

Article

Barriers to the Implementation of On-Grid Photovoltaic Systems in Ecuador

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Abstract: Ecuador has significant solar potential, and the growing demand calls for sustainable energy solutions. Photovoltaic (PV) microgeneration in buildings is an ideal alternative. Identifying barriers to the widespread adoption of this technology is based on expert consultation and multi-criteria analysis, followed by proposals to overcome these challenges. The methodology of this study includes a systematic literature review (SLR), surveys of industry professionals, and statistical analysis of the collected data. The results highlight barriers such as the high initial cost, government-subsidized tariffs, bureaucratic processes and permits, ineffective regulations, limited awareness, lack of financing, distribution and operational network challenges, and insufficient government incentives. The proposed solutions suggest developing incentive policies to promote investment in PV microgeneration, training programs to enhance technical and cultural knowledge of solar energy, simplifying regulatory processes to facilitate project implementation, and providing accessible financing to reduce economic barriers. Additionally, the recommendations include the implementation of demonstration and outreach projects to showcase the feasibility and benefits of PV microgeneration, thus improving the social and technical acceptance of these systems. These actions aim to foster a faster and more effective energy transition in Ecuador.

Keywords: barriers; urban environments; photovoltaic generation system



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1. Introduction

Currently, energy demand in Ecuador is experiencing a significant increase. According to the Ministry of Energy and Mines, energy consumption grew by 11.3% compared to 2020 and 8.3% compared to 2021, reaching 93.5 million Barrels of Oil Equivalent (BOE) [1]. In 2024, Ecuador also faced an energy crisis due to its heavy reliance on hydroelectric power, exacerbated by the impact of droughts caused by climate change, leading to prolonged blackouts across the country [2]. The distribution of energy sources in Ecuador, starting with the most significant renewable energy sources and ending with thermal energy sources, is as follows: hydroelectric energy leads with 58.38%, followed by thermal MCI at 22.96%. Biomass contributes 1.62%, wind energy accounts for 0.80%, and biogas makes up 0.09%. On the thermal side, turbogas constitutes 10.62%, and the thermal steam turbine contributes 5.19%.

Among the potential solutions, photovoltaic generation systems (PV systems) stand out due to their potential, especially given the country's favorable climate conditions. However, their widespread adoption faces economic, technical, environmental, and cultural challenges [3]. Although the considerable growth in clean and low-cost technologies achieved by solar and wind technologies is expected to reach 95% by 2030 [4], several aspects must be addressed to achieve the same growth rates in Ecuador. Research on PVs in urban environments in Ecuador is highly relevant, given the country's strong solar potential

and the urgent need for sustainable energy solutions. This study focuses on identifying and mitigating the barriers that hinder the implementation of PVs. By understanding and addressing these obstacles, effective proposals can be developed to promote the adoption of solar energy in urban areas.

As background, between 2008 and 2018, Ecuador allocated more than twelve billion dollars to its electric sector, achieving significant improvements in service quality and system modernization. By the end of this period, the country's installed capacity reached 8826.89 MW, with a notable 59.84% from renewable sources (hydroelectric energy, mainly, followed by lesser proportions of wind, biomass, and biogas). In contrast, 40.16% came from non-renewable sources. Although the growth in solar energy was modest between 2019 and 2023, increasing from 0.32% to 0.33%, it reflects progress toward greater energy mix diversification with the expansion of PV generation [5,6].

Thanks to its geographic location, Ecuador receives high solar radiation, ranging from 3.12 to 5.82 kWh/m² per day, making it an ideal country for developing PVs. The highest irradiation places include northern Chile, where the daily average irradiation can reach 9 kWh/m², and areas similar to Ecuador include Spain, with a 4.7 kWh/m² daily average. There are also countries with less solar irradiation availability like England and Germany, where in the most irradiated areas of those countries, less than 3.0 kWh/m² or 3.4 kWh is expected per day on average [7]. In the Andean mountain range, the main advance corresponds to irradiation stability throughout the year, since seasonal variations are relatively low [8]. This potential is distributed across both coastal and mountainous regions, facilitating the utilization of solar energy. In this global context, PVs emerge as a promising energy solution, particularly in locations with abundant solar radiation like Ecuador. The country has significant solar potential due to its advantageous geographic location, which positions it strategically to lead the adoption of clean energy and reduce its dependence on fossil fuels. The promotion of solar projects aligns with the Sustainable Development Goals, contributing to energy security and democratization, economic growth, and climate change mitigation [9,10].

PV solar potential in buildings and cities has been explored in Ecuador also. In Cuenca, Ecuador, it has been estimated that the solar potential could supply over 3.2 times the estimated entire power demand [11]; in Quito, the capital city also located in the Andean power range, it has been determined that roof power PV potential could reach 2.3 times, as a consequence of the reduced energy requirements because of the good climate conditions throughout the entire year [12]. Building-integrated PV potential and architectural impact [13], and grid limitations [14], have also already been analyzed locally. Local stable irradiation combined with the high solar altitude throughout the year makes the equatorial region especially favorable for PV integration in cities and buildings. As a consequence, grid restrictions of peak irradiation are less disruptive than in seasonal places. The transition [13] to a sustainable energy matrix is a global priority in the fight against climate change and the pursuit of more sustainable and environmentally respectful development [15]. However, the implementation of grid-connected PVs in Ecuador faces significant obstacles that limit their widespread and efficient integration [16]. These barriers can be technical, economic, political, or otherwise, posing significant challenges to the deployment of PV technology [17]. The complexity of the Ecuadorian context, with its diverse geographic and socioeconomic factors, adds additional layers of challenges that require tailored and specific solutions [18].

The Ecuadorian government has implemented favorable policies to promote the development of solar energy, including incentives such as preferential tariffs and net metering systems that allow solar energy producers to inject their excess power into the grid. These measures, supported by a legal and regulatory framework, have encouraged investment in large-scale solar projects and the adoption of clean technologies, strengthening the diversification of the energy matrix and advancing towards a more sustainable and resilient future [19–21].

Given all the aforementioned points, the general objective of this research was to identify the barriers that hinder the effective implementation of grid-connected PV generation systems in urban environments. To achieve this goal, three specific objectives were set: first, to identify the most recurrent barriers that impede the adoption of these systems in urban settings; second, to define detailed perspectives on the current situation through expert consultation; and third, to develop a proposal that addresses and reduces the identified barriers, thereby promoting greater integration of solar energy in cities.

To overcome these obstacles, it is recommended to implement tax incentives, direct subsidies, and tax credits to reduce the initial cost, gradually replace electricity subsidies with renewable energy incentives, simplify administrative procedures, increase awareness of the benefits of PV systems, and modernize power grids. Actual power grids must perform as a Smart Grid concept, which implies that electrical grids must be able to incorporate thousands of microgenerators of electricity and serve as a virtual battery, so that those buildings that generate excess electricity at times deliver electricity to those that require energy [22]. Additionally, it is suggested to establish investment funds and offer incentives to private investors to address the lack of financing, along with long-term support policies to ensure stability and promote solar energy investment. On the other hand, numerous authors focus on the barriers that impact the development of PV generation systems. Consultations with experts to determine the local situation on technology-related topics have been widely used in other studies. Since each case is different due to conditions, techniques, and economic, social, or environmental factors, it is essential to focus the study on a specific reality. In this regard, Table 1 shows studies that employed surveys, the main barriers identified, and the sites where they were applied.

