

Systematic Review

Assessing Fire Risks in Photovoltaic Panels: A Literature Review in the Context of Blackout Concerns

Małgorzata Rataj *  and Iryna Berezovska

Department of Cognitive Science and Mathematical Modeling, University of Information Technology and Management in Rzeszow, 35-225 Rzeszow, Poland; iberezovska@wsiz.edu.pl

* Correspondence: mrataj@wsiz.edu.pl; Tel.: +48-17-866-11-97

Abstract

In recent years, Europe has faced several major blackouts, exposing weaknesses in its energy infrastructure and raising serious concerns about the continent's ability to manage such crises. As the shift toward sustainable energy accelerates, solar power has emerged as a critical component of this transition, not only for its environmental benefits but also because it is currently the most cost-effective method of electricity generation. Over the past two decades, the photovoltaic (PV) sector has experienced continuous growth to meet rising energy demands. Published scientific studies on the technology and implementation of photovoltaic panels mainly focus on the benefits and present case studies of success. The article aims to outline the current state of research on the danger of spontaneous ignition of photovoltaic panels. The analysis revealed the most common causes of PV self-ignition. Moreover, following consultations with experts in the field of photovoltaic panel installations, a scientific gap in this area was identified—to the authors' knowledge, no one has written on this topic so far—the use of flammable materials in the form of hermetically sealed quick connectors. The research is based on a literature review, employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to perform a bibliometric analysis of papers published between 2013 and 2024. The Web of Science Core Collection (WoSCC) and the ScienceDirect database are used for this purpose. A total of 62 papers are selected for analysis and categorized based on five fields: keywords in a title and abstract, total number of citations per paper, total number of publications per journal, total number of publications per affiliation, and funding name.

Keywords: green energy; renewable energy; photovoltaic panels; PRISMA; bibliometric analysis



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1. Introduction

The deployment of solar photovoltaic (PV) technology is experiencing a period of sustained growth across Europe. The robust expansion of photovoltaics is a logical consequence of the fact that this energy source is one of the most affordable ones and, therefore, one of the most significant potential power generation sources in the future.

PV systems have found wide application as energy sources installed on residential and public buildings [1]. The commercial use of this system is also increasing [2].

PV electricity generation does not involve the greenhouse effect. With its inherent sustainability, PV technology reduces the carbon footprint and contributes to efforts to combat climate change.

Production of solar-based energy is also characterized by decentralization, allowing power generation at the point of consumption, which increases energy security and

resilience [3]. Furthermore, Kittner states that the reduction in the cost of photovoltaic technology has rendered solar energy an increasingly competitive source of energy [4].

In many places on the Internet and even in the local press, the issue of photovoltaic fires is raised from time to time [5]. Undoubtedly, grids deriving energy from solar radiation are among energy installations and raise the fire risk of the facility.

What is the scientific literature saying about this problem? What is the scale of the problem? And what are the causes of the spontaneous ignition of photovoltaic panels? What are the most common causes and risk factors for the ignition of photovoltaic panels? This article reviews the literature in which the authors attempt to answer these questions.

National and international institutions have been established around the world to test methods of assessing the fire safety of Building Integrated Photovoltaics (BIPV) products and systems.

- An example of such an institution is the International Energy Agency (IEA), which, working on the Photovoltaic Power Systems Programme 2023, has mapped twenty countries around the world that are concerned with the fire safety of building products (Figure 1). Countries represented in this report are Australia, Austria, Brazil, Canada, China, France, Germany, Italy, Japan, Korea, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the Netherlands, the United Kingdom, and the United States.



Figure 1. Fire-safety testing facilities for building components can be found in most member countries of IEA-PVPS. Source: Enabling Framework for the Development of BIPV, https://iea-pvps.org/wp-content/uploads/2024/05/PVPS_Annual_Report_2023_v4-6.pdf (accessed 12 August 2024).

- The United Kingdom institution dealing with the problem discussed in this article is the BRE National Solar Centre, in their report entitled “Fire and Solar PV Systems—Investigations and Evidence”. According to this institution, the primary causes of ignition of PV-related fires are not perceived as conventional hazards within the traditional risk assessment framework. Nevertheless, the sourcing of incident data from the field, the undertaking of root cause analysis, and the preparation of reports are of the utmost importance. The overarching objective is to prioritize safety, with the goal of minimizing the risks associated with photovoltaic systems [6].
- In Poland, there are no specific regulations for the design of PV installations due to fire regulations. Nevertheless, Article 5 of the Construction Law prescribes the design of a building and related equipment, which includes PV installations, in such a way as to

ensure adequate fire safety. Nevertheless, currently, Building Integrated Photovoltaics in the European Union is supported by a few standards. By 2020, three specific international standards were approved for BIPV [7–9]. In Europe, members of the European Union and associated countries are obliged to follow European regulations and to implement them as part of their national regulations as soon as they enter into force [10–13].

The following section outlines the structure of the remainder of this paper. Section 2 outlines the methodology and datasets employed in the study. Section 3 presents the results of the findings. In conclusion, the implications and limitations of the paper are outlined, as well as future research directions.

