitations (Rane et al., 2024). Hence, larger, continuous land areas are commonly preferable for the further strategic development of solar PV farms (Spyridonidou et al., 2022).

Moreover, another issue for the future expansion of solar PV farms is land restrictions (Ünsal et al., 2024). Specific land categories, such as

protected ecosystems, agricultural zones, and areas with strict urban planning rules, can limit or entirely prohibit the development of solar PV plants (Sánchez-Lozano et al., 2014). Furthermore, certain regulatory frameworks should be considered when evaluating sites, as even technically available land may face significant regulatory constraints for long-term development. Studies have emphasized the importance of analyzing land classification policies and zoning regulations during the site evaluation process for future expansion (Abdel-Basset et al., 2021), (Chai et al., 2024). Additionally, future changes should be considered, as some land may be available today but may become restricted in the future due to alignment with environmental protection or community rules (Saraji et al., 2024).

Furthermore, given spatial constraints, the possibility of expanding infrastructure should be considered in the event of increased energy production needs (Heo et al., 2021). Hence, the road network around the area, as well as the capacity of substations and the flexibility of the local transmission grid, must be assessed not only to meet current needs but also to identify potential improvements in long-term energy generation and maintenance traffic (Hasanzaeh et al., 2024). Several studies that consider infrastructure development in the site selection process highlight that areas with upgraded or expandable nodes are preferable for accommodating future growth (Nafi'Shehab et al., 2024; Ruiz et al., 2020).

Additionally, another important yet overlooked factor is the policy and regulatory environment, given solar energy's high dependence on the consistency and clarity of national or local policies (Melek et al., 2024). For instance, incentives such as renewable energy credits, tax breaks, and streamlined permit acquisition processes significantly influence investor interest and flexibility (Bölük and Kaplan, 2022). Moreover, sustainable, long-term-oriented renewable energy targets present a strong government commitment and enhance interest in private or international funding (Sicuaio et al., 2024). Several studies found that even highly technically capable sites can be underutilized if there is a lack of fair policy frameworks and continuity (Deveci et al., 2021).

4.2. Economic viability

Economic viability encompasses installation costs, return on investment (ROI), subsidies, and land prices. Sites near roads and grids reduce expenses and increase flexibility.

4.2.1. Investment

Investments are a crucial part of solar PV plant site selection, as they are fundamental for the project initiation phase (Melek et al., 2024). We have discussed technical feasibility and spatial scalability in previous sections; however, this subsection focuses on the economic considerations and their influence on investors, which highly affects the decision-making process of whether the site will be attractive for funding and further development.

From an investment perspective, one of the primary barriers to solar PV farm development is the cost of installation, which typically includes expenses for land preparation, transportation of PV modules, grid interconnection, labor, and other related costs (Kannan et al., 2021). Hence, high investments for installation, particularly in regions with limited economic support mechanisms, are more likely to deter public and governmental bodies from selecting the area (Rediske et al., 2019). Therefore, it is crucial to consider cost optimization strategies when evaluating solar PV farm locations. Furthermore, capital investment is closely tied to the return on investment (ROI), which determines the attractiveness of solar PV sites from a business perspective (Ayough et al., 2022). Hence, locations with high solar resources, low land costs, and opportunities for future expansion tend to generate better ROI even in the short term (Hassan et al., 2023). As a result, during the site selection process, areas with optimized costs are preferred over technically capable sites with higher financial risks in the future (Rogna,

2020). However, in a long-term perspective, financial models are increasingly sensitive to curtailment risk, where oversupply leads to forced output reductions, directly impacting the long-term ROI and economic resilience of the solar facility (Madavan et al., 2023).

Furthermore, investment decisions are highly influenced by policy incentives, such as tax credits and subsidized loans, which significantly support solar project development (Cohen et al., 2020). Several studies highlight that subsidiary mechanisms not only reduce financial burden but also increase investor confidence, specifically for emerging markets or regions actively involved in global energy transition processes (Wu et al., 2014). Moreover, for more efficient decision-making, several studies employ cost-benefit analysis (CBA) to compare long-term financial and environmental benefits to initial capital and operational costs (Goh et al., 2021). CBA considers expected energy output, infrastructure needs, and maintenance to evaluate potential sites (Pojudas and Abundo, 2022). Thus, CBA has become a widely used method, ensuring the financial transparency and objectivity of solar projects (Qureshi et al., 2024). Lastly, governmental or supporting mechanisms such as loan guarantees, public or private partnerships, and green financing platforms are critical to reducing investor risk in solar infrastructure. Areas affected by such mechanisms tend to be more financially attractive even when technical suitability is lower compared to other sites (Demir et al., 2023; Wang et al., 2022).

4.2.2. Infrastructure

From an economic viability perspective, infrastructure is one of the key factors determining not only the initial development and feasibility of solar PV farms but also their cost-efficient operations over time (Ruiz et al., 2020). We discussed other aspects of infrastructure, such as transmission line access and proximity to roads. However, this subsection emphasizes the economic implications of solar infrastructure, including savings, construction efficiency, and financial performance.

Proximity to transmission lines is a widely used factor in solar PV farm site selection as it affects the technical integration of solar farms and determines their financial efficiency (Hooshangi et al., 2023; Noorollahi et al., 2022). Moreover, building new transmission infrastructure often requires high capital investment and can be delayed by complicated permitting procedures (Heo et al., 2021). As a result, such solar projects lose their financial attractiveness and are at risk of being initiated. Therefore, locations that offer the possibility of utilizing existing transmission infrastructure with minimal investment are considered economically viable (Abdelhady, 2021).

Similarly, proximity to roads and ports is also strongly connected to the economic dimension (Mokarram et al., 2020). The long transportation distance for photovoltaic modules, construction machinery, and supporting structures incurs additional costs, particularly in areas with complex topography (Sánchez-Lozano et al., 2014). Therefore, logistical efficiency has a direct impact on the costs of solar PV farm installations. Additionally, some solar projects include international components, such as imported PV panels, and a short distance to ports can significantly reduce expenses (Uyan and Dogmus, 2023). Moreover, proximity to roads means lower costs for solar PV plant maintenance, emergency response, and, lastly, monitoring of solar farm operations (Demir et al., 2023).

Furthermore, access to essential utilities can be an important factor for evaluating the financial outcome of establishing solar PV farm sites. For instance, some solar farms might be located in dusty regions may require frequent cleaning and maintenance (Qian et al., 2024). Hence, closeness to water infrastructure ensures a reduction in maintenance costs. Also, proximity to telecom infrastructure can reduce labor force expenses by enabling the effective monitoring of maintenance systems (Hasti et al., 2023).

4.2.3. Land costs

Among economic factors, land cost is one of the most significant determinants influencing the feasibility of solar PV farm sites (Sun et al.,

2023). A site may be highly suitable for an optimal solar PV farm location, but the affordability of the land can affect the project's profitability (Kuru, 2023). The price of land per square meter or hectare is a commonly used measurement for further site suitability analysis, and it highly varies depending on the location's proximity to urban areas, land use, and real estate prices (Demir et al., 2023). Moreover, technically suitable areas can still be excluded from consideration if the costs of land acquisition are higher compared to the general capital expenditure (Hooshangi et al., 2023). In such cases, even marginally less optimal locations with significantly lower land prices might be prioritized, as this will balance technical efficiency and ensure the project's future economic feasibility.

Additionally, the opportunity cost of land use can significantly influence the site selection process as well (Hooshangi et al., 2023). For instance, utilizing areas for solar projects that are agriculturally productive or have a high potential for further urban development can be controversial and result in financial inefficiency (Spyridonidou et al., 2022). This consideration is particularly relevant in regions with high land competition, as well as in locations where solar development may conflict with food security and housing opportunities. Therefore, many studies consider the opportunity cost of the land as an important factor and prioritize marginal, underutilized areas to avoid trade-off issues and align site planning with sustainability goals (Demir et al., 2023).

