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WORLD ASSOCIATION FOR SUSTAINABLE DEVELOPMENT

World Journal of ENTREPRENEURSHIP, MANAGEMENT AND SUSTAINABLE DEVELOPMENT

ISSN: 2042-5961 (Print) | 2042-597X (Online)

WJEMSD V22 N1-2 2026

DOI: 10.47556/J.WJEMSD.22.1-2.2026.7

RESEARCH

Transition Towards Sustainability through Micro Producers and Rooftop Solar Projects in Kerala

Ajith Naramthatta Keepat
Research Scholar, Department of Management Studies,
Noorul Islam Centre for Higher Education, Tamil Nadu, India
Email: ajithmes@gmail.com
ORCID: 0009-0004-5089-6500

Vellaiyan Perumal Velmurugan
Associate Professor, Department of Management Studies,
Noorul Islam Centre for Higher Education, Tamil Nadu, India
Email: vpvharini@gmail.com
ORCID: 0000-0001-8181-0942

ABSTRACT

PURPOSE: This paper aims to examine the factors influencing the adoption of rooftop solar technology by micro-scale producers in Kerala, a region with distinct socioeconomic and environmental characteristics, to support climate change mitigation and sustainable energy security.

DESIGN/METHODOLOGY/APPROACH: A quantitative research approach was adopted, using survey data collected from 370 respondents out of a potential 12,000 micro-scale producers. Statistical analyses, including regression, ANOVA, and correlation, were conducted using SPSS to identify key adoption drivers and barriers.

FINDINGS: The study found that increased awareness and perceived benefits, particularly cost savings, significantly enhance adoption rates. However, high initial investment costs and limited rooftop space remain key obstacles to wider implementation.

CITATION: Keepat, A. N. and Velmurugan, V. P. (2026): Transition Towards Sustainability through Micro Producers and Rooftop Solar Projects in Kerala. *World Journal of Entrepreneurship, Management and Sustainable Development,* Vol. 22, Nos. 1-2, pp.111-129.

RECEIVED: 11 December 2025 / **REVISED:** 19 January 2026 / **ACCEPTED:** 30 January 2026 / **PUBLISHED:** 12 February 2026

ORIGINALITY/VALUE: This paper contributes to the limited literature on rooftop solar adoption in Kerala's micro-production sector, offering insights and strategies to improve adoption rates. It is helpful to policymakers, energy planners, and sustainability seekers for region-specific approaches to renewable energy deployment..

KEYWORDS: *Rooftop Solar; Micro-Scale Producers; Renewable Energy; Sustainable Energy Transition; Adoption Barriers; Kerala; Cost Savings.*

INTRODUCTION

Globally, sustainable energy needs to be driven by the rising demand to manage climate change and the depletion of limited fossil fuel sources (Izam *et al.*, 2022). The availability of rooftop solar panels provides a solution by using solar energy (Ferdyansyah and Stefanie, 2023). To meet rising energy demands and reduce harmful greenhouse gas emissions, renewable, eco-friendly solar energy is a viable solution (Nordholm and Sareen, 2021).

The 21st century has marked the importance of a drastic shift from conventional fossil fuels to more renewable energy sources. Solar energy has become a solution for green energy by reducing greenhouse gas emissions (Tabassum *et al.*, 2021). Rooftop solar photovoltaic systems (PV) have enabled a transition from consumption to production for households and small businesses and have reduced their dependency on major power networks.

Decentralisation is a major feature of rooftop solar. Large solar farms can supply energy directly to the grid, but rooftop solar helps families, businesses, and institutions produce and consume electricity and act as prosumers (producer-consumers). This method is helpful in Kerala's objective of cultivating sustainable and self-sufficient energy policies. Kerala is commonly referred to as "God's Own Country", known for its natural beauty and greenery; however, it is experiencing issues with energy consumption and sustainability. Kerala requires more energy as its population is increasing and urbanisation is on the rise (Parsad *et al.*, 2020). The rising demand for traditional energy sources has raised environmental issues and increased dependence on traditional fuels.

In Kerala, there has been a shift from consumption to production through rooftop solar PV systems. Solar energy can be tapped by the state since micro-scale solar production among inhabitants, enterprises, and communities in Kerala can contribute significantly to the increasing energy requirements of the state (Bhanja *et al.*, 2020). This approach is helpful in reducing energy dependence, cost savings, and income generation by feeding excess generated energy to the grid and reducing carbon emissions.