Table 1. Background research summary.

Technologies	Country	#Barriers	#Respondents	Main Barriers	Reference
PV power plants	Spain	1	329	Lack of social acceptance	[23]
Residential building envelope for PVs	Egypt	4	20	High initial cost, lack of knowledge, lack of confidence in the quality of PV systems, high maintenance cost.	[24]
PVs in residential buildings	Philippines	3	234	High initial cost and lack of knowledge.	[25]
PVs on residential areas	India	4	443	Lack of governmental political support, the challenge of changing behaviors, institutional structures, and high initial cost.	[26]
PVs on Buildings	Singapore	18	99	High initial costs, long payback period, low energy conversion efficiency of PV systems, difficulty integrating PV systems into the grid, unclear maintenance procedures, and lack of knowledge.	[27]
PV power plants	Nigeria	2	740	Lack of awareness and information.	[28]

The SLR on barriers to the implementation of PVs in different contexts reveals a variety of obstacles that vary by country and the type of renewable technology examined. The actual policies and regulations in Ecuador are supposed to encourage grid-connected PV systems, but Ecuador remains slow to introduce micro self-supply systems. Thus, deciphering the main barriers would be very helpful in improving actual policies and regulations or introducing efficient actions to speed up new grid PV systems.

2. Methodology

2.1. Research Location

This research was conducted in Ecuador, which is located on the equatorial latitude in South America. Continental Ecuador is divided into three regions: the Andean highlands, the eastern forests, and the Pacific coastal lowlands. It has five climate floors: the warm floor, the temperate floor, the cold floor, the paramo/moor floor, and the glacial floor. The altitudes range from 0 to 3000 m above sea level, with temperatures ranging from 25 °C to less than 0 °C, respectively.

However, because it is close to the equator and lacks seasonal changes, solar energy could be harnessed to mitigate the growing electricity demand. The global radiation in Ecuador varies from 2.9 to 6.3 kWh/m² per day, with 75% of the country receiving more than the recommended 3.8 kWh/m² per day for efficient PV generation. However, the installed capacity represents 0.32% of the total energy generated considering all sources that produce electricity.

2.2. Research Focus

Given the diversity of environmental, social, economic, and technical factors, a triangulation methodology is used to validate the data by comparing the SLR with the perspectives of field experts. This multidisciplinary approach ensures a thorough and accurate assessment of the current situation. The primary objective is to identify the barriers limiting the development and promotion of PV systems in Ecuador. Through the analysis of the state of the art and consultations with specialists, the main obstacles to the expansion of PV technologies are highlighted, providing a deep understanding of the specific challenges faced by the solar energy sector in the country.

Exploratory research aims to increase familiarity with new or poorly understood topics, generating initial ideas or hypotheses. In contrast, descriptive research systematically details and characterizes a specific phenomenon or population, offering a precise and detailed representation.

2.3. Methodological Process

Figure 1 shows the process followed in carrying out this research. In the first stage, a literature review was conducted on the current situation in Ecuador, highlighting the energy balance, solar energy availability, and urban land use. In the second stage, a SLR was carried out in both global and national contexts to identify recurrent barriers by applying bibliographic review criteria and expert reviews in the area of interest. This systematic review allows not only an understanding of the specific challenges of the country, but also enriches the academic dialogue on the adoption of PV systems in urban environments.

Interviews were conducted with local actors. These surveys were administered both physically and through Google Forms, using closed-ended questions based on the Likert scale. This methodology, as used by Nwokocha et al. [28], is designed to systematically capture and analyze data on these barriers. Quantitative data are collected on participants' opinions, perceptions, and attitudes regarding PV systems.

The survey was conducted among 85 professionals in the electricity sector, academic experts (professors and researchers), public workers, and private individuals, with 51 responses validated. A form was designed and distributed to key individuals involved locally in the development of PV energy in Ecuador. Profiles of people in companies related to the installation of PV, teachers with knowledge of renewable energies, and professionals from electric companies were reviewed, and potential collaborators were identified through recommendations. The selection of the surveyed individuals was based on meeting at least two of the following characteristics: having knowledge about PV systems, engaging in professional activities related to distribution systems, or having academic activity and training associated with renewable energies. The survey targeted professionals from various fields, with 98% being engineers (electrical, electronic, mechanical, chemical) and 2% architects, of which 24% had postgraduate studies. The participants came from the public sector (20%),

private sector (56%), and academic sector (24%). The participants were from different cities across the country (Quito, Guayaquil, Cuenca, Ambato, Machala, and Loja). Subsequently, the data were validated using two statistical tools: mean scoring and Cronbach's analysis. The former provides the researcher with a single value that summarizes the responses to each question in the survey. This generated a discussion on whether or not participants agree with the absence or presence of certain barriers to PV systems in urban environments.

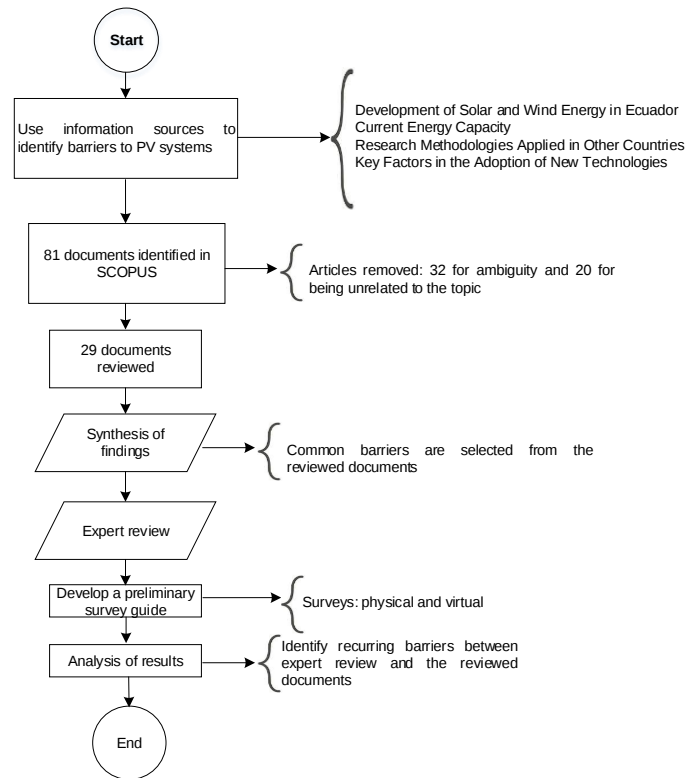


Figure 1. Identification of barriers in the implementation of grid-connected PV systems.

Using Equation (1), a formula is provided to calculate the mean score (P_m), which depends on the points (i) from the Likert scale, the number of responses (P_i) that gave each score, and F_i , which is the proportion of responses for each score. F_i is determined as the ratio between P_i and the total number of responses [29].

$$CCC = \sum_{i=1}^5 iF_i \quad (1)$$

Cronbach's α coefficient is applied to observe the reliance by comparing the answers of related questions through Equation (2), where k represents the number of questions, S_i^2 is the sum of the variances per question, and S_t^2 is calculated as the variance of the sum of responses per item.

