



A study of constraints affecting adoption of solar technologies among farmers in Haryana and Maharashtra

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ABSTRACT

Solar photovoltaic technologies offer a sustainable alternative to conventional energy sources for Indian agriculture, yet farm level adoption remains limited. This study analysed the major constraints influencing adoption and non-adoption of solar photovoltaic technologies among 480 farmers (240 solar technology adopters and 240 non-adopters) in Haryana and Maharashtra. Constraints were identified through literature review and field interactions, and classified into technical, financial, personal, and institutional categories. The Preference Selection Index method was employed to prioritise the perceived severity of constraints. The results indicated that among adopters, constraints in user knowledge and skills, limited duration of subsidy support, post-installation service limitations, non-availability of spare parts, and high initial investment constituted the most severe constraints. Among non-adopters, high initial investment, inadequate subsidy support, fear of technology failure, and procedural complexity in accessing government incentives emerged as the dominant constraints. The study highlights the need for strengthening decentralised service infrastructure, simplifying administrative procedures, improving access to affordable credit, and reinforcing extension activities through training and demonstrations. Implementing policy recommendations will accelerate the diffusion of solar photovoltaic technologies, and enhance their contribution to sustainable and climate-resilient agriculture in India.

Keywords: Climate resilient agriculture, Government incentives, Preference selection index, Technology adoption

Agriculture remains pivotal to the Indian economy, providing livelihoods over half the country's workforce and contributing approximately 17–18% to GDP (IES 2025). However, the sector has become increasingly energy intensive because of escalating irrigation, mechanisation, and groundwater dependence. Currently, Indian agriculture relies on nearly 20 million electric and 9 million diesel pump sets, with an annual addition of approximately 0.5 million pumps (CEIC 2022). Unreliable grid power and heavy fossil fuel reliance escalate operational costs, strain public subsidies, and drive-up agricultural greenhouse gas emissions (India Energy Outlook 2015, Ritchie and Roser 2024). In this context, solar photovoltaic (PV) technologies have emerged as promising, decentralised, and environmentally sustainable energy solution for Indian agriculture, supported by India's abundant solar radiation (4–7 kWh/m²/day) (MNRE 2023). Applications like solar

PV irrigation, dryers, fencing, and lighting enhance land-use efficiency, reduce post-harvest losses, mitigate human-wildlife conflict, and lower operational emissions (Rajesh *et al.* 2024, Kumar and Meena 2025). These applications enable farmers to reduce dependence on fossil fuels, improve energy reliability, enhance farm efficiency, and promote sustainable agricultural practices (Lokesh *et al.* 2024).

Despite strong policy support and proven benefits, farm level adoption remains far below potential. Fewer than 2,40,000 solar pumps are currently deployed against a potential of 3.5 million, while applications like dryers and fencing remain largely restricted to scheme-driven pilot interventions (PIB 2025). This gap highlights that adoption is constrained by a complex mix of financial, technical, institutional, and socio-behavioural barriers (Priyadarshi 2024). While existing literature highlights technical feasibility and environmental benefits, systematic empirical research on farmer-perceived constraints across diverse solar applications remains limited (Durga *et al.* 2024). Understanding these barriers is critical, as early adopters' experiences directly influence broader technology diffusion. Addressing this gap, the study analysed major farmer-level constraints across solar PV applications in

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India to inform targeted policy interventions, extension strategies, and institutional frameworks.

MATERIALS AND METHODS

The study was carried out in Haryana and Maharashtra which were purposively selected based on their higher concentration of farmers adopting solar PV technologies, particularly solar water pumps. According to data from the Ministry of New and Renewable Energy (MNRE), Maharashtra and Haryana ranked top among the states nationwide for standalone solar pump installations under Component-B of the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) scheme. Also, the total no. of PM-KUSUM beneficiaries were highest in Haryana (96,227 farmers) followed by Maharashtra (81,747 farmers). Furthermore, both states possess highly active policy environments driving this adoption. Haryana provides 75% capital subsidy, while Maharashtra supplements central schemes with its own scheme providing 90–95% capital subsidy making them ideal representations of rapid solar diffusion in Indian agriculture. In the second stage, Hisar and Sirsa districts from Haryana, and Nashik and Beed districts from Maharashtra were purposively selected due to greater prevalence of solar PV technology users. From each district, three blocks were randomly selected, and 40 farmers (20 adopters, 20 non-adopters) were chosen per block using proportionate random sampling, resulting in a total sample size of 480 (240 adopters and 240 non-adopters) for the study.

