University-Led Solar Energy Initiatives in Support of SDG 7 and SDG 13: A Literature Review (2015–2025)

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Abstract:

This paper presents a literature review of studies published between 2015 and 2025 after the launch of the Agenda 2030, and examines how universities integrate solar energy technologies and whether they are linked with SDG 7 and SDG 13. The search was conducted using the Scopus database, where a total of 25 papers met the defined criteria. Our interest was to study how universities implement photovoltaic and solar energy and whether SDGs are clearly mentioned, what is the geographical distribution of the studies and how these technologies are used in the everyday operation of the university, and how results are applied. The interest in Solar energy was found to increase over time. Studies address issues such as the installation of photovoltaic systems on

university buildings, energy saving measures, linking solar energy with research and teaching, and measuring energy efficiency and carbon emissions. Although it was found that universities are integrating solar energy into both their daily operations and research activities, there is still substantial room for action to integrate solar energy and achieve SDGs 7 and 13.

Keywords: Climate Action, Higher Education, Carbon Monitoring, Clean Energy

1. Introduction

SDGs 7 and 13 aim to ensure universal access to affordable, clean energy and act to reduce the impacts of climate change. Transition from fossil-fuels to renewable energy sources that are also more efficient is the main path to achieve these goals (UN DESA 2021; World Bank et al. 2025). There are recent reports such as Tracking SDG 7 and the Vienna Energy Forum that refer to the close connection of energy transition and climate change and the need to decarbonize at all levels, from national grids to individual energy consumers (UNIDO 2015). Studies show that a socially just energy transition that promotes both SDG 7 and SDG 13 can be supported by digital technologies that help coordinate policies, and actively engage (Sheraz et al. 2024).

Universities can play an important role in achieving sustainable development, as they are at the forefront of knowledge and technology development (Chankseliani and McCowan 2021; Filho et al. 2024). Through the provision of education and research as well as through their operation, they can develop knowledge, and behaviors that support the energy transition to cleaner forms of energy. In international frameworks universities are described as testbeds for new sustainability ideas and institutions that can initiate wider social change. In UNESCO IESALC (2020), the EAUC (2017) guidance, and the HAW Hamburg review on SDG engagement universities hold a significant role as sustainability stakeholders, as noted by Filho et al. (2023). Universities work as "living laboratories," meaning they integrate the SDGs into teaching, research, and institutional planning (Serafini et al. 2022; Lim et al. 2022; Figueiró and Raufflet 2015).

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One of the most practical ways for universities to exhibit climate responsibility and support SDG7 and SDG13 is to use energy more efficiently and to produce energy from renewable sources within their own facilities (Munaro and John 2024). For this reason, energy management has become one of the most active areas of sustainability on university campuses. HEIs usually have high energy needs because they operate large campus facilities, and this creates opportunities for testing and expanding low-carbon technologies (Filho et al. 2024).

In the last decade, the number of studies on renewable energy in higher education has increased. Many studies focus on photovoltaic systems because they combine technical feasibility, relatively low costs, and educational benefits (Akbulut et al. 2025; Saputri et al. 2025; Aguilar Pinzón et al. 2025). Solar energy projects in HEIs have multiple roles, as indicated by the increasing number of studies. One main reason is the reduction of operational costs, as the installation of photovoltaic systems helps reduce electricity costs and carbon emissions, while also improving the energy security of the institution (Govindarajan et al. 2024; Niu et al. 2024; Kusznier 2023).

An additional benefit is the use of photovoltaic installations at the educational level. In this way, they function as learning sites, because they support sustainability teaching and they provide practical experience to engineering and environmental science students (Chakraborty et al. 2019; Rey-Hernández et al. 2018; Yasay 2021). Solar projects create opportunities for interdisciplinary research on topics such as grid integration, hybrid systems, and optimization methods (Güven et al. 2024; Toti et al. 2024). There are examples from different regions showing that universities in both developed and developing countries are increasingly investing in photovoltaic systems. Case studies from Europe, Asia, the Middle East, and Latin America indicate that universities have different motivations for using photovoltaic systems, such as reducing energy costs, increasing energy autonomy, and showing leadership in sustainability (Cristea et al. 2022; Rey-Hernández et al. 2018; Navothna and Thotakura 2023; Govindarajan et al. 2024; Niu et al. 2024; Awad et al. 2023; Alfaoyzan and Almasri 2023; Aguilar Pinzón et al. 2025). Through early examples we see that such initiatives can reduce

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greenhouse gas emissions significantly and serve as useful models for national energy transitions (Jo et al. 2017; Castrillón-Mendoza et al. 2020; Munaro and John 2024).