2. Materials and Methods

As outlined in the Introduction, this article aims to explore the current state of research and future directions concerning the risk of spontaneous ignition in photovoltaic panels. To achieve this, the authors conducted a literature review. Articles published between 2013 and 2024 (including early access articles) were analyzed, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. The review was complemented by a bibliometric analysis, enabling the examination of a large volume of publications and the identification of emerging research trends and patterns within the specified field [15]. This approach provided a comprehensive overview of the expanding body of knowledge and helped assess key research areas, while also mapping the structure of current understanding of the risk of spontaneous ignition in photovoltaic panels [16].

The study was conducted in December 2024.

The search process used the Web of Science (WoS) Core Collection database, which is the leading database for classifying academic research. The Web of Science Core Collection contains over 21,100 peer-reviewed, high-quality scholarly journals published worldwide in over 250 scientific disciplines. Conference proceedings and book data are available as well [17]. All articles in journals included in the Web of Science undergo rigorous peer review by experts. Publications of this level require authors to adhere to high standards when preparing their work.

The second used database was ScienceDirect. ScienceDirect is a comprehensive web-based bibliographic database and full-text repository provided by Elsevier. Elsevier applies strict publishing standards that guarantee the highest quality of content.

ScienceDirect is offering over 18 million publications from more than 4000 academic journals and 30,000 e-books.

The databases were searched to select appropriate publications using the following search query: “photovoltaic panels” OR “fire” AND “spontaneous ignition/ignition”. The search fields included title, abstract, or keywords.

The search resulted in creating a database that includes 262 documents (151 from ScienceDirect and 111 from WoS). The database was formatted as an XLSX file and a TXT file.

The base comprises articles, book chapters, proceedings papers, and reviews. All unpublished early access articles for 2024 were collected. The first article that appeared on this topic was from the International Scientific Conference on Electric Power Engineering in 1990, “Voltage and Reactive Power Regulation in the 110 kV Distribution Power Networks”, which was written in Czech by R. Habrych. But the search was limited to only English articles, which allowed for effective processing. Therefore, the article in Czech was excluded.

Moreover, because photovoltaic technology has advanced a lot, the focus was on articles from the years 2013 to 2024 (early access), and the database was narrowed to 259 records.

It has been confirmed that there are no duplicate records in the database and that there are no empty fields in the records.

Additionally, publications were excluded if they did not align with the research interest. The publications collected for analysis were reviewed by 2 independent reviewers, the author of this article and a practitioner, who is the owner of a company engaged in PV, as mentioned before the References Section. No automation process was used in the analysis. First, the title was considered, then the abstract, and, finally, the content of the article.

After the reviewers prepared their report, they consulted each other on their findings. The final decision was based mainly on Grzegorz Rataj's practical knowledge. If any data raised his concern, then other articles with similar content were checked to verify possible misrepresentations. These articles dealt mainly with the general risk analysis of fire in buildings, equipment failure, thunderstorms and lightning, and the ignition of electrical wiring.

The database consisted of 189 documents.

Additionally, articles irrelevant to the review aim ($n = 94$) and 29 proceedings papers from the years 2015 to 2021 that were never cited have been removed from the database.

Furthermore, 2 articles from the journals with an impact factor below 1 were removed from the database.

Following the consolidation of the initial set of databases, a total of two articles were identified as duplicates and were consequently eliminated from the final database ("Development of fire safety best practices for rooftops grid-connected photovoltaic (PV) systems installation using systematic review methodology" and "Failures of Photovoltaic modules and their Detection: A Review").

The final database contained 62 documents, including 44 articles, 8 reviews, and 10 proceedings (Figure 2).

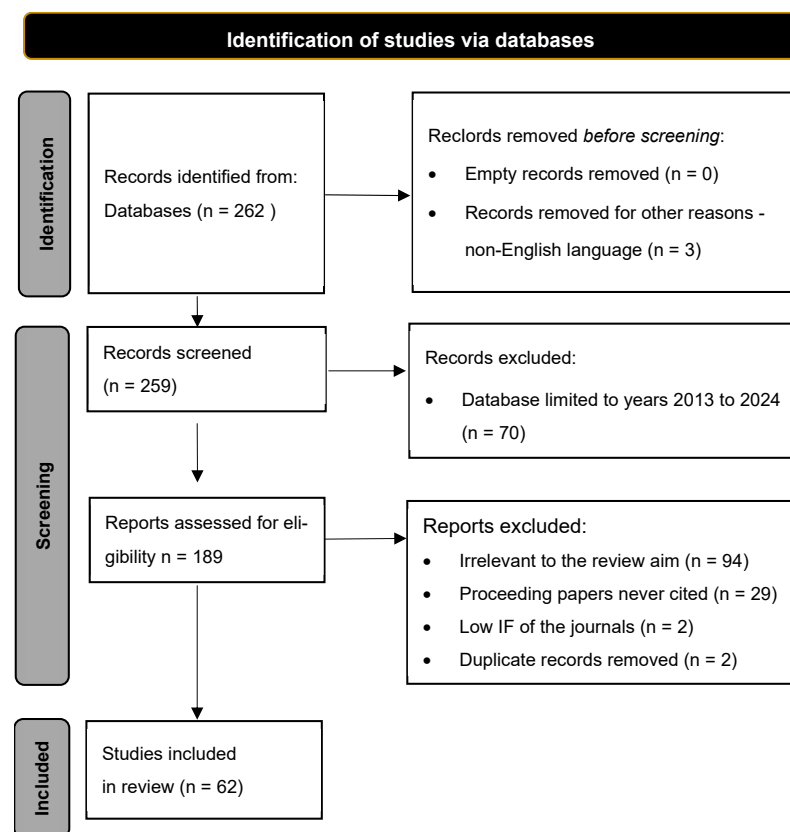


Figure 2. PRISMA flow chart. Source: own study.

