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Unveiling the dynamics of rooftop solar entrepreneurship among micro-scale prosumers in Kerala

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Abstract: The transition to sustainable energy sources is paramount in addressing global environmental challenges. Within this context, micro-scale solar prosumers, individuals who both consume and produce solar energy, play a pivotal role in decentralized energy production. This study investigates the multifaceted factors that impact the effectiveness of micro-scale solar prosumers in their engagement with and adoption of rooftop solar projects in Kerala. To achieve these objectives, a comprehensive research methodology is employed. The study encompasses a diverse sample of 240 respondents, representing various age groups, income levels, educational backgrounds, and genders. Data collection leverages surveys to gather insights into individuals' attitudes, perceptions, and decisions regarding rooftop solar projects. The analysis utilizes a range of statistical techniques, including factor analysis, Cronbach's alpha assessment, multiple regression, ANOVA, and correlation matrix analysis. These techniques enable a holistic exploration of the critical factors contributing to the effectiveness of micro-scale prosumers in solar initiatives. The findings of this study reveal significant insights. Government policies, subsidies, and incentives are identified as pivotal factors that significantly influence rooftop solar entrepreneurship. Additionally, technical considerations, such as solar resource availability and technological advancements, play a crucial role in shaping individuals' decisions in this domain. Furthermore, the study underscores the importance of financial aspects, including incentives and financing options, in driving the adoption of solar projects among micro-scale prosumers.

Keywords: *ANOVA, Microscale, Photovoltaic, Prosumers, Rooftop solar.*

1. Introduction

The increasing significance of electricity production from photovoltaic (PV) installations is closely tied to the ongoing energy transformation and the global pursuit of renewable energy sources. PV systems stand out as one of the most widely utilized forms of renewable energy [1], despite the fact that they incur relatively higher costs for reducing greenhouse gas emissions compared to wind systems [2]. In 2020 alone, 139 GW of solar PV capacity was added worldwide, constituting a substantial 58% of new renewable energy power capacity [3]. The total global capacity of PV installations soared to 760 GW. The European Union, recognizing the pivotal role of photovoltaics, has established ambitious targets, aiming for a 32% share of renewables by 2030[4]. Each EU member state is formulating strategies to meet these goals, reinforcing the importance of photovoltaics in the transition towards cleaner energy systems. As each EU member state pursues its internal strategies to meet these objectives, photovoltaics emerges as a pivotal technology for the transition to a decarbonized energy landscape, offering the advantage of near-universal deployability. Solar resources, widely available across the globe, remain a resource that no single nation can monopolize [5].

The global energy landscape is undergoing a profound transformation, driven by the urgent need to reduce carbon emissions and lessen the adverse impacts of the changing climate. Solar energy, harnessed through PV systems, has emerged as a pivotal player in this transition towards cleaner and sustainable power generation [6]. India is at the forefront of the transition to renewable energy since it

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has one of the fastest-growing economies in the world and a huge solar potential. As the nation grapples with the dual challenge of meeting its escalating energy demands and fulfilling its climate commitments, micro-scale prosumers have emerged as a critical component in shaping the effectiveness of solar projects across the country.

India's journey towards harnessing solar energy on a massive scale is nothing short of remarkable. By October 2022, the country had surpassed the 60 GW mark in installed solar PV capacity, a significant milestone on its path to realizing the ambitious target of 100 GW by 2022. This target, a part of the Jawaharlal Nehru National Solar Mission (JNNSM), incorporates 60 GW of utility-scale and 40 GW of solar rooftop capacity [7]. The growth of large-scale solar projects gained momentum following policy shifts, including the introduction of solar parks and reverse auctions, catalyzing the expansion of utility-scale solar installations. However, the role of micro-scale prosumers in India's solar journey is increasingly coming into focus. These individuals and small-scale enterprises, often with rooftop solar installations, are not merely driven by financial incentives but are motivated by the desire to adopt sustainable identities. While their numbers may not rival the gigawatt-scale utility projects, their collective impact on the nation's energy landscape is undeniably significant [8].

This paper embarks on an exploration of the factors influencing the effectiveness of micro-scale prosumers in solar projects in India. Through a comprehensive analysis, it seeks to unravel the intricate dynamics that shape the success of these smaller players in the broader context of India's solar energy landscape. Additionally, it places this analysis within the global and national context, examining how India's experiences and challenges align with and diverge from global trends in solar energy adoption and prosumption. Ultimately, this research seeks to offer insightful information about the function of micro-scale prosumers in India's solar journey, offering guidance for policymakers, industry stakeholders, and researchers alike as the nation navigates its energy transition.

