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OVERVIEW OF RENEWABLE ENERGY APPLICATIONS FROM PHOTOVOLTAIC PANELS

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Purpose: The study aims to provide an in-depth understanding of current research trends in photovoltaic (PV) applications through a bibliometric approach. Specifically, it seeks to identify the main areas of research, the geographical leaders, the temporal trends, and the recurring themes to guide future development.
Design/methodology/approach: The authors used a five-step procedure based on Hart's methodology, involving data collection, verification, bibliometric analysis, visualization, and results interpretation. The Scopus database was searched using specific keyword combinations, and tools like VOSviewer and Excel were employed for co-occurrence, temporal, geographical, and thematic analysis of publications.
Findings: China, the United States, and India dominate PV application research, with significant contributions in materials science, engineering, and energy fields. Six application domains were analyzed: industry, household, transportation, solar farms, remote locations, and military, with industry and household applications being the most researched.
Research limitations: The study is limited to the Scopus database. This database is broad. However, it may exclude relevant work from other databases. Additionally, studies with unconventional terminology or interdisciplinary scope may be omitted from keyword-based searches.
Practical implications: By mapping PV research trends and dominant regions, the study can guide policymakers, investors, and researchers toward areas with high potential for development and innovation. The identified application domains can help prioritize funding and international collaboration in the most promising PV sectors.
Originality: This research offers the first comprehensive bibliometric analysis explicitly focused on PV applications rather than general PV technology. It contributes to filling the knowledge gap by structuring research areas, identifying emerging topics, and revealing underexplored application domains.
Keywords: renewable energy, photovoltaic panels, application of photovoltaics.
Category of the paper: Research paper.

1. Introduction

One of the most challenging issues facing people in the 21st century is the need to protect the environment (Al Doghan et al., 2022; Arkorful et al., 2024; İnançoğlu et al., 2020). It necessitates a transition to renewable energy sources that are zero-emission during use (Ofstad et al., 2017). Furthermore, considering the entire life cycle of the technology required to generate this energy, its use should result in lower greenhouse gas emissions (Mularczyk, Zdonek, 2022). Consequently, there has been a recent worldwide interest in solar energy, with a particular emphasis on photovoltaic technology (Garcia et al., 2018; Hysa, Mularczyk, 2024; Mostafa et al., 2020).

Photovoltaics (PV) is one of the leading technologies for obtaining energy from renewable sources (All Photovoltaic Barometers Archives…, 2025). It enables the direct conversion of solar radiation energy into electrical energy. A significant increase in PV activity has been observed over the last two decades of the 21st century (Liu, Huo, 2024; Masson et al., 2024; Mularczyk, Zdonek, 2022; Novas Castellano et al., 2024; Stec et al., 2024; Wolniak, Skotnicka-Zasadzień, 2022). It has resulted in a rapid increase in the use of photovoltaic modules in various applications.

Recent research documents a wide range of photovoltaic (PV) applications (Franco, Franco, 2025; Garcia et al., 2018). For example, Vivar et al. (2024) explore water-related PV systems, including floating, submerged, agrivoltaics, aquavoltaics, and PV-integrated water disinfection technologies (Vivar et al., 2024). The integration of photovoltaics with agriculture is described by Qazi (2016), who highlights standalone PV systems for rural, remote, and disaster-prone areas, emphasizing affordability and resilience (Qazi, 2016). Mamun et al. (2022) discuss agrivoltaics as a strategy to enhance rural energy access while supporting local agricultural practices (Mamun et al., 2022). Smith et al. (2013) report on flexible photovoltaic modules for portable device charging, field-deployable arrays, and niche markets (Smith et al., 2013). Hao et al. (2022) focus on PV-powered self-sustaining applications, with particular attention to energy harvesting, maximum power point tracking, and power management for specialized use cases (Hao et al., 2022).

In comparison to the previously mentioned studies, this particular study is distinguished by its contribution to the scientific literature on photovoltaic applications research through the utilization of bibliometric analysis. This study provides an in-depth understanding of current research trends in the use and application of photovoltaics over the years.

Therefore, the main objective of the study is to analyze the key areas and trends in photovoltaic applications. Using bibliometric analysis to identify research trends and knowledge gaps to discover the most promising areas for the development of photovoltaic uses in the world.

Therefore, the article intends to answer the following research questions:

RQ1: What were the main areas/directions of published research?

RQ2: Which countries dominate photovoltaic research?

RQ3: How has research on photovoltaics changed over time?

RQ4: What issues and trends appear most frequently in the analyzed articles?

This article consists of five parts: The first part provides an introduction and justification of the study, as explained previously. The second part discusses the methods used in the study analysis. This section explains the selection of the database, keywords, and tools. The third section of the study presents the results and associated discussions. The final section is intended to provide a concise summary of the conclusions.

2. Methods

There are several literature review methodologies available, including structured reviews, model or framework reviews, meta-analyses, theoretical examinations, hybrid future research frameworks, bibliometric reviews, and systematic reviews (Al Mamun et al., 2022; Azarian et al., 2023; Munn et al., 2018; Oteng et al., 2021; Tawfik et al., 2019). The authors, following the methodology described in the literature (Czakon et al., 2023; Kumar, 2021; Vivar et al., 2024), adopted and proposed their own stages of procedure guided by the key principles underlying the Hart methodology (Hart, 1998). The five-step procedure (as shown in Figure 1) ensures the robustness and rigour of the study, eliminating subjectivity in data collection and analysis.

