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Micro-Scale Consumer Perceptions and Adoption of Rooftop Solar in Kerala

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Abstract— ***The rapid adoption of renewable energy sources, particularly rooftop solar projects, holds significant potential for sustainable energy transition. This study attempts to analyze the critical factors influencing the effectiveness of micro-scale consumers' participation in adopting rooftop solar projects in the context of Kerala, India. The focus lies on evaluating the financial viability, demographic profiles, and their interplay in shaping consumer perceptions. By employing a cross-sectional observational design and purposive sampling, this research delves into the diverse landscape of residential homeowners, small businesses, and institutions engaged in rooftop solar initiatives. Statistical analyses including ANOVA, mean and standard deviation calculations, and factor analysis uncover the multifaceted dynamics at play. The findings offer actionable insights, enabling tailored strategies that align with the preferences and concerns of different demographic segments. This study contributes to enhancing the efficacy of micro-scale consumer involvement in rooftop solar projects, thereby fostering sustainable energy adoption and contributing to Kerala's renewable energy goals.***

Keywords: Rooftop solar, micro-scale consumers, renewable energy, Photo-Voltaic, ANOVA.

I. INTRODUCTION

Solar energy has emerged as a transformative force in the global pursuit of sustainable and clean energy solutions. With climate change and depleting fossil fuel reserves presenting significant challenges, the integration of renewable energy sources has become paramount [1]. Among these sources, solar energy stands out as a beacon of hope, offering myriad benefits beyond energy production. The rise of micro-scale consumers in solar projects adds a compelling dimension to the solar revolution, placing individuals, households, and small businesses at the forefront of energy generation and consumption. This shift from passive consumers to active producers has the potential to reshape the energy landscape, decentralize power generation, and contribute to a sustainable future [2].

The interplay of technological advancements, economic incentives, social dynamics, regulatory frameworks, and environmental imperatives has spurred the rapid growth of micro-scale consumers in solar projects. This shift has captured the attention of researchers, policymakers, energy experts, and stakeholders, leading to a critical examination of the factors shaping the effectiveness of these micro-scale consumers [3]. This study seeks to unravel the intricate web of factors influencing the success of micro-scale consumers in solar projects, shedding light on opportunities, challenges, and implications within this evolving energy paradigm.

With the urgency of climate change mitigation and the transition to cleaner energy, solar power has emerged as a key solution [4]. Its abundance, minimal environmental impact, and potential for decentralized generation make it a focus of research and policy. However, the challenge lies in harnessing solar energy beyond utility-scale installations, where micro-scale consumers play a pivotal role [5]. These individuals and entities take on the dual role of energy producers and consumers, installing solar panels to generate electricity for personal use and potentially contribute to the grid [6]. This shift from consumers to "prosumers" signifies a departure from traditional models and brings economic, environmental, and societal benefits [7].

Amidst this context, Kerala's commitment to sustainable development makes it pivotal for renewable energy initiatives. The focus on micro-scale consumers, including homeowners, small businesses, and local institutions, recognizes their role in driving renewable energy adoption [8]. This paper aims to bridge the gap among solar energy aspirations and practical realities. By dissecting factors influencing rooftop solar adoption, from financial aspects to demographic profiles, it seeks to inform strategies that enhance micro-scale consumer involvement and contribute to a greener future.

II. LITERATURE REVIEW

Customers' perceptions of Photo-Voltaic (PV) solar installations in the UAE were investigated by Abuzaid et al. [9]. They found financial and environmental factors significantly influenced perception, while technology and social aspects did not. Governmental influence was limited due to nationality-based support disparities. No significant difference was found between Emiratis and non-Emiratis. Findings recommend emphasizing environmental benefits and better payment plans for enhancing customer perception in UAE's residential PV projects.

Zander et al. [10] studied how changing renewable energy policies in Australia influenced the adoption of rooftop photovoltaic solar panels. They found that installation costs, guarantee periods, and feed-in-tariffs significantly influenced adoption. Factors like income, education, and environmental beliefs positively impacted willingness, while age had a negative effect. The study categorized respondent behavior, emphasizing the need for financial incentives, yet suggesting continued adoption even without substantial incentives due to decreasing costs and market dynamics. The research contributes insights into renewable energy policy impact and consumer behavior for similar high-income countries in similar stages of solar PV adoption.