The success of rooftop solar adoption in Kerala is tied to the micro-scale level. National and state-level policies provide frameworks for green energy integration, and rooftop solar deployment occurs at the micro-scale, involving households, businesses, and communities (Nordholm and Sareen, 2021). Understanding the factors that influence micro-scale producer perceptions and adoption is vital for informed policy formulation, infrastructure development, and effective dissemination of clean energy technologies.

LITERATURE REVIEW

Antoniolli *et al.* (2022) discussed the increasing adoption of residential rooftop PV systems in Brazil, transforming consumers into prosumers. The authors suggested a technique for assessing the purpose and benefits of rooftop PV for prosumers, exemplified by the "Celesc PV Bonus Project" in Florianópolis, Brazil. Their methodology covered solar resource evaluation, the efficiency of PV systems, consumption profiles, emission reductions, and comparative analysis. According to this study, there was a decrease in the utility's annual power usage by 18%, and an increase in prosumers' yearly consumption by 8%. By utilising rooftop PV, it became advantageous due to a 54% decrease in the cost of electricity. The economic viability of residential rooftop photovoltaic systems in Brazil is attributed to the decreasing costs of PV technology.

The study by Monna *et al.* (2022), titled "Energy Challenges Meet High Solar Potential in Jordan", found the feasibility of rooftop photovoltaic systems on residential buildings. Using PV*SOL (a comprehensive software for designing, simulating, and visualising PV systems), villas and single houses produced 3 to 8 times their electricity consumption in 2021. The highest per-household production achieved by villas was 0.65 to 1.3 times their usage. An angle of 28° is the ideal tilt angle for maximum output. Factors such as overall efficiency, payback period, and cost, which varied by building type, made single houses and villas more attractive. In the Middle East, these findings highlighted the potential for energy sustainability. The study had limitations related to maintenance, cost factors, and efficiency. Life cycle analysis and cost aspects can be considered in future studies.

The study by Moser *et al.* (2021) found an increase in photovoltaics in German cities and examined potential occupants who receive solar power generated onsite. An estimated 3.8 million tenant households were found to be suitable for solar tenant electricity, but there was a limitation in the federal promotion scheme. Barriers and driving factors were identified through research. The legal framework and associated high transaction costs were primary barriers. Socially, resident inertia hindered adoption. The study emphasised that without regulatory changes, the diffusion of tenant electricity could remain constrained.

Inderberg *et al.* (2020) conducted a study on solar prosuming, focusing on national policymakers, grid companies, and prosumers in Norway. Through 65 in-depth interviews, including 33 pioneering prosumers, the research revealed that prosumers were primarily motivated by identity rather than financial gain.

Inderberg *et al.* (2018) studied the factors governing the expansion of prosuming in the UK, Norway, and Germany from 1997 to 2017. They found key factors including domestic settings, third-party installer markets, information availability, helpful programs, and legal provisions. The results revealed that information availability and the presence of third-party markets, as well as changes in helpful programs, had a significant impact on the development of prosumers in these nations. Additionally, background characteristics such as electricity prices and broader contextual arrangements in the electricity domain influenced prosumer attractiveness and feasibility. The study suggested that prosumer development typically involves phases including technical testing, third-party installer market establishment, and the transition to a mass market, each phase reducing barriers to prosumer participation.

Kerala State Electricity Regulatory Commission (2025) discusses the regulatory framework for renewable energy, the role of the Government and Electricity Regulatory Commissions, rules and notifications by the Central Government, the National Electricity Plan, renewable energy regulations by the Central Commission, and the evolution of state-level regulations on renewable energy.

Kerala State Electricity Board Limited (2025) also discusses subsidies and various other benefits, including important information, terms and conditions, and the minimum requirements for rooftop solar projects in Kerala.

The determinants influencing the performance of micro-scale consumers adopting and participating in rooftop solar projects, and the evaluation of their financial viability, include factors such as return on investment, government incentives, and cost-effectiveness.

While several studies have explored the adoption of rooftop solar systems in various global contexts, there is a noticeable research gap concerning micro-scale producer perceptions and adoption behaviour specific to Kerala. There have been studies focusing on geographical areas, countries, or states, but not on capturing the micro-level decision-making involved in rooftop solar installations for individual households, small businesses, and community organisations.

The existing literature primarily analyses quantitative aspects of adoption, the economic viability of solar systems, or the effect of government policies, which overlooks qualitative dimensions of behaviour and perception. An in-depth analysis of micro-scale producers' perceptions and adoption patterns in Kerala provides a wide range of information on the elements that govern their decision-making.