The database was downloaded into the TXT format to enable visualization in VOSviewer software, which only supports the formats CSV and TXT. The requisite calculations were also performed using Excel's pivot table functionality. Furthermore, VOSviewer software version 1.6.20 was used to determine keyword co-occurrences both quantitatively and visually [18].

3. Results

The search identified 62 published works in the last 11 years. The analyzed database is included in Supplementary Materials. To provide a holistic overview of the latest research on the topic of spontaneous ignition of photovoltaic panels, the results of the review are ordered according to (1) the number of publications between 2013 and 2024 and keyword clusters, (2) the most impactful papers, (3) leading journals, (4) leading affiliated institutions, and (5) the founder's name.

3.1. Total Number of Publications

The number of publications over time is a key indicator of the level of interest among scholars in a particular topic and of the importance of a field of research. Figure 3 illustrates the yearly distribution of the selected articles over the past decade.

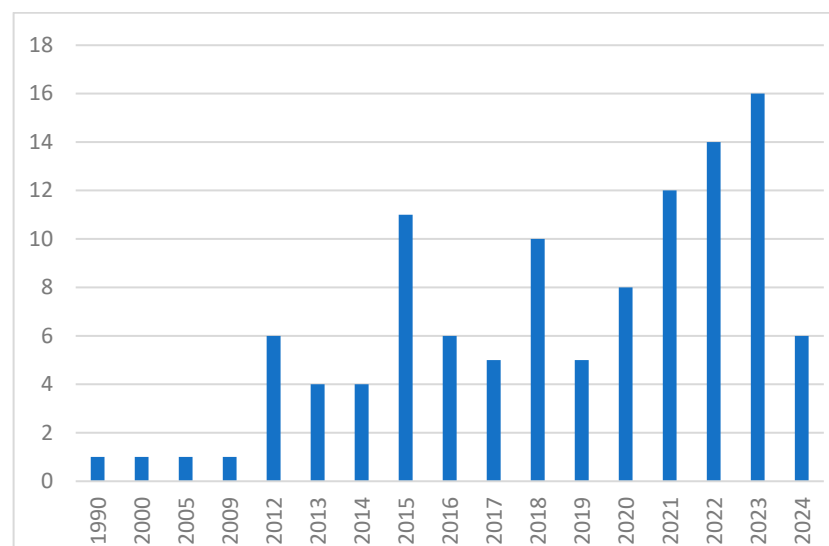


Figure 3. Total number of articles published in the years 1990–2024.

The variation in the number of publications on photovoltaic (PV) fire research may be associated with the periodic provision of subsidies by specific countries [19].

3.2. The Keyword Analysis

The keyword analysis was conducted using the VOSviewer software. Figure 4 presents a graphical representation of the co-occurrence of keywords from the title of the article and from the abstract. The analysis was limited to keywords that appeared at least five times in the sample. The font size and circle size of keywords indicate the frequency of their occurrence. The appearance of two or more keywords in proximity to one another is indicated by the linking of these items with a line. The thickness of the line between two keywords indicates the frequency of their co-occurrence in a single publication. Figure 4 illustrates the presence of five distinct thematic clusters, delineated by different colors.

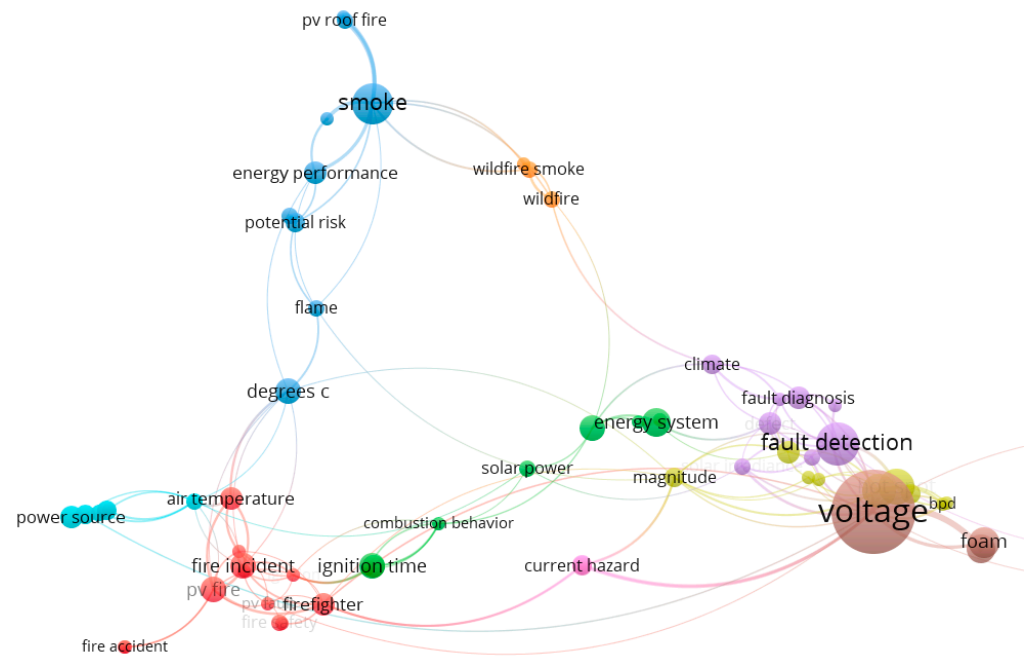


Figure 4. The keyword co-occurrence network.