This reliability measure helps determine the consistency of the survey, ensuring that the set of questions effectively captures the intended data and that the responses are dependable for further analysis [30].

$$P \propto = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^k S_i^2}{S_t^2} \right) \rightarrow \begin{cases} \alpha < 0.5 \therefore \text{Unacceptable} \\ 0.5 \leq \alpha < 0.6 \therefore \text{Low} \\ 0.6 \leq \alpha < 0.7 \therefore \text{Questionable} \\ 0.7 \leq \alpha < 0.8 \therefore \text{Acceptable} \\ 0.8 \leq \alpha < 0.9 \therefore \text{Good} \\ 0.9 \leq \alpha \leq 1.0 \therefore \text{High} \end{cases} \quad (2)$$

3. Results

3.1. Most Recurrent Barriers to the Implementation of PVs in Urban Environments

This section presents the most frequent barriers hindering the adoption of PV systems in urban areas, and is divided into two parts. First, barriers are identified based on an SLR, which provides a comprehensive overview of the common obstacles documented in the scientific literature. Second, the results of a preliminary survey conducted with industry experts are included.

3.1.1. Literature Review

To identify the barriers through the SLR, a screening process was conducted, starting with the collection of 81 documents obtained from various scientific databases. Documents that were not relevant, such as studies on isolated PV systems or those not focusing on urban areas, as well as those older than five years, were discarded. After this filtering, 29 articles were selected. In these 29 studies, a total of 16 initial barriers were identified, represented by the letter B.

Table 2 shows the consulted bibliography and the identified barriers. In this way, the barriers that are more frequent are identified and, therefore, those that should be analyzed in the local environment. Each barrier is classified as follows:

- B1: Lack of management of PV waste
- B2: Impact on biodiversity
- B3: Land occupation for PVs
- B4: Lack of knowledge among professionals and users
- B5: Lack of social acceptance
- B6: Absence of specific policies
- B7: Lack of effectiveness in regulations
- B8: High initial cost of PV systems
- B9: Perceived long-term profitability
- B10: Lack of financing
- B11: Absence of electric rates for PV systems
- B12: Aesthetic considerations
- B13: Ineffectiveness in design, such as lack of standards and codes
- B14: Low efficiency of solar panels
- B15: High maintenance and component replacement costs
- B16: Inadequate electrical grid infrastructure.

Table 2. Identified barriers based on various studies.

Research	Reference	Barriers Analyzed															
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
A1	[31]				X				X								X
A2	[32]	X															
A3	[23]					X											
A4	[33]	X															
A5	[34]							X					X				
A6	[24]				X				X						X	X	
A7	[35]		X						X						X		
A8	[36]				X			X		X			X				
A9	[37]								X	X							
A10	[38]			X			X			X							

Table 2. Cont.

Research	Reference	Barriers Analyzed															
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16
A11	[39]						X		X	X	X			X			
A12	[40]							X				X		X			
A13	[41]						X	X		X	X			X			
A14	[42]	X						X	X	X						X	
A15	[43]				X				X		X						
A16	[17]					X	X			X	X			X	X		
A17	[44]								X	X							
A18	[45]				X		X		X		X				X		
A19	[46]				X				X					X			
A20	[47]						X		X					X			
A21	[48]								X								X
A22	[26]					X	X	X	X								
A23	[27]				X			X	X	X				X	X	X	
A24	[49]							X				X					
A25	[50]				X			X	X								
A26	[51]							X	X	X							
A27	[52]								X					X			
A28	[53]				X				X								
A29	[54]				X				X							X	
Total		3	1	1	10	3	7	10	19	10	5	2	1	9	5	4	2

As shown in Table 3, some barriers appear more frequently in the studies compared to others. In particular, barriers B4, B6, B7, B8, B9, and B13 have a significant number of occurrences: 10, 7, 10, 19, 10, and 9, respectively. Conversely, certain barriers, such as B2, B3, and B12, were identified only once, which necessitated the establishment of a selection criterion to ensure the relevance of the identified barriers. The criterion applied was to discard barriers with a frequency less than 15% of the total number of all incidences.

Table 3. Classification of PV system barriers for Ecuador.

Type	Code	Barriers	Description	Reference
Environmental	B1	Lack of management of PV waste	It refers to the need to develop and implement strategies for the recycling or proper disposal of solar panels at the end of their useful life.	[32]
Social	B4	Lack of knowledge among professionals	It points to the need for specialized training for professionals who install and maintain PV systems, as well as informing end-users on how to maximize the benefits of these systems.	[24,25]
	B5	Lack of social acceptance	It indicates the resistance of communities or individuals to adopt PV systems due to various concerns or negative perceptions.	[23]

Table 3. Cont.

Type	Code	Barriers	Description	Reference
Policies and regulations	B6	Lack of policies	It refers to the absence of government guidelines to support the implementation of PV systems.	[38]
	B7	Absence of government guidelines	Existing regulations that do not adequately promote the adoption of PVs	[34]
Profitability barriers	B8	High initial cost	It represents the initial investment required for the acquisition and installation of PV systems	[31]
	B9	Perceived long-term profitability	Expectation of sustainable profits over time	[36]
	B10	Financial restrictions	Limited financial resources for projects or needs	[41]
	B15	High maintenance and/or replacement costs for PV system components	It involves associated costs with regular maintenance and replacement required throughout the system's lifespan.	[42]
Technical barriers	B13	Ineffectiveness of PVs design	PV design that fails to meet objectives or satisfy operational or strategic needs	[34]
	B14	Low efficiency of PV panels	It points to the current limitations in PV technology that affect the amount of electrical energy that can be generated from solar radiation	[27]

After applying this selection process, the number of barriers was reduced to a total of eleven, which were classified into five categories: environmental, social, policy or regulatory, economic, and technical. This approach allowed for a focus on the most significant and recurrent barriers, providing a better understanding of the challenges in implementing PV systems in urban environments.

3.1.2. Preliminary Survey

In addition to the findings mentioned, a preliminary survey was conducted on the barriers to the adoption of PV systems in Ecuador, targeting experts in the field. A preliminary survey identifies the factors that are most important in the Ecuadorian environment. In Table 4, the repeatability of each is shown, allowing the identification of those that may influence the local environment. The barriers identified through this survey were categorized under the letter “R”.

The main barriers found include the absence of government incentives (R1), financing difficulties (R2), and high costs and scarcity of components (R3). Additionally, subsidized electricity rates (R4) and regulatory instability (R5) also affect the adoption of PV systems. Other obstacles include lengthy bureaucratic processes to obtain permits (R6), lack of clear regulations for waste recycling (R7), design and operational issues (R8), and insufficient electrical distribution network infrastructure (R9). Furthermore, high maintenance costs (R10), the visual impact of PV systems (R11), technical barriers (R12), lack of training (R13), and limited dissemination of the benefits of these systems (R14) contribute to the limited implementation of PV systems in the country.

When analyzing the barriers identified by experts, it was observed that some barriers appeared more frequently, such as R1 and R6, which were mentioned six times each, and R14, which was mentioned five times. Barriers R4, R5, R9, R12, and R13 were also highlighted, each with four mentions. In contrast, some barriers, such as R2, R7, and R10, were mentioned only once. Therefore, a selection criterion was established, eliminating barriers with fewer than four mentions. This process identified six key barriers that were

the most recurrent and were integrated with the barriers obtained from the systematic literature review:

R1: Government Incentives

R4: Government-Subsidized Rates

R6: Permitting and Administrative Processes

R9: Distribution and Operational Power Grids

R12: Technical Issues

R14: Dissemination.

Table 4. Recurrent barriers to PV systems in urban environments in Ecuador.