Research Questions

What are the socio-demographic characteristics of micro-scale producers in Kerala, and how do these characteristics relate to their perceptions of rooftop solar technology?

How does micro-scale producers' awareness of rooftop solar technology affect their likelihood of adopting rooftop solar systems?

What are the perceived benefits of rooftop solar technology among micro-scale producers, and how do these influence their adoption decisions?

Objectives of the Study

To examine how various demographic factors influence micro-scale producers' perceptions of rooftop solar technology.

To evaluate the impact of awareness levels on the adoption rates of rooftop solar systems among micro-scale producers.

To assess the effect of perceived advantages on the adoption decisions of micro-scale producers regarding rooftop solar technology.

RESEARCH METHODOLOGY

The research methodology section traces the systematic approach and techniques that will be applied to accomplish the study objectives and address the questions of research effectively. In this section, there are different aspects such as the design research, data collection, sample, variables, and data and method analysis.

Conceptual Framework

The proposed study will be an exploration of the multifaceted association between the socio-demographic profile and rooftop solar technology among micro-scale producers in Kerala. Factors such as age, income, education, and awareness influence individuals' consideration of solar technology. The conceptual framework of the research is shown in Figure 1.

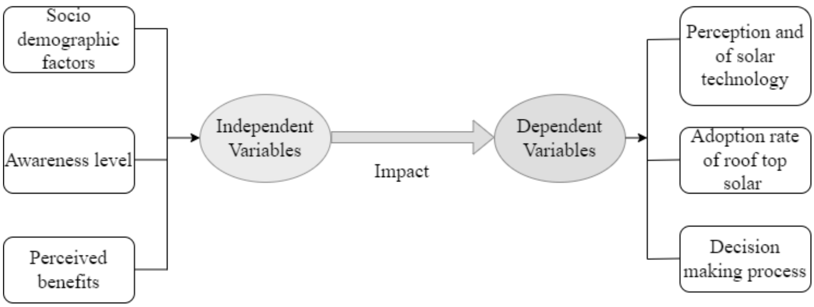

Figure 1: Conceptual Framework of the Proposed Research

Source: Constructed by authors

Research Design

The research combines qualitative and quantitative approaches.

Data Collection

The survey questionnaire has been designed according to the current literature and the study objectives.

Measurement of Variables

The dependent variables (rooftop solar adoption, perceptions, and awareness of solar technology) and the independent variables (socio-demographic factors such as age, income, and education, and perceived benefits such as energy cost savings) are the variables used in the study.

Sampling Technique

This study focuses on micro-scale producers in Kerala, including individual households, community organisations, and small businesses. A stratified random sampling method is adopted to obtain a representative sample from different subgroups within the diversity of this population. The strata are established according to socio-demographic factors, such as education, geographical area, and income.

Sample Size

The Cochran formula was used to determine the size of the sample needed for the survey. This estimation was based on a 95% confidence level, a 5% margin of error, and an estimated proportion of 0.5. According to the available figures, the population comprises approximately 10,000 micro-scale producers who are either already engaged in or planning to engage in rooftop solar projects in Kerala. By substituting these values into the formula, the obtained sample size is:

$$n = \frac{N.Z^2.\wp\,(1-\wp)}{e^2} \qquad n = \frac{10{,}000 \times (1.96)^2 \times 0.5 \times (1-0.5)}{0.05^2}$$

n= 384.76

At a 95% confidence interval (z = 1.96), n represents the sample size, N represents the population size, Z represents the z-score (1.96), p represents the estimated proportion (0.5), and e represents the margin of error (0.05).

Nevertheless, of the questionnaires distributed, only 370 were returned. Thus, the proposed research uses a final sample size of 370.

Data Analysis

The proposed research will use appropriate statistical analysis of the data and will employ the following methods. All analyses are carried out using SPSS (Statistical Package for the Social Sciences) software, which ensures data processing, detailed visualisation, and proper interpretation of the results.

Descriptive Statistics: Descriptive statistical methods are used to analyse the quantitative data obtained from the survey. These include the calculation of means and standard deviations to describe the characteristics of the sample and key variables.

Inferential Statistics: Correlation and regression analysis are among the inferential statistical methods used to test hypotheses and examine the relationships among variables. These help identify important factors affecting perceptions and adoption rates.

ANOVA (Analysis of Variance): ANOVA tests are used to evaluate the significance of group differences. A significance level of $p < 0.05$ was chosen.

Data Validity and Reliability

Content Validity: The survey questionnaire underwent content validity assessment by domain experts to ensure that it effectively measures the proposed constructs of perceptions, adoption, awareness, benefits, and barriers.