The keyword “co-occurrence network” in Figure 4 serves to illustrate the multidisciplinary nature of the danger of spontaneous ignition of photovoltaic panels. A comprehensive analysis of the authors’ keywords and abstracts in the final database generated revealed the formation of thematic clusters.

The following five factors have been identified as the primary causes of photovoltaic installations catching fire (Table 1):

- The brown cluster—voltage is associated with hot-spots. One of the principal factors that elevate the risk of spontaneous ignition are so-called hot-spots, which are areas of localized overheating of photovoltaic (PV) modules. The occurrence of hot-spots is contingent upon the condition of individual cells within a PV module. When cells are damaged, unclean, or shaded, they are unable to conduct energy effectively, thereby acting as resistors and reaching elevated temperatures. Panels of inferior quality, exhibiting current path deficiencies, corrosion, or other forms of degradation, are more susceptible to hot-spots and spontaneous ignition.
- The purple cluster covers the issue of faults in the installation of photovoltaic panels. Keywords such as “fault diagnosis”, “fault detection”, and “defect” indicate that the focus is on understanding types of installation errors and the methodology for identifying them. Installation errors contribute significantly to photovoltaic installation fires. What are the most common problems? Incorrect bolt torque, poorly constructed DC switchgear, poorly routed branch circuits, incorrect timing of wires in the surge arrester, improper selection of connectors, incorrectly routed cables, too many parallel connections, and lack of earthing.
- The red cluster focuses on the risk assessment and consists of keywords such as “fire incident”, “fire incident”, “air temperature”, or “PV fault”. Risk assessment in photovoltaic (PV) fire involves identifying, evaluating, and mitigating the potential hazards associated with fires in PV systems, including both residential and commercial installations. The goal of a PV fire risk assessment is to prevent fire incidents, ensure system safety, and minimize potential damage if a fire were to occur.
- The blue cluster is associated with elevated temperatures, which have the potential to ignite photovoltaic panels. In this cluster, we find words such as “degrees c”, “smoke”,

“roof fire”, and “air temperature”. High temperatures can occur due to environmental conditions, system design flaws, component failures, or lack of proper maintenance. These elevated temperatures increase the likelihood of fires in various parts of a PV system, especially in sensitive components such as electrical connections, inverters, and batteries. Different materials of the cover layer or other structures in the product could lead to different fire hazard levels.

- The green cluster relates to flammable materials, which are PV installation modules, including roofing materials. Elevated temperatures in PV systems pose a significant fire risk, particularly when combined with factors like poor system design, inadequate ventilation, and component failure. The potential cause of PV cell fires is damage to the protective foil underneath the panels. Under the influence of high-voltage direct current, if the foil is damaged during transport or installation, it may start to burn [20]. Understanding how temperature affects the various components of a PV system—from panels and inverters to batteries—is crucial for preventing fire incidents. The issue of toxic hazards is also linked to the flammable nature of photovoltaic panels.

Table 1. The primary causes of photovoltaic installations catching fire—selected articles.