Survey	Barriers													
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
E1-A	X													X
E2-P					X				X					
E3-Pr				X										X
E4-A											X	X		
E5-Pr			X	X				X		X		X		
E6-P					X				X		X	X		
E7-Pr			X			X			X				X	X
E8-Pr						X		X					X	
E9-Pr	X	X					X							X
E10-P						X			X		X		X	
E11-A	X			X	X	X								
E12-Pr	X		X	X		X								X
E13-A	X				X							X		
E14-Pr	X					X							X	
E15-P		X									X		X	
Total	6	1	3	4	4	6	1	2	4	1	3	4	4	5

Note. E1 to E15 correspond to each expert-related answer: (A) Academic personal, (P) Public sector personal, (Pr) Private sector personal.

3.2. Statistical Analysis

Cronbach's α coefficient, both overall and in each sector (private, public, and academic), indicates levels of reliability that range from good to acceptable. Values above 0.8 in the general, private, and public sectors suggest high internal consistency, meaning that the items on the questionnaire are appropriate and reliably measure the construct in question. As seen in Table 5, in the academic sector, although the coefficient of 0.714 is slightly lower, it remains acceptable, indicating adequate internal consistency but with potentially higher variability in responses. In this case, the low rating may be because those consulted in the academic sector have training but not practice in the sector; therefore, some perceptions are not necessarily a result of the local situation but rather of international experiences.

Table 5. Indicators obtained with the Cronbach's alpha algorithm.

Parameters	Overall	Private Personal	Public Personal	Academic Personal
k	17	17	17	17
$\sum_{i=1}^k S_i^2$	16.4	18.78	16.6	11.29
S_t^2	68.37	77.55	67.49	34.41

Table 5. Cont.

Parameters	Overall	Private Personal	Public Personal	Academic Personal
α Grade	0.808 Good	0.805 Good	0.800 Good	0.714 Acceptable

Average Score

Table 6 presents the results of the barriers in urban environments in Ecuador, evaluated using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Each barrier was assessed by the respondents, and the average scores (Pm) reflect the perceived importance of each barrier. Additionally, they provide a clear view of the respondents' perceptions of the challenges in urban environments in Ecuador. Barriers with higher scores require priority attention to improve the urban environment, while barriers with lower scores, although important, may be considered less urgent.

Table 6. Average agreement with PV barriers in urban environments for Ecuador.

Likert Scale	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree		Σ	Pm
	1		2		3		4		5			
Barriers	Pi	Fi	Pi	Fi	Pi	Fi	Pi	Fi	Pi	Fi		
B1	4	0.08	6	0.12	8	0.16	13	0.26	19	0.38	50	3.7
B4	2	0.04	6	0.12	9	0.18	20	0.40	13	0.26	50	3.7
B5	6	0.12	6	0.12	11	0.22	17	0.34	10	0.2	50	3.4
B6	2	0.04	6	0.12	11	0.22	14	0.28	17	0.34	50	3.8
B7	1	0.02	3	0.06	8	0.16	18	0.36	20	0.4	50	4.1
B8	0	0.00	4	0.08	7	0.14	14	0.28	25	0.5	50	4.2
B9	1	0.02	8	0.16	9	0.18	19	0.38	13	0.26	50	3.7
B10	0	0.00	3	0.06	6	0.12	22	0.44	19	0.38	50	4.1
B15	3	0.06	14	0.28	16	0.32	11	0.22	6	0.12	50	3.1
B13	6	0.12	9	0.18	17	0.34	11	0.22	7	0.14	50	3.1
B14	7	0.14	12	0.24	16	0.32	10	0.20	5	0.1	50	2.9
R1	1	0.02	3	0.06	11	0.22	16	0.32	19	0.38	50	4
R4	1	0.02	2	0.04	9	0.18	13	0.26	25	0.5	50	4.2
R6	1	0.02	0	0.00	8	0.16	22	0.44	19	0.38	50	4.2
R9	1	0.02	3	0.06	7	0.14	23	0.46	16	0.32	50	4
R12	6	0.12	15	0.30	13	0.26	8	0.16	8	0.16	50	2.9
R14	0	0.00	4	0.08	9	0.18	15	0.30	22	0.44	50	4.1

Barrier B8 (high initial cost), with an average score of 4.2, stands out as the most significant according to the respondents' perception. This score suggests a strong consensus that this barrier has a critical impact on the urban environment, requiring priority attention. Similarly, barrier R4 (government-subsidized rates) also has an average score of 4.2, indicating it is perceived as an important barrier that needs to be addressed, as well as R6 (processing and permits), with an average score of 4.2. The same applies to B7 (ineffectiveness of regulations) and R14 (dissemination), both with an average score of 4.1. These barriers reflect a perception that there are significant issues in the implementation and operation of PV due to bureaucracy, ineffective regulation, and inadequate information.

Barriers B10 (lack of funding) and R9 (distribution and operation power grids), with average scores of 4.1, and R1 (government incentives), with a score of 4.0, are considered to be almost as significant. The high average scores for these barriers indicate that respondents agree they represent important obstacles in the urban context of Ecuador. Other barriers, such as B6 (lack of policies), B1 (lack of management of PV waste), B4 (lack of professional knowledge), and B9 (perceived long-term profitability), with average scores of 3.8 and 3.7, indicate that, while relevant, they are not considered as critical as those with higher scores, but still require attention.

Average scores of 3.4 for B5 (lack of social acceptance), and 3.1 for B15 (high costs for maintenance and replacement of PV components) and B13 (ineffectiveness of PV design), suggest these barriers are seen as moderately important. This implies that, while relevant, they are not considered as critical as those with higher scores. At the lower end of the spectrum are barriers B14 (low efficiency of solar panels) and R12 (technicians), both with an average score of 2.9. These barriers are perceived as less significant compared to others, but still represent challenges that need to be considered. The lowest average score indicates that, although a barrier, it is not seen as a major obstacle by the respondents.

3.3. Proposal for Reducing Identified Barriers

Table 7 presents a detailed analysis of the identified barriers and proposed improvements to promote the implementation of PV in Ecuador. The barriers include economic, regulatory, technical, and dissemination aspects, among others, that hinder the adoption of these systems in urban environments. To address these barriers, the proposals include tax incentives, direct subsidies, simplification of procedures, training for officials and technicians, modernization of distribution power grids, and long-term support policies. Together, these strategies aim to reduce the high initial cost, improve regulation and financing, and increase public awareness to create a more favorable environment for solar energy and accelerate the transition to a more sustainable energy matrix.

Table 7. Improvement proposals by an identified barrier.