Operationalisation and identification of constraints: In the present study, constraints were operationalised as the barriers that may limit farmers from the adoption and effective use of PV technologies in agriculture. The identification of constraints was carried out through a comprehensive review of relevant literature on renewable energy adoption and solar PV technologies in agriculture, followed by field-level interactions with Energy department officials and farmers. Based on this process, the identified constraints were systematically classified into technical, financial, personal, and institutional constraints categories to facilitate structured analysis and interpretation. To quantify the perceived severity, farmers were asked to rate each identified barrier on a 5-point continuum. In alignment with established methodologies for converting stakeholder responses into quantitative data for multi-criteria analysis (Asante *et al.* 2020), the linguistic response categories ranged from 1 (least severe) to 5 (extremely severe). The frequency of farmers assigning each specific severity score to a constraint subsequently served as the criteria for constructing the decision matrix in Preference Selection Index (PSI) analysis.

Pre-testing of interview schedule: Prior to final data collection, the draft interview schedule underwent pre-testing to ensure methodological validity. Initial open-ended discussions with agricultural extension personnel, energy department officials, and farmers were conducted to practically contextualise the identified constraints. The

schedule was then translated into local languages and pilot-tested on a non-sampled group of 60 farmers. Feedback from this exercise was used to eliminate technical jargon, simplify phrasing, and ensure the scale categories were easily comprehensible, thereby establishing the face and content validity of the final interview schedule.

Preference selection index method: To prioritise the identified constraints, the PSI method, a multi-attribute decision-making (MADM) technique proposed by Maniya and Bhatt (2010), was employed. PSI is a highly robust MADM tool uniquely advantageous for large-scale field studies as it objectively determines the importance of variables, based entirely on the inherent variation within the collected data. This data-driven approach eliminates the need for subjective pre-assignment of weights by the researcher, which is a common limitation in methods like TOPSIS, thereby ensuring a higher degree of objectivity. Furthermore, PSI is highly practical for extensive respondent bases as it processes overall preferences efficiently without requiring the cognitively demanding pairwise comparisons associated with the analytic hierarchy process. By providing a mathematically rigorous framework, PSI offers an unbiased, respondent-friendly, and statistically sound mechanism for evaluating farmer constraints unlike Garrett ranking. The PSI method was implemented using the following sequential steps (Chauhan *et al.* 2016, Asante *et al.* 2020, Trung Do *et al.* 2023).

Step 1: Construction of the decision matrix: For each category of constraints, a decision matrix was constructed by considering the individual constraints as alternatives. The present study employed linguistic response categories based on farmer perceptions as the criteria for analysis. The number of farmers assigning each severity score was treated as a separate linguistic criterion. Accordingly, the columns of the decision matrix represented the frequency of responses corresponding to different severity levels, while the rows represented the individual constraints. This frequency-based linguistic structure enabled the conversion of perception data into a numerical format suitable for PSI analysis. If the number of alternatives is i and the number of criterion's is j , then the decision matrix having an order of $i \times j$ is represented as:

$$X = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1j} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2j} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3j} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & x_{i3} & \cdots & x_{ij} \end{bmatrix} \quad (1)$$

Where X_{ij} , Performance value (frequency of farmer responses) of the i^{th} alternative (constraint) with respect to the j^{th} criterion (linguistic response category),

Step 2: Normalisation of the decision matrix: The decision matrix was normalised to transform all values into a dimensionless scale ranging between 0 and 1, following the standard normalisation procedure. This step ensured comparability among linguistic response categories and

prevented scale effects during index computation.

$$d_{ij} = \frac{X_{ij}}{X_{j\max}} \text{ for larger the better} \quad (2)$$

Where d_{ij} , Normalised value of the i^{th} alternative under the j^{th} criterion; X_{ij} , Original frequency value of farmer responses; $X_{j\max}$, Maximum frequency value observed in the j^{th} linguistic response category across all alternatives.

$$d_{ij} = \frac{X_j^{\min}}{X_{ij}} \text{ for smaller the better} \quad (3)$$

Step 3: Calculation of column-wise mean of the normalised decision matrix: The mean normalised value represents the average response level for each linguistic response category across all alternatives and is used for computing the preference variability in the subsequent step.

$$\Delta_j = \frac{1}{m} \sum_{i=1}^m d_{ij} \quad (4)$$

Where Δ_j , Mean normalised value of the j^{th} linguistic response category; d_{ij} , Normalised value of the i^{th} alternative with respect to the j^{th} criterion; m , Number of alternatives.

