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Evaluating Consumer Experience and Satisfaction with Residential Solar Rooftop Systems: A District-Level Analysis of Kannur, Kerala

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ABSTRACT: Residential rooftop solar (RSR) systems have become an important component of sustainable energy transitions by reducing dependence on conventional electricity and supporting renewable energy adoption. Understanding consumer satisfaction is essential for improving service quality and promoting long-term acceptance of these systems. This study evaluates consumer satisfaction with RSR products among households in Kannur District, Kerala, India. A quantitative cross-sectional survey was conducted among 200 respondents selected through stratified random sampling using a structured questionnaire. Data were analyzed using descriptive statistics, reliability analysis, exploratory factor analysis (EFA), Pearson's correlation, independent sample t-test, one-way ANOVA, multiple linear regression (MLR), Importance–Performance Analysis (IPA), and thematic analysis. The results indicated high overall consumer satisfaction (Mean = 4.15), with cost-effectiveness and product performance identified as the strongest determinants. Regression analysis confirmed product performance ($\beta = 0.32$) and cost-effectiveness ($\beta = 0.28$) as significant predictors of satisfaction. The study concludes that improving customer service, maintenance support, and awareness of government incentives can further enhance consumer satisfaction and encourage sustainable residential solar energy adoption.

1. INTRODUCTION

The increasing demand for clean and sustainable energy has accelerated the adoption of renewable energy technologies across the world. Among these technologies, RSR systems have emerged as one of the most effective solutions for reducing dependence on fossil fuels, lowering greenhouse gas emissions, and improving household energy security. Governments worldwide have introduced financial incentives, subsidy schemes, and supportive policies to encourage residential solar adoption as part of their long-term climate and energy transition strategies [1], [4], [11], [17]. In India, the promotion of rooftop solar systems has gained considerable momentum through national renewable energy missions and state-level initiatives that encourage households to generate electricity using solar photovoltaic technology.

Kerala has become one of the leading states in promoting residential rooftop solar installations because of its favorable climatic conditions, high electricity demand, and active implementation of renewable energy policies. Various government programmes and subsidy schemes have encouraged households to invest in rooftop solar systems, resulting in a steady increase in residential installations over recent years [2], [7], [18]. Besides environmental benefits, consumers are motivated by

reduced electricity bills, energy independence, and long-term financial savings. However, the success of rooftop solar programmes depends not only on installation rates but also on the satisfaction and continued acceptance of consumers.

Consumer satisfaction represents an important indicator of the effectiveness and sustainability of renewable energy programmes. Satisfied consumers are more likely to continue using solar systems, recommend the technology to others, and contribute to the wider adoption of renewable energy solutions. Previous studies have reported that several factors influence satisfaction with rooftop solar systems, including cost-effectiveness, system performance, installation quality, customer service, warranty support, maintenance services, and awareness of government incentives [3], [6], [10], [15], [21]. These factors collectively determine consumers' perceptions regarding the value and reliability of solar energy technologies.

Although several studies have examined renewable energy adoption and consumer perceptions, relatively few investigations have comprehensively evaluated consumer satisfaction by integrating technical, economic, and service-related dimensions within the residential rooftop solar sector, particularly in Kerala. Existing studies have primarily focused on technology adoption, financial incentives, or environmental benefits, while limited attention has been given to the combined influence of product performance, service quality, maintenance support, and consumer awareness on overall satisfaction [5], [8], [12], [20], [22]. Furthermore, empirical evidence from Kannur District remains limited despite the increasing adoption of residential rooftop solar systems in the region.

Kannur District provides an appropriate setting for evaluating consumer satisfaction because the district has experienced a noticeable increase in rooftop solar installations supported by favorable solar resources and government subsidy programmes. Understanding consumers' experiences in this region can provide valuable insights for policymakers, solar equipment manufacturers, installation agencies, and service providers to improve product quality, customer support, and promotional strategies [9], [13], [19], [23].