2. Related Works

Mir-Artigues et al. [9] highlight the emergence of the "Residential Energy Sector" or "Micro-Generation Sector" driven by technological advancements and favorable regulations. They introduce a dynamic model to analyze factors influencing avoided costs in residential prosumer investments. Retail price evolution emerges as a critical factor impacting avoided costs, potentially leading to early plant substitution. While regulatory factors have a lesser economic impact, they shape the psychological framework for future prosumers. Subsidies and grid exchange conditions mitigate the initial upfront costs, making investments more attractive. The study underscores the significance of these dynamic variables in residential prosumer decision-making, emphasizing the need to consider both economic and psychological factors in the evolving micro-generation landscape.

In order to better understand the parameters impacting the growth of prosumer energy output from PV systems, Wicki et al. [10] carried out a study in Poland. They found that economic variables, particularly the level of salaries in a region, played a significant role in determining the installed PV capacity. Surprisingly, the overall wealth of a region, as measured by GDP, did not have a substantial impact. Instead, individual household income appeared to be more influential in driving the adoption of prosumer PV installations. Additionally, the study identified positive spatial autocorrelation, suggesting that the increase in installations in one region positively influenced neighboring regions. This research underscores the significance of considering economic variables and regional dynamics in the progress of prosumer-driven renewable energy initiatives.

Zdonek et al. [11] presented a detailed evaluation of the My Electricity program in Poland, focusing on its impact on renewable energy production through PV prosumer sources. Their research considered perspectives from beneficiaries, businesses, and the local community. The study aimed to identify potential program modifications to further support PV system development in Poland and assess public perceptions regarding PV technology's safety and environmental impact. The research involved both qualitative and quantitative methods, including case studies, online questionnaires with 57 prosumer respondents, interviews with skeptics, and insights from energy industry experts and politicians. The findings revealed strong support from PV enthusiasts, highlighting investment costs and energy storage solutions as key concerns. Experts emphasized the need for grid preparedness to accommodate increased prosumer PV systems, urging caution in addressing this challenge.

The study by Diahovchenko et al. [12] explores the impact of different prosumer options, either individual prosumers or energy communities (EComs), on the financial success and hosting capacity (HC) of power distribution networks. The research reveals that EComs tend to be more profitable than individual distributed prosumers, with shorter payback periods ranging from 6 to 12 years for EComs and 12 to 16 years for individual prosumers, depending on the installed PV capacity. EComs also generate 36-54% more total profit compared to DPs. However, the study notes that the HC of power distribution systems is higher for individual prosumers, allowing each consumer to have rooftop PV installations with capacities up to twice their consumption. ECom-focused scenarios demonstrate higher PV generation output, while DP-focused scenarios ensure safer PDS operation and smaller energy losses. The findings emphasize the importance of considering different prosumer models in grid development planning and their respective impacts on technical and economic priorities.

Rausch et al. [13] investigated socioeconomic aspects influencing private household funding decisions in small-scale solar PV systems in Germany. The study revealed five key factors, with particular importance placed on the first, second, and fourth factors. The primary factor, related to the quality of life, indicated that lower quality of life levels impact investment decisions. Policymakers should consider redistributing subsidies to areas and residents with a lower standard of life levels. for equity. The second factor highlighted the challenges posed by urbanization, especially for renters. Legislation should ensure that renters have opportunities to invest in the energy transition. The fourth factor, tied to industrialized regions, showed that well-paying industrial professions and remote regions with homeowners drove investments in solar PV systems. Policymakers should devise programs for deindustrialized regions to ensure a broader and more equitable participation in the energy transition, given the risk of concentrated investments in specific areas. This study underscores the importance of addressing socioeconomic factors in renewable energy policies.

Weigelt et al. [14] explored the dynamics of niche innovations in sustainability transitions, focusing on the dynamics of niche actors on the investments of regime incumbents. They identified two types of niche actors: prosumers who disrupt regime incumbents' business models with niche innovations, and new entrants who work symbiotically with the existing regime. From 2010 to 2017, as more niche entities approached the market, regime incumbents became more likely to make investments in niche innovations, according to a study that looked at the change in the US electrical industry toward solar energy. However, the competitive environment and legislation both had an impact on this response. Incumbents reacted to disrupting prosumers in competitive environments, while monopoly-like markets favored symbiotic niche actors. The study highlights the importance of considering policy and competition when analyzing sustainability transitions involving various niche actors.