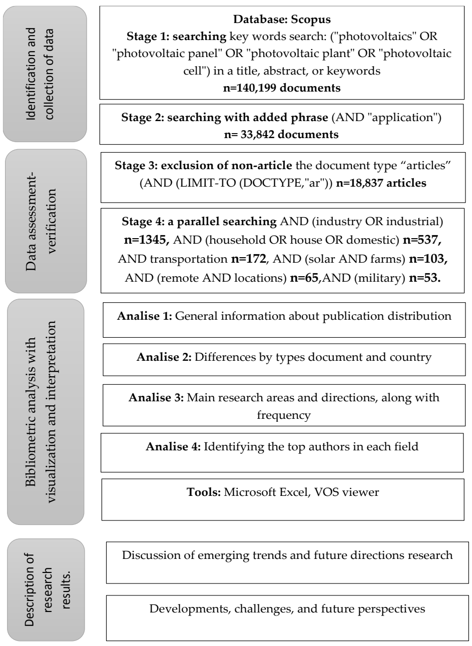

Figure 1. The five-step procedure adopted in the article.

Source: own work.

The methodology consists of the following stages: (1) identification and collection of data, (2) data assessment – verification, (3) bibliometric analysis, (4) visualization and interpretation, and (5) description of research results. The central part of the methodology is bibliometric analysis. Bibliometric analysis is a well-accepted scientific method used worldwide. It uses mathematical and statistical techniques for evaluation. A literature review was conducted to identify articles published on the topic until June 2025. The articles were classified according to the type of study, the authors' region, the main subject, and the application area. Geographic and temporal trends were analyzed. This study is based on the Scopus database because it contains a significant number of publications published over the last four decades on photovoltaic systems. VOSviewer (version 1.6.15) was used to perform co-occurrence analyses on terms from titles and abstracts to visualize the main topics of the publications. Co-occurrence analysis reveals how often two words appear together in the same text as well as the connections between terms. In the resulting visual network, each sphere represents a term, and the size of the sphere is proportional to the occurrence of the term. The links between the spheres represent the association between words: the thicker the line, the stronger the association (co-occurrence). The program identifies clusters of words that are very often cited together and likely refer to the same topic. Time trends, geographical analyzes, and journal analyzes were carried out in Microsoft Excel.

3. Results and discussion

The first three stages were intended to answer the first two research questions (RQ1: What were the main areas/directions of published research? and RQ2: Which countries dominate photovoltaic research?).

The first stage included searching the following terms: ("photovoltaics" OR "photovoltaic panel" OR "photovoltaic plant" OR "photovoltaic cell") in a title, abstract, or keywords. It resulted in 140,199 documents. The main information about the collection is presented in Table 1.

Most of the items found were articles (55%) and conference papers (37%). The main subject areas were engineering (56%), energy (43%), and materials science (30%). The most considerable number of affiliations came from China (19%), the United States (16%), and India (11%). In fourth place was Germany (5%), followed closely by the United Kingdom (5%) and Japan (4%).

Table 1
Main results of the first search

Description	Results		Description	Results	
Main information			**Main subject area**		
Timespan	1923:2025	(June)	Engineering	78,674	(56%)
Documents	140,200		Energy	59,874	(43%)
			Materials Science	42,675	(30%)
Document types			Physics and Astronomy	30,318	(22%)
Article	77,640	(55%)	Computer Science	23,231	(17%)
Conference Paper	51,505	(37%)	Mathematics	18,388	(13%)
Review	5,977	(4%)	Chemistry	16,730	(12%)
Book Chapter	2,714	(2%)	Environmental Science	11,259	(8%)
Conference Review	753	(1%)	Chemical Engineering	8,714	(6%)
Note	465		**Main country/territory**		
Book	354		China	27,287	(19%)
Editorial	177		United States	22,434	(16%)
Erratum	166		India	15,973	(11%)
Short Survey	149		Germany	7,045	(5%)
Retracted	125		United Kingdom	6,348	(5%)
Letter	94		Japan	6,163	(4%)
Data Paper	53		Italy	5,634	(4%)
Report	27		South Korea	4,917	(4%)

Source: based on Scopus.

To specify the search scope, the phrase (AND "application") was added in the second step. It resulted in 33,842 documents (Table 2).

Table 2
Main results after the second stage

Description	Results		Description	Results	
Main information					
Timespan	1949:2025	(June)	**Main subject area**		
Documents	33,842		Engineering	17,957	(53%)
			Materials Science	13,198	(39%)
Document types			Energy	11,465	(34%)
Article	18,837	(56%)	Physics and Astronomy	8,660	(26%)
Conference Paper	10,281	(30%)	Chemistry	6,082	(18%)
Review	2,866	(8%)	Computer Science	4,603	(14%)
Book Chapter	1,118	(3%)	Mathematics	3,611	(11%)
Conference Review	354	(1%)	Chemical Engineering	2,901	(9%)
Book	205	(1%)	Environmental Science	2,132	(6%)
Note	43		**Main country/territory**		
Short Survey	25		China	6,557	(19%)
Erratum	24		United States	5,583	(16%)
Editorial	23		India	4,273	(13%)
Retracted	23		Germany	1,916	(6%)
Report	16		United Kingdom	1,646	(5%)
Data Paper	14		Italy	1,526	(5%)
Letter	13		South Korea	1,335	(4%)

Source: based on Scopus.

Once more, most of the items found were also articles (56%) and conference papers (37%). The main subject areas were engineering (53%), materials science (39%), and energy (34%). The most significant number of affiliations came from China (19%), the United States (16%), and India (13%). In fourth place again was Germany (6%), followed by the United Kingdom (5%), and then Italy (also approximately 5%).

In the third step, we decided to limit the document type to articles (AND (LIMIT-TO (DOCTYPE, "ar")). A total of 18,837 articles were identified (Table 3).

Table 3
Main results after the third stage

Description	Results		Description	Results	
Main information					
Timespan	1949:2025	(June)			
Documents	18,837		**Main country/territory**		
Main subject area			China	4,442	(24%)
Materials Science	9,083	(48%)	United States	2,931	(16%)
Engineering	8,196	(44%)	India	1,991	(11%)
Energy	6,374	(34%)	Germany	1,190	(6%)
Physics and Astronomy	5,671	(30%)	United Kingdom	1,002	(5%)
Chemistry	4,747	(25%)	South Korea	1,001	(5%)
Chemical Engineering	2,145	(11%)	Italy	878	(5%)
Environmental Science	1,383	(7%)	Japan	740	(4%)
Mathematics	1,130	(6%)	Saudi Arabia	716	(4%)
Computer Science	1,104	(6%)	Spain	697	(4%)

Source: based on Scopus.