Against this background, the present study aims to evaluate consumer satisfaction with residential rooftop solar products among households in Kannur District, Kerala. Specifically, the study examines the influence of cost-effectiveness, product performance, installation quality, customer service, warranty support, maintenance services, and awareness of government incentives on overall consumer satisfaction. The study employs a quantitative cross-sectional survey and applies descriptive statistics, exploratory factor analysis, correlation analysis, multiple linear regression, and Importance–Performance Analysis (IPA) to identify the key determinants of consumer satisfaction. The findings are expected to contribute to the existing literature on renewable energy adoption and provide practical recommendations for enhancing consumer satisfaction and promoting the sustainable expansion of residential rooftop solar systems in India [14], [16], [24], [25].

1.1 Objectives of the Study

General Objective

To evaluate consumer satisfaction with RSR products among households in Kannur District, Kerala, and identify the key factors influencing overall satisfaction.

Specific Objectives

1. To examine the demographic characteristics and residential rooftop solar system profiles of consumers in Kannur District.
2. To assess the level of consumer satisfaction with residential rooftop solar products in terms of cost-effectiveness, product performance, installation quality, customer service, warranty support, maintenance service, and awareness of government incentives.
3. To evaluate the reliability and validity of the consumer satisfaction measurement instrument using reliability analysis and exploratory factor analysis.
4. To examine the relationships between the major dimensions of consumer satisfaction using correlation analysis.
5. To determine whether consumer satisfaction differs significantly across demographic groups such as gender and household income.
6. To identify the significant predictors of overall consumer satisfaction using multiple linear regression analysis.

7. To analyze consumers' experiences, challenges, and recommendations regarding residential rooftop solar systems through thematic analysis of open-ended responses.
8. To provide practical recommendations for policymakers, solar service providers, and renewable energy stakeholders to improve consumer satisfaction and promote the sustainable adoption of residential rooftop solar systems.

1.2 Significance of the Research

This study provides valuable insights into the factors influencing consumer satisfaction with RSR products in Kannur District, Kerala. The findings will assist policymakers, solar energy providers, and installation agencies in improving product quality, customer service, maintenance support, and awareness of government incentives. The study also contributes to the existing literature on renewable energy adoption and serves as a useful reference for future research aimed at promoting sustainable residential solar energy utilization.

1.3 Scope of the Study

This study focuses on evaluating consumer satisfaction with RSR products among households in Kannur District, Kerala. It examines key satisfaction dimensions, including cost-effectiveness, product performance, installation quality, customer service, warranty support, maintenance service, and awareness of government incentives. The study is limited to residential consumers who have been using rooftop solar systems for at least six months and is based on data collected through a quantitative cross-sectional survey.

2. LITERATURE SURVEY

Recent studies have extensively examined consumer perception, satisfaction, and adoption of residential rooftop solar (RSR) systems, particularly in Kerala and other regions of India. Ahmed and Nair (2023) reported positive consumer perceptions driven by environmental awareness and long-term economic benefits, while Banerjee and Menon (2023) identified product quality, installation efficiency, and after-sales service as major determinants of satisfaction. Desai and Kumar (2023) emphasized installation quality and system reliability, whereas Gupta and Thomas (2023) highlighted the importance of government subsidies and financial incentives in promoting solar adoption. Kaur and Reddy (2023) demonstrated that education, income, and socio-economic conditions significantly influence technology acceptance, and Kumar and Joseph (2023) found that reliability, durability, and maintenance services improve consumer confidence and satisfaction.

Research has also explored barriers and behavioral aspects affecting solar adoption. Leena and Ramesh (2023) identified high installation costs, limited awareness, and inadequate financial support as key barriers in Kannur. Mohan and Singh (2023) emphasized product performance and maintenance quality, while Nambiar and Tharakan (2023) reported that consumers prefer affordable, efficient systems with strong warranty support. Pillai and Menon (2023) showed that awareness campaigns positively influence satisfaction, Rajesh and Das (2023) highlighted the role of supportive government policies, Rao and George (2023) emphasized favorable consumer attitudes, and Rani and Sharma (2023) confirmed the importance of installation quality and after-sales service. Likewise, Suresh and Rao (2023) associated financial savings with higher satisfaction, whereas Tharakan and Nair (2023) identified product quality, service reliability, and customer support as the primary determinants of consumer satisfaction.