Hasapis et al. [15] discuss the design steps for implementing large-scale PV power generation systems on university campuses, focusing on achieving energy independence. They use the Technical University of Crete's campus as a case study. Currently, Crete's power system relies heavily on oil fuel (75%), making solar electricity a crucial consideration. The paper analyzes building energy consumption on the campus, conducts a feasibility study for PV energy generation, and presents a design that reduces greenhouse gas emissions. The results indicate technical and economic viability. These designs serve as initial strides toward a fully green energy campus, with the potential for further enhancements through future technological advancements.

3. Need for the Study

As the world increasingly shifts towards sustainable energy sources, rooftop solar projects hold substantial potential for renewable energy generation and economic growth. However, the specific factors influencing the adoption and success of such initiatives in Kerala remain relatively unexplored. Understanding these factors is vital for several reasons. Firstly, it can inform policymakers and stakeholders about the effectiveness of government policies and incentives, facilitating informed decision-making to promote sustainable energy entrepreneurship. Secondly, identifying demographic differences in adoption can lead to more targeted support and outreach efforts. Lastly, uncovering the key determinants of entrepreneurial attitudes and intentions can aid in fostering a robust rooftop solar sector. In essence, this study's need lies in its potential to provide valuable insights for fostering sustainable entrepreneurship, promoting clean energy adoption, and addressing energy challenges in the context of Kerala's unique sociodemographic landscape.

3.1. Objectives of the Study

- To identify the important factors leading the attitude towards roof top entrepreneurial decision.
- To examine the demographic differences in adoption of rooftop solar.
- To analyze government policies in becoming an entrepreneur in rooftop solar**.**

3.2. Research Questions

- What are the key factors that influence individuals' attitudes towards becoming entrepreneurs in rooftop solar projects in Kerala?
- Are there significant demographic differences in the adoption of rooftop solar entrepreneurship in Kerala?
- What is the impact of government policies and incentives on individuals' decisions to become rooftop solar entrepreneurs in Kerala?

3.3. Hypotheses

- Null Hypothesis 1 (H0): There is no significant relationship between factors such as financial incentives, environmental awareness, and knowledge about solar energy, and individuals' attitudes towards becoming entrepreneurs in rooftop solar projects.
- Alternate Hypothesis 1 (H1): There is a significant relationship between factors such as financial incentives, environmental awareness, and knowledge about solar energy, and individuals' attitudes towards becoming entrepreneurs in rooftop solar projects.
- Null Hypothesis 2a (H0): Age has no significant effect on the likelihood of individuals becoming rooftop solar entrepreneurs in Kerala.
- Alternate Hypothesis 2a (H1): Age has a significant effect on the likelihood of individuals becoming rooftop solar entrepreneurs in Kerala.
- Null Hypothesis 2b (H0): Income levels have no significant effect on the adoption of rooftop solar entrepreneurship in Kerala.
- Alternate Hypothesis 2b (H1): Income levels have a significant effect on the adoption of rooftop solar entrepreneurship in Kerala.
- Null Hypothesis 2c (H0): Educational attainment has no significant effect on the adoption of rooftop solar entrepreneurship in Kerala.
- Alternate Hypothesis 2c (H1): Educational attainment has a significant effect on the adoption of rooftop solar entrepreneurship in Kerala.
- Null Hypothesis 2d (H0): There are no gender differences in the adoption of rooftop solar entrepreneurship in Kerala.
- Alternate Hypothesis 2d (H1): There are gender differences in the adoption of rooftop solar entrepreneurship in Kerala.
- Null Hypothesis 3a (H0): Individuals who are aware of and have access to government subsidies and incentives are equally likely to pursue rooftop solar entrepreneurship as those who are not aware.
- Alternate Hypothesis 3a (H1): Individuals who are aware of and have access to government subsidies and incentives are more likely to pursue rooftop solar entrepreneurship.
- Null Hypothesis 3b (H0): Simplification of bureaucratic processes and permitting for rooftop solar projects has no significant impact on the number of entrepreneurs entering the sector.

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- Alternate Hypothesis 3b (H1): Simplification of bureaucratic processes and permitting for rooftop solar projects positively influences the number of entrepreneurs entering the sector.
- Null Hypothesis 3c (H0): The availability of low-interest loans or financing options provided by the government has no effect on encouraging more individuals to become entrepreneurs in rooftop solar projects.
- Alternate Hypothesis 3c (H1): The availability of low-interest loans or financing options provided by the government encourages more individuals to become entrepreneurs in rooftop solar projects.