Barriers	Improve Proposals
Higher initial costs (B8)	• Implement tax incentives such as deductions for the installation of PVs. • Offer direct subsidies that cover a significant portion of the initial cost.
Subsidized tariffs (R4)	• Gradually replace electricity subsidies with renewable energy incentives, such as tax credits and feed-in tariffs specifically for solar energy. • Implement campaign awareness on the benefits of PV energy and the need to transition to sustainable energy sources.
Processing and permits (R6)	• Create a one-stop system for obtaining permits and handling procedures related to the installation of PVs using online platforms to streamline the process. • Train officials and develop clear and uniform regulations to facilitate the installation of PVs.
Lack of effectiveness of regulations (B7)	• Involve all relevant stakeholders (government, private sector, academia, and civil society) in the development and review of regulations to ensure their effectiveness. • Implement educational campaigns and mass dissemination about the benefits of PVs through traditional and digital media. • Develop pilot programs and demonstrative projects in urban areas to show the feasibility and benefits of PVs.
Diffusion (R14)	• Implement educational and mass dissemination campaigns about the benefits of PVs through traditional and digital media. • Develop pilot programs and demonstrative projects in urban areas to showcase the feasibility and benefits of PVs.
Financial restrictions (B10)	• Create specific investment funds and grant programs to finance PV projects, in collaboration with national and international entities. • Offer tax incentives and guarantees to private investors to reduce associated risks and encourage investment in PVs.
Distribution and operation power grids (R9)	• Invest in the modernization of power grids to allow bidirectional energy flows, using advanced management and storage technologies. • Develop training programs for technical personnel responsible for operating electrical grids and ensuring the efficient integration of PVs.
Government incentives (R1)	• Introduce financial incentives such as tax credits, feed-in tariffs, and subsidies. • Develop long-term support policies to ensure the stability and continuity of government incentives.

The subsidized cost of electricity in Ecuador hinders the growth of urban PV systems. The average subsidized electricity price is around 0.04 USD/kWh, compared to the costs of PV technology, which can reach up to 0.12 USD/kWh. This suggests that for these technologies to be adopted by communities as a viable option, real market prices must be applied. However, implementing such reforms inevitably depends on political decisions that affect Ecuadorian society.

To promote solar PV systems in cities, urban planning must integrate energy considerations as a cross-cutting issue. This includes demand management through energy efficiency and the use of renewable energy sources. Targeted incentives and regulations encouraging new constructions to incorporate designs that include PV systems are recommended measures that could succeed at the local level. Incentives could also come from the financial sector, as green loans for small users might provide a solution for those without the initial capital. Still, this option must be accompanied by adjustments to final energy prices to ensure a return on investment.

Although Ecuador's solar resources are high compared to other regions with seasonal variability (capacity factors between 14% to 19%), the technology is not widely known. Its use and associated benefits should form part of a comprehensive energy efficiency plan, enabling the community to opt for this or other solutions that lower energy bills and reduce dependence on external energy sources. The productive sector must also participate in reducing the carbon footprint of products through the use of clean technologies. Not only should citizens choose products manufactured with clean energy, but governmental regulations must also require companies to follow guidelines that shift the local energy model toward sustainability.

As of this article's publication, three regulations have been enacted concerning the interconnection of PV systems to the grid. Although improvements have been made, especially regarding connection requirements, timelines and standards vary depending on local distributors. Understanding these standards by both users and regulators is essential for the design and implementation of these technologies. Unnecessary requirements or demands misaligned with the scale of small projects can hinder the deployment of these systems. Therefore, proper training and consistent application of standards are necessary.

To foster public trust, regulations should include standardization of the equipment used in projects. Poor-quality inverters or panels can tarnish the reputation of the technology. Universities in Ecuador, along with regulators, should promote the use of equipment tested locally. Likewise, qualified personnel who design, inspect, and approve projects can instill confidence among end-users. Electrical grids were originally designed for unidirectional power flow. So far, the limited adoption of distributed generation has had little impact on the distribution network, but this is due to its marginal incorporation. A significant increase in PV technology is expected to raise the thermal capacity of networks and increase voltage levels. To prevent issues, current policy limits generation based on its potential impact on the grid and neighboring users. Any scenario involving a substantial increase in PV generation and the adoption of new loads, such as electric vehicles, should be incorporated into the distributors' expansion plans. However, this must also be formulated as a mandatory national policy to address future challenges for the grid.

4. Discussion

According to the results obtained, it is observed that the eight barriers requiring the most attention are B8 (high initial cost), R4 (government-subsidized rates), R6 (processing and permits), B7 (lack of effectiveness of regulations), R14 (dissemination), B10 (lack of financing), R9 (distribution and operation power grids), and R1 (government incentives). The high initial cost of grid-connected PVs in urban environments remains a significant barrier to their adoption [24]. In the Philippines and Hong Kong, the initial cost is a considerable barrier, exacerbated by limited supporting infrastructure and high technology import costs. Singapore, with its high level of development and favorable government policies, faces a high initial cost, but this is partially offset by financial incentives and

support schemes [27]. In India, although the initial cost remains high, the drop in solar panel prices and government support through subsidies and feed-in tariffs have made the adoption of PVs more accessible [26].

Based on the research of various authors, the main challenge remains the significant initial investment in PVs, which must be balanced through support policies or by the long-term profitability of these systems. In Ecuador, the initial investment is also considerable; that is, the capital required for the purchase and installation of PVs in the country presents a similar challenge to that of other countries.

Barrier R4, related to subsidized tariffs, poses an obstacle to the implementation of PVs in urban environments as it distorts the energy market and disincentivizes the adoption of emerging technologies. By keeping electricity prices artificially low through subsidies, consumers do not perceive the economic need to invest in alternative solutions, such as solar energy, since potential savings do not justify the initial installation cost of these systems.

Moreover, subsidies hinder fair competition in the energy market, which can stifle innovation and the development of more sustainable infrastructures. To overcome this barrier, the government must reevaluate its subsidy policy and consider a gradual transition strategy toward a pricing model that reflects the true cost of electricity, thereby encouraging the adoption of renewable energy sources and contributing to long-term urban sustainability.

Barrier R6, which refers to the processing and permits necessary for the implementation of PVs in urban environments, represents a significant obstacle to their development. This issue is particularly relevant in private and academic sectors, as evidenced by the responses of respondents P.S. and X.C., as well as the company Airis. The complexity and time required to obtain the necessary permits disincentivize investment and slow down the adoption of PV technologies, especially in urban areas where regulations may be more restrictive and administrative procedures more complicated. The need to simplify and expedite these processes is crucial to fostering the transition toward more sustainable and accessible energy sources.

The lack of effectiveness of regulation (B7) presents itself as a significant barrier to the implementation of PVs in various urban environments around the world. In California, it has been shown that more efficient and less bureaucratic local permitting processes significantly increase the rate of residential solar installations, underscoring the need for clear and effective regulations [49]. Similarly, in Chile, regulatory barriers such as the lack of clear incentives and the complexity of regulations have hindered the growth in the residential prosumer segment; however, identifying these barriers has allowed for the development of opportunities to improve policies and encourage active consumer participation in solar energy generation [51].

In Sweden, the implementation of PVs in buildings has revealed that the lack of clear regulations (B7) and the need to adapt existing standards to emerging technologies are critical barriers, highlighting the importance of developing specific and updated regulations [34]. The situation is similar in the European Union, where regulatory barriers to the integration of PV and wind energy into the distribution grid are prominent due to the lack of harmonization between national policies and European regulations, complicating the adoption of PVs [36].

Similarly, other studies based on communities employing PVs have noted that the lack of clear support policies (B7) and regulatory complexity are significant barriers, underscoring the need for regulatory frameworks that facilitate community participation in renewable energy generation [41].