There are still issues that need to be addressed, such as monitoring, standardization, and the institutional integration of actions. In many cases, universities implement these projects without using comprehensive assessment frameworks or without linking their actions to the overall sustainability strategy of the institution (Serafini et al. 2022; Filho et al. 2023). Several recent studies, including the 25 articles reviewed in this paper, have focused on the technical, economic, and policy aspects of solar energy projects in universities during the period 2015–2025. This helps to address some of these gaps. These studies show that HEIs can function as small-scale examples of low-carbon communities and support both SDG 7 and SDG 13 through innovation, practical application, and education. Although more studies examine solar energy applications in higher education, the literature is still fragmented and often focuses on separate technical or economic aspects through individual case studies. The challenge of synthesizing fragmented scientific evidence is not unique to renewable energy research. In several interdisciplinary fields, systematic literature review methods have been successfully applied to organize dispersed knowledge, identify emerging themes, and support future research directions (Kitchenham & Charters, 2007; Snyder, 2019,). There are still no comprehensive reviews that clearly link university-based solar energy initiatives with SDG 7 and SDG 13, while also examining issues of institutional governance and the outcomes of these actions. To address this gap, the present review examines the studies as a whole, in order to identify common elements and to show how university-based solar energy initiatives are linked to SDG 7 and SDG 13. In this way, it becomes clearer how solar energy initiatives in HEIs contribute to clean energy and climate action at the institutional level. This paper presents a systematic literature review of solar energy initiatives in universities over the last decade, with a focus on how these efforts support the energy transition and climate action. This review looks at the geographical distribution of studies and main trends, groups the main themes of the literature, including technical, economic, educational, and institutional aspects, and discusses how university solar energy initiatives contribute to SDG 7 and SDG 13. As

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the mitigation of climate change is closely linked to the reduction of emissions and the use of clean forms of energy, this review shows how HEIs can use their facilities to promote sustainability and contribute to a cleaner and more climate-resilient future.

2. Methods

This study applies a systematic literature review (SLR) to identify, classify, and analyze solar energy initiatives led by universities, with a particular focus on how these efforts contribute to SDGs 7 and 13. Following the guidelines for systematic reviews in applied sciences (Kitchenham & Charters 2007) and general principles of transparent and rigorous review design (Snyder, 2019) the approach combines both quantitative descriptive analysis and qualitative thematic exploration to provide a broad and balanced understanding of the topic. More specifically, the review examines how research on solar energy within higher education institutions has evolved over the past decade and in which regions it is most active; it also organizes the existing studies into the main technical, economic, and institutional themes that emerge from the literature. Finally, it examines how these university-based initiatives contribute, in practice, to the advancement of SDG 7 and SDG 13, helping to link global sustainability goals with local academic contexts.

The review was carried out using the Scopus database, which was chosen because it offers wide coverage of peer-reviewed and multidisciplinary publications in sustainability, engineering, and higher education. The search was conducted in Scopus on August 5, 2025, and the full query is provided in Appendix A. The search focused on articles published between 2015 and 2025, a period that matches the start and development of the 2030 Agenda for Sustainable Development.

To build the search query, Boolean operators were used to combine key terms and make the search both broad and precise. The main keywords included: ("SDG 7" OR "SDG 13" OR "Sustainable Development Goal*" OR "climate action" OR "clean energy" OR "low-carbon" OR "emission reduction" OR "renewable energy")) AND (TITLE-ABS-KEY ("university" OR "Higher Education Institution*" OR "HEI" OR "campus")) AND (TITLE-ABS-KEY ("energy

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efficiency" OR "carbon reduction" OR "sustainability strategy" OR "sustainability assessment" OR "energy management"))

The search was limited to peer-reviewed journal articles written in English. Only open-access articles were included to ensure transparency, full accessibility, and reproducibility, in line with international open-science guidelines that promote unrestricted access to scientific knowledge (UNESCO 2021). In total, the search produced 25 relevant articles, which were used as the main dataset for the analysis.

To make sure the selected studies were relevant to the aims of this review, several inclusion criteria were used. First, the publications needed to focus on solar photovoltaic systems, hybrid renewable systems, or other types of solar-based energy management that were implemented or examined within higher education institutions. Second, the studies had to be clearly linked to topics such as sustainability, energy efficiency, or climate mitigation. Third, only empirical work, modeling studies, or techno-economic analyses based on real case studies, simulations, or performance assessments of university systems were considered.

The exclusion criteria removed articles that discussed renewable energy without any connection to HEIs, studies that were purely theoretical or lacked empirical evidence, and reports or non–peer-reviewed documents with insufficient methodological detail.

After applying these criteria, the final selection was made based on each study's focus on solar energy in higher education, its relevance to SDG 7 and/or SDG 13, and its publication in a peer-reviewed journal. As shown in Figure 1, in total, 47 documents were initially identified. As shown in Figure 1, a total of 47 records were initially identified. After removing 5 duplicates, 42 records were screened by title and abstract. Seventeen records were excluded at this stage, leaving 25 full-text articles for eligibility assessment. No additional articles were excluded after full-text assessment, and all 25 were included in the final review. (Appendix A provides the full search query and serves as a reference to the screening process.)