Moreover, another factor that is connected to land use in terms of economic viability is the type of land ownership. Public or private lands have different implications for pricing and the ease of the purchasing process (Dhunni et al., 2019). These rules vary from country to country, as some of them offer more flexible leasing options or lower acquisition costs for publicly owned lands. This situation is particularly expected in countries where governmental incentives align with global renewable energy goals (Kennedy and Qayyum, 2024). On the contrary, private or mixed ownership can result in prolonged negotiations, higher capital or transactional costs, and delay the initiation of the project (Deveci, Cali et al.). Additionally, in the case of high-capital projects, investor decision-making is highly dependent on the clarity of the legal and institutional system's reliability, specifically for developing countries, as clarity of laws and regulations regarding land ownership, energy developments, and secure agreements highly reduce investment risk in the future (Lamhamedi and de Vries, 2022; Wang et al., 2023).

4.3. Social acceptance

Social acceptance depends on minimizing disruptions, respecting local culture, and ensuring clarity of land ownership.

4.3.1. Community impact

The development of solar PV farms has a significant impact on local communities, and the community's perception of this impact is a crucial aspect of their social acceptance (Abdel-Basset et al., 2021). Even when the site meets optimal requirements for technical sustainability as well as economic feasibility, resistance from residents can significantly affect, delay, or even cancel project development (Kannan et al., 2021). Thus, community impact is a crucial factor and should be evaluated during the selection of a solar PV plant location (Barzehkar et al., 2021). One of the commonly discussed issues at the community level is the visual or esthetic impact of large-scale photovoltaic installations (Sánchez-Lozano et al., 2014). If solar PV farms are located near residential areas, natural landmarks, or historical sites, they may be perceived as visually disturbing factors in the landscape (Fard et al., 2022). Nevertheless, solar panels generate clean energy; their presence might still lead to "Not in My Backyard" (NIMBY) responses if residents feel that their existence disrupts the visual appeal of specific zones and surroundings (Asokan et al., 2024). To avoid such issues, several papers have included visual buffer zones or esthetic considerations for solar PV farms in order to improve public perception (Dickerson, 2018).

On the other hand, employment opportunities that arise from solar project development can positively impact the community's attitude (Pojudas and Abundo, 2022). Nonetheless, solar projects are considered labor-intensive, and as they start operations, the construction phase may create short-term additional employment opportunities for residents (Sindhu et al., 2017). Furthermore, maintenance, security, and infrastructure services can offer long-term employment opportunities, particularly in less economically developed areas (Kannan et al., 2021). If the public perception and benefits of solar projects for local communities are well-communicated, residents tend to support renewable energy projects and perceive them as development opportunities (Wu et al., 2019).

Furthermore, in addition to visual and practical concerns, noise, glare, and land use are the most common issues that lead to community opposition (Abdel-Basset et al., 2021). Nonetheless, solar PV farms do not produce noise during operation; auxiliary systems, such as inverters or transformers, can still cause low-frequency noise, particularly in areas that are not well-planned or densely populated (Bahtiarian, 2020). Moreover, glare from panels is a common issue for farms located near airports or roadways (Stavrou, 2021). However, technological and planning improvements can significantly reduce such risks. Therefore, it is crucial to evaluate such issues during the solar site planning process.

Lastly, communities often have health and safety concerns, typically based on misconceptions, that can also influence their attitude toward solar PV farms. Some misconceptions about health issues related to solar plants include electromagnetic radiation, soil contamination, and fire hazards (Stavrou, 2021). In such cases, communication transparency and community engagement are crucial to gaining social acceptance, as well as public education initiatives, which can significantly mitigate biased fears and increase confidence in society. Thus, safety compliance and transparent environmental impact assessment of solar PV farms tend to decrease community resistance and gain social acceptance. Importantly, solar PV farms that provide clear evidence of safety compliance and openly share environmental impact assessments tend to encounter less public resistance (Chen et al., 2025; Roddis et al., 2020).

4.3.2. Policy

Policy frameworks considerably influence the formation of public trust and community acceptance (Sward et al., 2021). Beyond technical permissions or financial incentives, policy frameworks significantly shape social sustainability guidelines for managing interaction between solar PV farm developers and communities affected by solar projects (Sindhu et al., 2017). One example of such guidelines is local zoning regulations, which determine whether solar farms have a legal permission for specific locations and under what conditions they must operate (Noorollahi et al., 2022).

Moreover, zoning regulations reflect community-level decision-making regarding the prioritization of land use possibilities (Kurowska et al., 2022). When the government or solar project developers change land use rules without properly involving and informing the public, it is often met with resistance (Sward et al., 2021). Recent research indicates that social feasibility nowadays faces broader issues of energy justice, land tenure, and social conflict (Shyu, 2025). Therefore, it is important for analysis to dive deeper than only social acceptance to evaluate how land acquisition impacts local livelihoods and whether the site selection process respects existing land rights and historical usage (Yenneti and Day, 2016). However, in locations where zoning rules are clearly defined and supported by the local community, solar projects are typically more successfully implemented with minimal conflict (Wang et al., 2023).

Another crucial aspect is the level of public participation in planning processes (Sward et al., 2021). More stakeholder participation tends to decrease opposition within communities to solar project implementation (Sicuaio et al., 2024). Moreover, early public engagement can help avoid costly mid-project revisions, as community concerns are addressed and agreed upon in advance. This approach is particularly

effective in areas with historical or cultural significance and numerous protected areas (Vrinceanu et al., 2022).

Furthermore, another important factor in improving social acceptance is the implementation of fair compensation laws (Pojudas and Abundo, 2022). When the community benefits from solar projects, including receiving compensation for land use, profit-sharing schemes, and employment possibilities, they tend to support the development of solar PV farms (Melek et al., 2024). However, a lack of clarity and consistency in compensation frameworks often creates a perception of unequal benefit distribution (Yenneti and Day, 2016). Therefore, it is crucial to evaluate policy frameworks to ensure that they guarantee equitable economic returns for host communities (Deveci et al., 2021).

Moreover, it is crucial to mention that policy transparency and enforcement consistency define trust in solar project planning; however, even technical and legal compliance in such projects can cause community resistance if not communicated clearly (Hess et al., 2025). Hence, social acceptance encompasses not only the transparency of the communication process but also the implementation of policies and their practical impact on local communities (Melek et al., 2024).

4.4. Environmental feasibility

Environmental feasibility considers solar potential, terrain, and the protection of ecologically sensitive areas for sustainable development.

4.4.1. Climate

Environmental factors are essential for assessing the suitability of a solar PV farm site, particularly in evaluating climatic conditions for the long-term sustainability and successful operation of renewable energy infrastructure (Raza et al., 2023). While measuring technical performance is crucial for understanding how efficiently photovoltaic systems respond to radiation and temperature, environmental feasibility is more closely tied to how consistently the climate can support clean, reliable energy production while causing minimal environmental impact (Wang et al., 2023). As mentioned, one of the primary fundamental indicators for solar PV farm site screening is GHI. High GHI levels generally indicate favorable long-term energy yield and are usually considered the primary criterion for optimal site selection (Melek et al., 2024). Similarly, DNI is critical for certain technologies, such as concentrated solar power or fixed-tilt PV systems, which are highly dependent on direct sunlight and are better suited to areas with less cloud cover for improved efficiency (Sun, Jiang et al.).