The main subject areas of articles in question were materials science (48%), engineering (44%), energy (34%), physics and astronomy (30%), and chemistry (25%). In turn, the countries with the highest number of published articles to date are China (24%), the United States (16%), and India (11%), with Germany (6%), United Kingdom (5%), South Korea (5%), and Italy (5%) following. For comparison, Poland ranked 16th with 375 articles (2%). Figure 2 displays the countries of publication for the articles found.

China, the United States, and India have dominated photovoltaic research. On the one hand, one could argue that the size of these countries compared to most other countries has had a significant impact on this result, but countries such as Russia and Brazil do not confirm this thesis. On the other hand, the explanation is probably the greater number of scholarly centers in these countries, which translates into higher research potential.

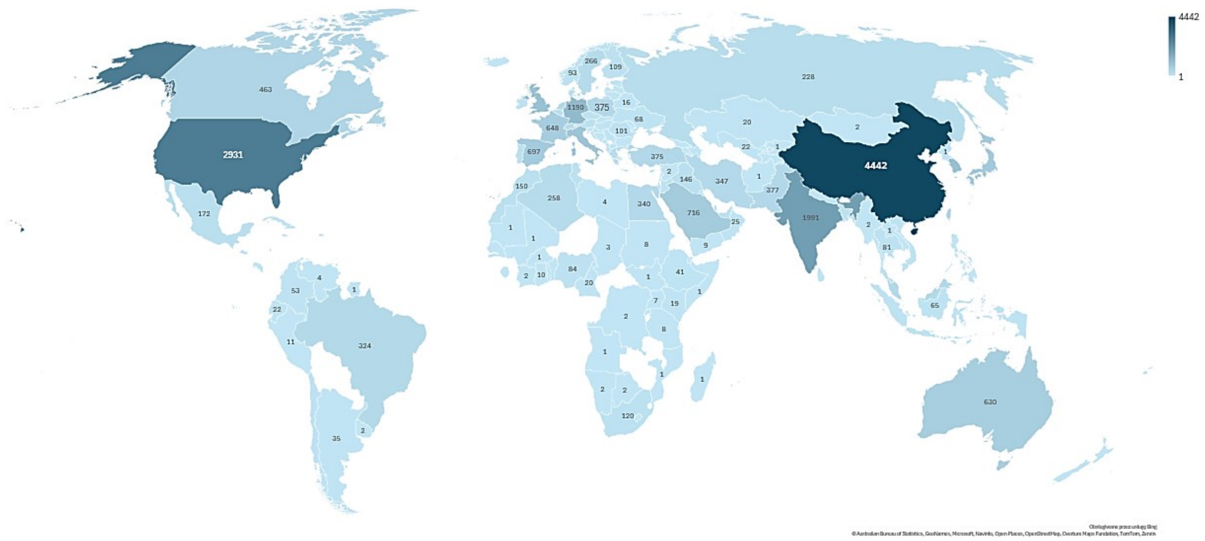

Figure 2. Article affiliation locations.

Source: own calculations.

To answer the third research question (RQ3: How has research on photovoltaics changed over time?), graphs of time series showing the publication dates of the studied publications were constructed and analyzed. Therefore, Figure 3 presents the number of items for all three searches over the years.

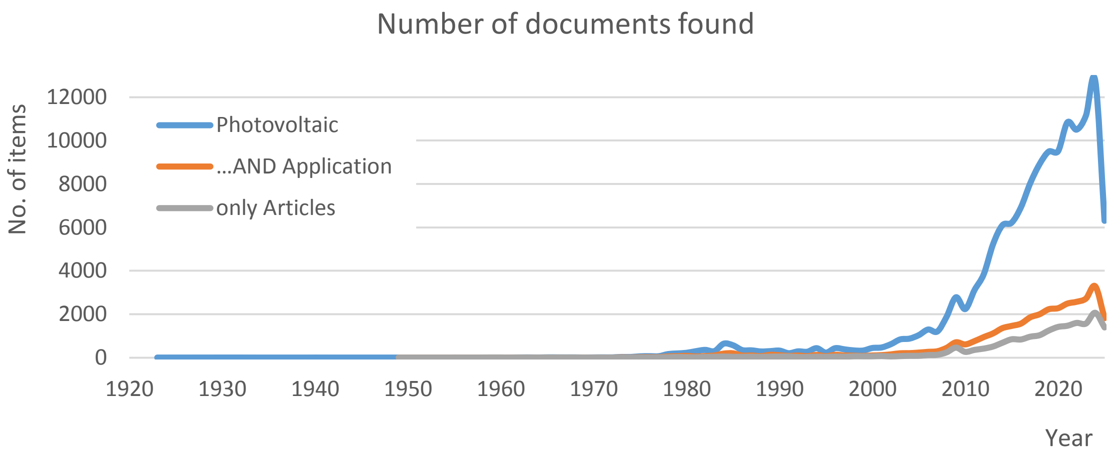

Figure 3. Number of documents in steps I to III over the years.

Source: Scopus.

The earliest document, found at the first stage, was printed in 1923 (Garrison, 1923). Also, in the second and third stages, the oldest document dates back to 1949 (Yurkstas, Manly, 1949). However, it was not until another article from 1957, entitled "Converting Solar Energy into Electricity", that the subject under investigation was presented (Pearson, 1957). Still, the number of works was not at a significant level until the first decade of the XXI century. From that point, the fast-growing trend is visible. This trend is a consequence of the sudden growth of photovoltaic technology worldwide, observed by the authors cited above (Liu, Huo, 2024; Masson et al., 2024; etc.).