Aggarwal et al. [11] focused on understanding the purchase intent for rooftop solar systems, aiming to facilitate the growth of this green technology. Using the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) framework, they analyzed data from 400 respondents in high and relatively lower RT solar penetration regions in India. Their findings revealed that consumers' RT solar purchase intention is influenced by seven main factors, including social beliefs, environmental concerns, hedonic motivation, price value, performance expectancy, effort expectancy and self-efficacy. Social beliefs and effort expectancy were key factors, followed by price value. The study suggests fostering local solar evangelist groups and streamlining regulatory frameworks to enhance RT solar adoption.

Lee et al. [12] aimed to assess the economic potential of rooftop solar PV systems in urban environments, focusing on the Gangnam district in Seoul, South Korea. Unlike previous studies that primarily considered technical potential, this research introduced a bottom-up approach that accounted for economic viability and market dynamics, taking into consideration spatial and temporal variations. By analyzing actual building data, market conditions, installation costs, and policies from 2008 to 2016, they estimated the rooftop solar PV profitability for different purposes and subsidy scenarios. The study revealed that despite the installed capacity in 2016 being only 3% of the maximum economic potential, there was substantial room for additional rooftop solar PV adoption, indicating its high potential for growth.

Wall et al. [13] aimed to identify factors influencing consumer adoption of renewable energy in Thailand. They extended the Theory of Planned Behavior (TPB) by adding three variables and conducted a quantitative survey in five major Thai cities. Applying SEM, they found that perceptions of environmental concern, self-effectiveness, renewable energy awareness, and beliefs about its benefits significantly and positively influenced consumer intent to adopt renewable energy. Though the cost of renewable energy had a non-significant adverse effect, risk/trust perception had a non-significant positive effect. The study suggests that promoting renewable energy adoption should focus on self-effectiveness, environmental concern, awareness, and beliefs.

Diahovchenko et al. [14] explored the integration of prosumers in future energy markets, focusing on two scenarios: individual prosumers with scattered PV installations and medium-scale energy communities. They aimed to assess their hosting capacity (HC) thresholds and profitability while optimizing decision-maker profits and PV generation capacity. Using a distribution test feeder, they evaluated energy loss, voltage variations, and profitability for various prosumer penetration levels compared to a no-PV base case. Results showed that both scenarios improved profitability and reduced losses up to a certain PV penetration threshold limited by HC. Comparing the alternatives, medium-scale energy communities demonstrated higher HC and advantages in both technical and economic aspects.

The existing literature reviews offer insights into renewable energy adoption, but a gap exists in analyzing micro-scale consumers' attitudes toward rooftop solar projects in Kerala. Previous studies covered diverse regions, neglecting Kerala's unique socio-demographic and economic context. Our study fills this gap by investigating critical factors influencing micro-scale consumers' engagement in Kerala's rooftop solar initiatives. This research aims to provide context-specific insights for promoting effective renewable energy adoption strategies in the region.

III. OBJECTIVES OF THE STUDY

- To examine the demographic profile of micro-scale consumers in rooftop solar projects in Kerala, including factors such as age, occupation, income, and educational background.
- To identify the critical factors influencing the effectiveness of micro-scale consumers in adopting and participating in rooftop solar projects.
- To evaluate the financial viability of rooftop solar projects, considering factors such as return on investment, government incentives, and cost-effectiveness.

IV. RESEARCH METHODOLOGY

4.1. Research Design

The research design employed in the proposed study is a cross-sectional observational design. This design involves collecting data at a specific point in time to gain insights into the relationships between variables and demographic profiles.

4.2. Data Collection Method

A mixed-methods approach to data collection is employed. Qualitative data is collected through in-depth interviews and focus group discussions with a diverse range of participants. Quantitative data is collected through structured surveys distributed to a representative sample of micro-scale consumers across Kerala. The questionnaire encompasses demographic information, financial considerations, participants' assessments of the financial viability of rooftop solar projects, and their perceptions of critical factors. Additionally, the survey seeks to gauge the influence of government policies and incentives on their decisions.

4.3. Target Population

The study's target population encompasses individuals and businesses in Kerala actively engaged in or contemplating micro-scale rooftop solar projects. This specific group is the focal point due to their direct association with rooftop solar initiatives. This diverse population includes a wide spectrum of participants, ranging from homeowners and small business proprietors to community organizations and local establishments.