Nonetheless, the amount of sunlight is not the only factor identifying whether a site meets the criteria for solar farm use. Factors such as average cloud cover, rainfall, and humidity also need to be considered. Persistent cloudiness and heavy rainfall can reduce the solar irradiance reaching the surface, while high humidity is associated with increased material degradation and maintenance needs (Mokarram et al., 2020). Therefore, many studies consider these factors as constraints or exclusion criteria for filtering locations with unpredictable and unstable climatic conditions (Yavari et al., 2022). Furthermore, suitability analysis needs to concentrate more on climate change-adjusted models rather than only on historical data. As long-term viability of the projects depends on taking into account shifting cloud cover patterns, extreme heat as it impacts panel efficiency, and increased disaster risks (such as floods or wildfires), overall, all climatic conditions are driven by current climatic instability (Ünsal et al., 2024; Shorabeh et al., 2019).

Additionally, another important factor is temperature extremes, as high temperatures not only reduce panel efficiency but also increase the need for additional cooling infrastructure (Wati and Meukam, 2024). Moreover, extremely high temperatures increase the need for higher water usage, which can also impact environmental sustainability in specific regions (Nguyen et al., 2022). Similarly, locations that tend to have heat waves or severely cold temperatures are considered risky for system durability and long-term sustainability (Shorabeh et al., 2019). Thus, such sites are considered less favorable for environmentally

resilient solar installations.

4.4.2. Topography

Another critical component of environmental feasibility is topography. It has a direct effect on the lasting sustainability and reliability of solar PV farm projects (Dhunni et al., 2019). Topography in the environmental context defines how the physical landscape affects or restricts solar infrastructure with minimal environmental disruption (Ali et al., 2019).

The slope is one of the key considerations under topography. Flat surfaces are generally preferred not only for the ease of panel installation and maintenance but also for reducing the need for significant land modification (Kuru, 2023). Hence, evaluating slope and incorporating specific preferred measures of slope steepness can significantly influence the solar PV farm development process and address ecological issues during construction (Doorga et al., 2019).

Another important aspect of topography is elevation, as it highly defines site suitability (Rekik and Alimi, 2024). Higher elevations can be more efficient for solar irradiance or cooling; however, they also have disadvantages, such as greater wind exposure, limited access, and logistical challenges (Sari and Rusen, 2025). For instance, areas in high mountains may incur additional costs for road development and land modification (Kircali and Selim, 2021). Therefore, selecting such areas for solar PV plant development can lead to higher costs and potential environmental trade-offs (Vrinceanu et al., 2022).

Furthermore, another important topographic factor is terrain ruggedness, which can be described as the degree of elevation variation at a particular site (Amjad and Shah, 2020). As uneven terrain tends to increase construction costs and requires significant land modifications, many GIS-based site suitability studies are used to identify or mark unsuitable regions, thereby avoiding the complexity of solar project implementation (Noorollahi et al., 2022).

4.4.3. Land use

Considering land use as an important aspect of solar PV farm site identification is vital to project environmental feasibility (Mokarram et al., 2020). We have already covered land ownership and land prices under the economic and social dimensions. However, from an environmental perspective, land use is evaluated in terms of how current or planned land use aligns with the environmental and regulatory goals of

the region (Ünsal et al., 2024). For instance, areas such as abandoned industrial sites, degraded land, and desert zones are preferable because they have minimal biodiversity and low economic value, as they are not developed in the same manner as urban areas (Prieto-Amparán et al., 2021). Therefore, such sites are highly suitable for solar PV farm development due to the ease of permitting and the potential for reduced trade-offs (Nguyen et al., 2022).

On the other hand, the use of productive agricultural land can trigger local resistance, as such sites are usually characterized by ideal topographic and irradiance conditions but compromise the potential to leverage the land for agricultural purposes (Kircali and Selim, 2021). However, the development of agrivoltaic systems that combine crop cultivation with elevated solar panels is an innovative solution that enables land use for both agricultural and clean energy production without compromising environmental and economic benefits (Moore et al., 2022). Nevertheless, regions with protected areas, forests, and wetlands, as well as locations with high biodiversity value, are generally excluded due to international and national regulations (Kuru, 2023; Mehrian et al., 2024). Even technically feasible sites that fall under such a filter can violate environmental protection laws, undermine biodiversity conservation efforts, and result in delays, project cancellations, and reputational risks (Kuru, 2023).

Fig. 2 illustrates the proposed framework for factors influencing the selection of solar PV farm sites. The figure presents four main dimensions for evaluating site suitability. Technical sustainability encompasses grid connectivity, energy efficiency, and future expansion possibilities. Economic viability includes developing long-term operational and development plans that ultimately lead to economic viability. Social acceptance includes community impact and policy compliance to avoid unnecessary resistance and delays during project initiation. Environmental feasibility examines climate, topography, and land use in detail and underscores the importance of environmental conservation in the selection process.

To connect the theoretical framework and the presented subfactors to their practical implications, Table 6 was created to synthesize parameters and thresholds commonly used for solar PV farm siting. The parameters and thresholds for the technical, environmental, economic, and social pillars are derived from the most frequently cited paper among the 103 papers included in a systematic literature review. These studies provide statistically accurate usage of thresholds for GHI, slope,

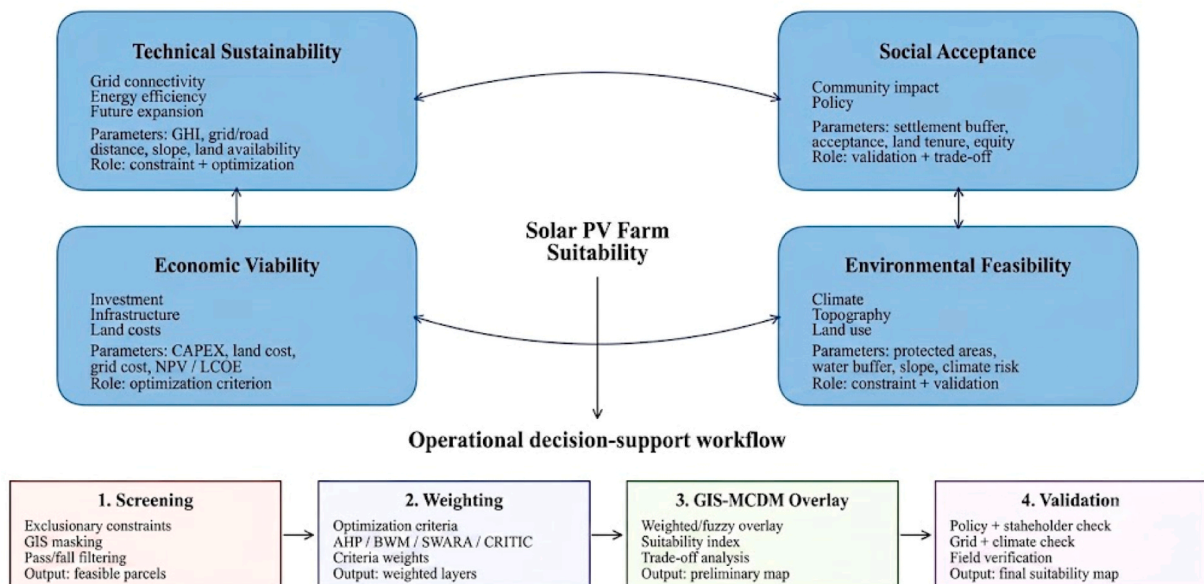


Fig. 2. The framework of factors for evaluating site suitability for solar farms (Created by the authors.).

Table 6
Synthesized representative parameters and ranges for solar PV siting.