Step 4: Computation of preference variation (PV_j) and deviation in preference variation value: Using the normalised decision matrix and the mean normalised values, the PV_j was computed for each linguistic response category to assess the dispersion of normalised frequency values across alternatives. Based on PV_j values, the deviation in preference value (Φ_j) was subsequently derived which reflects the relative stability and consistency of each linguistic response category. Lower variability results in a higher deviation value, indicating greater consistency in farmer responses.

$$PV_j = \sum_{i=1}^m [d_{ij} - \Delta_j]^2 \quad (5)$$

$$\Phi_j = 1 - PV_j \quad (6)$$

Step 5: Calculation of overall preference value: The overall preference value (W_j) for each linguistic response category was obtained by normalising the deviation in preference values (Φ_j), such that the sum of preference values across all response categories equaled unity. These W_j represent the relative importance of each linguistic response category in determining the overall severity of constraints.

$$W_j = \frac{\Phi_j}{\sum_{j=1}^n \Phi_j} \quad (7)$$

Where W_j , Overall preference value of the j^{th} linguistic response category; Φ_j , Deviation in preference value; n , Number of response categories. Moreover, the total overall preference value of all the criteria should be one.

Step 6: Calculation of preference selection index and ranking of constraints: Finally, the PSI value was computed for each alternative by aggregating the weighted normalised values across all linguistic response categories. The PSI value represents the composite severity score of each constraint.

$$PSI_i = \sum_{j=1}^n d_{ij} \times W_j \quad (8)$$

After the calculation of PSI_i , the alternatives are then ranked and the alternative with the highest PSI_i is ranked first.

RESULTS AND DISCUSSION

Socio-economic profile of the respondents: A comparative analysis of the socio-economic and demographic profiles of the respondents was conducted to better contextualise the adoption dynamics. The findings indicated that demographic factors such as age and education were largely homogeneous across the sample. Adopters had an average age of 44.21 (± 8.09) years with 7.58 (± 4.72) years of schooling, while non-adopters averaged 45.16 (± 7.92) years of age with 7.25 (± 4.78) years of schooling. Regarding total annual income, adopters reported higher absolute mean ($\text{₹}71,456.18 \pm 33,117.14$) compared to non-adopters ($\text{₹}67,559.52 \pm 19,682.91$). While this difference is comparatively low, the substantially larger standard deviation among adopters indicates a wider economic variance, suggesting that adopters possess higher financial liquidity. However, adopters possessed substantially larger farms (3.45 ± 1.48 ha) compared to non-adopters (2.58 ± 1.02 ha) ($t = 7.56$) suggesting that larger holdings enhance their capacity to absorb initial solar investments. Furthermore, adopters demonstrated significantly higher levels of mass media exposure ($t = 2.98$), social participation ($t = 3.47$), innovativeness ($t = 3.92$), risk orientation ($t = 5.14$), and agricultural trainings received ($t = 7.29$).

Constraints faced by adopters of solar PV technologies: A consolidated decision matrix comprising technical (T), financial (F), personal (P), and institutional (I) constraints was constructed using frequency distributions of severity perceptions (Supplementary Table 1). The decision matrix was normalised using the larger-the-better criterion as specified in eq. (2). The resulting normalised decision matrix is presented in Supplementary Table 2. After following the detailed computational steps and applying relevant equations, the PSI values were calculated and the constraints were ranked according to their composite severity scores derived from the normalised response frequencies (Supplementary Table 2 and 3).