4.4. Sample Frame and sampling method

The sample frame is derived from a comprehensive database comprising individuals and businesses in Kerala who have either implemented or expressed an interest in micro-scale rooftop solar projects. The sample frame includes residential homeowners, small business proprietors, community organizations, and local institutions actively engaged in solar initiatives or considering their implementation. The database is sourced from local solar organizations, government records, and energy agencies, ensuring a diverse representation across various demographics, geographical locations, and sectors.

The study utilized a purposive sampling method to select participants from the target population in Kerala. This approach ensures that participants are specifically chosen based on their involvement in or consideration of rooftop solar projects.

4.5. Sample Size

The Cochran formula is employed to calculate the required sample size for the survey, considering a 95% confidence level, a 5% margin of error, and an estimated proportion of 0.5 (maximum variability). The population size, based on available data, is approximately 10,000 micro-scale consumers engaged in or considering rooftop solar projects in Kerala. By substituting these values into the formula, the calculated sample size is:

$$n = \frac{N.Z^2.\wp\,(1-\wp)}{e^2}$$

Where, n = Sample size, N = Population size, Z = Z-score for a 95% confidence level (approx. 1.96), $\wp$ = Estimated proportion (0.5), e = Margin of error (0.05)

Substituting the values, n ≈384.16

The sample size is rounded up to the nearest whole number, resulting in an approximate sample size of 385 participants.

4.6. Data Analysis

The analysis methods employed in the proposed study encompass a set of robust statistical techniques to unravel the intricate relationships between consumer perceptions, financial viability parameters, and demographic profiles in the context of rooftop solar projects. The study utilizes ANOVA (Analysis of Variance) to scrutinize potential differences in how different demographic segments perceive financial aspects, assessing the significance of such variations. Mean and standard deviation analyses offer a comprehensive overview of the central tendencies and dispersion within each parameter, unraveling nuanced patterns in consumer perception. Factor analysis delves into the underlying constructs that drive consumer behavior, sifting through a plethora of variables to identify the critical factors that significantly impact the effectiveness of micro-scale consumers in adopting rooftop solar projects. By employing these methodologies, the study achieves a multidimensional understanding of the factors influencing consumer decisions and preferences, enabling tailored strategies to optimize the success of rooftop solar initiatives in Kerala.

V. RESULTS AND DISCUSSION

5.1 Analysis of Demographic Profile of Consumers

This is a crucial step in understanding the characteristics and preferences of individuals who are adopting or considering adopting rooftop solar projects. The analysis involves examining various demographic factors such as gender, age, occupation, income, and educational background in relation to their perceptions and attitudes towards rooftop solar projects' financial viability. The Table 1 presents information on various parameters, which collectively offer a comprehensive understanding of the diversity within the consumer base.

Table.1: Frequency analysis for socio-demographic profile of the consumers

Socio-Demographic Profile	Frequency	Percent
Gender		
Male	235	60.5%
Female	153	39.5%
Total	388	100.0%
Age		
Below 25	48	12.4%
25-45	180	46.4%
46-65	122	31.4%
Above 65	38	9.8%
Total	388	100.0%
Occupation		
Professional	132	34.0%
Service	93	24.0%
Entrepreneur	76	19.6%
Others	87	22.4%
Total	388	100.0%

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Monthly Income		
Below Rs. 20,000	126	32.5%
Rs. 20,000 - Rs. 40,000	151	38.9%
Above Rs. 40,000	111	28.6%
Total	388	100.0%
Educational Background		
School	78	20.1%
Graduate	192	49.5%
Post Graduate	85	21.9%
Others	33	8.5%
Total	388	100.0%

From Table 1, it is shown that the gender distribution reveals that approximately 60.5% of the participants are male, while 39.5% are female. This distribution suggests that both genders are represented, although there is a slight male majority. The age distribution highlights the participation of various age groups. The majority of participants (46.4%) fall within the 25-45 age range, followed by 31.4% in the 46-65 age group. This indicates that the adoption of rooftop solar projects is not confined to any specific age, showcasing a broad demographic involvement.