Cronbach's Alpha: The internal consistency of the survey instrument is assessed using the Cronbach's alpha coefficient. This ensures that the questions within each construct are reliable and internally coherent.

FINDINGS AND ANALYSIS

Demographic Distribution of the Respondents

Table 1 shows the demographic distribution of the respondents and factors influencing rooftop solar adoption. All figures are shown in Indian currency, INR (₹).

Table 1: Demographic Distribution of the Respondents and Factors Influencing Rooftop Solar Adoption

Demographic Factor	*Category*	*Frequency*	*Percentage (%)*
Age	18-30	72	19.46
	31-40	98	26.49
	41-50	97	26.22
	51-60	73	19.73
	61+	30	8.11
Gender	Male	226	61.08
	Female	144	38.92

Demographic Factor	*Category*	*Frequency*	*Percentage (%)*
Education Level	High School or Below	60	16.22
	Undergraduate Degree	145	39.19
	Postgraduate Degree	125	33.78
	Other	40	10.81
Income Level (Annual)	Below ₹5,00,000	160	43.24
	₹5,00,000 - ₹10,00,000	115	31.08
	₹10,00,000 - ₹20,00,000	60	16.22
	Above ₹20,00,000	35	9.46
Awareness of Rooftop Solar	High Awareness	152	41.08
	Moderate Awareness	120	32.43
	Low Awareness	98	26.49
Perceived Benefits of Solar	Cost Savings	230	62.16
	Environmental Impact	150	40.54
	Energy Independence	100	27.03
	Government Incentives	60	16.22
Rooftop Space Availability	Yes	175	47.30
	No	195	52.70
Perceived Barriers to Adoption	High Initial Investment	180	48.65
	Lack of Knowledge	115	31.08
	Maintenance Concerns	90	24.32
	Space Constraints	125	33.78
Current Use of Solar Technology	Using Solar Energy	100	27.03
	Not Using Solar Energy	270	72.97

Source: Compiled by Authors Based on Survey Data Collected from 370 Micro-Scale Producers in Kerala

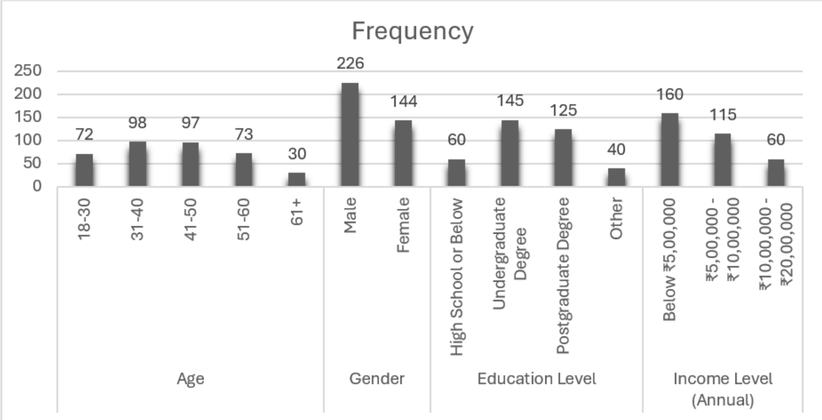

Figure 2: Demographic Distribution of the Proposed Research

Source: Analysed by authors

Figure 2 shows the demographic distribution of the proposed research. A large proportion of the respondents are between the ages of 31–40 and 41–50, indicating that middle-aged individuals are significantly interested in rooftop solar adoption. The gender distribution is biased towards males, with 61.08% male respondents and 38.92% female. Education has a significant impact on the awareness and comprehension of technological advancements among the respondents, as the majority hold undergraduate or graduate degrees. A majority proportion (43%) earns less than ₹5,00,000 annually, which supports the assumption that solar energy solutions are affordable.