Ranking of constraints faced by solar PV technology adopters

Technical constraints: Among all technical constraints, difficulty in timely repair of solar panels emerged as the most severe technical constraint ($PSI = 0.78$), followed by non-availability of spare parts ($PSI = 0.73$) for farmers of Maharashtra (Table 1). In Haryana, lack of nearby servicing and maintenance facilities was ranked as the most severe constraint ($PSI = 0.75$). Analytically, this divergence reflects localised bottlenecks, viz. servicing facilities in Haryana are geographically distant, conversely, Maharashtra's hurdle is staff non-responsiveness. Despite these regional nuances, this prominence of maintenance related challenges aligns strongly with findings from Ghana, where the lack of servicing and maintenance facilities was identified as a

Table 1 Preference Selection Index (PSI)-based ranking of technical constraints in adoption of solar PV technologies

Sl. no	Technical constraints	Maharashtra		Haryana	
		PSI	Ranking	PSI	Ranking
T1	Lack of servicing and maintenance facilities near by the villages	0.70	IV	0.75	I
T2	Timely repair of solar panels and solar systems is difficult	0.78	I	0.65	IV
T3	Efficiency of panels gets decreased during winter and rainy days	0.71	III	0.70	II
T4	Battery storage solutions are expensive and have a limited lifespan	0.68	V	0.64	V
T5	Spare parts for solar water pumps are not easily available in the market	0.73	II	0.69	III
T6	The water available through the solar water pumps is not sufficient for farming	0.64	VII	0.63	VI
T7	Poor product quality and inefficiency of indigenous solar cells and modules	0.65	VI	0.61	VII

critical technical barrier to renewable energy development (https://energypedia.info/wiki/After_Sales_Service_for_Solar_Systems#; Asante *et al.* 2020). Furthermore, the struggle to procure spare parts and access timely repairs echoes broader infrastructural deficits in developing regions, where underdeveloped supply chains and a lack of trained maintenance technicians frequently compromise the long-term viability of solar PV installations (Ibegbulam *et al.* 2023, Durga *et al.* 2024). Additionally, the decreased efficiency of panels during winter and rainy days ranked highly across both. For states like Haryana, this constraint is geographically amplified by dense winter fog and smog that significantly diminish solar irradiance (Durga *et al.* 2024). Constraints such as high cost and limited lifespan of battery storage solutions, insufficient water output, and poor product quality of indigenous solar PV modules were ranked relatively lower (Ibegbulam *et al.* 2023) in both states, indicating that these issues are less critical than servicing and maintenance-related challenges.

While poor product quality and the proliferation of substandard panels remain major impediments in other developing markets (Durga *et al.* 2024), the lower severity perceived by farmers in this study suggests that domestic solar PV module manufacturing and quality assurance standards in these regions may be comparatively more robust. Across both states, the similarity in high-ranked

constraints indicates that technical barriers are largely structural rooted in post installation service deficits, maintenance accessibility, and operational reliability rather than inherent technological limitations of solar PV technologies (Mustafa and Malik 2023).

Financial constraints: The PSI analysis of financial constraints (Table 2) indicated that in both states, constraints related to limited duration of subsidy support and high initial investment cost consistently secured the top ranks, indicating that financial barriers remain a major impediment to solar PV technology adoption and reflected farmers concerns regarding affordability and long-term financial security (Ibegbulam *et al.* 2023). This perception of prohibitively high initial costs is universally recognised as the primary barrier to solar photovoltaic adoption across both developing and developed economies (Karakaya and Sriwannawit 2015). Overall, the PSI values suggest that while solar PV technologies are economically beneficial over their operational life, the upfront capital requirement combined with uncertainty in subsidy continuity significantly constrains adoption (GEF 2024). Beyond these universal barriers, a deeper analysis of the moderately ranked constraints revealed distinct regional financial challenges. In Haryana, the inadequacy of the PM-KUSUM subsidy ranked notably higher than in Maharashtra. Analytically, Haryana's highly intensive paddy–wheat crop cycles require larger, high-horsepower water pumps. Because schemes like PM-KUSUM enforce strict capacity caps and subsidy ceilings, farmers requiring larger systems face a significantly heavier financial burden.