Pillar	Key Parameter	Range / Threshold	References
Technical	Solar Irradiance (GHI)	> 1600–2000\$ kWh/m ² /year	(Al Garni and Awasthi, 2017; Ali et al., 2019)
	Distance to Grid	< 5–10 km (Ideal); < 20–25 km (Limit)	(Sun et al., 2021) (Ali et al., 2019)
	Distance to Roads	< 2 km (Optimal); < 10 km (Practical limit)	(Ali et al., 2019; Tao et al., 2025; Yilmaz et al., 2024)
	Site Potential Score	High consistency with ML-based suitability	(Tao et al., 2025; Yilmaz et al., 2024)
Environmental	Topographic Slope	< 3° – 5° (Optimal); < 10° (Strict Limit)	(Al Garni and Awasthi, 2017; Ali et al., 2019)
	Flood Risk/ Water Buffer	> 200–500 m distance from water bodies	(Ali et al., 2019)
	Protected Area Buffer	> 1000 m exclusionary zone	(Al Garni and Awasthi, 2017) (Yilmaz et al., 2024)
	Land Use Restrictions	Excluding: Forests, wetlands, and fertile croplands	(Heidary Dahooie et al., 2022; Wang et al., 2022)
Economic	Financial Feasibility	Positive Net Present Value (NPV) & Externality Balance	(Pojadass and Abundo, 2022)
	Cost factors	Minimization of land acquisition and grid connection costs	(Wang et al., 2022)
Social	Urban/ Residential Buffer	> 500–1000 m (Standard); > 2000 m (High)	Al Garni et al., (Al Garni and Awasthi, 2017); Ali (2019)
	Social Justice Metrics	Fair distribution of benefits/costs for local communities	Yenneti and Day (Yenneti and Day, 2016)
	Matching Alignment	Preference-based matching with local socio-environmental needs	Irie et al. (Irie et al., 2022)

and infrastructure proximity. However, parameters related to social dimensions, such as matching alignment and social justice metrics, are synthesized from less-cited yet specialized research on niche factors that are not commonly used in PV farm site selection papers employing MCDM-GIS models. By combining high-impact studies with regional analyses, Table 6 provides a comprehensive overview of the currently dominant threshold criteria in the solar PV siting literature. It is worth noting that these thresholds remain indicative and ranges can still vary across different geographical locations; hence, practitioners must adjust and leverage them in line with localized regulations, geographic, and socio-economic requirements.

5. Discussion

Developing solar PV farms has faced technical, economic, social, and environmental challenges. This study addressed these challenges by conducting a systematic literature review, encompassing 103 peer-reviewed papers, to identify key factors for evaluating solar farm site suitability. This article developed an integrated operational framework encompassing four dimensions: technical sustainability, economic viability, social acceptance, and environmental feasibility. The review of the papers highlighted the need for an inclusive framework for solar PV farm site selection, whereas most of the included studies prioritize geographic or technological factors. To address this, the following analysis proposes a practical implementation strategy for the proposed framework as a multi-stage decision logic, demonstrating how the identified factors function as a pathway rather than a static list.

While the proposed framework in Section 4 categorizes factors into four pillars (Technical, Economic, Social, and Environmental), in practice, these criteria operate under a decision-making logic. Based on the frequency analysis of the 103 reviewed studies (Tables 3–5), we propose that stakeholders approach the framework as a three-phase decision pathway:

- **Primary exclusion screening:** Initially, high-dominance factors such as Slope, GHI, and land use act as exclusionary filters. These criteria can be understood as a baseline: a failure in any one (e.g., a slope >10%) results in immediate site rejection, even if performance in other categories is significant.
- **Technical and economic optimization:** Once feasible land is identified, technical and economic factors such as grid connectivity and land costs are applied. In this phase, the criteria are no longer exclusionary; for instance, a site farther from the road can still be selected based on its proximity to high-capacity substations that will yield high ROI in the future.
- **Socio-climatic validation:** The final selection is refined by assessing social acceptance and the current socio-environmental challenges identified in this review, such as climate change resilience and social justice. These factors ensure that the site is selected not only for its technical viability, but also for its long-term social and environmental sustainability. The practical utilization of this phase is demonstrated in countries characterized by high-density, for instance, Japan, where final validation of the site for PV farms is determined by matching algorithms to align technical specifications of the region with society's preservation preferences and needs (Irie et al., 2022).

To understand how this logic is applied in practice, it is necessary to examine the framework's specific dimensions, particularly those that dominate the initial screening and optimization phases. This logic is primarily driven by technical sustainability, which serves as the foundational pillar for both of these phases.

Starting with technical sustainability, one of the fundamental factors discussed across the studies, the most frequently cited criteria were grid connectivity, solar resource availability, topography, and potential for future expansion. Saraji, Streimikiene et al. (Saraji et al., 2024) Yilmaz, Kocer et al. (Yilmaz et al., 2024) confirmed that siting decisions based on technical dimensions are driven by access to energy infrastructure and natural conditions that ensure energy efficiency. For instance, several GIS- and MCDM-based models indicate that grid integration and energy output are optimized in areas closer to substations and transmission lines. This stage is commonly used in high-mountain regions such as south-central Vietnam, where initial screening includes high-resolution GHI mapping and land-surface temperature research to evaluate the site's technical suitability (Nguyen et al., 2022). Moreover, Sun et al. (2021) and Al Garni et al., (Al Garni and Awasthi, 2017) highlighted the importance of scalability, infrastructure readiness, and supportive policy conditions for long-term development of solar sites, which aligns with the future expansion subfactor introduced in the proposed framework.

Furthermore, three key subfactors were addressed within the framework for economic viability: investment, infrastructure, and land costs. It is concluded that economic feasibility is often a primary concern for decision-makers and investors. For instance, Li et al. (2024) and Siciu et al. (2024) found that sites with high investment costs, a lack of infrastructure, or complex ownership arrangements often result in delayed or canceled projects, despite being technically suitable. Additionally, the relevance of financial mechanisms and the consideration of CBA were included in many studies. Pojadass and Abundo (2022) and Zhang and Zhao (2025) concluded that the use of CBA enables the balancing of financial returns with environmental and operational costs. It shows the importance of economic factors during site evaluation. Similarly, tropical region countries: Thailand and Vietnam, are good

examples of how economic viability for site selection is commonly affected by policy-driven qualitative factors together with the challenges in land use and acquisition, which need to be considered with the existing physical constraints (Ali et al., 2019; Wang et al., 2022). Moreover, a recent study from the Philippines highlights the importance of including spatial cost-benefit-externality modeling in the screening phase to identify suitable solar PV farm sites (Pojudas and Abundo, 2022).

When it comes to social acceptance, the framework focuses on community impact and policy-related factors. Several studies confirm that public resistance, driven by concerns over visual or noise impacts, policy transparency, and inequality in benefit sharing, is one of the leading causes of solar project interruptions and cancellations (Melek et al., 2024; Wang et al., 2021). However, when the project development process includes transparent communication, stakeholder engagement, and fair compensation mechanisms, social resistance tends to decrease. Including social sustainability as one of the core dimensions of the developed framework in this study aligns with the conclusions by Deveci et al. (2021) which highlight the importance of local participation, clarity of land rights, and trust in institutional processes.

Lastly, under environmental feasibility, the commonly used sub-factors included climatic suitability, topographic features, and land use compatibility. High solar irradiance remains a baseline requirement across most siting analyses, while rugged terrain, protected areas, and agricultural competition frequently appear as constraints. Wati and Meukam (2024), Heidary Dahooie et al. (2022) and Saraji et al. (2024) underline that unsuitable land use or environmentally sensitive zones, even when technically feasible, are excluded to avoid further ecological and legal risks.

Furthermore, the increase in publications since 2015 reflects the influence of global sustainability goals and international agreements, such as the Paris Agreement. These global policy directions have increased attention to environmental and climate targets and triggered research focusing on energy transition planning and site suitability, particularly in emerging economies. It also reflects the growing interest in policy, academia, and the private sector in ensuring that solar projects produce clean energy while also achieving long-term feasibility, policy compliance, and public legitimacy.