Subsequently, to answer the fourth research question (RQ4: What issues and trends appear most frequently in the analyzed articles?), an analysis of the co-occurrence of keywords and terms from titles and abstracts was conducted to examine the subject matter of the articles obtained. Shrivastava, Mahajan (2016) and Oteng et al. (2021) point out that keyword analyses are essential for identifying key research areas within a given field of science (Oteng et al., 2021; Shrivastava, Mahajan, 2016). Keywords characterize the main research of a published article and demonstrate the scope of the research area. A keyword network provides insight into the connections and organization of topics within a research domain, offering a good picture of the research area. We examined the network of co-occurring keywords using VOSviewer software. Figure 4 and Figure 5 display the keywords and their connections for the identified articles, a visualization of keyword frequency and co-occurrence.

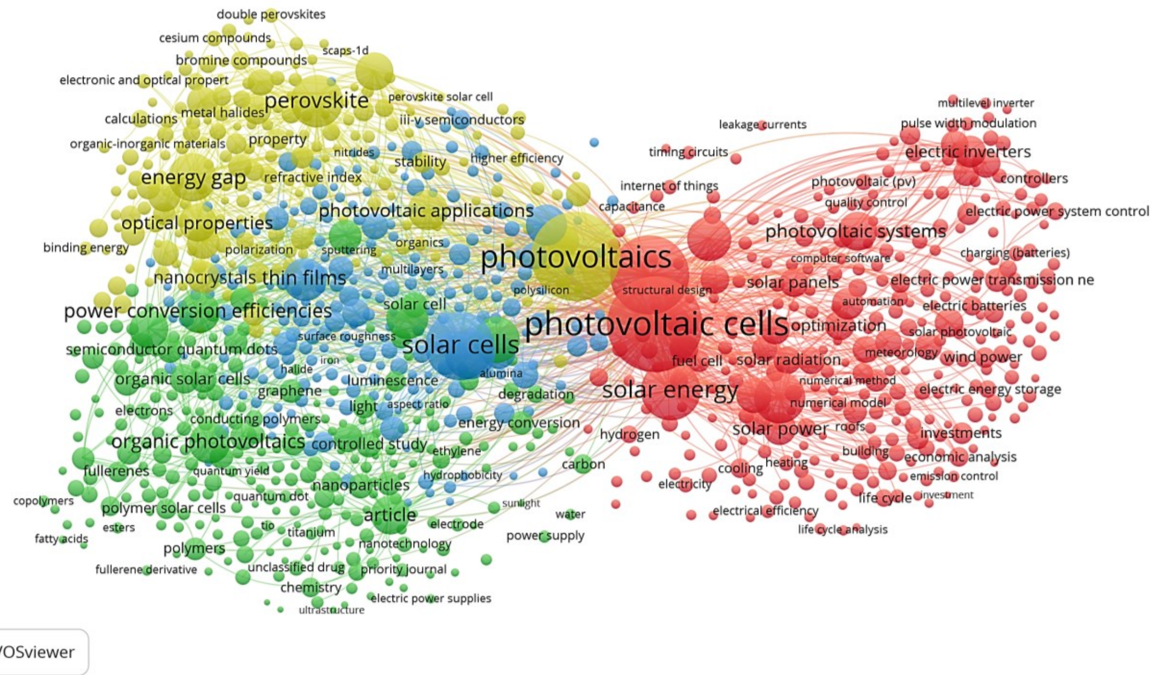

Figure 4. Main keywords in the researched articles consolidated in clusters.

Source: own calculations.

Figure 4 highlights four clusters marked with different colours. On the contrary, the colours in Figure 5 indicate the period in which they appeared in the publications studied. The yellow cluster in Figure 4, as compared to Figure 5, includes the newest keywords, such as perovskite, optical properties, nanocrystals, and other materials. The green one – the oldest. The red cluster contains words associated with solar power, solar energy, batteries, and optimization.

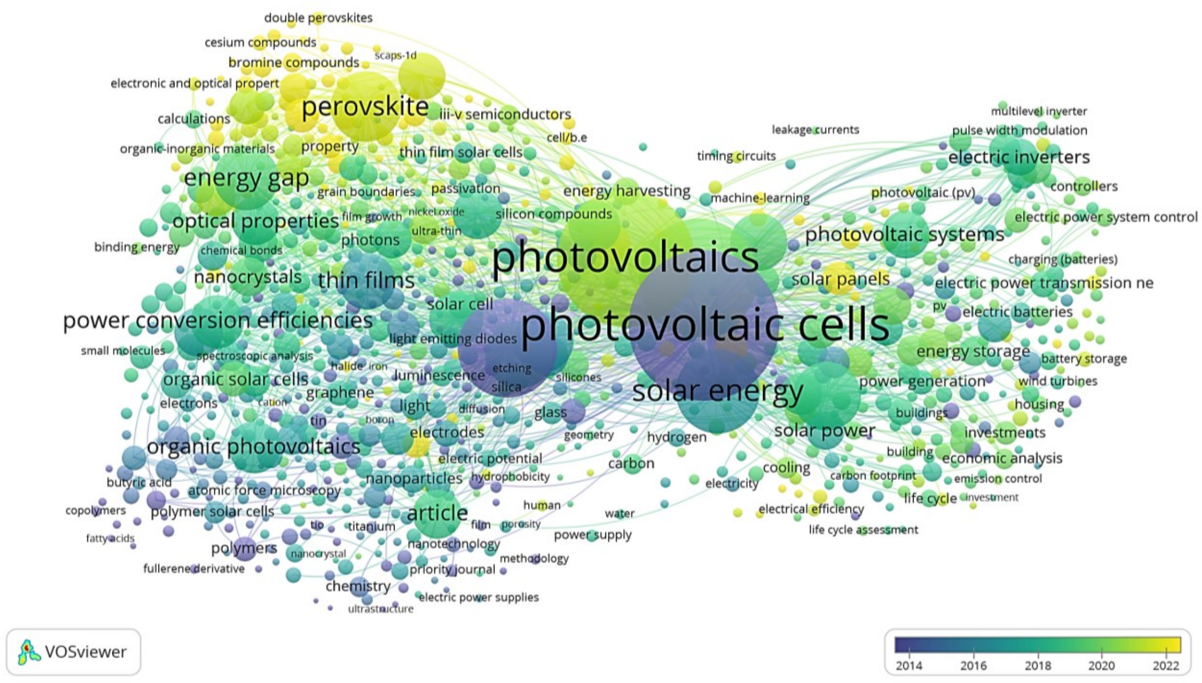

Figure 5. Main keywords in the researched articles over the years.