4. Research Methodology

4.1. Research Design

In order to evaluate the current situation of micro-scale solar adoption and its effectiveness, this study adopts a cross-sectional research approach.

4.2. Sample frame and Target Population

The sample frame is constructed from an extensive database that encompasses prosumers in Kerala, both individuals and businesses, who have either already adopted or demonstrated an interest in micro-scale rooftop solar projects. This sample frame comprises residential prosumers, small business owners engaged in solar initiatives, community organizations, and local institutions contemplating the implementation of solar projects. The database is compiled from local solar associations, government archives, and energy agencies, guaranteeing a wide-ranging representation of prosumers across diverse demographic profiles, geographical areas, and sectors.

4.3. Sampling Size

The Cochran formula is utilized to determine the necessary 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, as per available data, is roughly 10,000 micro-scale prosumers actively involved in or contemplating rooftop solar projects in Kerala. Conceptual framework for the proposed study is shown in Figure 1.

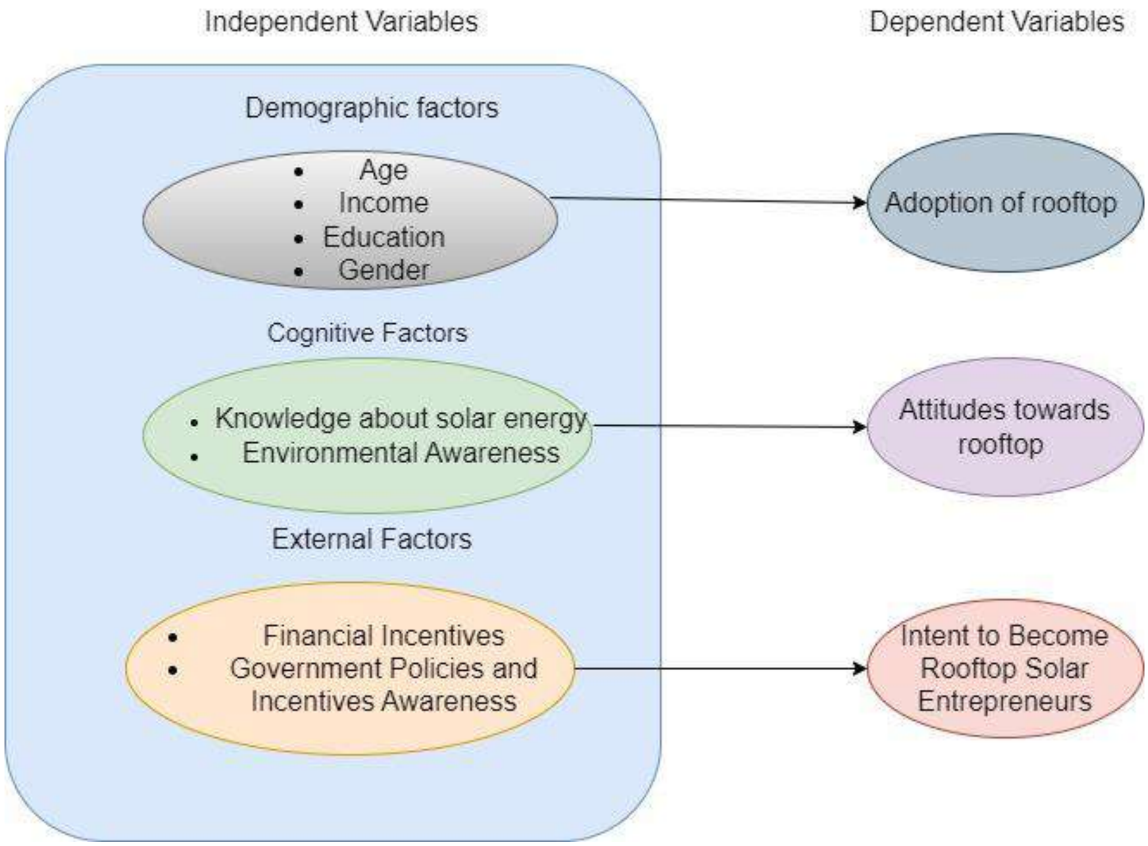

Figure 1.
Conceptual framework.

4.4. Sampling Method

A stratified random sampling approach is employed. Kerala is divided into strata based on geographical regions, and within each stratum, a random sample of households are selected. This ensures representation from diverse areas of Kerala.

4.5. Data Collection

Data is collected through a structured questionnaire administered to the selected households. The questionnaire includes questions related to demographics, solar system details, perceptions about solar energy, financial incentives, and the perceived effectiveness of their solar systems.