Conversely, farmers in Maharashtra prioritised high repairing and maintenance costs as a relatively greater burden (Rank III, PSI = 0.70) compared to those in Haryana (Rank V, PSI = 0.71). Ultimately, these findings emphasise that strengthening subsidy frameworks, extending financial support over longer durations, and improving access to

Table 2 Preference Selection Index (PSI) analysis of financial constraints affecting solar PV technology Adoption

Sl. no	Financial constraints	Maharashtra		Haryana	
		PSI	Ranking	PSI	Ranking
F1	Subsidy is provided only for short period of time	0.79	I	0.84	I
F2	High initial investment for the farmers compared to other technologies	0.72	II	0.81	II
F3	Inadequate subsidy through PM-KUSUM scheme	0.64	IV	0.76	III
F4	Repairing and maintenance costs in case of damage of the panels are high	0.70	III	0.71	V
F5	Poor credit accessibility and bank loans are limited	0.63	V	0.74	IV

affordable credit are critical for enhancing the financial viability and wider adoption of solar PV technologies in Indian agriculture.

Personal constraints: Human and behavioural dimensions emerged as critical determinants of solar PV technology adoption (Table 3). The analysis showed that deficiencies in user knowledge and operational skills constitute the most pronounced personal constraint in Maharashtra and Haryana, with identical PSI values (0.83). Studies from emerging economies consistently identify severe technical skill gaps and lack of operational knowledge among rural farmers as primary bottlenecks that hinder the effective utilisation of decentralised solar PV technologies (Ibegbulam *et al.* 2023, Makinde and Obikoya 2024). Alongside these limitations, apprehension regarding technology failure or inadequate performance was consistently ranked second, reflecting farmers' risk perceptions and uncertainty associated with relatively new technologies (Sindhu *et al.* 2016). This reflects deep-seated risk perceptions and traditional mindsets prevalent among farmers, where novel innovations are frequently viewed with skepticism regarding their dependability unless overwhelming evidence of success is visible (Ibegbulam *et al.* 2023, Makinde and Obikoya 2024).

Constraints linked to limited awareness of the benefits, cost savings, available technologies, and subsidy provisions occupied moderate positions, indicating that informational gaps persist but are secondary to practical usability concerns. The near-uniformity in ranking patterns between the two states suggests that personal constraints transcend regional contexts, remaining deeply rooted in universal adopter psychology and risk aversion. These findings highlight the need for focused capacity-building interventions, experiential learning approaches, and continuous handholding support to improve farmer confidence and effective utilisation of solar PV technologies.

Institutional barriers: In both states, procedural

Table 3 Preference Selection Index (PSI) analysis of personal constraints in solar technology adoption

Sl. no	Personal constraints	Maharashtra		Haryana	
		PSI	Ranking	PSI	Ranking
P1	Fear of technology failure or inadequate performance discourages investment	0.81	II	0.82	II
P2	Unaware of the benefits and potential savings associated with solar technologies	0.80	III	0.75	III
P3	Lack of awareness about available solar technologies and subsidies provided	0.73	IV	0.74	IV
P4	Lack of knowledge and skill in effective use of solar panels	0.83	I	0.83	I

complexities in availing government incentives and subsidies were ranked as the most severe institutional constraint (Table 4), indicating that administrative hurdles significantly limit farmers' access to policy benefits (Kumar *et al.* 2020). Analytically, this underscores a universal frustration with bureaucratic red tape, complicated paperwork and disjointed disbursement channels create high transaction costs that significantly limit farmers' access to intended policy benefits. Operational delays also featured prominently, with delay in installation of solar panels and lack of post-installation follow-up services consistently occupying the second and third ranks (Ibegbulam *et al.* 2023). This reveals a critical gap in private-sector accountability, where farmers frequently encounter poor post-sale support and operational delays from solar firms that compromise the long-term reliability of their systems (Makinde and Obikoya 2024).

Constraints related to limited demonstrative support and inadequate training by extension agencies, along with insufficient motivational programmes for promoting solar technologies, were ranked at moderate levels, suggesting gaps in extension outreach and institutional engagement (Sindhu *et al.* 2016). The uniformity in ranking patterns reflects the structural character of institutional constraints, largely associated with implementation procedures and service delivery frameworks. Addressing these challenges through simplified procedures, strengthened extension-vendor coordination, and improved accountability in post-installation support is essential for enhancing the institutional environment for solar PV technology adoption in agriculture.