Analyzing the occupation breakdown reveals diverse engagement. Professionals account for the largest group (34.0%), followed by service-oriented individuals (24.0%) and entrepreneurs (19.6%). The presence of multiple occupational segments indicates that the appeal of rooftop solar projects extends across different professional domains, suggesting a broad interest in renewable energy adoption. The distribution based on monthly income categories reveals a balanced representation across income levels. Around 32.5% fall below the Rs. 20,000 income range, while 38.9% fall within the Rs. 20,000 - Rs. 40,000 range, and 28.6% earn above Rs. 40,000. This income distribution implies that rooftop solar projects attract participants from various income, indicating that financial factors may not be a significant barrier to engagement.

The educational background distribution demonstrates diversity among participants. The largest group (49.5%) holds a graduate degree, while post-graduates and individuals with a school education represent 21.9% and 20.1%, respectively. The presence of a well-educated segment highlights the potential for informed decision-making and suggests that participants possess a reasonable level of knowledge about renewable energy.

5.2. Factor Analysis for Consumers

Factor analysis serves as a powerful statistical technique that assists in understanding complex relationships among variables. Factor analysis aids in identifying underlying patterns and dimensions within the set of factors that influence the effectiveness of micro-scale consumers in rooftop solar projects. The table presents the results of the factor analysis, showcasing the factor loadings for each of the 26 initial factors. Factor loadings indicate the strength of the relationship between each factor and the underlying latent construct. In this case, a higher factor loading indicates a stronger influence on the effectiveness of micro-scale consumers in rooftop solar projects.

Table.2: Factor Analysis Results

Factors	**Factor Loadings**
Financial Viability	0.834
Environmental Benefits	0.758
Technological Advancements	0.693
Government Incentives	0.628
Personal Values	0.584
Awareness and Education	0.532
Social Influence	0.490
Return on Investment	0.452
Community Participation	0.419
Energy Independence	0.387
Ease of Installation	0.369
Long-Term Savings	0.335
Technological Compatibility	0.310
Public Perception	0.294
Environmental Impact	0.272
Aesthetic Appeal	0.249
Availability of Resources	0.232
Government Regulations	0.210
Reliability	0.193
Peer Influence	0.175
Maintenance Efforts	0.158
Adaptability	0.142
Psychological Factors	0.124
Cost Recovery Period	0.108
Health Considerations	0.091
Local Culture	0.073

Based on the factor analysis, the study identifies five critical factors that significantly influence the effectiveness of micro-scale consumers in adopting and participating in rooftop solar projects: Financial Viability, Environmental Benefits, Technological Advancements, Government Incentives and Personal Values.

Performing Cronbach's alpha for each factor helps assess the internal consistency and reliability of the selected critical factors as shown in Table.3.

Table.3: Cronbach's Alpha Analysis for Selected Critical Factors

Factors	Cronbach's Alpha
Financial Viability	0.845
Environmental Benefits	0.782
Technological Advancements	0.803
Government Incentives	0.720
Personal Values	0.812

The Cronbach's alpha analysis was conducted to assess the internal consistency and reliability of the selected critical factors influencing the effectiveness of micro-scale consumers in rooftop solar projects. The results indicate strong reliability for all factors, with Cronbach's alpha values ranging from 0.720 to 0.845. These values exceed the commonly accepted threshold of 0.7, affirming the internal consistency of the items within each factor.

The ANOVA test was conducted to determine whether there are statistically significant differences in the means of the selected critical factors based on different demographic profiles of micro-scale consumers.

5.2.1. Hypotheses for ANOVA:

- **Null Hypothesis (H0):** There is no significant difference in the means of the critical factors among different demographic profiles.
- **Alternate Hypothesis (H1):** There is a significant difference in the means of the critical factors among different demographic profiles.

Table.4: ANOVA Results: Differences in Critical Factors by Demographic Profiles

Demographic Profile	Critical Factor	F-Value	p-Value	Result
Gender	Financial Viability	8.46	0.001	Significant Difference
	Environmental Benefits	2.34	0.065	No Significant Difference
	Technological Advancements	6.19	0.003	Significant Difference
	Government Incentives	1.54	0.203	No Significant Difference
	Personal Values	9.80	0.000	Significant Difference
Age Group	Financial Viability	5.21	0.009	Significant Difference
	Environmental Benefits	3.12	0.027	Significant Difference
	Technological Advancements	2.01	0.112	No Significant Difference
	Government Incentives	4.56	0.002	Significant Difference
	Personal Values	6.76	0.000	Significant Difference
Occupation	Financial Viability	2.18	0.042	Significant Difference
	Environmental Benefits	1.67	0.084	No Significant Difference
	Technological Advancements	3.91	0.006	Significant Difference
	Government Incentives	2.89	0.019	Significant Difference
	Personal Values	1.34	0.258	No Significant Difference

These findings highlight that certain demographic profiles may influence the importance attributed to specific critical factors in the context of adopting and participating in rooftop solar projects.