Moreover, this study also analyzed how different studies prioritize and weigh identified factors. Prioritization methods vary by region and the methodologies used. For instance, studies using AHP or Fuzzy AHP methods (Al Garni et al., (Al Garni and Awasthi, 2017), Heidary Dahooie et al. (2022) often assign higher weight to technical factors such as solar radiation and slope, while hybrid approaches such as GIS-TOPSIS tend to balance environmental and economic indicators more equally (Sun et al., 2021; Yilmaz et al., 2024).

6. Conclusions

Studies in developing countries show that having the right policies and infrastructure is important for the selection of solar PV sites. Institutional support and resource availability are crucial in these areas. Different strategies for site assessments highlight the need to adapt these frameworks locally, which supports the creation of a unified model proposed in this study.

The present research integrates various selection criteria for solar PV sites into a single framework, thereby supporting well-balanced, interdisciplinary research. The suggested model provides researchers, decision-makers, and investors with a common tool for identifying the most appropriate locations for solar PV farms. The subsequent planning of solar PV farms ought not to be based solely on technical considerations but also on social, economic, and environmental factors. The review highlights the imperative need for site selection processes that comply with policy, engage with communities, and use data to advance national climate goals without leaving local communities and project effectiveness behind.

Policy recommendations

- During the solar PV farm siting process, decision-makers should develop integrated strategies across local, national, and regional planning. As site suitability is highly dependent on technical, environmental, social, and economic considerations, decision-makers should adopt a cross-sectoral planning approach that includes collaboration among land-use authorities, grid operators, environmental regulators, and community representatives to develop zoning maps for solar PV farm development. Moreover, prioritized zones should be identified using multi-criteria analysis tools that include solar radiance, grid capacity, and land availability. Additionally, governments should support integrated planning, update land-use plans, and revise policies and regulations to meet long-term solar infrastructure needs.
- Policymakers should create a simple and quick approval process for solar projects. They should also support financial tools like tax credits, subsidies, and grants, as these are important for building investor confidence and scaling up renewable energy projects. This support is especially needed in areas where grid upgrades or high land costs are issues, as these factors greatly influence investment choices.
- It is crucial to consider societal needs and implement benefit-sharing mechanisms to enhance social acceptance. As social resistance can result in project delays or even cancellations, developers should be legally required to conduct stakeholder engagement before site acquisition. Public participation in land-use planning through participatory zoning, co-benefit planning, and other approaches should be encouraged. Moreover, policymakers should introduce transparent compensation mechanisms, such as local job-creation quotas, community investment funds, and measures to ensure the area's long-term development, alongside public support.
- It is also vital to consider the development of grid infrastructure, substation capacity, and transport access. Therefore, national energy regulators should integrate solar expansion potential into infrastructure development plans, including road and substation development, particularly in prioritized regions.
- Additionally, policymakers should implement mandatory exclusion zones to protect environmentally sensitive areas, such as forests, wetlands, and cultural heritage sites. Moreover, strategies such as agrivoltaics should be strengthened to simultaneously balance solar PV farms and agricultural development. To achieve this aim, MCDM and GIS-based spatial analysis methods should be promoted and widely applied. Furthermore, national energy agencies should provide open-access data, as well as technical and capacity-building programs, to support further development and enhance local decision-making.
- Lastly, governments and funding institutions should prioritize allocating funds for research and development in solar PV farm-siting methodologies, specifically the integration of novel indices such as the Construction Suitability Index (CSI) and the Consumption Intensity Index. Moreover, interdisciplinary training should be available to engineers, planners, and environmental analysts to develop skilled specialists capable of addressing the complexity of the solar PV farm development process. Developing partnerships with universities and research centers is recommended to create locally tailored tools and models that address specific needs.

Limitations and recommendations for future research

There are several limitations to this study: as the review was limited to peer-reviewed articles published in English and indexed in Scopus or Web of Science, this may have excluded other important literature such as regional reports, gray literature, government support, and planning documents, case studies published in other languages or other formats, suggesting purely practical implication, particularly for developing

countries. Moreover, the proposed framework identifies and classifies crucial factors affecting solar PV farm site selection; however, it does not empirically test their importance in real-world projects for specific regions.

Future studies could extend the timeframe to include newly published papers from 2025 onward, evaluating evolving priorities in solar PV farm site selection and tracking shifts in policy, climate, and technology development. As the current study focuses on peer-reviewed articles, future research can expand its scope by including energy or governmental reports and gray literature, and by presenting a practical understanding of solar farm siting challenges. Moreover, further research could employ comparative empirical analysis to examine how different site suitability frameworks, such as AHP and GIS-MCDM, perform across various socio-economic and geographical settings.

Furthermore, future studies could include more criteria than are commonly used in current studies. In selecting sites for solar PV farms, slope and solar radiation should not be the only considerations. Long-term land security, social acceptance, and the ability to cope with climate risks need to be included in site selection. This would foster a deeper understanding of sustainability in the development of solar PV farms.

Funding

This paper was funded by the project “A novel evaluation framework for selecting the best solar farm locations: A case study of Lithuania and Poland”, which has received funding from the Research Council of Lithuania (LMT) under the DAINA 3: Polish–Lithuanian Funding Initiative (agreement No. S-LL-24-8). This research was funded in whole or in part by the National Science Center, Poland, Grant/Project No. 2024/52/L/HS4/00052.

CRediT authorship contribution statement

Vishnu Suresh: Supervision. **Mahyar Kamali Saraji:** Writing – review & editing, Project administration, Methodology, Conceptualization. **Dalia Streimikiene:** Supervision. **Mariam Kasradze:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.egy.2026.109613](https://doi.org/10.1016/j.egy.2026.109613).

Data availability

No data was used for the research described in the article.