Five Factors	The Following Selected Articles Are Grouped Together Under the Overarching Theme of Causes of Photovoltaic Installations Catching Fire:
Hot-spots	• Dhimish, Mahmoud and Ghadeer Badran. “Current limiter circuit to avoid photovoltaic mismatch conditions including hot-spots and shading.” <i>Renewable Energy</i> 145 (2020): 2201–2216. • Pierluigi Guerriero, Pietro Tricoli, Santolo Daliento, “A bypass circuit for avoiding the hot spot in PV modules”, <i>Solar Energy</i>, Volume 181, 2019, https://doi.org/10.1016/j.solener.2019.02.010.
Faults in the Installation	• Wang, Q., Paynabar, K., & Pacella, M. (2021). Online automatic anomaly detection for photovoltaic systems using thermography imaging and low rank matrix decomposition. <i>Journal of Quality Technology</i>, 54(5), 503–516. https://doi.org/10.1080/00224065.2021.1948372 • A. Demetriou, C. A. Charalambous and D. Buxton, “Stray current DC corrosion blind spots inherent to large PV systems fault detection mechanisms: Elaboration of a novel concept,” 2017 <i>IEEE Manchester PowerTech</i>, Manchester, UK, 2017, pp. 1–1, https://doi.org/10.1109/PTC.2017.7980934
Risk Assessment	• Gallardo-Saavedra, S., Hernández-Callejo, L., Duque-Pérez, Ó. (2019). “Analysis and Characterization of Thermographic Defects at the PV Module Level”. In: Nesmachnow, S., Hernández Callejo, L. (eds) <i>Smart Cities</i>. ICSC-CITIES 2018. Communications in Computer and Information Science, vol 978. Springer, Cham. https://doi.org/10.1007/978-3-030-12804-3_7 • Nur Aliah Fatin Mohd Nizam Ong, Mohd Zahirasri Mohd Tohir, Mays Mahmood Mutlak, Muhammad Adnan Sadiq, Rozita Omar, Mohamad Syazarudin Md Said, “BowTie analysis of rooftop grid-connected photovoltaic systems”, 2nd <i>International Conference & Exhibition Loss Prevention Asia</i>, 2022, https://doi.org/10.1002/prs.12338
Elevated Temperatures	• Lulu Yin, Yong Jiang, Rong Qiu, “Combustion Behaviors of CIGS Thin-Film Solar Modules from Cone Calorimeter Tests”, <i>Materials</i> 2018, 11(8), https://doi.org/10.3390/ma11081353 • Huang Y-C, Lee S-K, Chan C-C, Wang S-J. “Full-scale evaluation of fire-resistant building integrated photovoltaic systems with different installation positions of junction boxes”. <i>Indoor and Built Environment</i>. 2018; 27(9): 1259–1271. https://doi.org/10.1177/1420326X17713256
Flammable Materials	• Guomin Zhao, Min Li, Lv Jian, Zhicheng He, Jin Shuang, Sun Yuping, Qingsong Zhang, Liu Zhongxian, “Analysis of Fire Risk Associated with Photovoltaic Power Generation System” (2018), https://doi.org/10.1155/2018/2623741 • Baisheng Liao, Lizhong Yang, Xiaoyu Ju, Yang Peng, “Experimental study on burning and toxicity hazards of a PET laminated photovoltaic panel”, 2019, <i>Solar Energy Materials and Solar Cells</i>, https://doi.org/10.1016/j.solmat.2019.110295 • Mohamed Muhsin Mohamed Baseer, A.; Ang Ye, X.; Rhonda Tan Jia, H.; Tung Li, S.; Xiao, X.; Maloy, D.; Ng, L. “Investigating the Fire Dynamics of Mounted PV Weathering Effects and Material Changes”. Available at SSRN: https://ssrn.com/abstract=4914306

The orange cluster focuses on the wildfire as a reason for the PV fire. Following the initial collation of 101 documents, those articles which attributed the ignition of photovoltaic panels to external factors—like wildfire, thunderstorms and lightning strikes, hail, and snow, which can damage panel surfaces, increasing the risk of hot-spots, and subsequent fire, dust, leaves, bird droppings, and other debris can block parts of the PV modules, causing shading and leading to localized overheating—have been excluded from the database. The issue of wildfires is only addressed by the authors in the final database of 62 articles and does not represent the primary focus of the research. Wildfire is not intended to be a bibliographical analysis of this article.

The complete database of journals analyzed in this article can be found in the appendices.

3.3. Total Number of Citations per Paper

An article with the highest number of citations is cited almost three times as frequently as any other article in the field (see Figure 5).