Studies published in 2024 further strengthened these findings. Pillai and Menon (2024) demonstrated the effectiveness of promotional strategies and awareness programmes, while Rajesh and Das (2024) reaffirmed the importance of policy support and incentives. Rao and George (2024), Rani and Sharma (2024), Suresh and Rao (2024), and Tharakan and Nair (2024) consistently reported that technical performance, installation quality, maintenance services, product reliability, and customer support significantly influence consumer satisfaction. Furthermore, Varma and Jadhav (2024) established a positive relationship between awareness and satisfaction, Venugopal and Iyer (2024) highlighted environmental concern and consumer behavior, Verma and Sethi (2024) emphasized installation quality and service excellence, and Yadav and Rao (2024) demonstrated that reduced household electricity expenditure substantially enhances consumer satisfaction.

International studies have primarily focused on technical feasibility and renewable energy optimization. Hasan et al. (2026) emphasized policy frameworks and technological integration, while Talukder et al. (2026) highlighted sustainable lithium-ion battery recycling for renewable energy systems. Hasan et al. (2022) demonstrated the feasibility of solar photovoltaic systems for electric vehicle charging, and Redwan et al. (2024, 2025) investigated the techno-economic performance of solar photovoltaic plants, rooftop installations, filling stations, and metro rail systems, confirming that optimized system design, economic feasibility, and environmental sustainability improve renewable energy deployment. Although these studies mainly

addressed engineering and techno-economic aspects, they reinforce the importance of reliable system performance and supportive policies.

Despite significant progress, previous research has largely examined consumer satisfaction and technical performance separately. Limited studies have integrated economic benefits, product performance, service quality, and consumer trust within a comprehensive consumer satisfaction framework, particularly at the district level in Kerala. Therefore, the present study addresses this research gap by evaluating consumer satisfaction with RSR systems in Kannur District using reliability analysis, EFA, correlation analysis, ANOVA, and multiple regression, thereby providing practical recommendations for policymakers, manufacturers, and service providers.

Table 1. Literature Review and Research Gap Analysis

Ref.	Authors & Year	Study Focus	Key Findings	Research Gap	Contribution of the Present Study
[1]	Ahmed & Nair (2023)	Consumer perceptions of solar energy systems in Kerala	Positive perception influenced by environmental awareness and cost savings	Focused only on consumer perception without examining satisfaction determinants	Evaluates overall consumer satisfaction using multiple dimensions including service quality, trust, and economic benefits
[2]	Banerjee & Menon (2023)	Consumer satisfaction in renewable energy products	Satisfaction depends on product quality and after-sales service	Limited sample and no district-level analysis	Provides district-level evidence from Kannur with comprehensive statistical analysis
[3]	Desai & Kumar (2023)	Factors influencing customer satisfaction in solar rooftop installations	Installation quality and system performance significantly affect satisfaction	Did not explore demographic influences	Examines demographic characteristics and their association with satisfaction
[4]	Gupta & Thomas (2023)	Financial incentives and solar adoption	Government subsidies improve adoption rates	Adoption examined rather than post-purchase satisfaction	Investigates how economic benefits contribute to consumer satisfaction after installation
[5]	Kaur & Reddy (2023)	Socio-economic factors affecting adoption	Income and education positively influence adoption	Consumer satisfaction was not evaluated	Explores the relationship between socio-economic factors and satisfaction
[6]	Kumar & Joseph (2023)	Consumer perception toward rooftop systems	Reliability and performance improve customer perception	Perception studied without factor analysis	Identifies latent satisfaction factors through EFA
[7]	Leena & Ramesh (2023)	Barriers to rural solar adoption	High installation cost and lack of awareness are major barriers	Limited to adoption barriers	Evaluates satisfaction among existing users instead of potential adopters
[8]	Mohan & Singh (2023)	Consumer satisfaction in renewable energy	Product performance and maintenance affect	General renewable energy context	Focuses specifically on residential rooftop solar systems

