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Environmental and social impact of solar farms: Insights and perspectives from solar professionals

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Abstract

Solar energy professionals, with their knowledge of ground realities regarding project impacts and deep understanding of economic and policy challenges, are uniquely positioned to provide insights into the opportunities and barriers facing the solar industry. The current study surveys 81 solar energy professionals using a structured online survey questionnaire. The survey included questions about 40 different data points in four major areas, i.e., environmental, social, economic, and policy. Environmental concerns were further classified into short- and long-term categories. Analysis of the survey data revealed several major issues in all areas. For example, responses to environmental impact-related questions indicated that impact on biodiversity, land use, and improper solid waste management were major concerns in the short-term implementation of the project. Among long-term environmental concerns, life-cycle assessment and the disposal of solar panels at the end of life could represent major environmental concerns. For social concerns, the safety of onsite workers, awareness of solar energy, and compliance with environmental impact assessment studies and management plans were the major concerns. The economic concerns to be addressed included the high cost of investment, long payback period, and difficulty of regulatory procedures. Policy-related concerns included the support from local government, research and development needs, and the stability of government policies. All these identified areas are areas where major improvements are envisaged in the future. Overall, such types of studies help in understanding industry requirements in the day and aid planning, strategizing, and policymaking in various areas for holistic, sustainable development.

Keywords: Solar energy; Solar professionals; Environmental impacts; Social impacts; Solar energy projects

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1. Introduction

The rapid increase in global energy consumption and greenhouse gas (GHG) emissions is a challenge to limiting global warming below the 1.5°C threshold.[1] Consequently, low-GHG emission solutions, such as solar energy, have emerged as some of the most promising options due to their scalability, decreasing costs, and abundant availability of solar radiation.[2] The development of solar energy has been robust in recent years, with solar capacity expanding 20 times compared to the last decade.[3] This is reflected in the policies worldwide, including India's emphasis on allocating a maximum of 100 GW out of 175 GW to solar energy, underscoring its role in the clean energy transition.

Despite its promise, solar energy adoption brings numerous challenges that are beyond technological feasibility. The challenges can be classified into environmental, social, policy, and economic dimensions. Environmental challenges include land-use conflicts, particularly in densely populated locations.[4,5] Policy issues include the design of effective net metering systems.[6] From a social perspective, the unequal distribution of solar energy adoption in a geographical area is one of the key challenges.[7,8] Economic constraints include the need for optimizing resource utilization at various stages of the solar project life-cycle.[9] While all these difficulties are being addressed, it is equally critical to encourage a fair transition to solar energy—one that ensures social and economic equity in access and benefits.[10]

Despite growing scholarly interest in solar energy, the current research remains fragmented. Instead of acknowledging the interdependence of these elements, most studies analyze the obstacles to solar deployment separately, focusing only on the environmental impacts,[11] the economic viability, or regulatory frameworks.[12] In addition, numerous studies rely primarily on techno-economic modeling or secondary data sources, with limited input from experts working in the subject.[6,13,14] The lack of practitioner viewpoints causes a disconnect between the theoretical knowledge of solar deployment and the actual conditions encountered during project execution. Furthermore, the lack of comparative assessments between national and international perspectives remains, and it raises questions regarding which problems are context-specific and which are universal.[15-17]

This study aims to address these gaps by capturing the experiences and perspectives of 81 solar energy professionals with diverse roles across multiple regions worldwide. The study contributes ground-level expertise that enhances scholarly and policy-based discourse by directly referencing practitioner ideas. Crucially, rather than examining environmental, social, policy, and economic aspects independently, the research takes a comprehensive approach that incorporates all of them. Furthermore, by contrasting national and international professional perspectives, this study reveals context-dependent variations as well as common challenges, providing valuable insight that can help investors, policymakers, and local stakeholders support an equitable and effective solar energy transition. This study seeks to answer the following research questions:

(i) How do solar energy professionals perceive the environmental, social, policy, and economic impacts of solar projects?
(ii) In what ways do the perspectives of national professionals differ from those of international professionals, and what challenges or benefits are universally recognized?
(iii) How do solar energy professionals assess the short-term versus long-term environmental impacts of solar energy deployment?
(iv) The objective of this study was:
(v) To assess how experts in solar energy view the economic, social, political, and environmental effects of solar energy projects.
(vi) To uncover context-specific difficulties and globally shared concerns by comparing the viewpoints of national and international professionals.
(vii) To gauge experts' opinions regarding the immediate and long-term environmental effects of solar energy implementation.

2. Methodology

The current study assesses the impacts and barriers associated with solar energy projects by surveying 81 solar energy professionals globally. Respondents were selected using a purposive sampling approach, targeting individuals with proven professional experience in solar projects. The survey was distributed using Google Forms, in the form of multiple-choice questions. The survey was distributed through professional networking platforms, such as LinkedIn. The survey was carried out from April 2022 to March 2023.