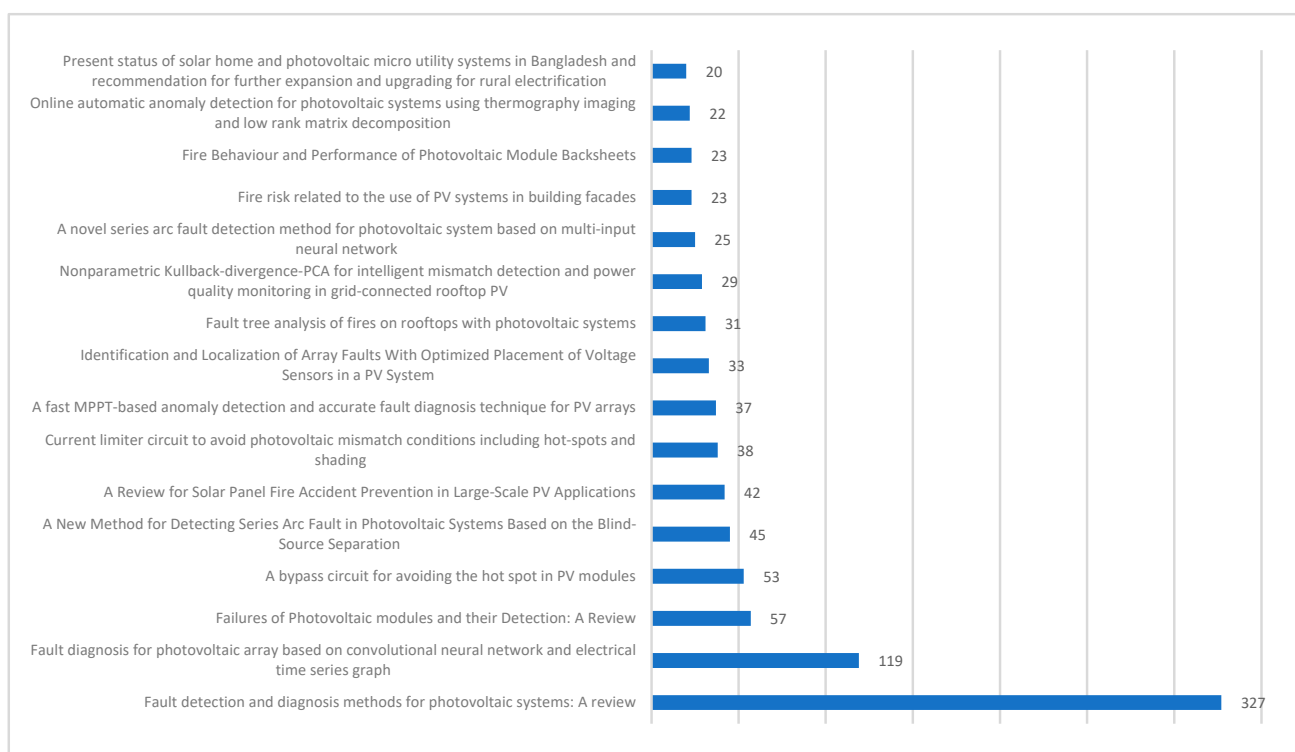


Figure 5. Total number of citations per paper.

The three most-cited articles were published by Elsevier.

The article that has been referenced most frequently is a research article published in the journal *Renewable and Sustainable Energy Reviews* in 2018 by researchers from Algeria and Italy. The article is entitled “Fault detection and diagnosis methods for photovoltaic systems: A review” [21]. The research focuses on analyzing faults in any components (modules, connection lines, converters, inverters, etc.) of photovoltaic (PV) systems. Some of the faults can lead to the risk of fire.

Second, the article entitled “Fault diagnosis for photovoltaic array based on convolutional neural network and electrical time series graph” [22] was published in 2019, in the journal *Energy Conversion and Management*. The article, authored by scientists from China, emphasizes the need for fault diagnosis for photovoltaic arrays and proposes the Maximum Power Point Tracking technology, which reduces the risks of fire hazards.

Third, the article entitled “Failures of Photovoltaic modules and their Detection: A Review” [15] was published in the journal *Applied Energy* in 2022. The researchers from China and Pakistan focus on module failures, fire risks associated with PV modules, failure detection/measurements, and computer-/machine vision- or artificial intelligence (AI)-based failure detection in PV modules.

Although the articles listed here are mainly of a theoretical nature from university research, there are also experimental studies related to the risk of photovoltaic systems catching fire published in reputable technical industry publications [23–26].

3.4. Total Number of Publications per Journal

Further analysis was conducted with 62 articles published in 44 different journals. The Impact Factor (IF) of the journals ranged from 16.3 for *Renewable and Sustainable Energy Reviews* to 1.1 for *Civil and Environmental Engineering*. Among 62 scientific journals, there is no journal that is a leader in this field.

The proceedings from the “International Conference on Systems for Energy-Efficient Built Environments” and journals that are published by ScienceDirect—*Sustainable Cities and Society* and *Renewable and Sustainable Energy Reviews* each contained three publications on the topic we investigated.

The “International Conference on Systems for Energy-Efficient Built Environments”: The main goal of the conference is to advance research and development of systems that optimize energy efficiency in buildings, cities, and transportation. The conference serves as a platform for researchers and practitioners to share their work and collaborate on innovative solutions for energy-efficient systems.

Sustainable Cities and Society (with an Impact Factor equal to 10.5) is an international journal focusing on fundamental and applied research aimed at designing, understanding, and promoting environmentally sustainable and socially resilient cities.

Renewable and Sustainable Energy Reviews (with an Impact Factor equal to 16.3) is a journal that shares problems, solutions, novel ideas, and technologies to support sustainable development, the transition to a low-carbon future, and achieve our emissions targets as established by the United Nations Framework Convention on Climate Change (UNFCCC).

The other journals published two or one articles.

3.5. Total Number of Publications per Affiliation

The database under study included 49 affiliated institutions. One of the basic criteria for bibliographic analysis is the index of affiliated institutions that contribute most to this field. The most productive in this field were researchers from China. They come from two academic institutions: the Chinese Academy of Science and the University of Science and Technology of China. According to the data given in the Total Number of Citations Per Paper section, their articles are also the most cited. It is noteworthy that, as the analysis demonstrates (Figure 6), Chinese institutions have been the primary supporters of research into the self-ignition of photovoltaic panels. In second place, with two articles related to the topic, are the Polytechnic University of Turin, the Polytechnic University of Milan, the University of Sherbrooke, the University of Edinburgh, the University Putra Malaysia, Universidad de Cordoba, the Technical University of Denmark, Ghent University, and Concordia University in Canada.