References

- (IEA), I. E. A., 2024. WEO2024 " Retrieved 2024. <https://www.iea.org/reports/world-energy-outlook-2024>, 2024, from.
- Abdel-Basset, M., Gamal, A., Elkomy, O.M., 2021. "Hybrid multi-criteria decision making approach for the evaluation of sustainable photovoltaic farms locations." J. Clean. Prod. 328, 129526.
- Abdelhady, S., 2021. "Performance and cost evaluation of solar dish power plant: sensitivity analysis of levelized cost of electricity (LCOE) and net present value (NPV). Renew. Energy 168, 332–342.
- Al Garni, H.Z., Awasthi, A., 2017. "Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia. Appl. Energy 206, 1225–1240.
- Ali, S., Taweekun, J., Techato, K., Waewsak, J., Gyawali, S., 2019. "GIS based site suitability assessment for wind and solar farms in Songkhla, Thailand. Renew. Energy 132, 1360–1372.
- Amjad, F., Shah, L.A., 2020. "Identification and assessment of sites for solar farms development using GIS and density based clustering technique-a case of Pakistan. Renew. Energy 155, 761–769.
- Ara, A., Zohora, F.T., Nurul, N., Tanvir, A., Ahmed, N., 2024. "Optimal site selection for solar plant using analytical hierarchy process (AHP): a case study in Bangladesh. Environ. Progress. & Sustain. Energy 43 (2), e14272.
- Asokan, V.A., Sioen, G.B., Kawazu, E., 2024. "Why not in my backyard?(W-NIMBY): the potential of design-driven environmental infrastructure to foster greater acceptance among host communities. Glob. Sustain. 7, e26.
- Ayough, A., Boshruel, S., Khorshidvand, B., 2022. "A new interactive method based on multi-criteria preference degree functions for solar power plant site selection. Renew. Energy 195, 1165–1173.
- Aziz, A.S., Tajuddin, M.F.N., Adzman, M.R., Ramli, M.A., 2021. "Impacts of albedo and atmospheric conditions on the efficiency of solar energy: a case study in temperate climate of Choman, Iraq. Environ. Dev. Sustain. 23, 989–1018.
- Bahtiarian, M., 2020. Noise evaluations of solar energy facilities. INTER-NOISE and NOISE-CON Congress and Conference Proceedings. Institute of Noise Control Engineering.
- Barzehkar, M., Parnell, K.E., Mobarghaee Dinan, N., Brodie, G., 2021. "Decision support tools for wind and solar farm site selection in Isfahan Province, Iran. Clean. Technol. Environ. Policy 23, 1179–1195.
- Bedewy, B.A.H., Al-Timimy, S.R.A., 2023. "Estimate suitable location of solar power plants distribution by GIS spatial analysis. Civ. Eng. J. 9 (5), 1217–1229.
- Bohra, S.S., Anvari-Moghaddam, A., 2022. "A comprehensive review on applications of multicriteria decision-making methods in power and energy systems. Int. J. Energy Res. 46 (4), 4088–4118.
- Bölük, G., Kaplan, R., 2022. "Effectiveness of renewable energy incentives on sustainability: evidence from dynamic panel data analysis for the EU countries and Turkey." Environ. Sci. Pollut. Res. 1–18.
- Chai, S., Kong, F., Liu, Y., Liang, M., Liu, Q., 2024. "Photovoltaic solar farms site selection through "policy constraints–construction suitability": a case study of Qilian County, Qinghai. Land 13 (9), 1420.
- Chen, C.-R., Huang, C.-C., Tsuei, H.-J., 2014. "A hybrid MCDM model for improving GIS-based solar farms site selection. Int. J. Photo 2014 (1), 925370.
- Chen, H.-C., Lee, C.-H., Seekings, T.B.W., Nguyen, L.B., 2025. "Assessing the public's social acceptance of renewable energy management in Taiwan. Land 14 (1), 121.
- Cohen, J.J., Elbakidze, L., Jackson, R., 2020. "Solar bait: how US states attract solar investments from large corporations. Energy J. 41 (2), 167–190.
- Demir, A., Dinçer, A.E., Yılmaz, K., 2023. "A novel method for the site selection of large-scale PV farms by using AHP and GIS: a case study in İzmir, Türkiye." Sol. Energy 259, 235–245.
- Deveci, M., Cali, U., Pamucar, D., 2021. "Evaluation of criteria for site selection of solar photovoltaic (PV) projects using fuzzy logarithmic additive estimation of weight coefficients. Energy Rep. 7, 8805–8824.
- Dhunni, A., Doorga, J., Allam, Z., Lollchund, M., Boojhawon, R., 2019. "Identification of optimal wind, solar and hybrid wind-solar farming sites using fuzzy logic modelling. Energy 188, 116056.
- Dickerson, Z., 2018. A Solar Farm in My Backyard? Resident Perspectives of Utility-Scale Solar In Eastern North Carolina. East Carolina University.
- Doorga, J.R., Rughooputh, S.D., Boojhawon, R., 2019. "Multi-criteria GIS-based modelling technique for identifying potential solar farm sites: a case study in Mauritius. Renew. Energy 133, 1201–1219.
- Fard, M.B., Moradian, P., Emarati, M., Ebadi, M., Chofreh, A.G., Klemes, J.J., 2022. "Ground-mounted photovoltaic power station site selection and economic analysis based on a hybrid fuzzy best-worst method and geographic information system: a case study Guilan province. Renew. Sustain. Energy Rev. 169, 112923.
- Finn, T., McKenzie, P., 2020. "A high-resolution suitability index for solar farm location in complex landscapes. Renew. Energy 158, 520–533.
- Giamalaki, M., Tsoutsos, T., 2019. "Sustainable siting of solar power installations in Mediterranean using a GIS/AHP approach. Renew. Energy 141, 64–75.
- Goh, H.H., C. Li, D. Zhang, W. Dai, C.S. Lim, T.A. Kurniawan and K.C. Goh (2021). "Using multi-criteria decision making (MCDM) and choosing by advantages (CBA) to determine the optimal location for solar photovoltaic (PV) farms."
- Gul, M., Kotak, Y., Muneer, T., Ivanova, S., 2018. "Enhancement of albedo for solar energy gain with particular emphasis on overcast skies. Energies 11 (11), 2881.
- Halder, B., Banik, P., Almohamad, H., Al Dughairi, A.A., Al-Mutiry, M., Al Shahrani, H.F., Abdo, H.G., 2022. "Land suitability investigation for solar power plant using GIS, AHP and multi-criteria decision approach: a case of megacity Kolkata, West Bengal, India." Sustainability 14 (18), 11276.
- Hasanzaeh, M., Kamran, K.V., Feizizadeh, B., Mollabashi, S.H., 2024. "GIS based spatial decision-making approach for solar energy site selection, Ardabil, Iran. Int. J. Eng. Geosci. 9 (1), 115–130.
- Hassan, I., Alhamrouni, I., Azhan, N.H., 2023. "A CRITIC–TOPSIS multi-criteria decision-making approach for optimum site selection for solar PV farm. Energies 16 (10), 4245.
- Hasti, F., Mamkhezri, J., McFerrin, R., Pezhooli, N., 2023. "Optimal solar photovoltaic site selection using geographic information system–based modeling techniques and assessing environmental and economic impacts: The case of Kurdistan. Sol. Energy 262, 111807.
- Heidary Dahooie, J., Husseinazadeh Kashan, A., Shoaie Naeini, Z., Vanaki, A.S., Zavadskas, E.K., Turskis, Z., 2022. "A hybrid multi-criteria-decision-making aggregation method and geographic information system for selecting optimal solar power plants in Iran." Energies 15 (8), 2801.