To mitigate these challenges, various specific strategies have been implemented that have proven to be effective in different contexts. In California, the permitting process has been simplified through the implementation of online platforms that streamline the review and approval of solar projects, significantly reducing the time and bureaucracy involved [49]. This measure has allowed PV installers to obtain permits more quickly and

efficiently, contributing to an increase in the adoption rate of residential solar technologies. In Chile, identifying regulatory barriers has led to the creation of pilot programs aimed at simplifying and clarifying existing regulations. These programs include the development of practical guides for consumers and prosumers, as well as training municipal and regional officials on the new regulations, thereby facilitating a more favorable environment for PV installation [51]. In Sweden, efforts have been made to adapt existing regulations to be more inclusive of emerging technologies. This includes updating building codes and creating specific standards for the integration of PVs in buildings, allowing developers and builders to follow clear and standardized procedures for the installation of PVs. These strategies can prove effective by providing a clearer and more accessible regulatory framework, reducing the complexity of barriers and facilitating the adoption of PVs in urban environments.

Barrier R14, related to dissemination, refers to the limited outreach and awareness about the benefits and possibilities of PV generation systems in urban environments. The lack of adequate and accessible information can lead to ignorance or distrust among potential users and decision-makers. This, in turn, hinders the adoption and growth of this technology in urban areas. The situation is worsened by the absence of effective educational campaigns and the lack of visible and successful implementation examples that can serve as references. This barrier is particularly relevant in the context of respondents from the private sector, as three out of five respondents identified it, underscoring the need for more robust and targeted dissemination strategies to promote PV energy in cities.

The lack of financing presents itself as a significant barrier to the implementation of PVs in various urban environments around the world. This issue manifests in different ways across regions, negatively influencing the adoption of solar technologies due to the high initial investment and lack of access to suitable financing sources.

In Brazil and Latvia, the lack of financial incentives (B10) has been identified as a key barrier to the dissemination of grid-connected PVs in urban environments [41,45]. The analysis of PV green roofs in cities like New York and Hong Kong highlights that, although these systems offer multiple benefits, they face significant limitations due to high initial costs (B8) and installation complexity [43].

To mitigate these challenges, various specific strategies have been implemented that have proven effective in different contexts. In Brazil, government programs providing financial support and the creation of collaboration networks among different stakeholders in the sector have facilitated access to the necessary financing [45]. In Latvia, the creation of financial frameworks and the simplification of regulatory procedures have improved access to financing for consumers and prosumers. In PV green roof projects in cities like New York and Hong Kong, the creation of policies that facilitate access to financial resources and the implementation of specific incentives have been essential to overcome current limitations [43]. Finally, in Poland, the flexibility and integration capacity of PVs have been supported by specific programs aimed at facilitating the necessary financing [39].

These strategies have proven effective by providing a clearer and more accessible financial framework, reducing economic barriers and facilitating the adoption of PVs in urban environments.

Barrier R9, related to the distribution and operation of power grids, represents a significant challenge for the implementation of PVs in urban settings. This obstacle primarily manifests in the integration and adaptation of existing infrastructure to manage the grid distribution of solar energy. Traditional distribution power grids are not designed to handle bidirectional energy flows, which can lead to stability and efficiency problems in the operation of the electrical system.

Furthermore, upgrading these power grids requires substantial investments in technology and equipment, as well as training technical personnel to ensure proper operation. Public sector actors recognize this barrier and emphasize the need for policies and regulations that facilitate the modernization of distribution power grids, promoting a favorable environment for the integration of PV energy and ensuring an efficient and sustainable energy transition in urban areas.

Barrier R1, referring to the lack of government incentives, is a critical obstacle to the implementation of PVs in urban environments. The absence of adequate incentives can disincentivize both individuals and businesses from investing in PV technology due to the high initial costs associated with installation. This is reflected in the responses from respondents, where several from both the academic and private sectors acknowledge this barrier. In urban environments, where space costs and competition for land use are high, the lack of government support can significantly limit the deployment of these sustainable technologies. Government incentives, such as subsidies, tax credits, and feed-in tariffs, are essential to reduce the payback period and make investment in PV more attractive and viable in the long term.

5. Conclusions

Specialists in the field identified several recurrent barriers that significantly hinder the adoption and expansion of PV systems in urban environments in Ecuador. These barriers include high initial costs, government-subsidized fuel tariffs, complex administrative procedures and permitting, ineffective regulations, challenges in information dissemination, lack of financing, distribution and operation limitations of power grids, and insufficient governmental incentives.

Surveys conducted with professionals in the sector revealed a widespread perception that the primary barriers are economic and regulatory. The results of Cronbach's analysis indicated a high level of internal consistency ($\alpha > 0.8$) among respondents, suggesting the reliability of their opinions. Furthermore, the mean scores from the survey underscored that professionals particularly emphasized barriers with mean scores of 4.0 or higher as critical priorities for addressing.

To promote the adoption of grid-connected PV systems in Ecuadorian urban areas, fiscal incentives are essential. Ecuador has historically allocated more public expenditure toward fuel and energy subsidies than health and education, with USD 34,458 million spent on fossil fuel subsidies between 2010 and 2019. A redirection of these subsidies, combined with tax credits to reduce high initial costs for PV systems, could help shift the energy landscape while creating local jobs. Phasing out electricity subsidies in favor of renewable energy incentives, along with awareness campaigns, would further support this transition.

Streamlining administrative procedures by implementing a one-stop system, coupled with the training of officials and engagement of relevant stakeholders in developing effective regulations, is also crucial. Additionally, the dissemination of PV through public education campaigns, demonstration programs, the establishment of investment funds, and offering tax incentives to private investors could help overcome the financing gap. Modernizing the distribution grids and training technical personnel to manage bidirectional energy flows are key steps toward integrating distributed PV systems into the existing energy infrastructure.

Financial incentives and long-term support policies are necessary to sustain momentum and address current barriers. Countries such as Germany and Spain, which implemented substantial subsidies in the early development of distributed PV systems, demonstrate the success of such approaches. Globally, the proportion of distributed PV systems is expected to grow significantly between 2023 and 2028, with distributed PVs already accounting for half of utility-scale PV installations over the past decade.

In Ecuador, where high population density, rich biodiversity, and limited land for PV farms pose challenges, alternative solutions such as agrovoltaics present a promising option. This approach could enhance both energy production and agricultural productivity, but current restrictions on private investment in the power sector hinder its development. Future research should focus on assessing the feasibility of agrovoltaics and reforming local regulations to allow for private sector participation.

Finally, further studies are required to explore the technical grid limitations, as well as the economic and societal acceptance of PV technologies, given their low current pene-

tration in Ecuador. Addressing these challenges will be crucial to advancing the country's renewable energy agenda.