Constraints faced by non-adopters of solar PV technologies: The pattern of constraints observed among non-adopter farmers suggests that non-adoption is influenced

Table 4 Preference Selection Index (PSI) analysis of institutional constraints in solar technology adoption

Sl. no	Institutional constraints	Maharashtra		Haryana	
		PSI	Ranking	PSI	Ranking
I1	Complicated procedures for availing government incentives and subsidy	0.81	I	0.81	I
I2	Absence of demonstrative assistance and very few training's on solar panel use and maintenance by KVK/ Agriculture/ Horticulture department	0.76	IV	0.73	V
I3	Delay in installation of solar panels by the companies	0.79	II	0.78	II
I4	Lack of motivational programmes for adoption of solar energy technology	0.72	V	0.74	IV
I5	No follow up services by the solar companies after installation	0.79	III	0.77	III

Table 5 Constraints faced by the non-adopters of solar PV technologies

Sl. no	Constraint	Maharashtra		Haryana	
		PSI	Ranking	PSI	Ranking
Financial constraints					
F1	Subsidy is provided only for short period of time	0.83	III	0.90	II
F2	High initial investment for the farmers compared to other technologies	0.94	I	0.92	I
F3	Inadequate subsidy through PM-KUSUM scheme	0.86	II	0.89	III
F4	Repairing and maintenance costs in case of damage of the panels are high	0.76	V	0.79	V
F 5	Poor credit accessibility and bank loans are limited	0.81	IV	0.86	IV
Personal constraints					
P1	Fear of technology failure/ inadequate performance discourages investment	0.83	I	0.85	I
P2	Unaware of the benefits and potential savings associated with solar technologies	0.79	III	0.77	IV
P3	Lack of awareness about available solar technologies and subsidies provided	0.82	II	0.83	II
P4	Lack of knowledge and skill in effective use of solar panels	0.79	III	0.79	III
Institutional constraints					
I1	Complicated procedures for availing government incentives and subsidy	0.85	I	0.83	I
I2	Absence of demonstrative assistance and very few training's on solar panel use and maintenance by KVK/ Agriculture/ Horticulture department	0.80	III	0.79	III
I3	Lack of motivational programmemes for adoption of solar energy technology	0.84	II	0.81	II

PSI, Preference selection index.

by a combination of financial, perceptual, and institutional factors rather than by any single limiting condition (Table 5). The prominence of investment- and subsidy-related barriers

indicates that economic considerations and the design of support mechanisms continue to play a central role in shaping adoption decisions. At the same time, the high salience of concerns related to technology performance points to the importance of uncertainty and perceived risk in discouraging initial uptake.

Institutional impediments, particularly procedural complexity in accessing incentives, further indicate that the manner in which programmes are implemented may condition farmers' willingness to participate in solar promotion schemes. The similarity in the pattern of constraints across the two states suggests that these barriers are largely systemic in character, highlighting the need for coordinated financial, informational, and institutional efforts to facilitate wider diffusion of solar PV technologies among non-adopter farmers.

This study applied the PSI approach to analyse solar PV adoption constraints among farmers in Haryana and Maharashtra. Findings revealed that adoption is governed by interrelated financial, technical, personal, and institutional barriers rather than isolated technological flaws. Across both states, high initial investment, procedural subsidy bottlenecks, poor post-installation service, and knowledge gaps emerged as dominant, structural constraints. The strong cross-state consistency highlights systemic weaknesses in service delivery and institutional support. Consequently, accelerating solar PV diffusion requires moving beyond technology distribution toward simplifying administrative procedures, strengthening decentralised maintenance infrastructure, and expanding extension-led capacity building to ensure sustainable, climate-resilient agricultural development in India.