The survey covered 40 data points across major categories, including environmental, social, economic, and policy. The environmental section was further divided into two categories: short-term environmental impacts on various factors, such as air, water, noise, and others, as well as long-term environmental impacts, including life-cycle emissions and disposal of solar panels.

The use of a practitioner survey has several advantages: it allows for the rapid collection of first-hand insights from different regions and contexts, as well as access to on-the-ground experience that is frequently lacking in secondary

analyses or solely academic perspectives. However, this method has inherent limitations: the reliance on voluntary participation may introduce self-selection bias, and the sample size, while geographically diverse, is not statistically representative of all professionals worldwide. The online distribution limits participation to individuals who use digital media, potentially under-representing specific regions or professional groups.

The survey predominantly comprised multiple-choice questions to maintain uniformity and facilitate analysis while still covering a broad range of topics. The rationale for this methodological approach is to obtain diverse, comparative perceptions on a standardized set of impact categories, allowing for both descriptive and comparative analysis in accordance with the study's multidimensional objectives.

Figure 1 illustrates the methodology adopted for this study, while Table 1 presents the various data points included in the survey.

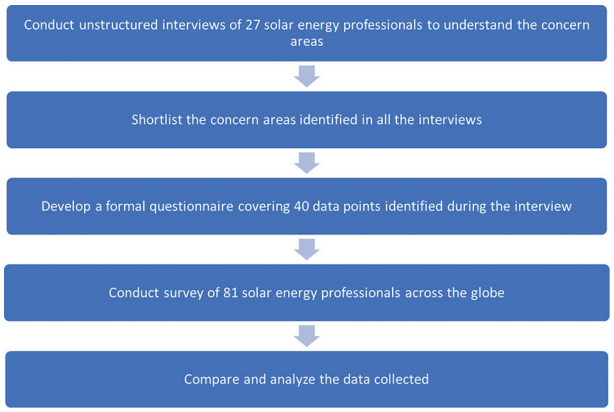


Figure 1. The methodology of this study

Table 1. Data points captured across categories for the study

Categories	Data points
Environmental	
Short-term	Air pollution, water withdrawal, discharge of wastewater into nearby water bodies, biodiversity, noise pollution, soil contamination, land use, and improper solid waste management
Long-term	Emissions during production and transportation, disposal of solar panels, change in land use, impact on water resources, change of local microclimate, and damage to biodiversity
Social	Cultural heritage, employment opportunities for the locals, issues with migrant workers, negative outlook of local communities, visual aesthetic, public disagreement due to loss of other income, increased traffic, improper waste management, occupational safety, resettlement and rehabilitation, lack of awareness, EIA/EMP available, and EMP followed
Economic	High tariff rate per kWh, T&D losses, increased investment cost and long ROI, high-risk investment, insufficient facilities to increase the number of investors in solar energy, and unpredictability of nature
Policy	Tedious regulatory procedures, regulations of local government, the necessity of numerous research and innovations, instability of the supply chain, unavailability of local manufacturers/suppliers/vendors for solar panels, the requirement of a stable government policy, and energy storage and distribution

Abbreviations: EIA: Environmental impact assessment; EMP: Environmental management plan; ROI: Return on investment; T&D: Transmission and distribution.

3. Results

3.1. Demographics of surveyed solar energy professionals

The surveyed professionals came from various countries worldwide. The majority of respondents (47%) were from India, with another 17% from Asian countries other than India, 17% from African countries, and 11% from North American countries. The remaining 8% were from Europe, Australia, and South American regions. In terms of gender, 10% of the respondents were females and 90% were males. The average age of the respondents was 34 years, with an average experience of 6 years in the solar industry. The minimum years of experience was 1 year, and the maximum was 17 years. The types of experiences held by professionals in the solar industry are shown in Figure 2, with the majority of respondents having experience as a project manager or engineering, procurement, and construction contractor.

3.2. Survey results

3.2.1. Short-term environmental impact

The analyses of the environmental impact survey emphasize a few important points. First, the majority of respondents believe that the activity under evaluation has little effect on air pollution. This suggests that the activity is not seen to have a significant detrimental impact on air quality by individuals polled.

Second, the majority of respondents consider the influence on water withdrawal to be low to medium. This implies that respondents are aware of a moderate, rather than an overly high, impact on water supplies. Even if some water withdrawal may exist, it is believed to be within reasonable limits.

The majority of respondents think that the evaluated activity has a low to medium impact on biodiversity. This suggests that the local environment has been disturbed or altered to some extent. It might still be required to make efforts to mitigate potential effects and ensure biodiversity preservation.

It is interesting to note that responses from national and international respondents perceive the influence of noise differently. International respondents often rate the activity with medium to high noise effect, indicating that they believe the activity significantly elevates noise pollution. However, respondents from India believe that the impact is little, which may be because they are less aware of the risks associated with noise.

Moreover, many respondents hold the belief that the evaluated activity has a medium to high influence on land use. This implies that the project or activity is thought to have a sizable land footprint, which could lead to the relocation or modification of natural ecosystems or habitats.