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References

1. Ministerio de Energía y Minas. Balance Energético Nacional 2021. Available online: https://www.recursoyenergia.gob.ec/wp-content/uploads/2022/08/Balance_Energe%CC%81tico_Nacional_2021-VF_opt.pdf (accessed on 6 July 2024).
2. Ministerio de Energía y Minas del Ecuador. El Domingo 28 de Abril no Habrá Cortes de Energía en todo el Ecuador—Ministerio de Energía y Minas. Available online: <https://www.recursoyenergia.gob.ec/el-domingo-28-de-abril-no-habra-cortes-de-energia-en-todo-el-ecuador/> (accessed on 9 October 2024).
3. Ministerio de Energía y Recursos Naturales No Renovables. Plan Maestro de Electricidad—Corporación Eléctrica del Ecuador. Available online: <https://www.celec.gob.ec/plan-maestro-de-electricidad/> (accessed on 9 October 2024).
4. International Energy Agency. Renewables 2024. Analysis and Forecast to 2030. 2024. Available online: www.iea.org (accessed on 13 October 2024).
5. Yajamín, G.S.I.; Carrión, D.F.C.; Gualán, D.F.V.; Zurita, R.C.B.; Carrion, H.D.C. Evaluación de la actualidad de los sistemas fotovoltaicos en Ecuador: Avances, desafíos y perspectivas. *Cienc. Lat. Rev. Científica Multidiscip.* **2023**, *7*, 9493–9509. [CrossRef]
6. Agencia de Regulación y Control de Energía y Recursos Naturales No Renovables. Panorama eléctrico 2024. Available online: <https://controlrecursoyenergia.gob.ec/wp-content/uploads/downloads/2024/03/PanoramaElectricoXXI-Marzo-Baja.pdf> (accessed on 6 July 2024).
7. Global Solar Atlas. Mapa Solar Global. 2024. Available online: <https://globalsolaratlas.info/map?c=11.523088,8.173828,3> (accessed on 6 July 2024).
8. Zalamea-León, E.; Mena-Campos, J.; Barragán-Escandón, A.; Parra-González, D.; Méndez-Santos, P. Urban Photovoltaic Potential of Inclined Roofing for Buildings in Heritage Centers in Equatorial Areas. *J. Green Build.* **2018**, *13*, 45–69. [CrossRef]
9. Lino Toala, E.J. Análisis del Potencial Energético Solar Para el Sistema de Bombeo de Agua Para la Comuna Joa. March 2024. Available online: <https://repositorio.unesum.edu.ec/bitstream/53000/6186/1/LINO%20TOALA%20ELVIS%20JEFFERSON.pdf> (accessed on 9 October 2024).
10. Naciones Unidas Ecuador. Sustainable Development Goal 7: Energía Asequible y no Contaminante | Naciones Unidas en Ecuador. Available online: <https://ecuador.un.org/es/sdgs/7> (accessed on 9 October 2024).
11. Barragán-Escandón, E.A.; Zalamea-León, E.F.; Terrados-Cepeda, J.; Vanegas-Peralta, P. Energy self-supply estimation in intermediate cities. *Renew. Sustain. Energy Rev.* **2020**, *129*, 109913. [CrossRef]
12. Tapia, M.; Ramos, L.; Heinemann, D.; Zondervans, E. Evaluación del Potencial Fotovoltaico en Tejados en el Cantón Quito. *Perfiles* **2023**, *1*, 47–56. [CrossRef]
13. Zalamea-León, E.; Mena-campos, J.; Moscoso-Cordero, S.; Barragán-escandón, A.; Mendez-Santos, P. Perspectivas de cubiertas fotovoltaicas y arquitectura en contextos urbanos patrimoniales. *Archit. City Environ.* **2018**, *13*, 301–324. [CrossRef]
14. Zambrano-Asanza, S.; Zalamea-León, E.F.; Barragán-Escandón, E.A.; Parra-González, A. Urban photovoltaic potential estimation based on architectural conditions, production-demand matching, storage and the incorporation of new eco-efficient loads. *Renew. Energy* **2019**, *142*, 224–238. [CrossRef]

15. Spiru, P. Assessment of renewable energy generated by a hybrid system based on wind, hydro, solar, and biomass sources for decarbonizing the energy sector and achieving a sustainable energy transition. *Energy Rep.* **2023**, *9*, 167–174. [CrossRef]
16. Reinoso Recalde, G.P. Obstáculos a la Transición Energética en Ecuador: El Caso de la Generación Eléctrica a Partir de Fuentes Fotovoltaicas. 2023. Available online: <https://repositorio.uasb.edu.ec/bitstream/10644/9311/1/T4076-MCCSD-Reinoso-Obstaculos.pdf> (accessed on 9 October 2024).
17. Razmjoo, A.; Ghazanfari, A.; Østergaard, P.A.; Abedi, S. Design and Analysis of Grid-Connected Solar Photovoltaic Systems for Sustainable Development of Remote Areas. *Energies* **2023**, *16*, 3181. [CrossRef]
18. Icaza-Alvarez, D.; Jurado, F.; Flores, C.; Ortiz, G.R. Ecuadorian electrical system: Current status, renewable energy and projections. *Heliyon* **2023**, *9*, e16010. [CrossRef]
19. Ley Orgánica de Eficiencia Energética, Suplemento Oficial Año II—Nº 449. 2019. Available online: https://www.recursosyenergia.gob.ec/wp-content/uploads/2022/12/20190319-S_R_O_449_19_MARZO_LEY-ORGANICA-DE-EFICIENCIA-ENERGETICA.pdf, (accessed on 9 October 2024).
20. Barragan Escandon, E.A.; Espinoza Abad, J.L. Políticas para la Promoción de las Energías Renovables en el Ecuador. In *Energías Renovables en el Ecuador: Situación Actual, Tendencias y Perspectivas*; Universidad De Cuenca: Cuenca, Ecuador, 2015; pp. 1–28.
21. Barragán-Escandón, A.; Jara-Nieves, D.; Romero-Fajardo, I.; Zalamea-Leon, E.F.; Serrano-Guerrero, X. Barriers to renewable energy expansion: Ecuador as a case study. *Energy Strategy Rev.* **2022**, *43*, 100903. [CrossRef]
22. Putrus, G.A.; Bentley, E.; Binns, R.; Jiang, T.; Johnston, D. Smart grids: Energising the future. *Int. J. Environ. Stud.* **2013**, *70*, 691–701. [CrossRef]
23. Rodríguez-Segura, F.J.; Osorio-Aravena, J.C.; Frolova, M.; Terrados-Cepeda, J.; Muñoz-Cerón, E. Social acceptance of renewable energy development in southern Spain: Exploring tendencies, locations, criteria and situations. *Energy Policy* **2022**, *173*, 113356. [CrossRef]
24. Marzouk, M.A.; Salheen, M.A.; Fischer, L.K. Functionalizing building envelopes for greening and solar energy: Between theory and the practice in Egypt. *Front. Environ. Sci.* **2022**, *10*, 1056382. [CrossRef]
25. Bunda, N.; Sunio, V.; Palmero, S.S.; Tabañag, I.D.F.; Reyes, D.J.; Ligot, E. Stage model of the process of solar photovoltaic adoption by residential households in the Philippines. *Clean. Responsible Consum.* **2023**, *9*, 100114. [CrossRef]
26. Padmanathan, K.; Govindarajan, U.; Ramachandaramurthy, V.K.; Rajagopalan, A.; Pachaivannan, N.; Sowmmiya, U.; Padmanaban, S.; Holm-Nielsen, J.B.; Xavier, S.; Periasamy, S.K. A sociocultural study on solar photovoltaic energy system in India: Stratification and policy implication. *J. Clean. Prod.* **2019**, *216*, 461–481. [CrossRef]
27. Lu, Y.; Chang, R.; Shabunko, V.; Yee, A.T.L. The implementation of building-integrated photovoltaics in Singapore: Drivers versus barriers. *Energy* **2019**, *168*, 400–408. [CrossRef]
28. Nwokocha, C.O.; Okoro, U.K.; Usuh, C.I. Photovoltaics in Nigeria—Awareness, attitude and expected benefit based on a qualitative survey across regions. *Renew. Energy* **2018**, *116*, 176–182. [CrossRef]
29. Eleftheriadis, I.M.; Anagnostopoulou, E.G. Identifying barriers in the diffusion of renewable energy sources. *Energy Policy* **2015**, *80*, 153–164. [CrossRef]
30. Malkewitz, C.P.; Schwall, P.; Meesters, C.; Hardt, J. Estimating reliability: A comparison of Cronbach’s α , McDonald’s ω and the greatest lower bound. *Soc. Sci. Humanit. Open* **2023**, *7*, 100368. [CrossRef]
31. Ahmed, T.Z.; Mohamed, A.; Ahmed, M.E.; Abdalgader, A.O.E.; Hassan-Sayed, M.G. Investigating energy policies to boost grid-connected rooftop solar PV in Sudan. *Clean Energy* **2023**, *7*, 994–1005. [CrossRef]
32. Rathore, N.; Panwar, N.L. Strategic overview of management of future solar photovoltaic panel waste generation in the Indian context. *Waste Manag. Res. J. A Sustain. Circ. Econ.* **2022**, *40*, 504–518. [CrossRef]
33. Adhikari, R.S.; Aste, N.; Del Pero, C.; Leonforte, F.; Sfolcini, F.; Diab, K. Photovoltaics in Circular Economy: Future PV Waste Projections for Different Scenarios. In Proceedings of the 2023 International Conference on Clean Electrical Power (ICCEP), Terrasini, Italy, 27–29 June 2023; pp. 903–910.
34. Winkler, C. Implementing solar photovoltaic systems in buildings: A case of systemic innovation in the construction sector. *Constr. Innov.* **2023**, *24*, 102–123. [CrossRef]
35. Sharmeela, C.; Sanjeevikumar, P.; Sivaraman, P.; Joseph, M. *IoT, Machine Learning and Blockchain Technologies for Renewable Energy and Modern Hybrid Power Systems*; CRC Press: Boca Raton, FL, USA, 2023; pp. 121–148. [CrossRef]
36. Bartoszewicz-Burczy, H. Barriers for Large Integration of PV and Onshore Wind Energy in the Distribution Network on the Selected European Union Electricity Markets. *Stud. Ecol. Bioethicae* **2022**, *20*, 66–77. [CrossRef]
37. Guzman, L.; Henao, A. Are the current incentives sufficient to drive the use of solar PV in the Colombian residential sector?—An analysis from the perspective of the game theory. *Energy Strat. Rev.* **2022**, *40*, 100816. [CrossRef]
38. Braeuer, F.; Kleinebrahm, M.; Naber, E.; Scheller, F.; McKenna, R. Optimal system design for energy communities in multi-family buildings: The case of the German Tenant Electricity Law. *Appl. Energy* **2021**, *305*, 117884. [CrossRef]
39. Sysko-Romańczuk, S.; Kluj, G.; Hawrysz, L.; Rokicki, Ł.; Robak, S. Scalable Microgrid Process Model: The Results of an Off-Grid Household Experiment. *Energies* **2021**, *14*, 7139. [CrossRef]
40. Islami, M.S.; Urmee, T.; Kumara, I.N.S. Developing a framework to increase solar photovoltaic microgrid penetration in the tropical region: A case study in Indonesia. *Sustain. Energy Technol. Assess.* **2021**, *47*, 101311. [CrossRef]
41. Lazdins, R.; Mutule, A.; Zalostiba, D. PV Energy Communities—Challenges and Barriers from a Consumer Perspective: A Literature Review. *Energies* **2021**, *14*, 4873. [CrossRef]