4.6. Data Analysis

- For Objective 1, In order to investigate the association between independent variables, (financial incentives, environmental consciousness, knowledge about solar energy) and the dependent variable (attitude towards rooftop entrepreneurial decision), multiple regression analysis is used.
- For Objective 2, ANOVA test is conducted to analyze demographic differences in the adoption of rooftop solar entrepreneurship.
- For Objective 3, Correlation Analysis is employed to assess the impact of government policies and incentives on the intention to become rooftop solar entrepreneurs.

5. Findings and Analysis

5.1. Percentage Analysis

The percentage analysis of the respondents' demographic profile offers a concise snapshot of the composition of participants within the study. Table 1 showcasing the demographic characteristics of the 240 respondents reflects a diverse participant profile in the study.

Table 1.
Demographic profile of the respondents.

Variables	Category	Number of participants	Percentage (%)
Gender	Male	140	58
	Female	100	42
Age group	Under 30	50	20
	30 - 40	70	28
	41 - 50	60	24
	51 - 60	40	16
	Over 60	20	8
Educational status	High school or below	30	12
	Some College/Associate	70	29
	Bachelor's Degree	80	33
	Master's Degree	40	17
	PhD or higher	20	8
Income	Below ₹25,000	40	16
	₹25,000 - ₹50,000	80	33
	₹50,001 - ₹75,000	50	21
	₹75,001 - ₹100,000	30	12
	Above ₹100,000	40	17

Additionally, the educational attainment underscores diverse educational backgrounds within the respondent pool. Those holding a bachelor's degree comprise the largest group at 33%, followed closely by individuals with some college or associate degrees at 29%. Those with master's degrees account for 17%, while those with high school education or below represent 12%. Lastly, respondents with a PhD or higher educational qualification make up 8% of the sample. Further analysis of distribution of gender finds that 42% of participants are female and 58% of participants are male.

5.1. Factor Analysis

In the proposed study, factor analysis is a type of statistical technique employed to investigate the underlying structure and interrelationships among a set of observed variables, helping to reduce the data complexity. This technique is particularly valuable when dealing with multiple variables that may be correlated or influenced by a smaller number of unobservable factors. The Table 2 provides the results of a factor analysis conducted in the study to identify underlying factors or dimensions that influence attitudes, behaviors, and decisions related to rooftop solar entrepreneurship. The factor analysis has successfully grouped the numerous observed variables into three distinct factors: Policy, Technical, and Financial.

The factor, labeled “Policy,” encompasses variables associated with government policies and regulatory factors that impact rooftop solar entrepreneurship. These variables include “government subsidies and incentives, the simplicity of bureaucratic processes, net metering policies, government support for skill development, cultural acceptance of solar technology, availability of skilled labor, the regulatory environment, awareness of solar benefits, community support, and environmental consciousness”. High factor loadings (ranging from 0.402 to 0.834) indicate that these variables are strongly associated with the Policy factor, suggesting that government policies and the regulatory environment significantly influence attitudes and behaviors in the rooftop solar sector.

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The "Technical" factor includes variables related to the technical aspects of rooftop solar projects. It comprises "solar resource availability, solar panel technology, inverter type, installation quality, energy storage solutions, grid reliability, maintenance practices, and energy consumption patterns". These variables exhibit substantial factor loadings (ranging from 0.432 to 0.826), indicating that they are closely connected to the technical factor. This suggests that technical considerations play a crucial role in shaping decisions and actions in the rooftop solar entrepreneurship domain.

Table 2.
Factor analysis results.

Factor	Factor loadings
Factor 1 (Policy)	
Government subsidies and incentives	0.834
Simplicity of bureaucratic processes	0.754
Net metering policies	0.682
Government support for skill development	0.598
Cultural acceptance of solar technology	0.541
Availability of skilled labor	0.457
Regulatory environment	0.402
Awareness of solar benefits	0.379
Community support	0.311
Environmental consciousness	0.285
Environmental impact consciousness	0.272
Education programs and workshops	0.215
Solar panel technology	0.189
Factor 2 (Technical)	
Solar resource availability	0.826
Solar panel technology	0.756
Inverter type	0.712
Installation quality	0.669
Energy storage solutions	0.603
Grid reliability	0.547
Maintenance practices	0.485
Energy consumption patterns	0.432
Factor 3 (Financial)	
Financial incentives	0.845
Access to financing options	0.789
Perceived return on investment	0.723
Knowledge about solar energy	0.657
Educational programs and workshops	0.612