Finally, respondents from different countries have different perspectives about how the impact will affect solid waste management. There is potential for improvement as national respondents give the impact a low to medium rating. However, respondents from other countries deemed the impact as little, indicating that they already think proper solid waste management procedures are in place.

Overall, as Figure 3 illustrates, the survey results provide insightful information on the perceived environmental effects of the evaluated activity, showing the diverse viewpoints of the various respondent groups and illuminating potential areas for improvement. Despite this, there is currently little concern over how solar installations could impact the environment. Future regulations on the effective distribution of land use for solar projects might be in the works. In addition, strict regulations may be implemented in India to lessen the effects of wastewater discharge and solid waste management at project sites. At present, the majority of projects include a biodiversity assessment study. In the future, all projects may be mandated to conduct these assessments.

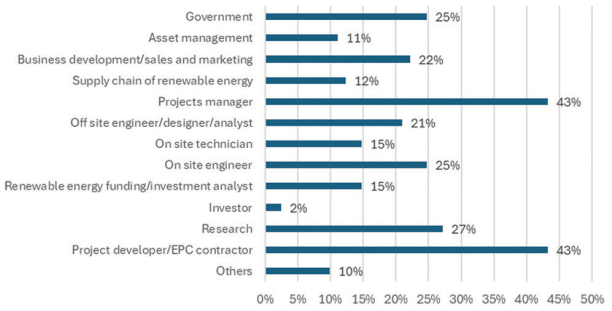


Figure 2. Types of experience held by respondents in the solar industry
Abbreviation: EPC: Engineering, procurement, and construction.

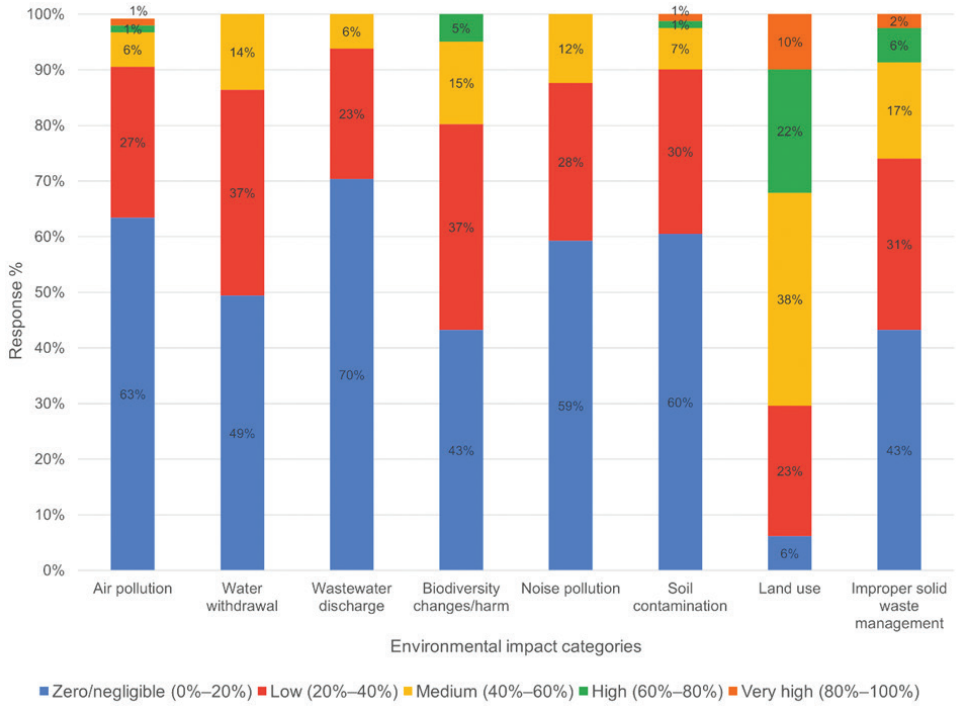
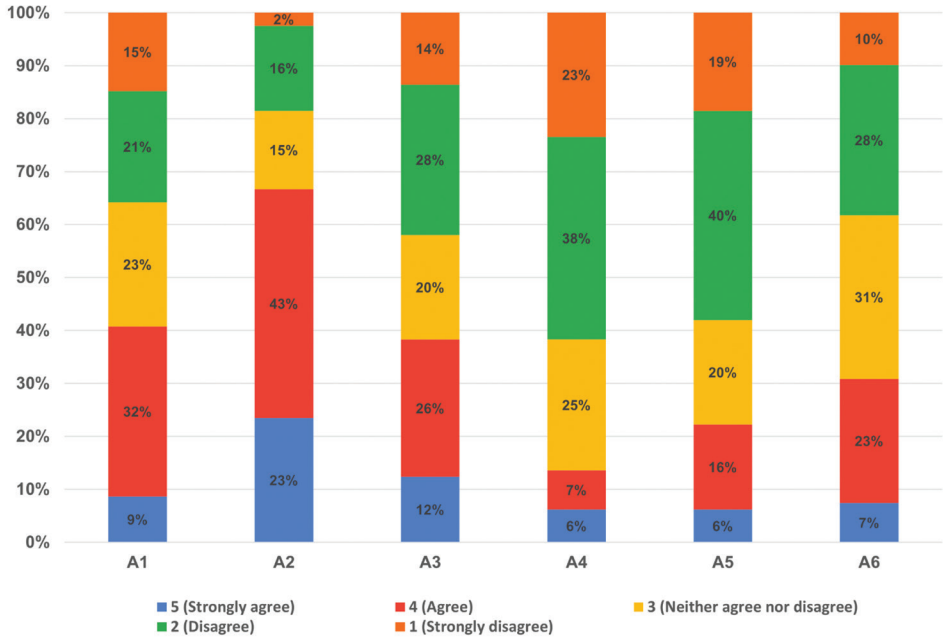