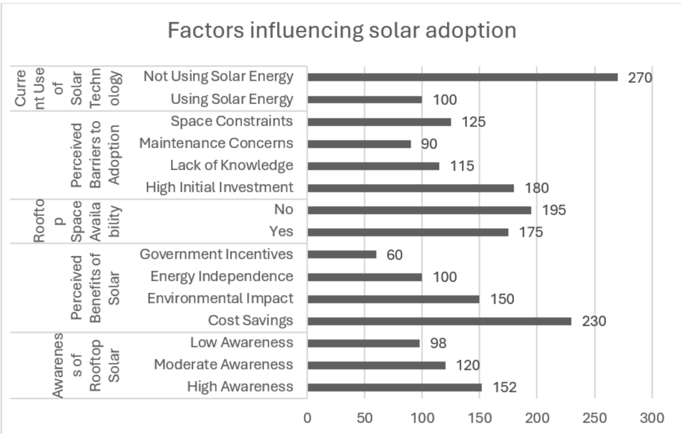

Figure 3: The Sample Distribution of Factors Influencing Rooftop Solar Adoption

Source: Analysed by authors

Figure 3 shows the sample distribution of factors influencing rooftop solar adoption. Rooftop solar technology is widely accepted, with 41% of the respondents indicating that they are extremely aware of it. 62% mentioned cost savings as a primary factor for solar adoption. Energy independence and environmental impact are also important factors to a certain extent. A total of 52.7% showed concern about the lack of space for rooftop solar.

Descriptive Statistics

Descriptive statistics are a crucial analytical tool used to summarise and interpret key characteristics of the data collected from the study participants. These statistics provide information on the central tendencies and variability within the data, as shown in Table 2. "Adoption Status" displays the proportion of respondents who have adopted rooftop solar (0 for non-adopters, 1 for adopters).

Table 2: Descriptive Statistics

Variable	*Mean*	*Standard Deviation*
Age (years)	42.5	8.2
Income (INR)	25,000	6,000
Education Level (1-5 scale)	3.2	0.9
Awareness Score (1-10 scale)	7.8	1.5
Perceived Benefit (1-7 scale)	5.4	1.2
Adoption Status (0/1)	0.65	N/A

Source: Analysed by authors

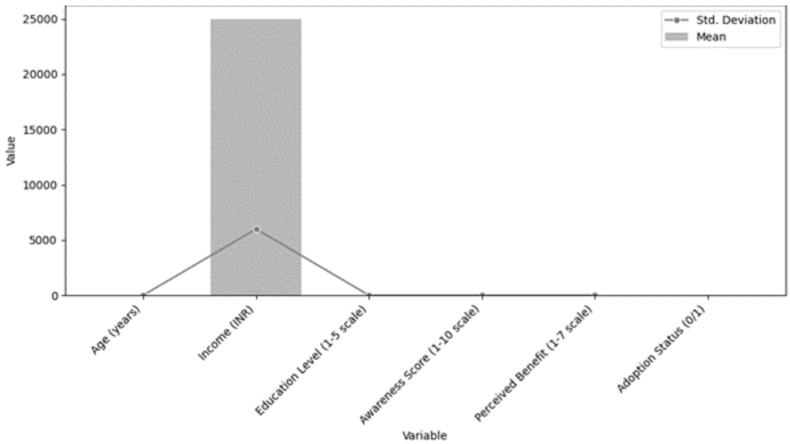

Figure 4: Descriptive Statistics

Source: Analysed by authors

Figure 4 shows descriptive statistics. The respondents, having an average age of 42.5 years and a standard deviation of 8.2 years, indicate a moderate degree of age variability in the sample. This is shown in Figure 4. Their average income stands at ₹25,000, with a relatively lower standard deviation of ₹6,000, indicating relatively lesser income disparity among participants. In addition, participants have a moderate level of education, with an average education level score of 3.2 on a 1–5 scale, a high awareness score (7.8), and a generally positive perception of benefits (5.4) towards the adoption of rooftop solar. The adoption status variable shows that, on average, approximately 65% of participants have adopted rooftop solar.

Inferential Statistics

This type of statistical analysis helps to make predictions, test hypotheses, and identify relationships within the population.

Regression Analysis

Table 3: Regression Analysis

Variable	*Coefficient (B)*	*p-value (Probability)*	*R-squared (Coefficient of Determination)*
Socio-demographic Characteristics	0.342	0.023	0.176
Awareness Levels	0.618	0.001	0.409
Perceived Benefits	0.482	0.005	0.264