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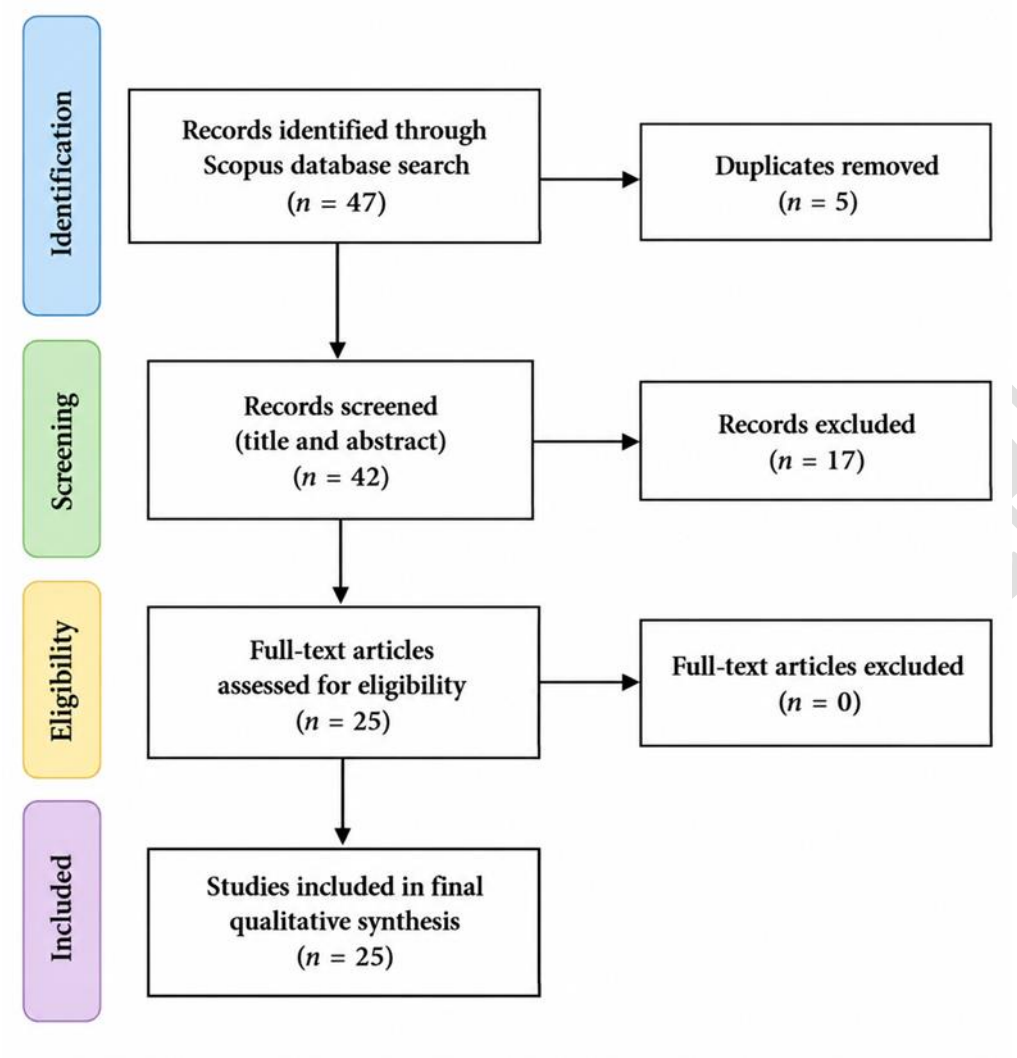
Figure 1



For each publication that met the selection criteria, the main information was collected manually and entered into a structured literature review table. The data extracted from each study included: the authors and year of publication, the country or region where the study was carried out, the type of institution involved (for example, public or private, technical or comprehensive university), the main research purpose (such as performance evaluation, optimization, or educational use), the type of solar system examined (grid-connected PV, hybrid systems, off-grid designs, or solar water heating), the

methodological approach used (experimental, simulation-based, or mixed), and the key results and their relevance to sustainability. This dataset provided the basis for both the descriptive analysis, which examined publication trends and geographic patterns, and the thematic analysis, which identified recurring themes and challenges across the studies.

The analysis was carried out in two stages. First, a descriptive overview was developed to show how research on university-based solar energy systems has evolved over time. This involved examining when the studies were published, where they were conducted, and what types of technologies and methods they focused on. Looking at publication years helped relate the growth of this research to the broader timeline of the SDGs, while the geographic and technological patterns showed whether certain regions or system types dominate the field. The review also compared the main methodological approaches used in the studies, ranging from simulations and optimization models to real-world monitoring and experimental work. Together, these descriptive observations provide a general picture of how interest in solar initiatives within higher education has expanded and diversified during the 2015–2025 period.

For the thematic analysis, an inductive approach inspired by Braun and Clarke (2006) was used to identify recurring ideas across the selected studies. Each article was reviewed for common patterns in its aims, methods, and findings, and four central themes gradually emerged. The first theme concerns technical optimization and system performance. Many studies focus on improving PV efficiency, testing hybrid configurations, and applying monitoring technologies, as seen in research by Akbulut et al. (2025), Güven et al. (2024), and others working on sensor-based control systems. A second theme relates to economic feasibility and energy management. Here, authors investigate issues such as payback periods, energy costs, and micro-grid control strategies, with examples from Saputri et al. (2025), Aguilar Pinzón et al. (2025), and Govindarajan et al. (2024).

A third theme highlights the growing importance of sustainability governance and institutional integration. Several papers examine how solar projects fit within campus sustainability plans, carbon

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reduction strategies, or broader policy frameworks, as reported in Cristea et al. (2022), Niu et al. (2024), and Munaro and John (2024). The fourth theme concerns educational and research synergies, where solar installations are used as living laboratories or teaching tools, supporting hands-on learning and interdisciplinary collaboration. Studies by Chakraborty et al. (2019), Rey-Hernández et al. (2018), and Toti et al. (2024) illustrate how such systems contribute to both academic training and applied research.