Figure 3. Responses to short-term environmental impacts of the implementation of solar energy



A1	Emissions during production and transportation of solar panels is not considered when speaking of environmental benefits
A2	Disposal of solar panels during end of life could result in major issue
A3	Agricultural land and other useful land parcels being replaced by solar projects
A4	High water requirement of solar projects could strain the nearby water resources
A5	Increases the temperature of the surrounding areas resulting in change of local microclimate
A6	Biodiversity is being harmed especially in case of floating solar projects

Figure 4. Responses to long-term environmental impacts of implementing solar energy

3.2.2. Long-term environmental impact

The long-term environmental survey results reveal several noteworthy findings, as shown in Figure 4. First, many respondents, both national and international, agreed that the consideration of life-cycle assessment (LCA) emissions in the context of solar installations is inadequate. However, international respondents express a higher level of disagreement, suggesting that they perceive a greater lack of consideration for LCA emissions compared to their national counterparts. Second, most respondents, irrespective of their nationality, agree that the disposal of solar panels will pose a significant issue in the future. This indicates a shared concern regarding the environmental challenges associated with managing the end-of-life of solar panels.

Furthermore, national respondents express a predominant agreement that the replacement of agricultural land by solar installations poses a major threat. In contrast, international respondents exhibit a higher level of disagreement on this issue, implying that they may perceive the threat to agricultural land as of lesser concern. Overall, 42% of respondents disagree with this concern, and 38% agree that it is a major concern.

Another point of contention lies in the impact of solar projects on local water resources. Overall, 61% of respondents do not think it is a major concern. National respondents adopt a neutral stance on the strain exerted on local water resources due to the water requirements of the project, while international respondents tend to disagree, suggesting that water availability is not a major issue in those areas.

In terms of the local microclimate, the survey indicates an overall disagreement (59%) among respondents regarding any potential changes resulting from the solar project. However, the survey does not provide specific information on whether this disagreement is primarily among national or international respondents. Finally, there is disagreement among respondents (38%), particularly international ones, concerning the potential harm to biodiversity caused by the solar project. In contrast, national respondents exhibit a neutral stance on this matter.

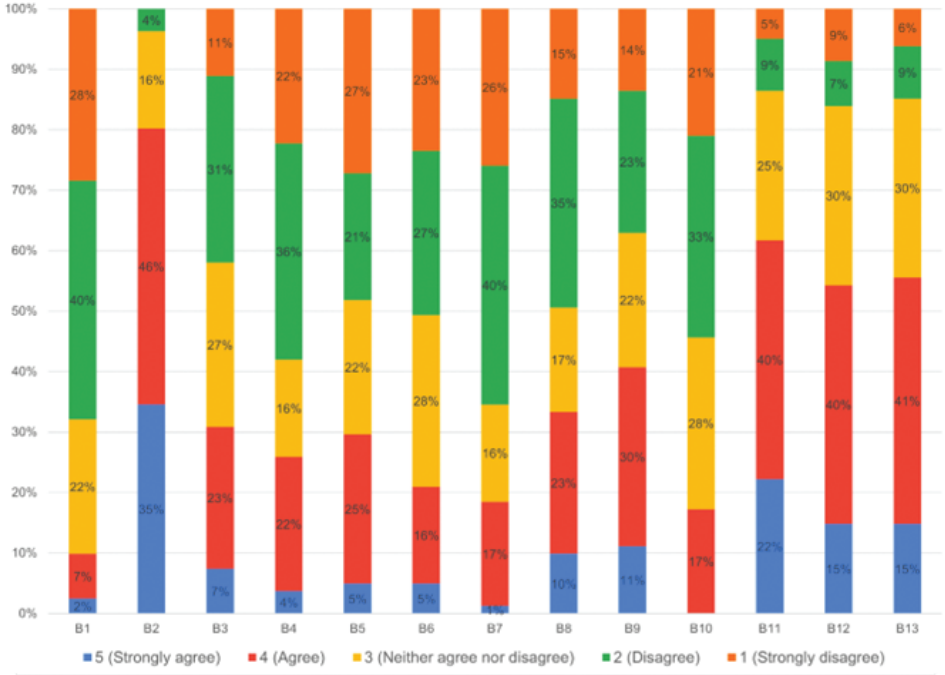
These findings highlight the varying perspectives and concerns surrounding the environmental impacts of solar installations, both within and between different respondent groups.