Source: Analysed by authors

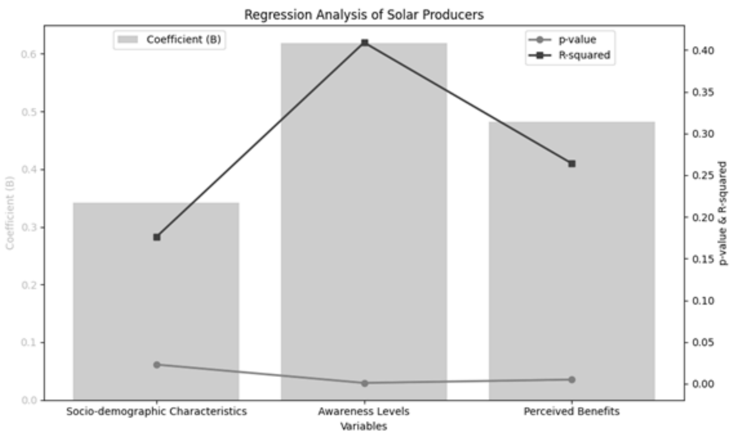

Figure 5: Regression Analysis

Source: Analysed by authors

Table 3 shows the regression analysis of micro-scale solar producers. Figure 5 shows the regression analysis. It indicates that certain socio-demographic characteristics are positively associated with favourable perceptions of rooftop solar technology among micro-scale producers (B = 0.342, p = 0.023). Awareness levels (B = 0.618, p = 0.001) and perceived benefits (B = 0.482, p = 0.005) are also positively associated with adoption. This primarily contributes to increased adoption rates, indicating that awareness campaigns are important and emphasising the role of perceived advantages in influencing producers' adoption decisions.

Correlation Analysis

Table 4: Correlation Metrics of Solar Producers

Variables	*Pearson Correlation (r)*	*p-value*	*Standard Deviation*
Awareness Levels vs. Adoption Rates	0.623	0.001	8.2
Perceived Benefits vs. Adoption Rates	0.481	0.011	6,000

Source: Analysed by authors

Correlation metrics of micro-scale solar producers are shown in Table 4. The correlation analysis, as depicted in Table 4, reveals strong positive relationships between awareness levels and adoption rates (r = 0.623, p = 0.001) and between perceived benefits and adoption rates (r = 0.481, p = 0.011).

Chi-square Analysis

Table 5: Chi-Square Tests

Variables	*Chi-square Value (χ^2)*	*Degrees of Freedom*	*p-value (Probability)*
Socio-demographic Characteristics vs. Adoption Status	15.237	1	0.001
Awareness Levels vs. Adoption Status	12.684	1	0.002

Source: Analysed by authors

Table 5 shows the chi-square tests. It indicates that there is a statistically significant relationship between socio-demographic characteristics and adoption status (χ^2 = 15.237, p = 0.001), as well as between awareness levels and adoption status (χ^2 = 12.684, p = 0.002) among micro-scale producers.

Hypotheses for ANOVA

Hypothesis 1:

Null Hypothesis (H01): There is no significant relationship between micro-scale producers' socio-demographic characteristics and their perceptions of rooftop solar technology.

Alternative Hypothesis (H1): There is a significant relationship between micro-scale producers' socio-demographic characteristics and their perceptions of rooftop solar technology.

Table 6: ANOVA Results for Hypotheses 1

Source of Variation	*Sum of Squares (SS)*	*Degrees of Freedom (df)*	*Mean Square (MS)*	*F-Value (Ratio of Variance)*	*p-Value*
Between Socio-demographic Groups	654.89	4	163.72	6.81	0.001
Within Socio-demographic Groups	1120.47	195	5.74		
Total	1775.36	199			

Source: Analysed by authors

Table 6 shows the ANOVA results for Hypothesis 1. The p-value (0.001) is less than the significance level (0.05), indicating that there is a significant relationship between micro-scale producers' socio-demographic characteristics and their perceptions of rooftop solar technology. Therefore, we reject the null hypothesis (H01).

Hypothesis 2:

Null Hypothesis (H02): Awareness levels do not significantly impact the adoption rates of rooftop solar systems among micro-scale producers.

Alternative Hypothesis (H2): Awareness levels significantly influence the adoption rates of rooftop solar systems among micro-scale producers.

Table 7: ANOVA Results for Hypotheses 2

Source of Variation	*Sum of Squares (SS)*	*Degrees of Freedom (df)*	*Mean Square (MS)*		*p- Value (Probability)*
Between Awareness Levels Groups	488.23	2	244.12	5.62	0.007
Within Awareness Levels Groups	1195.88	197	6.08		
Total	1684.11	199			

Source: Analysed by authors

Table 7 presents the results of the ANOVA for Hypothesis 2. Consequently, the p-value (0.007) does not exceed the level of significance (0.05), which means that awareness levels play a significant role in determining the adoption rates of rooftop solar systems by micro-scale prosumers. This leads to the rejection of the null hypothesis (H02). The box plot in Figure 6 shows the adoption rates by awareness level among micro-scale producers. The compact box and whiskers demonstrate that producers with high awareness have optimal adoption rates with a minimal degree of variability. The enhanced adoption appears to be closely related to greater awareness, implying that focused efforts to increase awareness have a major influence on the adoption rates of solar producers.