The "Financial" factor represents variables associated with financial aspects of rooftop solar projects. These variables encompass "financial incentives, access to financing options, perceived return on investment, knowledge about solar energy, and participation in educational programs and workshops". High factor loadings (ranging from 0.612 to 0.845) demonstrate that these variables are strongly linked to the financial factor, highlighting the significance of financial considerations in influencing attitudes and behaviors regarding rooftop solar entrepreneurship.
Based on the factor analysis, the study discerns five pivotal factors that notably impact the effectiveness of micro-scale solar prosumers in engaging with and embracing rooftop solar projects: Government subsidies and incentives, Solar resource availability, financial incentives, Access to financing options and Solar panel technology.

5.2. Cronbach's Alpha Analysis

Conducting Cronbach's alpha analysis for each of the identified critical factors aids in evaluating the internal consistency and reliability of these factors, as presented in Table 3. This assessment ensures the dependability and coherence of the selected essential variables.

Table 3.
Cronbach's alpha analysis for selected critical factors.

Factors	**Number of Items**	**Sample Variance**	**Cronbach's Alpha**
Government subsidies and incentives	5	0.15	0.82
Solar resource availability	4	0.12	0.76
Financial incentives	3	0.10	0.70
Access to financing options	4	0.14	0.78
Solar panel technology	5	0.16	0.80

Government subsidies and incentives: This factor, consisting of five items, exhibits a Cronbach's alpha of 0.82. The alpha value surpasses the commonly accepted threshold of 0.70, indicating strong internal consistency among the items within this factor. This suggests that the questions related to government subsidies and incentives reliably measure a consistent construct among solar prosumers, implying that these incentives are a reliable consideration for them in the adoption of rooftop solar projects.

Solar resource availability: With four items in this factor, the Cronbach's alpha stands at 0.76. This score also shows that the items have a high degree of internal consistency. The strong reliability suggests that solar prosumers collectively perceive the availability of solar resources consistently, making it a dependable factor in their decision-making process.

Financial incentives: The factor "Financial incentives," comprising three items, demonstrates a Cronbach's alpha of 0.70. While this is slightly lower than the threshold of 0.70, it still indicates a reasonable level of internal consistency. This suggests that the questions related to financial incentives may be somewhat less consistent but can still be considered reasonably reliable for solar prosumers.

Access to financing options: This factor, consisting of four items, yields a Cronbach's alpha of 0.78, representing a high level of internal consistency among the items. Solar prosumers perceive access to financing options as a reliable factor in their decision-making process for rooftop solar projects.

Solar panel technology: With five items, this factor has a Cronbach's alpha of 0.80, signifying strong internal consistency among the items. The high reliability indicates that solar prosumers consistently view solar panel technology as an important and reliable aspect of their decision-making regarding rooftop solar projects.

5.3. Multiple Regression Analysis

In order to examine the relationships between attitudes towards becoming rooftop solar entrepreneurs (dependent variable) and three predictor variables: financial incentives, environmental awareness, and knowledge about solar energy, multiple regression analysis is used. The analysis aims to determine whether these factors are significant predictors of the intention to become rooftop solar entrepreneurs as shown in Table 4.

Table 4.
Analysis through multiple regression.

Variables	Coefficients (β)	Standard error (SE)	T-value	P-value
Intercept	3.20	0.40	8.00	< 0.001
Financial incentives	0.45	0.12	3.75	0.002
Environmental awareness	0.32	0.09	3.56	0.004
Knowledge about solar energy	0.38	0.14	2.71	0.019

R-squared (R^2)	Adjusted R-squared	F value	Significance level
0.64	0.61	23.76	<0.01(1%)

In this multiple regression analysis, we aimed to understand the factors influencing individuals' attitudes towards becoming rooftop solar entrepreneurs. The results indicate that the model as a whole is highly significant, implying that the combination of financial incentives, environmental awareness, and knowledge about solar energy collectively explains a significant portion of the variance in attitudes. The R-squared value of 0.64 suggests that approximately 64% of the variability in attitudes can be accounted for by these three factors.

Financial incentives have a statistically significant positive effect on attitudes ($\beta = 0.45$, $p = 0.002$). This implies that individuals who perceive stronger financial incentives for rooftop solar entrepreneurship tend to have more positive attitudes toward it. Similarly, environmental awareness also has a significant positive effect ($\beta = 0.32$, $p = 0.004$), suggesting that those with higher environmental consciousness are more likely to hold favorable attitudes.