3.2.3. Social impact

The results of the social impact survey (Figure 5) provide insight into several characteristics of the project or activity that were evaluated, especially in relation to its social repercussions. First, a greater degree of disagreement is expressed by foreign respondents regarding issues between migrant workers and locals than by Indian respondents. Given that respondents from abroad expressed a higher degree of disagreement, this indicates that the impact of the issue between migrant workers and locals is negligible.

Second, regarding the negative view of the project by the local communities, national respondents appear to be unbiased, suggesting that they have differing opinions about how the project will affect their areas. Conversely, international respondents disagree with this data point, indicating that they have fewer concerns about the impact of solar projects on nearby populations.

National respondents report neutral views on the project's visual aesthetics, noting some impact but no significant concerns. On the other hand, international



B1	It affects the cultural heritage of the place
B2	It provides increased employment opportunities to the locals
B3	Migrant workers usually have issues with the locals
B4	Local communities usually have a negative outlook towards the project
B5	The project usually affects the visual aesthetic of the place
B6	Allocation of resources such as land/water for solar energy projects provokes public disagreement due to loss of other income (e.g., agriculture, tourism etc.)
B7	Increased traffic usually causes problems to the locals in the area
B8	Improper waste management at site usually causes problems to the locals
B9	Occupational safety of workers at site is usually a major concern
B10	Most projects involves resettlements and rehabilitation of the locals
B11	There is lack of awareness about solar energy among the locals
B12	Environmental and social impact assessment (ESIA/EIA) reports are prepared for most solar projects
B13	Environment and social management plans are made and regularly followed in all solar energy projects

Figure 5. Response summary for social concerns regarding solar energy implementation

respondents agree that there is an effect on visual aesthetics, suggesting that they observe discernible changes in the visual environment.

National respondents reacted neutrally when asked about public disagreement due to the loss of other sources of income, indicating that it may occasionally be a problem but not a significant one. International respondents, on the other hand, disagree strongly, suggesting that they do not believe the project would result in a major reduction in the local community's income or economic opportunities.

According to the poll, there is disagreement among national respondents on incorrect solid waste management and its effects on local communities. It appears that some respondents do not view improper waste management as a major issue, or that the locals' concerns on these matters are not captured effectively. Conversely, international respondents adopt an unbiased approach, implying that they identify several issues related to waste management within their own local context. Nevertheless, actual waste management of solar panels is a major concern worldwide.

The national respondents' indifferent reaction to occupational health and safety (OHS) indicates that this is a topic that requires a better understanding in the Indian setting compared to other countries. In contrast, international respondents agree that OHS is a major concern related to the project under review.

National respondents express a neutral view about resettlement and rehabilitation (R&R), suggesting that India faces more R&R problems than other countries due to India's dense population in numerous locations. Conversely, international respondents disagree with the R&R problems, indicating that it is of little significance there.

In general, respondents concur that there is a lack of awareness of solar energy, suggesting the need for outreach and education initiatives to raise public awareness and understanding of solar technology and its advantages.

Finally, the poll indicates that most respondents, regardless of nationality, generally concur that environmental management plans (EMP) and environmental impact assessment (EIA) studies are being followed, suggesting that they perceive some degree of compliance with these policies. National respondents, however, have an ambiguous position, implying that they may not be entirely in favor of the project under review, adhering to EMPs and EIA studies.

3.2.4. Economic concerns

As seen in Figure 6, the findings of the economic effect survey shed light on several different aspects of the evaluated solar energy projects from an economic standpoint. First, there is a general lack of consensus among respondents (69%) over the notion of a higher solar energy tariff rate. This implies that solar energy does not have a higher tariff rate compared to grid electricity, or that a higher tariff for solar is not an issue, as people are ready to pay for it. Most respondents (57%) disagree that solar has high transmission and distribution (T&D) losses, implying that numerous innovations in the industry have reduced T&D losses.