42. Maghrabie, H.M.; Elsaid, K.; Sayed, E.T.; Abdelkareem, M.A.; Wilberforce, T.; Olabi, A. Building-integrated photovoltaic/thermal (BIPVT) systems: Applications and challenges. *Sustain. Energy Technol. Assess.* **2021**, *45*, 101151. [\[CrossRef\]](#)
43. Shafique, M.; Luo, X.; Zuo, J. Photovoltaic-green roofs: A review of benefits, limitations, and trends. *Sol. Energy* **2020**, *202*, 485–497. [\[CrossRef\]](#)
44. Elbeheiry, N.; Amer, A.; Elgazar, S.; Shukri, S.; Metry, M.; Balog, R.S. Techno-Economic Evaluation of Residential PV Systems in Oil/Gas-Rich Economies: A Case Study of Qatar & Texas. In Proceedings of the 2020 2nd International Conference on Photovoltaic Science and Technologies (PVCon), Ankara, Turkey, 30 November–2 December 2020.
45. Garlet, T.B.; Ribeiro, J.L.D.; Savian, F.d.S.; Siluk, J.C.M. Paths and barriers to the diffusion of distributed generation of photovoltaic energy in southern Brazil. *Renew. Sustain. Energy Rev.* **2019**, *111*, 157–169. [\[CrossRef\]](#)
46. Mateus, R.; Silva, S.M.; de Almeida, M.G. Environmental and cost life cycle analysis of the impact of using solar systems in energy renovation of Southern European single-family buildings. *Renew. Energy* **2019**, *137*, 82–92. [\[CrossRef\]](#)
47. Afxentis, S.; Chatzigeorgiou, N.; Efthymiou, V.; Papageorgiou, I.; Armenakis, A.; Papagiannis, G.; Christoforidis, G.; Sancho, J.; Rodrigues, H.; Casimiro, C.; et al. Technical Assessment of Coupled PV and Battery Systems—A Case Study from the Mediterranean Region. In Proceedings of the 2019 1st International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED), Cagliari, Italy, 28–30 May 2019.
48. Eales, A.; Alsop, A.; Frame, D.; Strachan, S.; Galloway, S. Assessing the Market for Solar Photovoltaic (PV) Microgrids in Malawi. *Hapres J. Sustain. Res.* **2020**, *2*, e200008. [\[CrossRef\]](#)
49. White, L.V. Increasing residential solar installations in California: Have local permitting processes historically driven differences between cities? *Energy Policy* **2019**, *124*, 46–53. [\[CrossRef\]](#)
50. Sarker, T.; Haram, M.H.S.M.; Ramasamy, G.; Al Farid, F.; Mansor, S. Solar Photovoltaic Home Systems in Malaysia: A Comprehensive Review and Analysis. *Energies* **2023**, *16*, 7718. [\[CrossRef\]](#)
51. Osorio-Aravena, J.C.; de la Casa, J.; Töfflinger, J.A.; Muñoz-Cerón, E. Identifying barriers and opportunities in the deployment of the residential photovoltaic prosumer segment in Chile. *Sustain. Cities Soc.* **2021**, *69*, 102824. [\[CrossRef\]](#)
52. dos Santos, L.; Iano, Y.; Loschi, H.; Nascimento, D.; Razmjoo, N.; Chuma, E.; Bertolassi, C. EMC Issues in Grid-Connected Photovoltaic Systems: The Brazilian Regulatory and Standardization Scenario. *Smart Innov. Syst. Technol.* **2021**, *233*, 687–694. [\[CrossRef\]](#)
53. D’Adamo, I.; Gastaldi, M.; Morone, P.; Ozturk, I. Economics and policy implications of residential photovoltaic systems in Italy’s developed market. *Util. Policy* **2022**, *79*, 101437. [\[CrossRef\]](#)
54. Lopez, L. Removing Fuel Subsidies without Political Backlash: An Alternative to the Present Approach in Ecuador. *The Bulletin, A Blog by the Brandt School for Public Policy*, Erfurt, 13 May 2022. Available online: <https://thebulletin.brandtschool.de/removing-fuel-subsidies-without-political-backlash-an-alternative-to-the-present-approach-in-ecuador> (accessed on 6 July 2024).

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