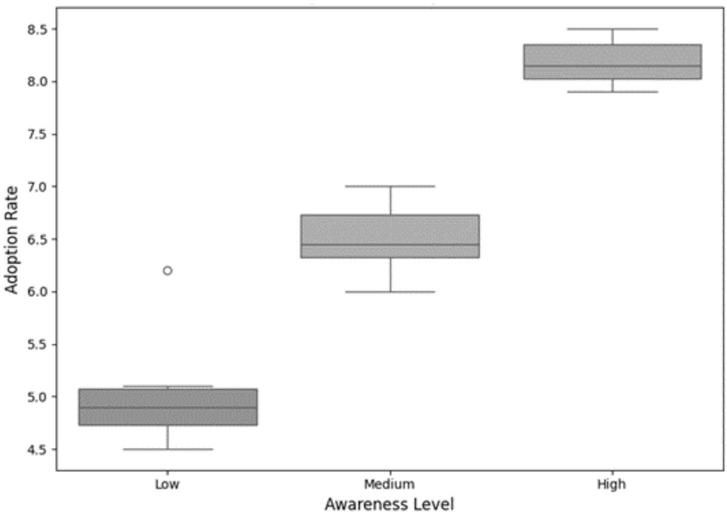

Figure 6: Box Plot for the Adoption Rates by Awareness Levels

Source: Analysed by authors

Hypothesis 3:

Null Hypothesis (H03): Perceived benefits have no significant influence on the decision-making process of micro-scale producers regarding the adoption of rooftop solar technology.

Alternative Hypothesis (H3): Perceived benefits significantly influence the decision-making process of micro-scale producers regarding the adoption of rooftop solar technology.

Table 8: ANOVA Results for Hypotheses 3

Source of Variation	*Sum of Squares (SS)*	*Degrees of Freedom (df)*	*Mean Square (MS)*	*F-Value*	*p-Value*
Between Perceived Benefits	392.67	3	130.89	4.28	0.009
Within Perceived Benefits	1291.45	196	6.60		
Total	1684.11	199			

Source: Analysed by authors

Table 8 shows the ANOVA results for Hypothesis 3. According to the ANOVA results in Table 8, the p-value (0.009) is less than the significance level (0.05), indicating that perceived benefits significantly influence the decision-making process of micro-scale producers regarding the adoption of rooftop solar technology. As a result, the null hypothesis (H03) is rejected in favour of the alternative hypothesis (H3).

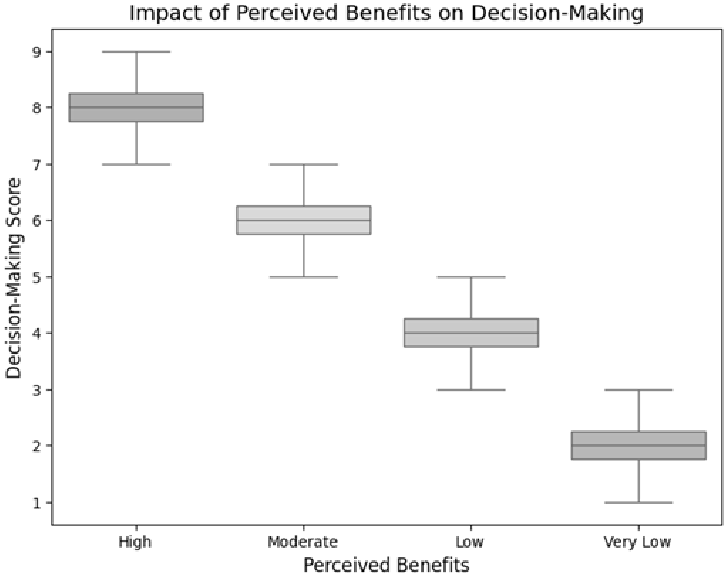

Figure 7: The Impact of Perceived Benefits on Decision Making

Source: Analysed by authors

Figure 7 shows the impact of perceived benefits on planning. This illustrates a box plot for the decision-making scores of micro-scale solar producers. Greater decision-making scores correspond to more perceived benefits, demonstrating a clear upward trend. Producers with high perceived benefits have the greatest scores and minimal variability, while producers with low perceived benefits have the lowest scores and some variability.

Content Validity and Reliability (Cronbach's Alpha)

The adequacy of survey items in covering the research objectives and variables is assessed by content validity. Here, we involved domain experts to review the survey items for relevance and clarity. Each item was rated by the experts on a scale of 1 to 5 for relevance, where 1 indicates "not relevant" and 5 indicates "highly relevant."