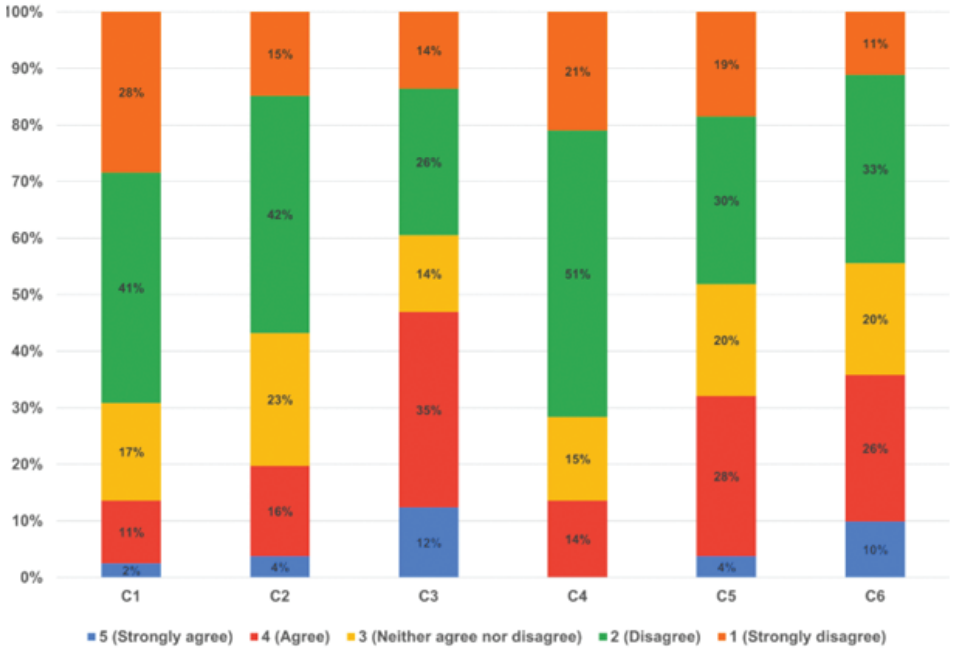
Second, the survey's findings indicate that respondents (47%) generally believe that the long payback periods and high investment costs make the financial viability of solar energy projects less attractive. The high capital cost required for setting up a solar plant not only makes it inaccessible to small investors but also increases the time required to obtain a return on investment (ROI). All these factors may hinder the growth of the solar industry.

Moreover, the findings indicate that 72% of respondents consider solar energy as a non-risky investment. This suggests that respondents view solar energy projects as stable and secure investments, demonstrating confidence in their economic viability and potential returns. However, there are areas of improvement that need to be addressed in the future.

There is agreement among international respondents regarding the availability of facilities that attract more investors in solar energy, but Indian respondents disagree with this statement. This suggests that robust facilities are available for solar investors in Europe and other regions, but improvements in this sector for India are still required. Overall, 49% of respondents believe proper facilities are in place for solar investors.

The unpredictability of nature emerges as a major concern when investing in solar power, with international respondents agreeing, while national respondents express disagreement. This suggests that international respondents deem the unpredictable nature of factors, such as weather conditions, as a significant challenge or risk when investing in solar power. In contrast, national respondents may have an optimistic outlook due to the predictable climate cycles in India. Overall, more than 44% of respondents agree that the unpredictability of weather is not a major concern for investing in solar, while 36% agree that it is a significant concern.

In conclusion, these survey results offer valuable insights into economic aspects associated with solar. While respondents have a negative opinion on issues like high tariffs, risky investments, and T&D losses, this indicates that these are not the most pressing worries in



C1	Solar projects have high tariff rate per kWh
C2	Solar has high transmission and distribution losses
C3	Higher investment costs and longer payback period makes renewable energy projects less lucrative
C4	Investing in renewable energy project is considered risky
C5	Facilities are not available to increase the number of investors in solar energy
C6	Unpredictability of nature is a major concern when investing in solar power

Figure 6. Response summary for economic concerns regarding the implementation of solar energy

the solar industry right now. They also have a neutral to negative perspective on investment prices and ROI times. The varying perspectives on risk and unpredictability, as well as the role of facilities for investors, suggest that improvements are needed in solar energy fields in certain geographical regions, such as India.

3.2.5. Policy and other concerns

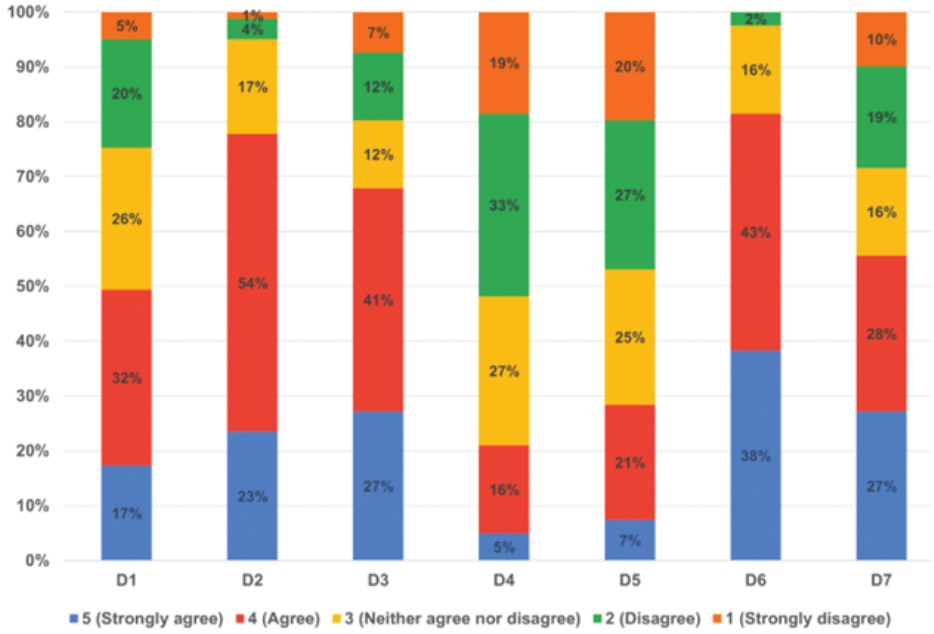
Figure 7 illustrates the survey results related to policy and other factors, providing insight into several issues affecting the solar industry. First, most respondents (49%) agree that solar-related regulatory processes are often tedious. It means that the respondents perceive legal requirements and regulatory procedures as complex and time-consuming, which sometimes hinder the development of solar projects.