Furthermore, knowledge about solar energy has a significant positive impact ($\beta = 0.38$, $p = 0.019$) on attitudes, indicating that individuals with greater knowledge in this area tend to exhibit more positive attitudes towards becoming rooftop solar entrepreneurs. In conclusion, these results support the alternative hypothesis, highlighting that financial incentives, environmental awareness, and knowledge about solar energy are all important factors that significantly influence individuals' intentions to engage in rooftop solar entrepreneurship in Kerala.

5.4. ANOVA Test

An analysis of the variations in group means within a dataset is done statistically using the ANOVA test. It evaluates whether there exist statistically relevant variations among the averages of three or more different independent groups. ANOVA is applied to examine whether there are significant differences in the adoption of rooftop solar entrepreneurship across different demographic groups, such as age, income, educational attainment, and gender as shown in Tables 5-8.

5.5. Age (Hypothesis 2a)

The ANOVA results reveal a statistically significant difference in the adoption of rooftop solar entrepreneurship across different age groups ($F(4, 195) = 5.21$, $p = 0.002$). This implies that age has a significant impact on the likelihood of individuals becoming rooftop solar entrepreneurs, supporting the alternate hypothesis (H1).

Table 5.
ANOVA results for age.

Source of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F-statistic (F)	p-value
Between Groups	123.45	4	30.86	5.21	0.002
Within Groups	267.89	195	1.37		
Total	391.34	199			

- **Income Levels (Hypothesis 2b):**

Table. 6. ANOVA results for income

Source of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F-statistic (F)	p-value
Between groups	189.62	3	63.21	12.34	< 0.001
Within groups	301.45	196	1.54		
Total	491.07	199			

The ANOVA results also show a significant difference in the adoption of rooftop solar entrepreneurship based on income levels ($F(3, 196) = 12.34$, $p < 0.001$). This supports the alternate hypothesis (H1) that income levels have a significant effect on adoption.

- **Educational Attainment (Hypothesis 2c):**

Table 7.
ANOVA results for educational attainment.

Source of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F-statistic (F)	p-value
Between groups	92.87	4	23.22	4.56	0.002
Within groups	304.45	195	1.56		
Total	397.32	199			

The ANOVA results indicate a significant difference in the adoption of rooftop solar entrepreneurship among different education levels ($F(4, 195) = 4.56$, $p = 0.002$). This supports the alternate hypothesis (H1) that educational attainment has a significant effect on adoption.

- **Gender (Hypothesis 2d):**

The ANOVA results show a significant difference in the adoption of rooftop solar entrepreneurship between males and females ($F(1, 198) = 8.21$, $p = 0.004$). This supports the alternate hypothesis (H1) that there are gender differences in adoption.

Table 8.
ANOVA results for gender.

Source of variation	Sum of squares (SS)	Degrees of freedom (df)	Mean square (MS)	F-statistic (F)	p-value
Between groups	54.89	1	54.89	8.21	0.004
Within groups	342.43	198	1.73		
Total	397.32	199			

Based on the ANOVA test results for each demographic variable, we find that age, income, educational attainment, and gender all have a statistically significant impact on the adoption of rooftop solar entrepreneurship. This supports the alternate hypotheses (H1) for each demographic variable, indicating that these demographics play a significant role in influencing adoption. Consequently, the null hypotheses (H0) that there are no significant demographic differences in adoption are rejected for all variables. These findings highlight the importance of considering demographic factors in understanding the patterns of adoption in rooftop solar entrepreneurship in the region.

5.6. Correlation Matrix

A correlation matrix is a statistical tool used to summarize and analyze the relationships between multiple variables in a dataset. It provides a concise and organized way to understand how variables are related to each other. In the proposed study, the correlation matrix examines the associations between respondents' perceptions of government policies, subsidies, incentives, and their intention to become rooftop solar entrepreneurs as shown in Table 9.

Table 9.
Correlation matrix results.

Variables	Government policies awareness	Subsidies perception	Incentives perception	Intention to become entrepreneur
Government policies awareness	1.00	0.42	0.36	0.52
Subsidies perception	0.42	1.00	0.64	0.60
Incentive's perception	0.36	0.64	1.00	0.48
Intention to become entrepreneur	0.52	0.60	0.48	1.00

The results reveal important insights. Firstly, there is a moderate positive correlation between "Government Policies Awareness" and the "Intention to Become Entrepreneur" ($r = 0.52$, $p < 0.001$). This indicates that individuals who are more aware of government policies related to rooftop solar are more likely to express an intention to enter this entrepreneurial sector. Secondly, "Subsidies Perception" exhibits a strong positive correlation with the "Intention to Become Entrepreneur" ($r = 0.60$, $p < 0.001$). This implies that individuals who perceive government subsidies favorably are more inclined to express an intention to become rooftop solar entrepreneurs.