Source: own calculations.

The keywords obtained primarily concerned the materials used to build photovoltaic panels and the methods of their production and operation. So understood, the keyword analysis presented above did not reveal the expected division into clear application areas. Therefore, based on the authors' research by Hao et al. (2022), Saidi et al. (2025), Díaz-Bello et al. (2025), Zhang et al., (2025), and Pietrzak et al., (2025), as well as their own experience (Hysa, Mularczyk, 2024), the authors decided to divide the searches into the six most important photovoltaic application areas using a deductive method (Table 4).

Table 4
Six photovoltaic application areas for further analysis

Sector	Key Applications
INDUSTRY	– Hybrid PV/T for combining electricity and heat. – Solar-powered sensors and nanomaterials for smart systems. – Recycled PV waste. – Enhancement of the durability of building materials.
HOUSEHOLD	– Rooftop PV panels. – Building-integrated PV (BIPV). – Hybrid PV/thermal systems for water heating. – Smart battery charging supporting off-grid PV usage. – PV greenhouses reduce emissions and support sustainable farming.
TRANSPORTATION	– Solar roofs for ventilation in vehicles. – PV-charging for electric vehicles. – Integrated solar panels in trains. – Curved FPV panels on cars to improve aerodynamics and power.
SOLAR FARMS	– Utility-scale PV for grid integration. – Use of tracking systems to optimize efficiency.

Cont. Table 4.

REMOTELOCATIONS	– PV + wind hybrid systems for telecom. – Islands and military outposts. – Autonomous sensor systems.
MILITARY	– Portable solar chargers for field operations. – UAVs powered by solar cells. – Off-grid base support systems.

Source: own work based on Hao et al. (2022), Saidi et al. (2025), Díaz-Bello et al. (2025), Zhang et al. (2025), Pietrzak et al. (2025), and Hysa, Mularczyk (2024).

Therefore, during the fourth stage of the analysis, parallel search was conducted in six areas according to the following criteria:

1. AND (industry OR industrial).
2. AND (household OR house OR domestic).
3. AND transportation.
4. AND (solar AND farms).
5. AND (remote AND locations).
6. AND military.

In Table 5, the main results are presented.

Table 5
Main results for the fourth stage

Description	Results		Description	Results	
INDUSTRY					
Main information					
Timespan	1965:2025	(June)	Documents	1,345	
Main subject area			**Main country/territory**		
Engineering	615	(46%)	China	317	(24%)
Energy	549	(41%)	United States	180	(13%)
Materials Science	541	(40%)	India	111	(8%)
Physics and Astronomy	315	(23%)	Germany	105	(8%)
Chemistry	228	(17%)	Australia	77	(6%)
HOUSEHOLD					
Main information					
Timespan	1976:2025	(June)	Documents	537	
Main subject area			**Main country/territory**		
Energy	322	(60%)	China	67	(12%)
Engineering	294	(55%)	India	63	(12%)
Environmental Science	113	(21%)	United States	50	(9%)
Materials Science	70	(13%)	United Kingdom	46	(9%)
Mathematics	63	(12%)	Germany	32	(6%)
TRANSPORTATION					
Main information:					
Timespan	1977:2025	(June)	Documents	172	
Main subject area			**Main country/territory**		
Engineering	85	(49%)	China	52	(30%)
Energy	83	(48%)	India	18	(10%)
Materials Science	41	(24%)	United States	17	(10%)
Environmental Science	33	(19%)	Germany	10	(6%)
Physics and Astronomy	29	(17%)	Australia	8	(5%)

Cont. Table 5

SOLAR FARMS					
Main information					
Timespan	1985:2025	(June)	Documents	103	
Main subject areas			**Main country/territory**		
Energy	64	(62%)	China	52	(50%)
Engineering	55	(53%)	India	18	(17%)
Environmental Science	28	(27%)	United States	17	(17%)
Mathematics	17	(17%)	Germany	10	(10%)
Materials Science	14	(14%)	Australia	8	(8%)
REMOTE LOCATIONS					
Main information					
Timespan	1979:2025	(June)	Documents	65	
Main subject areas			**Main country/territory**		
Energy	36	(55%)	India	11	(17%)
Engineering	34	(52%)	United States	8	(12%)
Environmental Science	14	(22%)	Australia	7	(11%)
Materials Science	9	(14%)	Malaysia	6	(9%)
Computer Science	7	(11%)	Spain	5	(8%)
MILITARY					
Main information					
Timespan	1984:2025	(June)	Documents	53	
Main subject areas			**Main country/territory**		
Engineering	37	(57%)	United States	15	(23%)
Energy	17	(26%)	China	11	(17%)
Materials Science	13	(20%)	Poland	6	(9%)
Physics and Astronomy	13	(20%)	Romania	4	(6%)
Mathematics	7	(11%)	Greece	3	(5%)

Source: based on Scopus.

Industry was the subject of 1,331 of the articles found. The earliest item was dated 1965. The main subjects of study were engineering (46%), energy (41%), and materials science (40%). China (24%), the United States (13%), India (8%), Germany (8%), and Australia (6%) were the most frequent countries of affiliation.