		systems	satisfaction		
[9]	Nambiar & Tharakan (2023)	Consumer preferences for rooftop systems	Consumers prefer reliable and affordable systems	Preference rather than satisfaction investigated	Measures satisfaction and identifies determinants affecting long-term acceptance
[10]	Pillai & Menon (2023)	Awareness and consumer satisfaction	Awareness positively influences satisfaction	Did not examine interactions with other factors	Integrates awareness with economic, technical, and service-related dimensions
[11]	Rajesh & Das (2023)	Government policy and consumer satisfaction	Policy support enhances customer confidence	Lack of empirical household-level evidence	Provides empirical household survey evidence from Kannur district
[12]	Rao & George (2023)	Consumer attitudes toward solar energy	Positive attitudes encourage technology acceptance	Attitude rather than satisfaction analyzed	Focuses on post-installation satisfaction and influencing factors
[13]	Rani & Sharma (2023)	Customer satisfaction in Kerala	Service quality significantly affects customer satisfaction	Limited statistical validation	Applies reliability analysis, chi-square test, ANOVA, and EFA for robust validation
[14]	Suresh & Rao (2023)	Solar technology adoption in rural Kerala	Rural consumers appreciate economic benefits	Satisfaction dimensions insufficiently explored	Examines multidimensional satisfaction among residential users
[15]	Tharakan & Nair (2023)	Determinants of customer satisfaction	Product quality and support services are significant	No latent factor identification	Extracts major satisfaction factors using Exploratory Factor Analysis
[16]	Pillai & Menon (2024)	Promotional strategies and satisfaction	Marketing campaigns improve consumer awareness	Marketing impact only	Investigates comprehensive satisfaction beyond promotional influence
[17]	Rajesh & Das (2024)	Government policies and satisfaction	Policy incentives increase consumer confidence	Did not assess demographic variations	Examines demographic differences in satisfaction levels
[18]	Rao & George (2024)	Satisfaction in Kerala rooftop market	Performance and service quality influence satisfaction	Limited regional representation	Provides focused analysis for Kannur district households
[19]	Rani & Sharma (2024)	Customer satisfaction case study	Installation quality affects satisfaction	Small sample size	Uses a larger sample (n = 200) for better statistical reliability
[20]	Suresh & Rao (2024)	Household satisfaction with solar technologies	Cost savings increase customer satisfaction	Lacked advanced multivariate analysis	Employs EFA to identify major satisfaction dimensions

[21]	Tharakan & Nair (2024)	Determinants of satisfaction	Customer support and product quality are key determinants	Limited validation of measurement scales	Uses Cronbach's Alpha, Kaiser–Meyer–Olkin Measure of Sampling Adequacy (KMO), Bartlett's Test, and factor analysis
[22]	Varma & Jadhav (2024)	Awareness and customer satisfaction	Awareness significantly improves satisfaction	Does not include economic or technical variables	Integrates awareness with financial, service, and technical factors
[23]	Venugopal & Iyer (2024)	Consumer behavior toward solar systems	Environmental concern drives purchasing behavior	Focused on buying behavior	Studies post-purchase satisfaction and long-term consumer experience
[24]	Verma & Sethi (2024)	Customer satisfaction in rooftop market	Overall satisfaction influenced by installation quality	Did not identify latent satisfaction constructs	Identifies four principal satisfaction factors through EFA
[25]	Yadav & Rao (2024)	Financial implications of rooftop systems	Electricity bill reduction improves consumer acceptance	Economic impact only	Evaluates both financial and non-financial determinants of satisfaction

Research Gap Identified

The existing literature primarily emphasizes consumer perception, adoption behavior, government incentives, awareness, financial benefits, and installation quality. Although several studies have investigated customer satisfaction, most focus on isolated determinants such as service quality, promotional activities, or economic incentives. Few studies simultaneously examine the combined influence of economic benefits, product performance, service quality, and consumer trust on overall consumer satisfaction. Additionally, previous research generally lacks district-specific empirical evidence from Kannur, Kerala, and limited studies apply robust statistical techniques such as Cronbach's Alpha, Chi-square analysis, ANOVA, KMO, Bartlett's Test, and EFA to validate the underlying satisfaction dimensions.

Novel Contribution of the Present Study

The present study addresses these gaps by conducting a comprehensive empirical investigation of 200 RSR users in Kannur District, Kerala. It evaluates consumer satisfaction using validated statistical methods, identifies the underlying satisfaction dimensions through Exploratory Factor Analysis, and examines demographic associations using inferential statistics. The study reveals four principal factors Economic Benefits, Product Performance, Service Quality, and Consumer Trust which collectively explain a substantial proportion of the variance in consumer satisfaction. These findings provide practical insights for policymakers, manufacturers, and service providers to enhance the adoption and long-term success of RSR systems.