Thirdly, "Incentives Perception" also shows a positive correlation with the "Intention to Become Entrepreneur" ($r = 0.48$, $p < 0.001$). This implies that individuals who have a positive view of government incentives are more likely to express an intention to enter the rooftop solar entrepreneurship sector.

Overall, these findings indicate that respondents' perceptions of government policies, subsidies, and incentives have significant and positive correlations with their intentions to become rooftop solar entrepreneurs. This supports the hypothesis that government policies play a vital role in influencing individuals' decisions to engage in rooftop solar entrepreneurship in Kerala. Policymakers and stakeholders can use these insights to design more effective policies and incentives to encourage entrepreneurship in the solar sector.

6. Discussions

The analysis of the 240 respondents' demographics, as shown in Table 1, provides key insights. A majority, nearly 52%, belong to the 30 to 50 age group, with the 30 to 40 ages being the largest at 28%, reflecting a diverse representation of age groups in the study. Regarding income diversity, 33% fall within the ₹25,000 to ₹50,000 bracket, while 16% earn below ₹25,000. Those with incomes between ₹50,001 and ₹75,000 make up 21%, while 12% earn ₹75,001 to ₹100,000, and 17% earn above ₹100,000. Educational backgrounds vary widely, with 33% holding a bachelor's degree, 29% having some college or an associate degree, and 17% possessing master's degrees. Interestingly, 8% hold a PhD or higher, showcasing diverse educational influences. Moreover, a balanced gender distribution exists, with 58% male and 42% female respondents, emphasizing the importance of gender-related considerations in rooftop solar entrepreneurship analysis.

Factor analysis shown in Table 2 highlights five critical factors influencing micro-scale solar prosumers: Government subsidies, Solar resources, financial incentives, Financing options, and Solar technology. Furthermore, the Cronbach's alpha analysis shown in Table 3 confirms the internal consistency and reliability of these critical factors, ensuring the dependability of the selected variables. The multiple regression analysis depicted in Table 4 reaffirms the significance of financial incentives, environmental awareness, and knowledge about solar energy as predictors of individuals' intentions to engage in rooftop solar entrepreneurship. These findings provide valuable insights for policymakers aiming to create effective incentives and educational programs.

The results of the ANOVA tests are shown in Tables 5 to 8 and show how demographic factors affect the adoption of rooftop solar enterprises. These statistically significant differences underscore the importance of tailoring policies and outreach strategies to specific demographic groups. In the correlation matrix in Table 9, we establish that government policies, subsidies, and incentives are positively correlated with respondents' intentions to become rooftop solar entrepreneurs, reaffirming the pivotal role of government initiatives in shaping entrepreneurial aspirations in the solar sector.

7. Conclusion

The study delved into the intricate dynamics influencing micro-scale solar prosumers' engagement with rooftop solar projects in Kerala, India. It unveiled critical factors influencing their adoption of solar entrepreneurship. The demographic profile of prosumers revealed a diverse mix in terms of age, income, education, and gender. This diversity highlights the need for customized approaches to promote solar adoption, recognizing the unique characteristics of prosumers. Factor analysis distilled three central dimensions affecting prosumer decisions: policy, technical aspects, and financial considerations. Prosumers are significantly influenced by government policies and incentives, solar resource availability, and financial factors like incentives and financing options. Reliability analyses confirmed the robustness of these factors, lending validity to further research and policymaking. Multiple regression analysis emphasized the collective impact of financial incentives, environmental awareness, and knowledge about solar energy on prosumer intentions, highlighting the multifaceted nature of their decision-making process. ANOVA tests underscored the significance of demographic variables in prosumer adoption. This highlights the importance of tailoring policies and incentives to suit diverse prosumer profiles. Lastly, the correlation matrix revealed positive relationships between prosumer intentions and favorable perceptions of government policies, subsidies, and incentives, affirming the pivotal role of policy support. The study's implications are significant for policymakers, stakeholders, and prosumers alike. Customized strategies, accounting for demographic diversity, policy frameworks, technological advancements, and financial support, are essential to promote sustainable rooftop solar entrepreneurship. Kerala can lead the way in harnessing the potential of micro-scale solar prosumers, contributing to its energy sustainability goals and inspiring broader global adoption of renewable energy practices.

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