In terms of household FV applications, 537 articles were identified (the earliest dating back to 1976). The main subjects of study were energy (60%), engineering (55%), and environmental science (21%). This time, India surpassed the United States, ranking second in terms of the number of affiliations, namely: China (12%), India (12%), the United States (9%), the United Kingdom (9%), and Germany (6%).

There were 172 articles about transportation, with the oldest dating back to 1977. The main subject areas included: engineering (49%), energy (48%), and materials science (24%). The most often affiliated countries were China (30%), India (10%), the United States (10%), Germany (6%), and Australia (5%).

Solar farms were the subject of 102 articles. The first was dated to 1985. The articles were published mainly in three subject areas: energy (62%), engineering (53%), and environmental science (27%). The five countries with the most frequent affiliations were China (50%), India (17%), the United States (17%), Germany (10%), and Australia (8%).

As many as 64 articles were found about the remote locations of PV applications, with the oldest dating back to 1979. Their subject areas were mainly: energy (55%), engineering (52%), and environmental science (22%). The most common countries of affiliation in this case differed slightly from those in previous instances. They were, namely: India (17%), United States (12%), Australia (11%), Malaysia (9%), and Spain (8%).

Finally, only 53 articles addressed the use of PV for various military applications. Military uses were niche but present. The earliest one found was dated to 1984. They were most often published in engineering (57%), energy (26%), materials science, and physics and astronomy (both of 20%). This time, the territory of affiliation also differed, including the United States (23%), China (17%), Poland (9%), Romania (6%), and Greece (5%).

The following two figures (Figure 6 and Figure 7) illustrate the number of articles published over the years in all six areas.

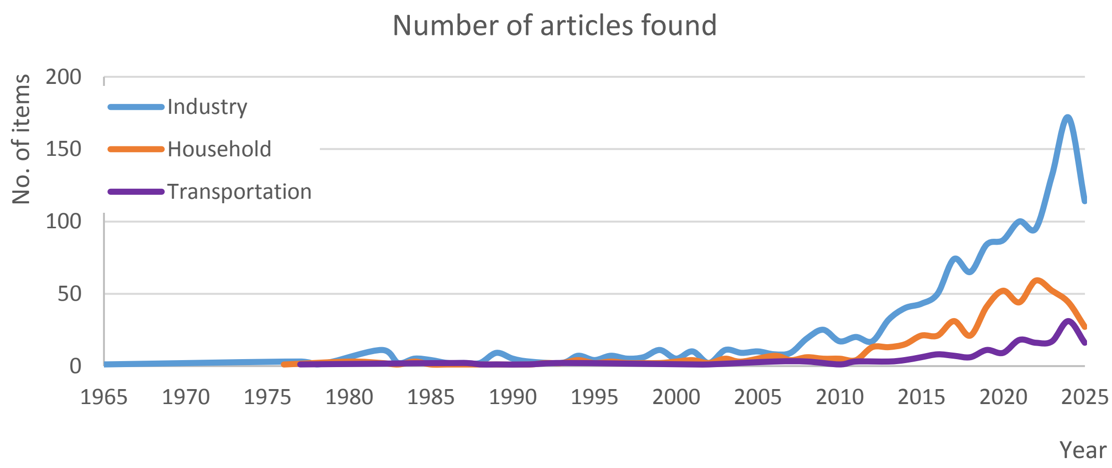

Figure 6. Number of articles in the first three areas published over the years.

Source: Scopus.

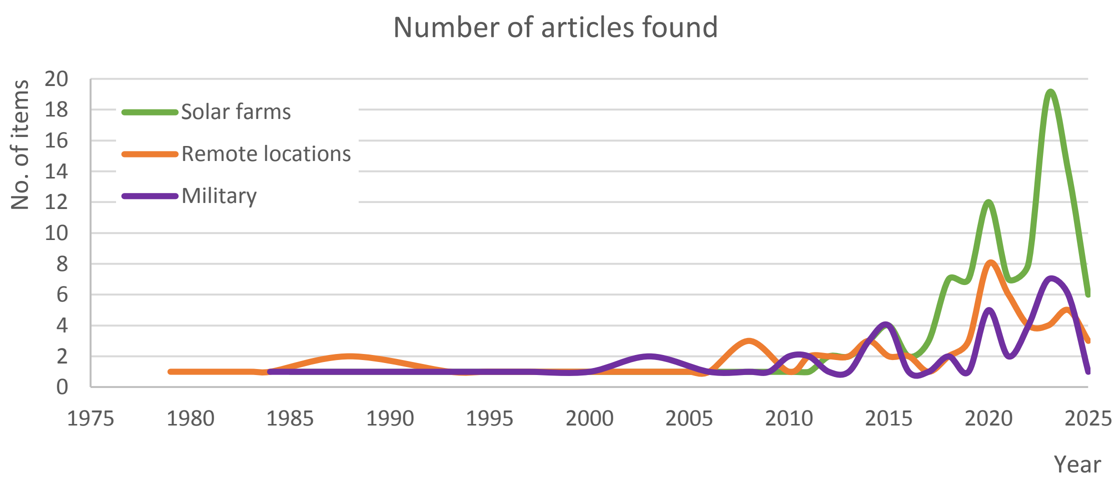

Figure 7. Number of articles in the last three areas published over the years.

Source: Scopus.

When analysing the abstracts and keywords of articles in specific areas, it is clear that terms such as "vehicle", "battery", "hybrid", "charging", and "range" dominate the field of transportation. The field of household highlighted "building", "façade", "rooftop", and "insulation design integration" issues. Papers on remote locations clustered around "off-grid", "island", "rural", and "standalone" topics. Solar farm articles emphasized "utility-scale", "large-scale", "grid", and "cost". Industrial applications focused on" manufacturing and process optimization", as well as "flexible roll-to-roll lines". Keywords in military articles included "tactical", "soldier", "lightweight", and "battlefield power".

Identifying the top authors in each area revealed interesting results presented in Table 6.