Taken together, the descriptive and thematic analyses provide complementary insights: while the descriptive overview shows how and where research activity has grown, the thematic analysis explains why these projects matter and how universities are using solar technologies to advance their sustainability and climate goals.

To strengthen the reliability of the review, several quality checks were carried out throughout the process. First, each study was assessed independently by two reviewers, who screened the records and resolved any disagreements through discussion to ensure that the articles met the inclusion criteria and directly addressed solar energy applications in higher-education settings. Second, the references of key papers in the field, such as Jo et al. (2017), a widely cited early study on campus PV systems, were checked to identify any important sources that might have been missed. This backward-search process did not reveal any significant gaps relative to the scope of the review. Finally, all extracted information was recorded in a structured dataset to ensure transparency and allow future researchers to replicate or extend the work.

All analytical steps were carried out manually to maintain interpretative depth, with spreadsheet-based coding used only for organizational purposes. The final set of 25 peer-reviewed studies provides a consistent and coherent foundation for the descriptive and thematic analyses presented in Section 3.

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3. Results

3.1 Descriptive Analysis

By looking into quantitative characteristics of the 25 studies such as the year of publication, the geographical location, the type of the institution and also the technological and methodological approach, an overview of the main trends was acquired. This descriptive analysis shows how research on university-related solar energy initiatives has changed during the period 2015 to 2025, after the launch of SDGs.

Over the decade, there is a growing body of literature on solar energy systems associated with higher education institutions. This growth, especially after 2020 is shown in Figure 2. Between 2017 and 2019 only a small number of papers were published (e.g., Azharuddin Shamshuddin et al. 2017; Chakraborty et al. 2019; Raihani et al. 2019), but there is a substantial increase after 2021. The number of studies on solar energy in higher education increased during the SDG period. The highest number of publications appears in the period 2023–2025, during which more than half of the selected studies were published.

The main contributing factors for this was the falling costs of PV installation that made them affordable for institutions and led to their wider use. Another factor was the growing familiarity with the SDG framework, as many universities adopted sustainability strategies linked to SDG 7 and SDG 13.

Figure 2. Number of publications from 2015 to 2025

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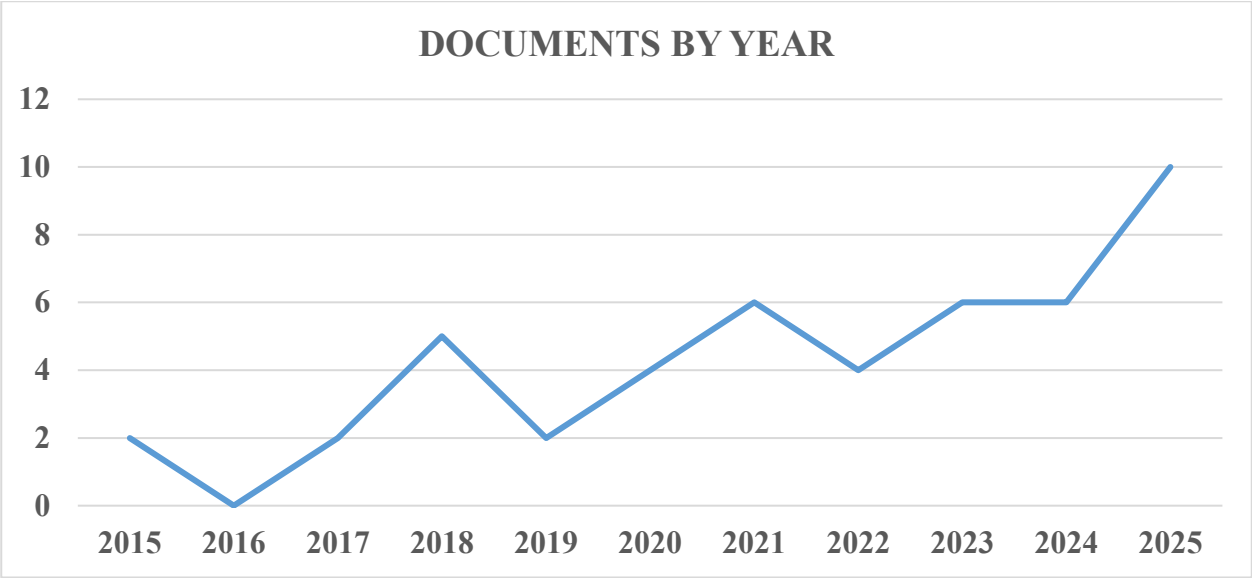

As shown in Figure 3, the studies cover a wide international landscape, although research is not evenly distributed across regions.

The largest body of studies comes from Asia, as there are studies from China, India, Indonesia, Malaysia, Saudi Arabia, and Middle Eastern countries

Europe is also represented in the reviewed studies, with papers from Romania, Spain, and Poland, while very few studies come from Latin America and Africa.