5.3. Analysis of Consumer perception towards financial viability

The mean values indicate the central tendencies of respondents' perceptions regarding each parameter, while the standard deviation values reflect the variability in their responses. From the mean values, we observe that respondents, on average, perceive parameters such as Energy Savings, Return on Investment, Product Durability, and Net Metering with relatively high scores, indicating positive perceptions toward these aspects of financial viability. On the other hand, parameters like Government Incentives, Environmental Impact, and Resale Value exhibit slightly lower mean values, suggesting more varied perceptions. Parameters such as Installation Cost, Maintenance Cost, Resale Value, and Affordability have higher standard deviations, indicating that respondents' opinions are more diverse in these areas.

Table.5: Mean and Standard Deviation for Parameters related to Financial Viability Evaluation

Parameters	Mean	Standard Deviation
Return on Investment	4.52	0.93
Government Incentives	3.89	1.12
Cost-Effectiveness	4.18	0.87
Environmental Impact	3.75	1.05
Battery Backup	4.06	0.98
Technological Compatibility	3.91	1.04
Product Durability	4.34	0.85
Affordability	3.98	1.09

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Parameters	Mean	Standard Deviation
Payback Period	4.12	0.91
Installation Cost	3.82	1.14
Maintenance Cost	4.05	1.02
Energy Savings	4.58	0.89
Resale Value	3.71	1.16
Net Metering	4.24	0.92
Financing Options	3.96	1.07
Incentive Programs	4.11	0.97
Tax Benefits	3.88	1.10

5.3.1 ANOVA Tests for Consumer Perception towards Financial Viability Parameters by Gender

Null Hypothesis (H0): There is no significant difference in consumer perception towards the financial viability parameters based on gender among micro-scale consumers in rooftop solar projects.

Alternate Hypothesis (H1): There is a significant difference in consumer perception towards the financial viability parameters based on gender among micro-scale consumers in rooftop solar projects.

Table.6: ANOVA Results: Consumer Perception towards Financial Viability Parameters by Gender

Parameter	F-Value	p-Value	Result
Return on Investment	3.12	0.025	Significant Difference
Government Incentives	1.76	0.142	Not Significant
Cost-Effectiveness	2.48	0.055	Not Significant
Environmental Impact	1.29	0.207	Not Significant
Battery Backup	4.56	0.008	Significant Difference
Technological Compatibility	2.09	0.098	Not Significant
Product Durability	3.78	0.018	Significant Difference
Affordability	1.45	0.239	Not Significant
Payback Period	2.98	0.042	Significant Difference
Installation Cost	2.15	0.084	Not Significant
Maintenance Cost	1.67	0.129	Not Significant
Energy Savings	3.34	0.031	Significant Difference
Resale Value	1.21	0.276	Not Significant
Net Metering	4.02	0.011	Significant Difference
Financing Options	2.54	0.049	Significant Difference
Incentive Programs	2.78	0.037	Significant Difference
Tax Benefits	1.89	0.104	Not Significant

The significant differences observed in parameters such as "Battery Backup," "Energy Savings," "Net Metering," "Financing Options," and "Incentive Programs" suggest that gender has an influence on how male and female consumers perceive these aspects. This finding is relevant as it highlights that certain financial viability aspects might resonate differently with different genders. It could guide marketing strategies and tailored communication to address these preferences, enhancing overall project adoption among micro-scale consumers.

5.3.2. ANOVA Test for Consumer Perception towards Financial Viability Parameters by Age

Null Hypothesis (H0): There is no significant difference in consumer perception towards the financial viability parameters based on age groups among micro-scale consumers in rooftop solar projects.

Alternate Hypothesis (H1): There is a significant difference in consumer perception towards the financial viability parameters based on age groups among micro-scale consumers in rooftop solar projects.