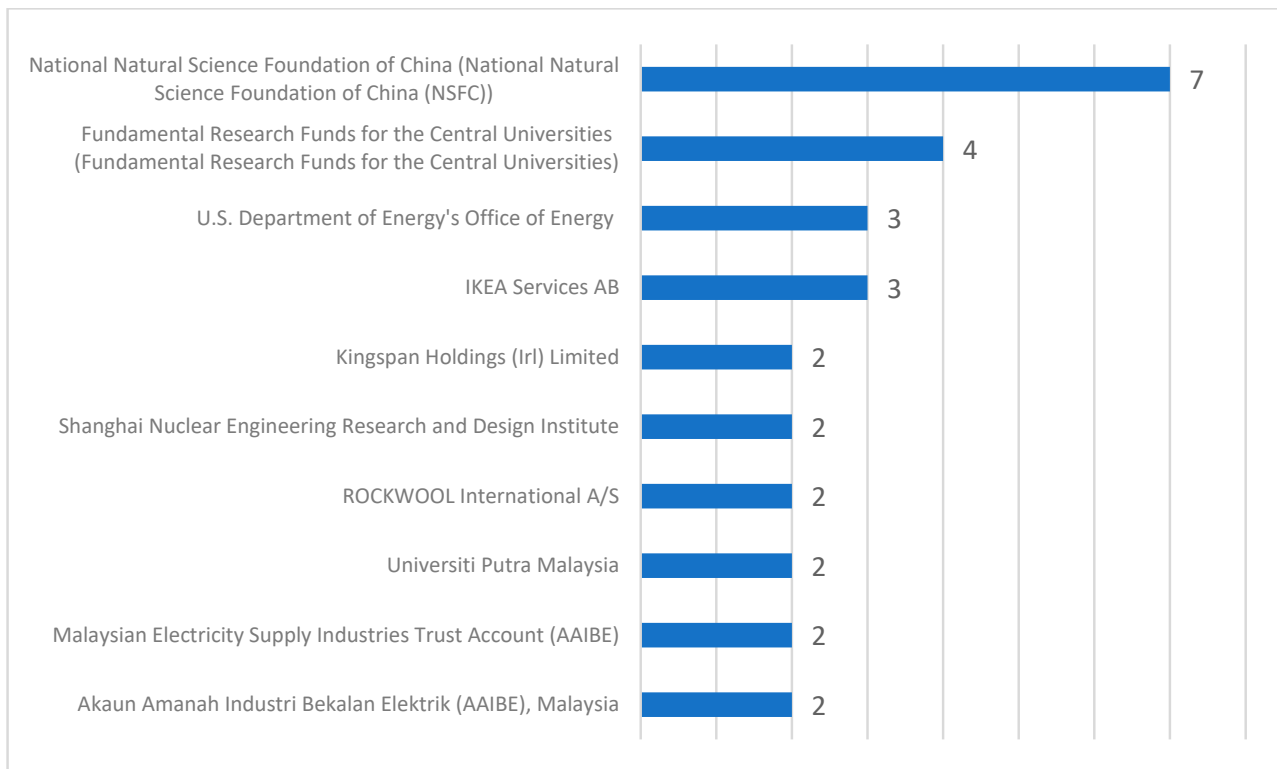


Figure 6. Founder's name.

There are 42 institutions that have provided financial support for research into the risk of spontaneous ignition of photovoltaic panels in the years from 2013 to 2024.

We do not know the sums with which individual institutions have supported scientists dealing with the problem of photovoltaic panel ignition. The funders who most often supported researchers in the field mentioned were the National Natural Science Foundation of China, Fundamental Research Funds for the Central Universities in China, the U.S. Department of Energy's Office of Energy, and the IKEA Services AB Foundation. In May 2022, the IKEA Foundation committed EUR 4.9 million to the Sustainable Energy for All's Universal Energy Facility, a results-based financing initiative [27]. This was followed in November of the same year by a EUR 21.14 million energy investment initiative, in partnership with Acumen, which aimed to provide renewable power generation and efficient appliances to people living in extreme poverty.

VOSviewer enables the observation of the manner in which collaboration between authors from disparate countries and academic institutions is evolving, as well as the extent to which individual universities are citing the work of their colleagues from across the globe.

It is regrettable that no international teams of researchers from specific countries or universities have emerged in the field of photovoltaic panel ignition. Furthermore, VOSviewer did not generate bibliographic links between scientists in this area.

However, the free exchange of ideas, results, and best practices through numerous publications, some of which are mentioned in this article, facilitates international partnerships on PV fires that are therefore not always formal, but remain effective.

4. Discussion and Conclusions

This review has provided a comprehensive overview of the research landscape on the spontaneous ignition of photovoltaic (PV) panels over the past 11 years. The study identified a total of 62 published works, which serve to illustrate the growing interest in

this critical safety issue. The temporal analysis indicates a fluctuating level of research activity, which is likely influenced by funding cycles and the emergence of global concerns about the safety of renewable energy technologies.

A keyword analysis identified five major thematic clusters: hotspots, installation faults, risk assessment, elevated temperatures, and flammable materials. These clusters reflect the complex and multifaceted nature of the problem, underscoring the necessity of comprehending both the technical and environmental elements that contribute to fire risks in PV systems.

The most frequently cited articles offered valuable insights into fault detection methods and risk mitigation strategies, with notable contributions from international researchers, particularly from China.

While no single journal can be identified as the dominant source of publications in this field, the existence of a diverse range of publications across various journals indicates some level of academic interest with limited specialization in this niche area.

Notwithstanding the considerable body of research, there is a dearth of formal international collaboration on this topic, indicating an opportunity for more cross-border partnerships and integrated approaches to address the challenge of PV panel ignition.

The International Energy Agency (IEA) launched Task 7 of the PV Power System program in 1997 to increase the quality and economic viability of photovoltaic systems. This international cooperation program was supposed to encourage the development of photovoltaics in Europe, the USA, Japan, and Australia.