Figure 3. Geographical distribution of publications

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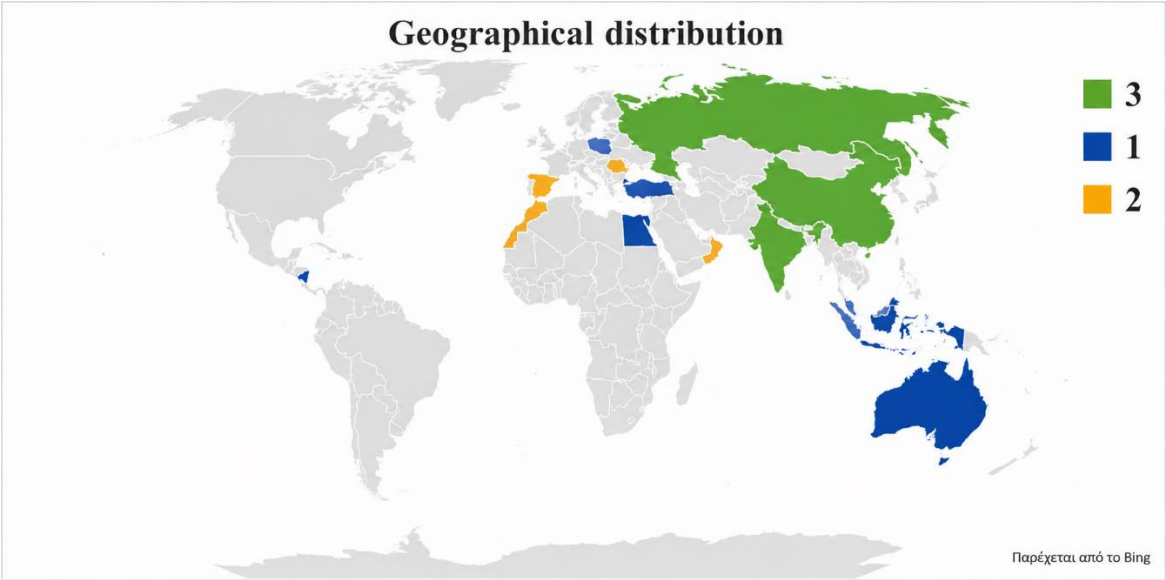

Most studies come from public universities, technical universities, or university research centers. The institutional settings examined fall into three main categories. The first includes campus-wide photovoltaic or hybrid systems, such as large rooftop installations, hybrid wind–solar systems, and building-level PV systems. Studies in this group examine system performance, integration issues, or operational aspects of campus energy systems.

A second category includes research-center prototypes and experimental setups. These involve laboratory-based systems such as hydrogen production using PV power, solar-thermal collector testing, or DC microgrid prototypes, and are mainly linked to engineering research activities.

The third category regards smart-building and micro-grid applications. In these cases, smart buildings, near Zero Energy Buildings (nZEBs), or specialized research facilities combine PV systems with energy storage, electric vehicles, or control technologies. The reviewed studies show that universities use solar technologies both in their everyday operations and in research.

The reviewed studies cover a wide range of solar technologies used in higher education campuses. Most publications focus on grid-connected photovoltaic systems, usually installed on rooftops or

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integrated into campus buildings. System capacities vary from small installations of a few tens-of-kilowatts to large multi-megawatt systems. Several studies examine hybrid renewable systems, where photovoltaic systems are combined with wind turbines, battery storage, fuel cells, biomass, or heat and power units. These works often rely on simulation models or optimization methods to evaluate system performance.

Fewer studies focus on off-grid or autonomous systems, including DC microgrids and experimental setups developed in university laboratories. These systems are often designed for rural or isolated applications rather than for main campus buildings.

A small number of studies examine solar thermal and other solar technologies, such as solar collectors, water-heating systems, or hydrogen production using photovoltaic power.

These studies show that universities use different types of solar energy systems, ranging from grid-connected photovoltaic installations to hybrid and solar thermal systems.

Across the 25 studies, different methodological approaches are used. Many studies rely on simulation-based analyses, using tools such as PVSyst, HelioScope, DesignBuilder, or MATLAB/Simulink to assess feasibility, optimize system design, or model energy performance. Other studies use experimental or monitoring-based methods, drawing on data from operating photovoltaic installations, prototypes, or laboratory setups, often collected over longer periods.

Several studies focus on optimization and control strategies, applying metaheuristic algorithms, classical optimization techniques, or priority-based controllers to improve the operation of photovoltaic systems or hybrid microgrids. In addition, some publications use mixed approaches, combining simulations, empirical measurements, and economic evaluations.

The reviewed studies use different methods to examine solar energy systems in higher education.

Based on these descriptive results, the following section examines the main themes identified in the reviewed studies.

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3.2 Thematic Analysis

The thematic analysis of the reviewed studies shows several repeating themes that describe how higher education institutions promote solar energy initiatives in relation to SDG 7 and SDG 13. These themes include technical development, economic and energy-management analysis, institutional governance, and the relationship between solar projects, education, and research.