Second, 77% of respondents agree that efficient local government policies are essential to the advancement of solar energy. This shows the crucial importance of local government policies and laws to the development and expansion of the solar energy industry. The feasibility of the project, the attractiveness of investments, and the general state of the market can all be strongly impacted by these restrictions.

Furthermore, most respondents (68%) agree that the solar industry requires extensive research and innovation. These innovations and technology breakthroughs are especially needed to resolve energy storage challenges, improve the efficiency of solar panels, and minimize the T&D losses of electricity generated.

Although there is a distinction between respondents from different countries in perceiving supply chain risk, the majority (52%) disagree and believe that an unstable supply chain is not a major problem in the solar Industry. Indian respondents express a neutral view toward the unstable supply chain, indicating some concerns in that area that may occur in the future. International respondents, on the other hand, have a sense of a stable supply chain in the solar industry.

In line with the above point, the study reveals a higher rate of disagreement (47%) on the availability of local



D1	Regulatory procedures for setting up solar energy projects are very tedious
D2	Local government regulations play an important role in determining the number of solar projects developed in the area
D3	Lot of research and innovation is required in solar energy before going for mass scale production
D4	Solar energy is high risk industry due to unstable supply chain
D5	Local manufacturers/suppliers/vendors for supplies required to implement solar energy are unavailable
D6	Stable government policies supporting solar energy are needed
D7	Energy storage and distribution is a major problem in the development of solar projects

Figure 7. Response summary for policy and other concerns regarding solar energy implementation

manufacturers, suppliers, and vendors for solar supplies at both national and international levels. This means that no major issues are observed with the procurement of items required for setting up solar plants.

Most respondents (81%) concur that the solar industry needs stable policies from the government. This indicates that, despite the development of various policies in the solar industry, they are subject to frequent modification, creating uncertainty among decision makers about which projects to build. Stability and long-term vision while developing these policies can lower uncertainty, boost investors' confidence, and promote sector expansion.

Finally, most respondents (55%) agreed that the solar industry faces serious issues regarding energy storage and distribution. This emphasizes the importance of having efficient energy storage systems and distribution networks in place to capitalize on the advantages and applications of solar energy, particularly in resolving intermittency issues and ensuring a stable supply.

To summarize, this survey presents respondents' views on regulatory processes, local government regulations, research and development, stable policies, and the challenges associated with energy distribution and storage in the solar energy industry, highlighting a negative perspective with various spaces for improvements. The respondents have a positive perspective toward the supply chain, indicating that the availability of raw materials, local supply chain, and unstable supply chain are not major issues currently.

4. Discussion

This study compares practitioner opinions with existing literature on environmental, social, economic, and policy aspects of solar energy. By bridging the gap between academic research and professional experience, this study answers a vital demand for evidence that is both comprehensive and grounded in practical importance.

This research represents a crucial endeavor, leveraging the on-the-ground insights of professionals

directly engaged in the field, to provide a nuanced and comprehensive understanding of the myriad issues and concerns within the renewable energy sector. By delving into the perspectives of those professionals, this approach offers a richer understanding of the challenges faced by the sector. Importantly, our findings expand current knowledge by revealing subtle practitioner priorities—such as the significance of Scope 3 emissions and community-level adoption—that are rarely addressed simultaneously. Beyond individual perspectives, these studies contribute to a broader understanding of how to strategically plan and develop renewable energy initiatives at the national or state level, shedding light on areas requiring heightened attention and strategies for fostering sustainable industry growth.

The survey reveals significant environmental impacts associated with implementing solar energy, particularly in terms of land use, biodiversity, and water withdrawal, as well as solid waste management, in the Indian context. Other studies[4,16] also show congruence on this matter, stating that land-use impacts due to solar projects are a major concern. In addition, the survey suggests that land-use problems could also affect agricultural land. The development of solar farms on agricultural land is predicted to have an impact on agricultural productivity; similar predictions have also been suggested in other studies.[18] Scope 3 emissions from solar projects and the disposal of solar panels at the end of their life-cycle were considered as some of the major long-term environmental concerns during this survey. Although it is contrary to the topics addressed in Environmental and Social Impact Assessment reports and other technical reports used in the industry[19,20], it is expected that in the future, calculating Scope 3 emissions or conducting LCA may become mandatory for solar projects.[21] It can also lead to some policy-related changes in the solar field, in the direction of sustainable development. Performing LCA and Scope 3 accounting of solar projects will also aid in resource optimization, as suggested in other research findings.[9]