The European Union and the United States issued a joint statement of intent to continue trade and technology cooperation at the Trade and Technology Council (TTC) meeting held in Leuven, Belgium, on 4 and 5 April 2024. The Secure and Resilient Supply Chains for the Clean Energy Transition and support of the EU-US Clean Energy Incentives Dialogue were among the key outcomes of the meeting.

The United Nations General Assembly declared the International Day of Clean Energy on 26 January 2024 to increase awareness and encourage the transition to clean energy all over the world.

Recently, the five-year collaboration in research and testing between Sika Sarnafil, based in Lyndhurst, New Jersey, USA, and Centroplan GmbH, its global partner for rooftop solar system design and installation, resulted in obtaining a certification for a roof-mounted rigid PV system under Approval Standard 4478, Examination Standard for Roof-Mounted Rigid Photovoltaic Module Systems issued by FM Approvals. The new system meets rigorous fire and wind uplift tests.

SolarPACES, which is one of the IEA Technology Collaboration Programmes (TCP), informs about the SolarHub Ignition 2024 Acceleration Program on its website. The goal of the program is to support early-stage startups, entrepreneurs, and researchers developing solar-relevant applications through mentorship, access to advanced technical infrastructure, training, networking, and funding opportunities.

Following consultation with two experts (practitioners: Grzegorz Rataj and Daniel Siembida) specializing in photovoltaic panel installations, it was concluded that a significant risk of PV cell fires is related to two main causes.

As stated in the Results Section, the presence of flammable materials is to be noted. As outlined in the article (preprint) “Investigating the Fire Dynamics of Mounted PV Weathering Effects and Material Changes” [28], significant information has been provided. It is stated therein that damaged protective foil underneath the panels may begin to burn. Under the influence of high-voltage direct current, if the foil is damaged during transport or installation, it may start to burn. Since there is airflow between the roof and the panels, the fire can spread rapidly across the entire roof.

Despite their critical role, there has been a lack of extensive research into foil fire performance after prolonged environmental exposure, resulting in a gap in understanding their long-term safety and reliability. Understanding the fire performance of these weathered foils is crucial for developing new strategies to mitigate flame spread.

Another serious cause of photovoltaic cell fires has been identified, which is connected to the use of flammable materials in the form of hermetically sealed quick connectors. Unfortunately, we have not come across articles on this specific topic; therefore, we describe this problem, which creates a scientific gap, below. The aforementioned expert, Daniel Siembida, participated in a specialized training program, during which experiments were conducted to demonstrate the seriousness of this phenomenon. Photovoltaic panels generate direct current. Such installations are more demanding because they require thick insulation and high-quality connectors. In the event of an electric arc, it is very difficult to interrupt it. In residential systems, photovoltaic panels are connected in series to increase the efficiency of the installation—the total voltage then exceeds 800V. Hermetically sealed quick connectors are used to connect the panels. However, these connections are not perfect.

By comparison, regular household electrical sockets—which are not exposed to weather conditions—use screw-type connections. If moisture enters the panels' connectors during transport or installation, sooner or later, that connector will become the cause of a failure—and potentially a cause of cell fires. Unfortunately, during installation, a technician cannot detect whether moisture has entered the connector.

To determine whether the system is safe, a thermal imaging inspection of the PV installation should be carried out once a year. In practice, no one does this, because there is a common belief that solar panels will operate without failure for 20 years.

Despite their critical role, there has been a lack of extensive research into foil fire performance after prolonged environmental exposure, resulting in a gap in understanding their long-term safety and reliability. Understanding the fire performance of these weathered foils is crucial for developing new strategies to mitigate flame spread. Also, hermetically sealed quick connectors are a research direction worth pursuing, and their results would be valuable for institutions responsible for certifying safety.

It would be beneficial for future endeavors to concentrate on the implementation of tailored risk mitigation strategies.

It should be noted that the study presented here has a number of limitations.

- Firstly, it should be noted that the research was conducted exclusively using the WOSCC and Science Direct databases. It is acknowledged that the value of the article is significantly limited by the omission of databases such as IEEE Xplore, Scopus, SpringerLink, Google Scholar, and regional databases. In subsequent studies, it would be advantageous to utilize the resources of alternative databases to ensure comprehensive coverage of the literature on this topic.
- The analysis presented here is quantitative; in subsequent studies, it would be beneficial to supplement this with a qualitative content analysis. This would allow for an overview of the available definitions, models, tools, and measures.
- The research methodology and good practices described were not included in the analyses.
- The investigation would be facilitated by the availability of statistical data that unequivocally links the fire to the photovoltaic panels. This would assist in determining the precise origin of the fire. Such statistics can be found on UK government websites, but they are incomplete and inaccurate. It is regrettable that they do not lend themselves to scientific study.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/en18133407/s1>.

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Abbreviations

BIPV	Building Integrated Photovoltaics
IEA	The International Energy Agency
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PV	Photovoltaic
PVPS	Photovoltaic Power Systems
TCP	Technology Collaboration Programmes
TTC	The Trade and Technology Council
UNFCCC	The United Nations Framework Convention on Climate Change
WoSCC	Web of Science Core Collection
VOSviewer	Software Stands for Visualization of Similarities

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