A large part of the literature focuses on the technical performance of solar systems installed at universities. Studies by Güven et al. (2024) and Toti et al. (2024) show that the use of optimization techniques, such as genetic algorithms and particle swarm optimization, can improve system efficiency under both grid-connected and off-grid conditions. Other research examines improvements at the component level. For example, Elazab et al. (2025) and Kuvshinov et al. (2021) explore new materials and surface treatments that enhance energy capture or reduce system losses. These studies indicate that universities are not only installing photovoltaic systems for operational purposes, but also using them as platforms for testing and developing new technologies. Hybrid structures, such as wind–PV–battery systems, are also examined, with studies like Raihani et al. (2019) highlighting their potential to support campus energy autonomy and enable real-time energy management research.

Another important theme relates to the economic side of solar installations. Several universities evaluate whether PV systems are financially viable and how quickly they can recover investment costs. For example, Akbulut et al. (2025) use regression analysis to assess the economic performance of a photovoltaic system installed at a university, while Saputri et al. (2025) present a techno-economic study for an Indonesian campus. These works show that solar energy can be a cost-effective solution for reducing electricity expenses.

Other papers focus on energy management. Moya et al. (2020), for instance, examine how smart-building approaches that combine photovoltaic systems, energy storage, and electric vehicles can minimize grid consumption. Studies such as Burton et al. (2020) highlight the influence of user

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behavior and shared energy systems, suggesting that technical solutions alone are not enough and need to be supported by appropriate management practices to achieve long-term sustainability.

Institutional governance is also discussed in several studies. In some cases, universities frame solar installations within broader sustainability or climate-action strategies. Cristea et al. (2022) and Munaro and John (2024) show that photovoltaic systems can support institutional sustainability targets when they are part of a coordinated plan.

Regional policy also plays a role. Studies such as Awad et al. (2023) and Almasri and Narayan (2021) explain how national or regional energy policies influence renewable energy adoption in the Middle East.

At the same time, several studies point out that many universities still do not use systematic monitoring tools or standardized frameworks to track their progress toward SDG 7 and SDG 13. This issue has also been raised in broader HEI sustainability studies (e.g., Serafini et al. 2022; Filho et al. 2023).

Finally, many studies emphasize the educational and research value of solar projects. Photovoltaic installations often serve as "living laboratories" where students and researchers can work with real-time data and gain practical experience. For example, Chakraborty et al. (2019) analyze how modelling and monitoring can support learning in energy management, and Rey-Hernández et al. (2018) describe the use of a near-zero-energy building for both research and teaching. Solar systems also support interdisciplinary research. Some projects, such as Aguilar Pinzón et al. (2025), connect solar system optimization with computational intelligence methods. Earlier work (e.g., Jo et al. 2017; Castrillón-Mendoza et al. 2020) suggests that visible renewable energy installations on campus can also strengthen campus identity and encourage engagement with sustainability issues. Overall, these findings show that solar energy initiatives support the core missions of higher education institutions, namely education, research, and sustainable campus operations.

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4. Discussion

The findings of this review show that universities around the world are increasingly using solar energy systems as part of their sustainability and climate strategies. The descriptive trends confirm that research activity on this topic has grown steadily, while the thematic analysis reveals that universities are becoming more active agents in the energy transition domain. These results agree with recent studies that highlight the role of higher education in supporting the SDGs, especially SDG 7 and SDG 13 (Chankseliani and McCowan 2021; Serafini et al. 2022; Filho et al. 2024).

The reviewed studies suggest that universities function as small-scale examples of how a sustainable community can operate. Because they combine teaching, research, and daily operations, HEIs have both the technical capacity and the social responsibility to test and promote renewable energy solutions (UNESCO IESALC 2020; EAUC 2017). Solar projects on campus, such as rooftop PV systems or hybrid microgrids, show how academic institutions can turn their buildings into practical laboratories for clean energy use.

Many recent discussions on clean energy also focus on decentralized and community-level solutions. (UN DESA 2021; Sheraz et al. 2024). In many cases, solar projects in universities are connected to wider national and regional energy objectives. Case studies from Jordan (Awad et al. 2023) and Malaysia (Govindarajan et al. 2024) show how universities help local communities move toward renewable energy using simple, small-scale solutions and information sharing.

In many universities, solar projects are included in sustainability planning. Early studies focused mainly on efficiency and system optimization (Azharuddin Shamshuddin et al. 2017; Güven et al. 2024; Toti et al. 2024). More recent studies also examine management issues, financial aspects, and long-term planning (Cristea et al. 2022; Munaro and John 2024).

Universities that include solar energy in their overall planning, such as energy plans or carbon-neutrality targets, often achieve better results. Sustainability offices and regular reporting help ensure that photovoltaic projects continue over time and are gradually improved. This shows that

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sustainability actions are more effective when they involve the whole institution (Filho et al. 2023; Serafini et al. 2022).

Costs are also an important issue. Several studies show that photovoltaic systems on university campuses can be economically viable. Akbulut et al. (2025) and Saputri et al. (2025) report payback periods of less than ten years. This means that solar installations can help universities reduce energy costs over time.