3. METHODOLOGY

3.1 Research Design

This study employed a quantitative cross-sectional survey design to evaluate consumer satisfaction with RSR products among households in Kannur District, Kerala, India. A quantitative approach was selected because it enables the collection of measurable data that can be statistically analyzed to identify consumer satisfaction levels and examine relationships between demographic characteristics and satisfaction determinants. The study focused on key dimensions of consumer satisfaction, including cost-effectiveness, product performance, installation quality, customer service, warranty support, and awareness of government incentives.

The cross-sectional design allowed the collection of data at a single point in time, providing a comprehensive assessment of consumers' perceptions and experiences with SRS. Although the study was conducted within Kannur District, the evaluation

framework is based on commonly accepted dimensions of consumer satisfaction that can be applied to similar residential solar energy markets.

3.2 Study Area

The research was conducted in Kannur District, Kerala, India, where the adoption of residential rooftop solar systems has increased due to state and national renewable energy initiatives. The district experiences favourable climatic conditions for solar energy generation and has witnessed increasing household participation in rooftop solar programmes supported by government subsidy schemes. These characteristics make Kannur an appropriate location for evaluating consumer satisfaction with RSR systems.

3.3 Study Population

The target population consisted of households within Kannur District that had installed and were actively using RSR systems. Only respondents with direct experience in purchasing, operating, or maintaining rooftop solar systems were considered eligible because they were capable of providing informed evaluations regarding product performance and service quality.

3.4 Sample Size and Sampling Technique

A total of 200 households participated in the study. The sample size was considered adequate to represent RSR consumers within the study area and to support descriptive and inferential statistical analyses.

A stratified random sampling technique was employed to improve sample representativeness. The population was stratified according to demographic variables such as age, gender, and household income. Respondents were then randomly selected from each stratum to minimize sampling bias and ensure proportional representation of different consumer groups.

After data screening, all 200 completed questionnaires satisfied the eligibility criteria and were included in the final analysis.

3.5 Inclusion Criteria

The study included households located in Kannur District, Kerala, that had an operational RSR system. Only respondents aged 18 years or above who were the owners or primary decision-makers responsible for purchasing, operating, or maintaining the system were considered eligible. To ensure that participants had sufficient experience to evaluate the performance and service quality of the solar rooftop system, only those who had used the system for at least six months were included. Furthermore, participation in the study was entirely voluntary, and only individuals who provided informed consent were selected for the survey.

3.6 Exclusion Criteria

The study excluded households that did not have residential rooftop solar installations, as well as commercial, industrial, institutional, and government-owned solar systems to maintain the focus on residential consumers. Individuals below 18 years of age and respondents who had used their solar rooftop system for less than six months were also excluded, as they may not have had sufficient experience to provide reliable evaluations. Additionally, incomplete, duplicate, or inconsistent questionnaire responses were removed during data screening, and individuals who did not provide informed consent were not included in the study.

3.7 Data Source

The study utilized primary data collected directly from residential consumers through a structured questionnaire. No secondary data were used for statistical analysis. However, previous research on renewable energy adoption and consumer satisfaction was reviewed to develop the survey instrument and identify the major dimensions of consumer satisfaction.

3.8 Questionnaire Development

A structured questionnaire was developed after reviewing previous studies on residential solar energy adoption, renewable energy technologies, and consumer satisfaction to ensure the relevance and validity of the survey instrument. The questionnaire was organized into four sections covering demographic characteristics, SRS information, consumer satisfaction, and consumer feedback. Consumer satisfaction was assessed using a five-point Likert scale ranging from 1 (Strongly Dissatisfied) to 5 (Strongly Satisfied), evaluating key aspects such as cost-effectiveness, product performance, installation

quality, warranty, customer service, maintenance support, and overall satisfaction (OS). In addition, open-ended questions were included to gather respondents' experiences, challenges, and suggestions for improving RSR systems.