- Heo, J., Moon, H., Chang, S., Han, S., Lee, D.-E., 2021. "Case study of solar photovoltaic power-plant site selection for infrastructure planning using a BIM-GIS-based approach. *Appl. Sci.* 11 (18), 8785.
- Hess, D.J., Seo, H., Belletto, K., 2025. "Strengthening local siting authority for utility-scale solar: effects on regulatory decisions and public opposition. *Clim. Change* 178 (3), 38.
- Hooshangi, N., Gharakhanlou, N.M., Razin, S.R.G., 2023. "Evaluation of potential sites in Iran to localize solar farms using a GIS-based Fermatean Fuzzy TOPSIS. *J. Clean. Prod.* 384, 135481.
- Hossain, M.S., Wadi Al-Fatlawi, A., Kumar, L., Fang, Y.R., Assad, M.E.H., 2024. "Solar PV high-penetration scenario: an overview of the global PV power status and future growth". *Energy Syst.* 1–57.
- Ibrahim, G.R.F., Hamid, A.A., Darwesh, U.M., Rasul, A., 2021. "A GIS-based Boolean logic-analytical hierarchy process for solar power plant (case study: Erbil Governorate—Iraq). *Environ. Dev. Sustain.* 23, 6066–6083.
- Irie, N., Iwamura, R., Sugiura, K., Kawahara, N., 2022. "Siting Renewable Energy Facilities Using a Matching Algorithm: A Case Study in Japan. *Land* 12 (1), 126.
- Islam, A., Shirowzhan, S., Pettit, C.J., 2025. "Geographic Information System Based Site Selection for NSW's Renewable Energy Zones: Addressing SDG 7. *Sustainability* 17 (6), 2708.
- Jathar, L.D., Ganesan, S., Awasarmol, U., Nikam, K., Shahapurkar, K., Soudagar, M.E.M., Fayaz, H., El-Shafay, A., Kalam, M., Bouadila, S., 2023. "Comprehensive review of environmental factors influencing the performance of photovoltaic panels: Concern over emissions at various phases throughout the lifecycle". *Environ. Pollut.* 326, 121474.
- Jbahi, O., Ouchani, F.-Z., Ghennoui, A., Ferfra, M., Cherkaoui, M., 2024. "Technical potential appraisal and optimal site screening comparing AHP and fuzzy AHP methods for large-scale CSP plants: A GIS-MCDM approach in Morocco. *Sustain. Energy Technol. Assess.* 68, 103877.
- Jong, F.C., Ahmed, M.M., 2024. "Multi-criteria decision-making solutions for optimal solar energy sites identification: a systematic review and analysis. *IEEE Access*.
- Kahatapitiya, C., Jayasooriya, V.M., Muthukumaran, S., 2023. "GIS-based weighted overlay model for wind and solar farm locating in Sri Lanka. *Environ. Sci. Pollut. Res.* 30 (44), 98947–98965.
- Kannan, D., Moazzeni, S., mostafayi Darmian, S., Afrasiabi, A., 2021. "A hybrid approach based on MCDM methods and Monte Carlo simulation for sustainable evaluation of potential solar sites in east of Iran. *J. Clean. Prod.* 279, 122368.
- Kennedy, S.F., Qayyum, F., 2024. "Land acquisition governance and its implications for renewable energy development in Indonesia and the Philippines. *J. Plan. Educ. Res.* 44 (4), 2056–2067.
- Kırcalı, Ş., Selim, S., 2021. "Site suitability analysis for solar farms using the geographic information system and multi-criteria decision analysis: the case of Antalya, Turkey. *Clean. Technol. Environ. Policy* 23, 1233–1250.
- Kocabaldır, C., Yücel, M.A., 2023. "GIS-based multicriteria decision analysis for spatial planning of solar photovoltaic power plants in Çanakkale province, Turkey. *Renew. Energy* 212, 455–467.
- Kurowska, K., Kryszk, H., Bielski, S., 2022. "Location and Technical Requirements for Photovoltaic Power Stations in Poland. *Energies* 15 (7), 2701.
- Kuru, A., 2023. "Solar power plant site selection modeling for sensitive ecosystems. *Clean. Technol. Environ. Policy* 25 (8), 2529–2544.
- Lamhamedi, B.E.H., de Vries, W.T., 2022. "An exploration of the land–(renewable) energy nexus. *Land* 11 (6), 767.
- Li, X.-Y., Dong, X.-Y., Chen, S., Ye, Y.-M., 2024. "The promising future of developing large-scale PV solar farms in China: A three-stage framework for site selection. *Renew. Energy* 220, 119638.
- Lindberg, O., Birging, A., Widén, J., Lingfors, D., 2021. "PV park site selection for utility-scale solar guides combining GIS and power flow analysis: A case study on a Swedish municipality". *Appl. Energy* 282, 116086.
- Madavan, A.N., Dahlin, N., Bose, S., Tong, L., 2023. "Risk-based hosting capacity analysis in distribution systems. *IEEE Trans. Power Syst.* 39 (1), 355–365.
- Mehrian, M., Qelichi, M., Tahouri, H., 2024. "Solar power plant site selection using fuzzy inference system: a case study in Iran. *Int. J. Environ. Sci. Technol.* 1–24.
- Melek, A.B., Gökmen, S., Haspolat, E., Çiçek, D.D., Deveci, M., Ögüz, E., Khorasanchi, M., 2024. "Fuzzy Einstein-based decision-making model for the evaluation of site selection criteria of floating photovoltaic system". *Ocean. Eng.* 301, 117521.
- Mengist, W., Soromessa, T., Legese, G., 2020. "Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX* 7, 100777.
- Mokarram, M., Mokarram, M.J., Gitizadeh, M., Niknam, T., Aghaei, J., 2020. "A novel optimal placing of solar farms utilizing multi-criteria decision-making (MCDM) and feature selection. *J. Clean. Prod.* 261, 121098.
- Mokarram, M., Mokarram, M.J., Khosravi, M.R., Saber, A., Rahideh, A., 2020. "Determination of the optimal location for constructing solar photovoltaic farms based on multi-criteria decision system and Dempster–Shafer theory. *Sci. Rep.* 10 (1), 8200.
- Moore, S., Graff, H., Ouellet, C., Leslie, S., Olwee, D., 2022. "Can we have clean energy and grow our crops too? Solar siting on agricultural land in the United States. *Energy Res. & Social. Sci.* 91, 102731.
- Nafi Shehab, Z., Faisal, R.M., Ahmed, S.W., 2024. "Multi-criteria decision making (MCDM) approach for identifying optimal solar farm locations: A multi-technique comparative analysis". *Renew. Energy* 237, 121787.
- Nguyen, D.-T., Truong, M.-H., Phan, D.-T., 2022. "GIS-based simulation for solar farm site selection in south-central Vietnam. *GeoJournal* 87 (5), 3685–3699.
- Noorollahi, Y., Senani, A.G., Fadaei, A., Simae, M., Moltames, R., 2022. "A framework for GIS-based site selection and technical potential evaluation of PV solar farm using Fuzzy-Boolean logic and AHP multi-criteria decision-making approach. *Renew. Energy* 186, 89–104.
- Onuoha, H., Denwigwe, I., Babatunde, O., Abdulsalam, K.A., Adebisi, J., Emezirinwune, M., Okharedia, T., Akindoyomi, A., Adisa, K., Hamam, Y., 2025. "Integrating GIS and AHP for Photovoltaic Farm Site Selection: A Case Study of Ikorodu, Nigeria. *Processes* 13 (1), 164.
- Pojadas, D.J., Abundo, M.L.S., 2022. "A spatial cost-benefit-externality modelling framework for siting of variable renewable energy farms: A case in Bohol, Philippines. *Renew. Energy* 181, 1177–1187.
- Prieto-Amparán, J.A., Pinedo-Alvarez, A., Morales-Nieto, C.R., Valles-Aragón, M.C., Álvarez-Holgúín, A., Villarreal-Guerrero, F., 2021. "A regional GIS-assisted multi-criteria evaluation of site-suitability for the development of solar farms. *Land* 10 (2), 217.
- Qian, Y., Leng, J., Wang, H., Liu, K., 2024. "Evaluating carbon emissions from the operation of historic dwellings in cities based on an intelligent management platform. *Sustain. Cities* 100, 105025.
- Qureshi, M.S., Nawaz, M.U., Umar, S., 2024. "Cost Benefit Analysis of Photovoltaic Systems in Urban Environments: A Comparative Study. *Rev. Esp. De. Doc. Cient.* 18 (02), 41–64.
- Rane, N.L., Günen, M.A., Mallick, S.K., Rane, J., Pande, C.B., Giduturi, M., Bhutto, J.K., Yadav, K.K., Tolche, A.D., Alreshidi, M.A., 2024. "GIS-based multi-influencing factor (MIF) application for optimal site selection of solar photovoltaic power plant in Nashik, India". *Environmental Sciences. Europe* 36 (1), 5.
- Raza, M.A., Yousef, M., Hassan, M., Numan, M., Kazmi, S.A.A., 2023. "Site suitability for solar and wind energy in developing countries using combination of GIS-AHP; a case study of Pakistan. *Renew. Energy* 206, 180–191.
- Rediske, G., Siluk, J.C.M., Gastaldo, N.G., Rigo, P.D., Rosa, C.B., 2019. "Determinant factors in site selection for photovoltaic projects: A systematic review. *Int. J. Energy Res.* 43 (5), 1689–1701.
- Rekik, S., Alimi, S.E., 2024. "A GIS based MCDM modelling approach for evaluating large-scale solar PV installation in Tunisia. *Energy Rep.* 11, 580–596.
- Roddis, P., Roelich, K., Tran, K., Carver, S., Dallimer, M., Ziv, G., 2020. "What shapes community acceptance of large-scale solar farms? A case study of the UK's first 'nationally significant' solar farm. *Sol. Energy* 209, 235–244.
- Rogna, M., 2020. "A first-phase screening method for site selection of large-scale solar plants with an application to Italy. *Land. Use Policy* 99, 104839.
- Ruiz, H., Sunarso, A., Ibrahim-Bathis, K., Murti, S., Budiarto, I., 2020. "GIS-AHP Multi Criteria Decision Analysis for the optimal location of solar energy plants at Indonesia". *Energy Rep.* 6, 3249–3263.
- Sánchez-Lozano, J.M., Antunes, C.H., García-Cascales, M.S., Dias, L.C., 2014. "GIS-based photovoltaic solar farms site selection using ELECTRE-TRI: Evaluating the case for Torre Pacheco, Murcia, Southeast of Spain". *Renew. Energy* 66, 478–494.
- Saraji, M.K., Streimikiene, D., Suresh, V., 2024. "A novel two-stage multicriteria decision-making approach for selecting solar farm sites: a case study. *J. Clean. Prod.* 444, 141198.
- Sari, F., Rusen, S.E., 2025. "Assessment of the criteria importance for determining solar panel site potential via machine learning algorithms, a case study Central Anatolia region, Turkey. *Renew. Energy* 239, 122145.
- Sekeroglu, A., Erol, D., 2023. "Site selection modeling of hybrid renewable energy facilities using suitability index in spatial planning. *Renew. Energy* 219, 119458.
- Shorabeh, S.N., Firozjahi, M.K., Nematollahi, O., Firozjahi, H.K., Jelokhani-Niaraki, M., 2019. "A risk-based multi-criteria spatial decision analysis for solar power plant site selection in different climates: A case study in Iran". *Renew. Energy* 143, 958–973.
- Shyu, C.-W., 2025. "Energy justice-based community acceptance of local-level energy transition to solar photovoltaic energy. *Energy Rep.* 13, 609–620.
- Sicuaio, T., Zhao, P., Pilesjö, P., Shindypin, A., Mansourian, A., 2024. "A Multi-Objective Optimization Approach for Solar Farm Site Selection: Case Study in Maputo, Mozambique. *Sustainability* 16 (17), 7333.
- Sindhu, S., Nehra, V., Luthra, S., 2017. "Investigation of feasibility study of solar farms deployment using hybrid AHP-TOPSIS analysis: Case study of India. *Renew. Sustain. Energy Rev.* 73, 496–511.
- Spyridonidou, S., Loukogeorgaki, E., Vagiona, D.G., Bertrand, T., 2022. "Towards a sustainable spatial planning approach for PV site selection in Portugal. *Energies* 15 (22), 8515.
- Sreenath, S., Sudhakar, K., Yusop, A., 2020. "Technical assessment of captive solar power plant: A case study of Senai airport, Malaysia. *Renew. Energy* 152, 849–866.
- Stavrou, G. (2021). "Solar glare hazard analysis of PV farms near airports."
- Sun, L., Jiang, Y., Guo, Q., Ji, L., Xie, Y., Qiao, Q., Huang, G., Xiao, K., 2021. "A GIS-based multi-criteria decision making method for the potential assessment and suitable sites selection of PV and CSP plants. *Resour. Conserv. Recycl.* 168, 105306.
- Sun, Y., Zhu, D., Li, Y., Wang, R., Ma, R., 2023. "Spatial modelling the location choice of large-scale solar photovoltaic power plants: Application of interpretable machine learning techniques and the national inventory. *Energy Convers. Manag.* 289, 117198.
- Sward, J.A., Nilson, R.S., Katkar, V.V., Stedman, R.C., Kay, D.L., Ifft, J.E., Zhang, K.M., 2021. "Integrating social considerations in multicriteria decision analysis for utility-scale solar photovoltaic siting. *Appl. Energy* 288, 116543.
- Tao, L., Hayashi, K., Gyltshen, S., Shimoyama, Y., 2025. "Spatial assessment of utility-scale solar photovoltaic siting potential using machine learning approaches: A case study in Aichi prefecture, Japan. *Appl. Energy* 383, 125329.
- Ukoba, K., Yoro, K.O., Eterigho-Ikelegbe, O., Ibegbulam, C., Jen, T.-C., 2024. "Adaptation of solar energy in the Global South: Prospects, challenges and opportunities. *Heliyon* 10 (7).
- Ünsal, Ö., Demir, G., Karakuş, C.B., Pamučar, D., 2024. "Application of Z-number based fuzzy MCDM in solar power plant location selection problem in Spatial planning". *Energy Rep.* 12, 4034–4054.