Several studies point out that better results are achieved when solar energy is used together with energy management practices. Smart control systems, energy storage, and electric vehicles, can reduce costs and lower emissions (Moya et al. 2020; Aguilar Pinzón et al. 2025). Many universities in the reviewed studies reported significant reductions in greenhouse gas emissions, supporting SDG 13. At the same time, solar installations help lower energy costs and contribute to climate action. This is in line with recommendations that encourage HEIs to consider environmental, social, and governance (ESG) principles when planning and managing their finances (World Bank et al. 2025). Recent studies in other organizational settings suggest that effective ESG governance and transparent ESG disclosure can strengthen sustainability performance, promote green innovation, and support long-term organizational development.

While universities operate in a different institutional context from corporate organizations, these findings, together with existing recommendations for HEIs (World Bank et al., 2025), highlight the potential value of integrating ESG principles into institutional sustainability planning.

By examining the reviewed studies, it becomes clear that solar installations offer important benefits for both education and research. Several studies describe how photovoltaic systems serve as “living laboratories” in engineering, environmental science, and sustainability courses (Chakraborty et al. 2019; Rey-Hernández et al. 2018). Students gain practical skills by working with real data, sensors, and monitoring systems.

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Solar projects often involve more than one academic field, bringing together engineering with economics, environmental management, and policy Studies by Aguilar Pinzón et al. (2025), Jo et al. (2017), and Castrillón-Mendoza et al. (2020) show that this type of work helps universities apply research in practice and stay connected with local communities. This role is closely linked to the educational mission of universities and their contribution to sustainable development (UNESCO IESALC 2020).

Despite growing the body of literature, important gaps remain. Most studies come from Europe and Asia, while Africa, parts of the Middle East, and Latin America are less represented. This reflects broader inequalities in research funding and renewable energy capacity (UN DESA 2021; World Bank et al. 2025). More international cooperation and funding would help reduce these imbalances. In addition, open-access repositories, shared research infrastructures, and digital collaboration platforms can facilitate knowledge exchange and improve participation by universities in underrepresented regions.

Another common issue is the lack of reliable methods for monitoring and reporting to track progress toward SDG 7 and SDG 13. Without transparent long-term monitoring and publicly available performance indicators, sustainability initiatives may be perceived as symbolic rather than evidence-based. Transparent reporting and stakeholder engagement therefore play an important role in strengthening the credibility of university sustainability actions and demonstrating measurable progress toward SDG 7 and SDG 13. Many projects are used as pilots without long-term follow-up or integration into institutional practices (Cristea et al. 2022; Munaro and John 2024). Existing frameworks, such as those proposed by Filho et al. (2023) and Serafini et al. (2022), could help universities compare performance and improve accountability.

The reviewed studies show that university-led solar projects support larger sustainability adaptation. When solar technologies are integrated into buildings, finances, and curricula, HEIs show how clean

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energy systems can work in practice. As centers of knowledge and innovation, universities provide practical examples for cities, industries, and other public institutions.

This supports the global view that climate solutions must be based on local action and technical expertise (UN DESA 2021; Sheraz et al. 2024). Solar installations show that universities can go beyond typical standards and achieve clear environmental results (Filho et al. 2024).

In conclusion, solar energy plans in HEIs address both SDG 7 and SDG 13 through technology, governance, and education. University campuses serve as real-world examples of how renewable energy can become part of everyday operations, while also supporting teaching and research. Although challenges remain in terms of topical inequality and governance structures, the evidence shows that universities play an important role in the global movement toward clean and resilient energy systems.

The reviewed studies also highlight important policy implications for HEIs. Solar energy projects appear to be most effective when they are embedded within a broader institutional sustainability framework that aligns energy planning with climate targets and SDG actions. Universities that adopt organizational arrangements such as sustainability offices, energy master plans, or carbon-neutrality roadmaps are better positioned to integrate solar investments with SDG 7 and SDG 13 in a systematic and measurable way. The long-term success of university solar initiatives depends on the interaction of governance strategies, technological infrastructure, institutional commitment, and supportive campus policies rather than on isolated technical interventions. This configurational perspective suggests that sustainable institutional transformation is achieved through the combined effect of organizational, technological, and environmental factors working together. Therefore, solar projects should not be treated simply as stand-alone technical solutions but as practical tools that support long-term institutional change.

From a policy perspective, the findings show the need for clearer indicators and shared monitoring frameworks to track progress on energy and climate goals. In this sense, MUDEIS (Martinis et al.

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2024; Kaloutsa et al. 2025) provides an example of how such monitoring can be organized in a more systematic way. By combining indicators with multi-criteria evaluation, frameworks like MUDEIS offer a structured approach for assessing university contributions. This would allow universities to better show their role, both at the campus level and at national and regional levels.

5. Conclusions

This review analyzed 25 peer-reviewed studies published between 2015 and 2025 to examine how universities around the world support SDGs 7 and 13 through the use of solar energy. By combining descriptive trends with thematic analysis, the study assessed how these initiatives are being used.

The findings show that universities increasingly adopt solar technologies not only to reduce costs or improve environmental performance but also to support their missions in education, research, and community engagement. This review provides a consolidated overview of how universities implement solar energy systems and how these initiatives contribute to SDG 7 and SDG 13. By combining findings from different areas, the review helps explain how HEIs contribute to the clean energy transition. It also points to practical ways universities can act as low-carbon examples and support future energy planning and sustainability governance.