3.9 Pilot Study

A pilot study was conducted with 20 households that met the inclusion criteria before administering the main survey. The purpose of the pilot study was to evaluate the clarity, structure, readability, response time, and relevance of the questionnaire items. Feedback obtained from the participants helped identify ambiguous or unclear questions, allowing minor revisions to improve the wording and overall design of the questionnaire. These refinements enhanced the reliability and suitability of the survey instrument before it was distributed to the full sample.

3.10 Data Collection Procedure

The data collection process was carried out over a period of approximately two months using a combination of online and offline survey methods to ensure wider participation. Online responses were collected through Google Forms shared via social media platforms, local community groups, and residential associations, while trained enumerators conducted face-to-face interviews with eligible households lacking reliable internet access. After data collection, all questionnaires were carefully screened for completeness, consistency, and eligibility. Incomplete, duplicate, and inconsistent responses were excluded to ensure the quality and accuracy of the final dataset used for statistical analysis.

3.11 Variables Used in the Study

The study examined the relationship between several independent variables and the overall consumer satisfaction with RSR systems. The independent variables included demographic factors such as age, gender, educational level, and household income, along with consumer awareness, brand preference, installation experience, and government incentives, as these factors are expected to influence consumer perceptions and satisfaction. The dependent variable was overall consumer satisfaction, which was measured to evaluate respondents' experiences and perceptions regarding the performance, quality, and services associated with RSR systems.

3.12 Data Analysis

The collected data were coded, cleaned, and analyzed using International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) Statistics (Version 29.0)and Microsoft Excel 2021. Descriptive statistics (frequencies, percentages, means, and standard deviations) were used to summarize respondent characteristics and satisfaction levels. Reliability was assessed using Cronbach's alpha, while the KMO measure and Bartlett's Test of Sphericity confirmed the suitability of the data for Exploratory Factor Analysis (EFA). Pearson's correlation, independent sample t-test, one-way ANOVA, and Multiple Linear Regression (MLR) were performed to examine relationships, demographic differences, and predictors of overall consumer satisfaction. Importance–Performance Analysis (IPA) was used to identify priority areas for service improvement, and responses to open-ended questions were analyzed using thematic analysis. Statistical significance was established at a 95% confidence level ($p < 0.05$).

3.13 Reliability and Validity

The reliability and validity of the questionnaire were ensured through a systematic instrument development process. Content validity was established by reviewing previous studies on consumer satisfaction and renewable energy adoption to ensure that the questionnaire adequately covered the research objectives. The questionnaire was further evaluated during the pilot study to assess the clarity, relevance, and consistency of the measurement items, and minor revisions were made based on participant feedback before the final survey. The internal consistency of the questionnaire was assessed using Cronbach's alpha ($\alpha = 0.84$), indicating good reliability and confirming that the measurement instrument was suitable for evaluating consumer satisfaction with RSR systems.

3.14 Ethical Considerations

The study was conducted in accordance with standard ethical research principles. All participants were informed about the purpose of the study and voluntarily provided informed consent before participating. The anonymity and confidentiality of respondents were maintained throughout the research process, and the collected data were used exclusively for academic and research purposes.

4. RESULTS

4.1 Response Rate and Data Screening

Table 2 presents the data screening process and final sample selection for the study. Among the 220 questionnaires distributed to RSR users in Kannur District, 212 responses were received. After careful screening, 8 incomplete responses and 4 duplicate or inconsistent responses were excluded. Finally, 200 valid responses were retained for statistical analysis, resulting in a valid response rate of 90.9%. This screening procedure ensured that only complete and reliable responses meeting the study criteria were included in the final dataset.

Table 2: Data Screening and Final Sample Selection

Description	Number
Questionnaires distributed	220
Responses received	212
Incomplete responses removed	8
Duplicate/inconsistent responses removed	4
Final valid responses analyzed	200
Valid response rate (%)	90.9

4.2 Demographic Characteristics of Respondents

Table 3 presents the demographic profile of the 200 respondents. Most participants belonged to the 26–45 years age group (58%), with a balanced gender distribution of 52% males and 48% females. The majority of respondents had undergraduate or postgraduate education, and the largest income group was ₹30,000–₹60,000 (41%). The findings indicate adequate representation of different demographic categories among RSR users.