- Uyan, M., Dogmus, O.L., 2023. "An integrated GIS-based ANP analysis for selecting solar farm installation locations: Case study in Cumra region, Turkey. *Environ. Model. & Assess.* 28 (1), 105–119.
- Vrînceanu, A., Dumitraşcu, M., Kucsicsa, G., 2022. "Site suitability for photovoltaic farms and current investment in Romania." *Renew. Energy* 187, 320–330.
- Wang, C.-N., Chung, Y.-C., Wibowo, F.D., Dang, T.-T., Nguyen, N.-A.-T., 2023. "Site selection of solar power plants using hybrid MCDM models: a case study in Indonesia. *Energies* 16 (10), 4042.
- Wang, C.-N., Dang, T.-T., Bayer, J., 2021. "A two-stage multiple criteria decision making for site selection of solar photovoltaic (PV) power plant: A case study in Taiwan. *IEEE Access.* 9, 75509–75525.
- Wang, C.-N., Dang, T.-T., Wang, J.-W., 2022. "A combined Data Envelopment Analysis (DEA) and Grey Based Multiple Criteria Decision Making (G-MCDM) for solar PV power plants site selection: A case study in Vietnam. *Energy Rep.* 8, 1124–1142.
- Wati, E., Meukam, P., 2024. "Impact of the climate change on the site suitability for solar farms: Case study of Cameroon. *Renew. Energy* 225, 120310.
- Wu, Y., Geng, S., Zhang, H., Gao, M., 2014. "Decision framework of solar thermal power plant site selection based on linguistic Choquet operator. *Appl. Energy* 136, 303–311.
- Wu, Y., Zhang, T., Xu, C., Zhang, B., Li, L., Ke, Y., Yan, Y., Xu, R., 2019. "Optimal location selection for offshore wind-PV-seawater pumped storage power plant using a hybrid MCDM approach: a two-stage framework. *Energy Convers. Manag.* 199, 112066.
- Wu, C., Zhao, Y., Li, W., Fan, J., Xu, H., Ling, Z., Yuan, D., Zeng, X., 2025. "Concentrated Solar Thermal Power Technology and Its Thermal Applications. *Energies* 18 (8), 2120.
- Yavari, R., Zaliwciw, D., Cibin, R., McPhillips, L., 2022. "Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management. *Environ. Res. Infrastruct. Sustain.* 2 (3), 032002.
- Yenneti, K., Day, R., 2016. "Distributional justice in solar energy implementation in India: the case of Charanka solar park. *J. Rural. Stud.* 46, 35–46.
- Yildiz, O.A., Cebi, S., Yildiz, O., 2025. "Multicriteria decision support for sustainable energy planning: an evaluation of alternative scenarios for the solar power plant site selection. *Environ. Dev. Sustain.* 1–35.
- Yilmaz, İ., Kocer, A., Aksoy, E., 2024. "Site selection for solar power plants using GIS and fuzzy analytic hierarchy process: Case study of the western mediterranean region of Türkiye." *Renew. Energy* 237, 121799.
- Zambrano-Asanza, S., Quiros-Tortos, J., Franco, J.F., 2021. "Optimal site selection for photovoltaic power plants using a GIS-based multi-criteria decision making and spatial overlay with electric load." *Renew. Sustain. Energy Rev.* 143, 110853.
- Zhang, Y., Zhao, Z., 2025. "A novel hybrid multi-criteria decision-making approach for solar photovoltaic power plant site selection based on the quantity and quality matching of resource-demand. *Expert. Syst. Appl.* 267, 126014.