REFERENCES

- Asante D, He Z, Adjei N O and Asante B. 2020. Exploring the barriers to renewable energy adoption utilising MULTIMOORA-EDAS method. *Energy Policy* **142**: 111479. <https://doi.org/10.1016/j.enpol.2020.111479>
- CEIC. 2022. Global Economic Data, Indicators, Charts and Forecasts Report. <https://www.ceicdata.com/en>. (Retrieved Feb 10, 2026)
- Chauhan R, Singh T, Thakur N S and Patnaik A. 2016. Optimisation of parameters in solar thermal collector provided with impinging air jets based upon preference selection index method. *Renewable Energy* **99**: 118–26. <https://doi.org/10.1016/j.renene.2016.06.046>
- Durga N, Schmitter P, Ringler C, Mishra S, Magombeyi M S, Ofosu A, Pavelic P, Hagos F, Melaku D, Verma S and Minh T. 2024. Barriers to the uptake of solar-powered irrigation by smallholder farmers in sub-saharan Africa: A review. *Energy Strategy Reviews* **51**: 101294. <https://doi.org/10.1016/j.esr.2024.101294>
- GEF. 2024. 66th Global Environment Facility Council Meeting on *Agrivoltaics*. Washington D C, February 5–9.
- Ibegbulam M C, Adeyemi O O and Fogbonjaiye O C. 2023. Adoption of solar PV in developing countries: Challenges and opportunity. *International Journal of Physical Sciences Research* **7**(1): 36–57. DOI: 10.37745/10.37745/ijpsr.17/vol7n13657

- IES. 2025. *Economic Survey 2024–25*. Ministry of Finance, Government of India.
- India Energy Outlook. 2015. *World Energy Outlook Special Report*. International Energy Agency, Paris. <https://www.iea.org/publications/freepublications/publication/IndiaEnergyOutlookWEO2015.pdf>
- Karakaya E and Sriwannawit P. 2015. Barriers to the adoption of photovoltaic systems: The state of the art. *Renewable and Sustainable Energy Reviews* **49**: 60–66. <https://doi.org/10.1016/j.rser.2015.04.058>
- Kumar S and Meena R S (Eds). 2025. *Agriculture Toward Net Zero Emissions*. Elsevier. 476p.
- Kumar V, Singh S S, Kaur A and Hundal B S. 2020. Determinants of farmers' decision to adopt solar powered pumps. *International Journal of Energy Sector Management* **14**(4): 707–27. DOI: <https://doi.org/10.1108/IJESM-04-2019-0022>
- Lokesh C, Avil Kumar K, Ramulu V and Neelima T L. 2024. Solar powered farming: Revolutionizing agriculture with agrivoltaic systems. *Science World* **4**(11): 5102–06. DOI: 10.5281/zenodo.14173657
- Makinde P F and Obikoya E. 2024. Implementation of solar system for electricity generation for rural farmers: A review. *World Journal of Advanced Research and Reviews* **22**(3): 458–71. <https://doi.org/10.30574/wjarr.2024.22.3.1705>
- Maniya K D and Bhatt M G. 2010. A selection of material using a novel type decision-making method: Preference selection index method. *Materials and Design* **31**: 1785–89. DOI: 10.1016/J.MATDES.2009.11.020
- MNRE. 2023. *Annual Report 2022–2023*. Ministry of New and Renewable Energy, Government of India, New Delhi. <https://mnre.gov.in/> (Retrieved 10th Feb, 2026)
- Mustafa M and Malik M O F. 2023. Factors hindering solar photovoltaic system implementation in buildings and infrastructure projects: Analysis through a multiple linear regression model and rule-based decision support system. *Buildings* **13**(7): 1786. <https://doi.org/10.3390/buildings13071786>
- PIB. 2025. *Energy Security in India*. Press Information Bureau. <https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/feb/doc202521493701.pdf> (Retrieved 10th Feb, 2026)
- Priyadarshi P. 2024. A study of role of solarization in the growth of the agriculture sector in India. *International Journal of Scientific Research and Engineering Trends* **10**(1): 51–56.
- Rajesh T T, Mohod A G and Dhande K G. 2024. Solar-powered irrigation systems: Sustainability, advancements and future prospects. *Journal of Agricultural Engineering* **61**(6). <https://doi.org/10.52151/jae2024616.1884>
- Ritchie H and Roser M. 2024. CO₂ Emissions. Our World in Data. Retrieved from: <https://ourworldindata.org/co2-emissions>
- Sindhu S, Nehra V and Luthra S. 2016. Identification and analysis of barriers in implementation of solar energy in Indian rural sector using integrated ISM and fuzzy MICMAC approach. *Renewable and Sustainable Energy Reviews* **62**: 70–88. <https://doi.org/10.1016/j.rser.2016.04.033>
- Trung Do D, Tran V D, Duong V D and Nguyen N T. 2023. Investigation of the appropriate data normalization method for combination with preference selection index method in MCDM. *Operational Research in Engineering Sciences: Theory and Applications* **6**(1).