Table 9: Content Validity Results

Survey Item	*Expert 1*	*Expert 2*	*Expert 3*	*Expert 4*	*Expert 5*	**Average Rating**
Perceptions of Solar Tech	5	4	5	4	5	4.6
Adoption Rates	4	5	4	4	3	4.0
Awareness Levels	5	5	4	4	4	4.4
Perceived Benefits	4	4	5	5	4	4.4

Source: Analysed by authors

Content Validity results are shown in Table 9. The overall Content Validity Index (CVI) is indicated by the average rating. Typically, a CVI above 0.80 indicates good content validity.

The Cronbach's Alpha method is used to evaluate the internal consistency of the survey instrument for reliability, specifically for the variables related to perceptions of rooftop solar technology, perceived benefits, and awareness levels. This is shown in Table 10.

Table 10: Reliability Results

Variable	*Cronbach's Alpha*
Perceptions of Rooftop Solar Technology	0.87
Awareness Levels	0.81
Perceived Benefits	0.89

Source: Analysed by authors

The alpha values of all Cronbach's coefficients are more than the recommended cut-off of 0.70. This shows that the survey instrument is highly reliable and internally consistent across each variable.

ANALYSIS

The paper on the transition towards sustainability through micro-scale producers and rooftop solar projects in Kerala highlights the decision-making of rooftop solar adoption. Income is among the factors that affect rooftop solar adoption. In descriptive statistics, the average income in Indian rupees lies within a scale supporting solar energy. Careful consideration should be given to Kerala's income distribution. Initial solar investment may prove costly for some micro-scale producers, although their income may be higher than the mean. These problems can be addressed by financial incentives. Another major factor is education. Higher levels of education are associated with greater interest in solar adoption. Awareness and the long-term benefits of solar can be enhanced through educational campaigns. Educational campaigns should be prioritised by policymakers, as they are needed for the economic, environmental, and energy security benefits of rooftop solar.

This study highlights the importance of attending to the socio-demographic diversity in Kerala's micro-scale producer population, including factors such as age, location, and occupation. Policymakers can consider these diversities to develop better strategies for each segment.

The suitability of rooftop solar energy for micro-scale producers in Kerala is indicated by this research. Addressing barriers such as income inequality, awareness, and education through initiatives tailored to each demographic group are key steps in the transition from consumption to production.

CONCLUSIONS

The conducted research unveiled several findings that affect adoption rates and perceptions of rooftop solar technology among micro-scale producers in Kerala. Socio-demographic factors play a critical role in shaping attitudes towards solar technology, with middle-aged and educated individuals showing a greater inclination towards solar adoption. The research demonstrated that awareness campaigns boost adoption rates, as evidenced by a significant correlation between high levels of awareness and increased adoption.

Other key decision factors are the perceived advantages of rooftop solar, environmental benefits, and cost considerations. Initial investment costs and spatial constraints are major challenges to implementation. The findings of this research are helpful for policymakers and energy planners, particularly in developing strategies that increase awareness, address financial burdens through subsidies or incentives, and overcome spatial limitations using innovative methods.

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BIOGRAPHY

Ajith Naramthatta Keepat is a research scholar at Noorul Islam Centre for Higher Education, Kumaracoil, Tamil Nadu. He received a B.Tech. degree in Electronics and Communication Engineering from Mar Baselios Christian College of Engineering and Technology, Peermade, Kerala, and an MBA in Human Resource Management from Bharathiar University, Coimbatore. He has three years of teaching experience in an engineering college and sixteen years of industrial experience in the power sector as a Distribution Engineer with Kerala State Electricity Board Limited. He has publications in Edelweiss Applied Science and Technology and the International Journal of Science, Engineering and Management.

Dr Vellaiyan Perumal Velmurugan is an Associate Professor at the Noorul Islam Centre for Higher Education, Kumaracoil, Tamil Nadu. He received his PhD in Finance from the Noorul Islam Centre for Higher Education, Kumaracoil. He has seventeen years of teaching experience in Management. He has publications in Edelweiss Applied Science and Technology, the International Journal of Professional Business Reviews, the International Journal of Psychosocial Rehabilitation, the Journal of Critical Reviews, the Journal of Emerging Technologies and Innovative Research, the Journal of Management, the Journal of Business and Management, the International Journal of Engineering and Technology, and the International Journal of Applied Business and Economic Research.