The survey results show that most respondents agreed with several positive social impacts, such as providing job opportunities to locals, which align with the literature review that suggests other social benefits, including poverty reduction in developing nations.[22] The survey also found that conducting EIA studies of solar projects and following an EMP during the construction and operation phases of solar are required. However, EIA/EMP studies are voluntary in most areas, and limited solar projects undergo EIA studies.[19,20] It is envisaged that these aspects will be a part of environmental law and policies in the future. Many local laws have already started to address these concerns. All these ensure that the development is sustainable. Some negative social concerns were also observed during the survey. For example, the lack of awareness of solar technologies among locals, issues with migrant labor and local inhabitants, impact on the visual aesthetic of the places, improper waste management at construction sites, and health and safety concerns of workers at sites. Some studies indicate that community-level solar power is not widely implemented, and several social/economic/policy factors need to be addressed.[11]

The economic concerns of the survey point toward several factors, including high investment costs and long payback period, which is in agreement with other literature where the high costs hindered investments from lower- and middle-class people.[23] Other economic concerns during the survey included the unavailability of facilities to facilitate investments in solar energy. Furthermore, the unpredictability of nature is also a major concern when investing in solar power, aligning with other studies.[15]

The major policy concerns observed during the survey include tedious regulatory procedures, involvement of local government, and unstable government policies, which are congruent with other studies.[5,16] In addition, focus is required on the research and development aspect, including curtailing losses due to energy storage and distribution, which is also a highlighted concern found in this survey.

4.1. New pathways and opportunities

By comparing practitioner perspectives with the existing literature, this study identifies several under-addressed areas—such as long-term environmental risks and community integration—that merit further empirical research and policy innovation. Based on our findings and those of other scholars, future solutions may include mandatory and standardized LCAs for all solar projects, enhanced regulatory clarity and streamlining, targeted social policies for local job creation, and robust educational campaigns to improve community awareness. Ultimately, future solar energy strategies should prioritize integrated, cross-sectoral approaches that consider the environmental, economic, social, and regulatory dimensions collectively.

In summary, this research not only deepens our understanding of the multifaceted landscape surrounding solar energy but also provides actionable and evidence-based insights into informed policymaking, sustainable development, and holistic industry growth.

5. Conclusion

This study presents a comprehensive examination of the environmental, social, economic, and policy

dimensions that influence solar energy deployment, based on the viewpoints of 81 solar energy professionals from various national and international contexts. Key findings show agreement on the low air pollution associated with solar projects, but also highlight areas of disagreement, particularly in terms of land usage, long-term environmental implications, agricultural land conversion, and resource management. Both national and international responders noted significant issues in biodiversity, water, and solid waste management, while also highlighting developing concerns, such as life-cycle emissions and solar panel disposal. Socially, the study reveals conflicting perspectives about community impacts, local acceptability, and labor relations, with noticeable regional differences. Economically, high investment costs, long payback periods, and the need for affordable access remain significant challenges. The unpredictable nature of energy generation and shortfalls in associated infrastructure further complicate investment decisions. On the policy front, respondents repeatedly highlight the regulatory complexity and instability, emphasizing the significance of clear, stable, and inclusive rules to promote equal access and sustainable industry growth.

This study's findings contribute to the literature by systematically comparing practitioner perspectives across contexts and identifying gaps that previous policy or technical assessments have not adequately addressed, particularly in terms of long-term environmental implications and cross-sector policy integration. Practically, these findings can help to shape comprehensive and adaptive regulatory frameworks, lead targeted awareness and training activities, and encourage greater stakeholder participation to address both environmental hazards and social acceptance.

While broad in scope, the study's sample size and reliance on standardized survey responses may restrict its ability to capture the depth and diversity of individual viewpoints. Future studies should expand on these findings by utilizing large, diverse samples and qualitative methods (e.g., interviews) to improve understanding. Furthermore, allowing different response channels, such as online, phone, and email, and providing options for respondent clarification can improve data quality.

Overall, this study provides actionable evidence for policymakers, project developers, and researchers working to advance the sustainable development of solar energy. The comparative approach not only clarifies national and international variations but also highlights the need for flexible, inclusive, and forward-thinking methods to fully leverage the benefits of solar power in the global renewable energy transition.

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Conflict of interest

The authors declare that they have no competing interests.

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Ethics approval and consent to participate

The research data were collected from solar professionals and ethics approval is not required for the study as per the university regulation where this was conducted. Informed consent was obtained from all survey participants included in the study. The survey is anonymous and no details of individual participants are revealed in this paper.

Consent for publication

All participants provided informed consent for the publication of the findings derived from this study. The authors affirm that all relevant consent forms have been obtained and are available upon request.

Availability of data

Data are available upon request through siddhika.sci@gmail.com.

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