Table 6
Top-cited authors in each area

Area	Author	Cited by
INDUSTRY	– Grätzel M., – O'Regan B., – Gao P., – Nazeeruddin M.K., – Moon S.-J.	41822 27196 9544 9344 8881
HOUSEHOLD	– Yang Y., – Li Y., – Li Z., – Yang H., – Wang Y.	2638 2052 1848 1617 1606
TRANSPORTATION	– Li Y., – Wang Y., – Grätzel M., – Zhang J., – Friend R.H.	6687 6257 5400 5066 5056
SOLAR FARMS	– Grätzel M., – O'Regan B., – Zhang J., – Wang Y., – Han Y.	28830 27176 1967 1885 1791
REMOTELOCATIONS	– Das B.K., – Wang Y., – Hoque N., – Mandal S., – Hou J.	824 660 614 614 544
MILITARY	– Kist J.A., – Essner J.B., – Baker G.A., – Polo- Parada L., – Wűrthner F.	251 251 251 251 219

Source: own work.

Grätzel M. and O'Regan B. dominate in every industrial or solar farm-related context, indicating a close connection between these areas. In contrast, the transport and household sectors appear to be more dispersed, and among authors in the field of applied energy are Yang Y., Li Y., Wang Y. Finally, remote-location initiatives are spearheaded by a distinct set of authors (e.g., Das B.K. et al.), who concentrate on standalone rural electrification and microgrids. Military PV remains a niche slice; a single 250-citation paper skews the ranking and places its author group at the top.

4. Summary

Photovoltaics is a broad research area due to its multidisciplinary applications in various fields. However, previous research on photovoltaics has focused on general applications, capacity building, exploring advantages and disadvantages, and side effects. Photovoltaic applications have diversified across key societal sectors. In industry, PV drives innovation and circularity; in agriculture, it powers eco-efficient cultivation; in households, it supports autonomy and resilience; in transport, it enhances mobility electrification; in construction, it promotes sustainable materials; and in infrastructure, it underpins systemic energy transitions. Each sector carries unique integration strategies and benefits.

The analysis of emerging trends in photovoltaics includes perovskite solar cells, nanocrystal integration, optical property optimization, and hybrid photovoltaic systems that combine energy generation with agricultural, water, or architectural functions. Future research directions may include the use of advanced materials, improving photovoltaic performance in diverse environments, and increasing affordability and durability in rural electrification and specialized applications. Challenges for the future of photovoltaics include continued innovation in materials and system integration, greater penetration in developing regions, expanding hybrid applications, and growing synergies between photovoltaic systems and smart grids or energy storage solutions.

References

1. Al Doghan, M.A., Abdelwahed, N.A.A., Soomro, B.A., Ali Alayis, M.M.H. (2022). Organizational Environmental Culture, Environmental Sustainability and Performance: The Mediating Role of Green HRM and Green Innovation. *Sustainability*, *14*, *12*, 12, doi: 10.3390/su14127510
2. Al Mamun, M.A., Azad, M.A.K., Al Mamun, M.A., Boyle, M. (2022). Review of flipped learning in engineering education: Scientific mapping and research horizon. *Education and Information Technologies*, *27*, *1*, pp. 1261-1286, doi: 10.1007/s10639-021-10630-z
3. All Photovoltaic barometers Archives (2025). *EurObserv'ER*. Retrieved from: https://www.eurobserv-er.org/category/all-photovoltaic-barometers/

4. Arkorful, V.E., Abdul-Rahaman, N., Arkorful, V.A. (2024). Determinants of citizens' willingness to participate in environmental governance – An empirical study. *Current Psychology*, *43*, *3*, pp. 2859-2874, doi: 10.1007/s12144-023-04547-8
5. Azarian, M., Yu, H., Shiferaw, A.T., Stevik, T.K. (2023). Do We Perform Systematic Literature Review Right? A Scientific Mapping and Methodological Assessment. *Logistics*, *7*, *4*, 4, doi: 10.3390/logistics7040089
6. Czakon, W., Jedynak, M., Kuźniarska, A., Mania, K. (2023). Social media and constructing the digital identity of organizations: A bibliometric analysis. *Entrepreneurial Business and Economics Review*, *11*, *4*, 4, doi: 10.15678/EBER.2023.110403
7. Díaz-Bello, D., Vargas-Salgado, C., Alcazar-Ortega, M., Alfonso-Solar, D. (2025). Optimizing photovoltaic power plant forecasting with dynamic neural network structure refinement. *Scientific Reports*, *15*, *1*, 3337, doi: 10.1038/s41598-024-80424-z
8. Franco, A.C., Franco, L.S. (2025). Photovoltaic solar energy and environmental impacts in the industrial sector: A critical overview of barriers and opportunities. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *47*, *1*, pp. 10083-10095, doi: 10.1080/15567036.2021.1960933
9. Garcia, G., Nogueira, E.F., Betini, R.C. (2018). Solar Energy for Residential Use and Its Contribution to the Energy Matrix of the State of Paraná. *Brazilian Archives of Biology and Technology*, *61*, e18000510, doi: 10.1590/1678-4324-smart-2018000510
10. Garrison, A. (1923). A determination of absolute single electrode potentials. *Journal of the American Chemical Society*, *45*, *1*, pp. 37-44, doi: 10.1021/ja01654a005
11. Hao, D., Qi, L., Tairab, A.M., Ahmed, A., Azam, A., Luo, D., Pan, Y., Zhang, Z., Yan, J. (2022). Solar energy harvesting technologies for PV self-powered applications: A comprehensive review. *Renewable Energy*, *188*, pp. 678-697, doi: 10.1016/j.renene.2022.02.066
12. Hart, C. (1998). *Doing a Literature Review: Releasing the Social Science Research Imagination*. SAGE.
13. Hysa, B., Mularczyk, A. (2024). PESTEL Analysis of the Photovoltaic Market in Poland – A Systematic Review of Opportunities and Threats. *Resources*, *13*, *10*, 10, doi: 10.3390/resources13100136
14. İnançoğlu, S., Özden, Ö., Kara, C. (2020). Green Corridors in Urban Landscapes, Case Study Nicosia Pedieos River. *European Journal of Sustainable Development*, *9*, *1*, 1, doi: 10.14207/ejsd.2020.v9n1p1
15. Kumar, A. (2021). Comparing scientific productivity using Scopus and Web of Science (WoS): A case of Indian R&D laboratories. *Asian Journal of Technology Innovation*, *29*, *3*, pp. 414-426, doi: 10.1080/19761597.2020.1816837
16. Liu, B., Huo, X. (2024). Prediction of Photovoltaic power generation and analyzing of carbon emission reduction capacity in China. *Renewable Energy*, *222*, 119967, doi: 10.1016/j.renene.2024.119967