Over the ten-year period, university projects on solar energy have changed a lot. Early studies focused mainly on technical aspects and system performance. Recent research includes as well, economic analysis, optimization, and institutional sustainability planning. This shows a shift from individual projects to more organized approaches. The studies cover a wide range of regions, including Europe, Asia, the Middle East, and Latin America. This shows that solar energy is widely seen as a flexible solution that supports both climate mitigation and energy access. However, important gaps remain, especially in Africa and small-island states, where research and implementation are still limited.

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Higher education institutions contribute to SDG 7 and SDG 13 through technological innovation, as universities test and refine solar technologies, hybrid systems, and monitoring tools. Economic viability is also a common consideration, since solar installations support greater energy independence and lower financial costs. Many universities now include solar projects within broader sustainability policies. Educational and research value is noted in studies where photovoltaic systems are used as learning platforms and research infrastructure. These insights show that universities advance technological development, support institutional sustainability, and generate wider social benefits through the use of solar energy systems.

The review confirms that universities can turn global sustainability goals into practical local actions. Their combined missions, teaching, research, and community outreach, allow them to connect technical innovation with social awareness and policy support.

Solar energy projects are an example of the "quadruple-helix" model, where universities work together with government, industry, and society. These partnerships help build local knowledge, test technologies, and encourage community engagment. Campus solar installations also strengthen the university's leadership role and offers useful examples for nearby cities and organizations.

The findings of this review suggest several important implications for universities that plan to expand their use of solar energy. Solar initiatives tend to be much more effective when they are part of a wider institutional sustainability strategy, supported by clear governance policies and long-term planning rather than treated as isolated technical projects. Financial aspect is also important, as mechanisms such as power purchase agreements, green bonds, and energy-as-a-service models can offer practical solutions for institutions that have limited budgets or face investment barriers. The results also show that capacity building is essential, especially through stronger regional and international partnerships that allow universities to share data, exchange technical knowledge, and learn from each other's experiences. Finally, the review highlights the need for better standardization. More consistent indicators and reporting systems are needed to monitor solar performance and to

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ensure that progress toward SDG 7 and SDG 13 can be measured in a transparent and comparable way across institutions.

Although this study presents the progress in this area, several challenges remain. Looking at the regional representation, global inequalities become evident. Limited access to renewable technologies and research funding is reflected in the absence of major regions. In many universities, solar projects are still not well connected to institutional policies which limits their long-term impact. There is also a lack of long-term performance data, making it difficult to understand the real sustainability outcomes of campus photovoltaic systems (UN DESA 2021; World Bank et al. 2025). Future studies should prioritize long-term monitoring and life-cycle assessments.

The review also points to several areas where further research would be useful. Comparative analysis university solar energy programs across different climate conditions and policy contexts could help identify patterns of development and adaptation. There is also growing interest in how digital tools, such as artificial intelligence, smart grids, and digital twin models, can improve monitoring and decision-making in campus energy systems. More broadly, digital transformation is shifting energy management from conventional infrastructure operation toward data-driven, intelligent, and algorithm-supported decision-making processes, creating new opportunities for optimizing institutional sustainability strategies. Future research should also investigate the practical integration of these technologies into university energy infrastructures, including issues related to data management, interoperability between monitoring systems, and the reliability of real-time energy analytics. More work is needed to understand the behavioral and cultural factors that influence how students, staff, and administrators engage with solar installations, as these factors can affect the long-term success of energy initiatives.

Strengthening the links between university renewable energy efforts and national climate policies is another important area, ensuring that institutional actions contribute meaningfully to broader decarbonization strategies. Finally, developing more comprehensive assessment frameworks that

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combine technical performance with financial outcomes and educational benefits would support a more complete evaluation of solar energy projects in higher education.

In summary, university-led solar projects offer a practical way to advance SDG 7 and SDG 13. Solar energy is becoming part of the daily operation of campuses and an important tool for teaching and research. As global pressure for decarbonization grows, universities can show how a sustainable energy transition works in practice. By combining technology, governance, and education, HEIs can help shape a cleaner and more resilient future.

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Appendix A. Scopus Search Query

The literature search was performed in Scopus on August 5, 2025 using the following search string. The query was designed to capture peer-reviewed journal articles addressing the intersection of solar energy, higher education institutions (HEIs), and the SDGs (SDG 7 and SDG 13).

(TITLE-ABS-KEY ("SDG 7" OR "SDG 13" OR "Sustainable Development Goal*" OR "climate action" OR "clean energy" OR "low-carbon" OR "emission reduction" OR "renewable energy")) AND (TITLE-ABS-KEY ("university" OR "Higher Education Institution*" OR "HEI" OR "campus")) AND (TITLE-ABS-KEY ("energy efficiency" OR "carbon reduction" OR "sustainability strategy" OR "sustainability assessment" OR "energy management")) AND PUBYEAR > 2014 AND PUBYEAR < 2027 AND (LIMIT-TO (EXACTKEYWORD , "Solar Energy")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))

This search was limited to:

Document type: Articles (ar)

Source type: Journals (j)

Language: English

Year range selected for analysis in Scopus: 2015–2025.

A total of 47 documents were initially retrieved. After screening and removing duplicates, 25 articles were retained for full review, while 22 were excluded due to access limitations or lack of relevance to university-level solar energy applications.

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