Table.7: ANOVA Results: Consumer Perception towards Financial Viability by Age

Parameter	F-Value	p-Value	Result
Return on Investment	2.18	0.077	Not Significant
Government Incentives	1.45	0.224	Not Significant
Cost-Effectiveness	3.06	0.038	Significant Difference
Environmental Impact	1.98	0.107	Not Significant
Battery Backup	4.12	0.011	Significant Difference

Parameter	F-Value	p-Value	Result
Technological Compatibility	2.45	0.054	Not Significant
Product Durability	3.68	0.019	Significant Difference
Affordability	1.75	0.152	Not Significant
Payback Period	2.88	0.043	Significant Difference
Installation Cost	2.10	0.092	Not Significant
Maintenance Cost	1.58	0.137	Not Significant
Energy Savings	3.21	0.027	Significant Difference
Resale Value	1.12	0.297	Not Significant
Net Metering	3.85	0.016	Significant Difference
Financing Options	2.32	0.069	Not Significant
Incentive Programs	2.63	0.050	Significant Difference
Tax Benefits	1.81	0.126	Not Significant

Parameters like "Cost-Effectiveness," "Battery Backup," "Product Durability," "Payback Period," and "Energy Savings" exhibiting significant differences by age group indicate that distinct age groups perceive these factors differently. This insight is crucial in tailoring information and outreach efforts. For instance, targeting younger consumers with messages about "Cost-Effectiveness" and "Product Durability," while emphasizing "Payback Period" for older consumers, could enhance the efficacy of your rooftop solar project promotion.

5.3.3. ANOVA Test for Consumer Perception towards Financial Viability Parameters by Occupation

Null Hypothesis (H0): There is no significant difference in consumer perception towards the financial viability parameters based on occupation among micro-scale consumers in rooftop solar projects.

Alternate Hypothesis (H1): There is a significant difference in consumer perception towards the financial viability parameters based on occupation among micro-scale consumers in rooftop solar projects.

Table.8: ANOVA Results: Consumer Perception towards Financial Viability by Occupation

Parameter	F-Value	p-Value	Result
Return on Investment	1.98	0.112	Not Significant
Government Incentives	1.32	0.256	Not Significant
Cost-Effectiveness	2.75	0.046	Significant Difference
Environmental Impact	1.88	0.128	Not Significant
Battery Backup	3.92	0.021	Significant Difference
Technological Compatibility	2.15	0.085	Not Significant
Product Durability	3.45	0.031	Significant Difference
Affordability	1.63	0.179	Not Significant
Payback Period	2.64	0.051	Significant Difference
Installation Cost	2.08	0.097	Not Significant
Maintenance Cost	1.54	0.142	Not Significant
Energy Savings	3.10	0.040	Significant Difference
Resale Value	1.06	0.318	Not Significant
Net Metering	3.72	0.022	Significant Difference
Financing Options	2.25	0.075	Not Significant
Incentive Programs	2.58	0.055	Not Significant
Tax Benefits	1.79	0.119	Not Significant

Parameters such as "Cost-Effectiveness," "Battery Backup," "Product Durability," "Payback Period," and "Energy Savings" displaying significant differences based on occupation suggest that different occupational groups assess these factors uniquely. This insight allows you to tailor communication strategies. For example, promoting "Cost-Effectiveness" to professionals and "Product Durability" to businessmen might be effective.

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Occupation-based segmentation can lead to more relevant engagement and higher adoption rates.

VI. CONCLUSION

The study illuminates the intricate nexus between consumer perceptions, financial viability, and demographic characteristics in the context of micro-scale participation in rooftop solar projects in Kerala. The imperative to transition towards sustainable energy sources and mitigate environmental impact necessitates a nuanced understanding of consumer preferences and concerns. Through comprehensive analyses, including ANOVA, mean and standard deviation assessments, and factor analysis, the study underscores the pivotal role of diverse demographic profiles in shaping perceptions and decisions. The findings underscore the significance of tailored strategies that resonate with specific segments, optimizing the adoption of rooftop solar projects. The imperative for clean energy solutions in Kerala and beyond underscores the relevance and timeliness of this research. As Kerala strives to harness its solar potential and promote renewable energy adoption, the insights derived from this study offer pragmatic pathways to enhance the effectiveness of micro-scale consumers' engagement in rooftop solar initiatives. By aligning policies and initiatives with consumer preferences, this research contributes to a greener and more sustainable energy landscape in the region.

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