17. Mamun, M.A.A., Dargusch, P., Wadley, D., Zulkarnain, N.A., Aziz, A.A. (2022). A review of research on agrivoltaic systems. *Renewable and Sustainable Energy Reviews*, *161*, 112351, doi: 10.1016/j.rser.2022.112351
18. Masson, G., Jäger-Waldau, A., Kaizuka, I., Lindahl, J., Donoso, J., de l'Epine, M. (2024). *A Snapshot of the Global PV Market* (p. 0568). IEEE, doi: 10.1109/PVSC57443.2024.10749131
19. Mostafa, A.A.A., Youssef, K., Abdelrahman, M. (2020). Analysis of Photovoltaics in Egypt using SWOT and PESTLE. *International Journal of Applied Energy Systems*, *2*, *1*, pp. 11-14, doi: 10.21608/ijaes.2020.169936
20. Mularczyk, A., Zdonek, I. (2022). Development of solar energy in Poland in the context of European Countries. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, *202*, pp. 171-186, doi: 10.29119/1641-3466.2022.161.12
21. Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., McArthur, A., Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*, *1*, pp. 143-143, doi: 10.1186/s12874-018-0611-x
22. Novas Castellano, N., Garcia Salvador, R.M., Portillo Rodriguez, F., Fernandez-Ros, M., Gazquez Parra, J.A. (2024). Chapter 19 – Renewable energy: The future of photovoltaic energy. In: T.M. Letcher (Ed.), *Living with Climate Change* (pp. 373-396), doi: 10.1016/B978-0-443-18515-1.00002-2
23. Ofstad, S.P., Tobolova, M., Nayum, A., Klöckner, C.A. (2017). Understanding the Mechanisms behind Changing People's Recycling Behavior at Work by Applying a Comprehensive Action Determination Model. *Sustainability*, *9*, *2*, 2, doi: 10.3390/su9020204
24. Oteng, D., Zuo, J., Sharifi, E. (2021). A scientometric review of trends in solar photovoltaic waste management research. *Solar Energy*, *224*, pp. 545-562, doi: 10.1016/j.solener.2021.06.036
25. Pearson, G.L. (1957). Conversion of Solar to Electrical Energy. *American Journal of Physics*, *25*, *9*, pp. 591-598, doi: 10.1119/1.1934565
26. Pietrzak, P., Kacperska, E., Kraciuk, J., Łukasiewicz, K. (2025). Publication Trends, Key Findings, and Research Gaps in Renewable Energy Applications in Agriculture. *Energies*, *18*, *2*, 2, doi: 10.3390/en18020371
27. Qazi, S. (2016). *Standalone Photovoltaic (PV) Systems for Disaster Relief and Remote Areas*. Elsevier.
28. Saidi, S., Brahim, T., Jemni, A. (2025). Experimental advances in photovoltaic-thermal (PVT) systems: A comprehensive review of cooling technologies, materials, and performance optimization. *Solar Energy*, *298*, 113650, doi: 10.1016/j.solener.2025.113650

29. Shrivastava, R., Mahajan, P. (2016). Artificial Intelligence Research in India: A Scientometric Analysis. *Science Technology Libraries*, *35*, *2*, pp. 136-151, doi: 10.1080/0194262X.2016.1181023
30. Smith, R., Crespo, C., Aboy, M. (2013). Review of Recent Patents on Flexible Photovoltaic Applications in Portable and Niche Markets. *Recent Patents on Engineering*, *7*, *3*, pp. 153-166, doi: 10.2174/18722121113076660004
31. Stec, M., Grzebyk, M., Caputa, W., Hejdukova, P. (2024). Levels of Renewable Energy Use in Selected European Union Countries – Statistical Assessment of Changes and Prospects for Development. *Comparative Economic Research. Central and Eastern Europe*, *27*, *3*, 3, doi: 10.18778/1508-2008.27.24
32. Tawfik, G.M., Dila, K.A.S., Mohamed, M.Y.F., Tam, D.N.H., Kien, N.D., Ahmed, A.M., Huy, N.T. (2019). A step by step guide for conducting a systematic review and meta-analysis with simulation data. *Tropical Medicine and Health*, *47*, *1*, 46, doi: 10.1186/s41182-019-0165-6
33. Vivar, M.,H.,S., Fuentes, M. (2024). Photovoltaic system adoption in water related technologies – A review. *Renewable and Sustainable Energy Reviews*, *189*, 114004, doi: 10.1016/j.rser.2023.114004
34. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of Photovoltaic Energy in EU Countries as an Alternative to Fossil Fuels. *Energies*, *15*, *2*, 2, doi: 10.3390/en15020662
35. Yurkstas, A., Manly, R.S. (1949). Measurement of occlusal contact area effective in mastication. *American Journal of Orthodontics*, *35*, *3*, 185-195, doi: 10.1016/0002-9416(49)90028-7
36. Zhang, A., Guo, X., Zhang, W., Liu, Z. (2025). Research on the mechanism by which digital transformation peer effects influence innovation performance in emerging industries: A case study of China's photovoltaic industry. *PLOS ONE*, *20*, *1*, e0313615, doi: 10.1371/journal.pone.0313615