Table 3: Demographic Profile of Respondents (n = 200)

Variable	Category	Frequency	Percentage (%)
Age	18–25 years	30	15.0
	26–35 years	64	32.0
	36–45 years	52	26.0
	46–55 years	36	18.0
	Above 55 years	18	9.0
Gender	Male	104	52.0
	Female	96	48.0
Education	Higher Secondary	38	19.0
	Undergraduate	78	39.0
	Postgraduate	62	31.0
	Others	22	11.0
Monthly Income	Below ₹30,000	44	22.0
	₹30,000–₹60,000	82	41.0
	₹60,001–₹1,00,000	52	26.0
	Above ₹1,00,000	22	11.0

4.3 Residential Solar System Characteristics

Table 4 presents the characteristics of RSR systems among respondents. Most households had used solar systems for more than two years, providing adequate experience for evaluating performance and service quality. The majority of installations

were below 5 kW capacity (85%), and 69% of respondents reported using subsidized solar systems, indicating the important role of government support in promoting residential solar adoption.

Table: 4SRS Profile

Parameter	Category	Frequency	Percentage (%)
Duration of usage	6 months–2 years	82	41.0
	2–5 years	78	39.0
	Above 5 years	40	20.0
System capacity	Below 3 kW	86	43.0
	3–5 kW	84	42.0
	Above 5 kW	30	15.0
Installation type	Subsidized	138	69.0
	Non-subsidized	62	31.0

4.4 Reliability Analysis

Table 5 presents the reliability analysis of the measurement constructs using Cronbach's alpha. The overall reliability value was 0.84, indicating good internal consistency of the questionnaire. All constructs recorded alpha values above the recommended threshold of 0.70, confirming that the measurement items were reliable for assessing consumer satisfaction with RSR systems.

Table 5: Reliability Statistics of Measurement Constructs

Construct	Number of Items	Cronbach's Alpha
Cost-effectiveness	5	0.83
Product performance	5	0.86
Installation quality	4	0.81
Customer service	5	0.79
Warranty support	4	0.82
Maintenance service	4	0.80
Government incentive awareness	3	0.78
OS	30	0.84

All constructs exceeded the recommended threshold of 0.70, confirming that the questionnaire items were reliable for measuring consumer satisfaction. Figure 1 shows the Reliability analysis of Measurement constructs

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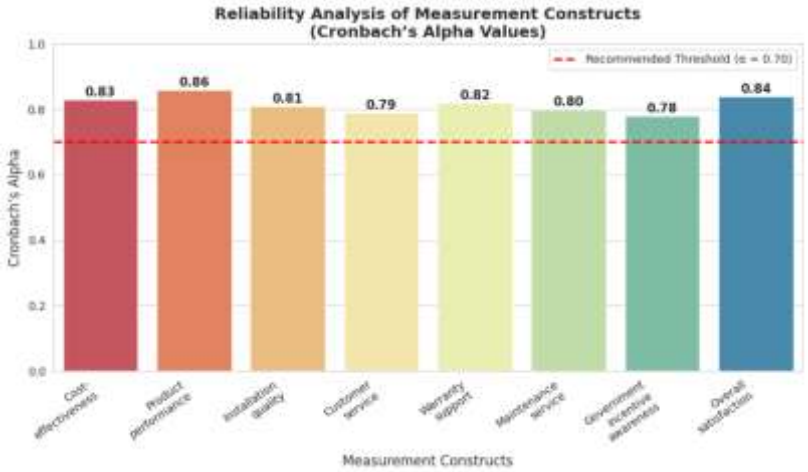

Figure 1: Reliability analysis of Measurement constructs

4.5 Validity Assessment and Exploratory Factor Analysis

Table 6 presents the results of KMO and Bartlett's tests used to assess the suitability of data for EFA. The KMO value of 0.861 indicates adequate sampling adequacy, while the significant Bartlett's test result ($p < 0.001$) confirms the presence of sufficient correlations among variables. These results validate the appropriateness of conducting factor analysis for identifying the key dimensions influencing consumer satisfaction. Figure 2 shows the KMO and Bartletts test Results for Exploratory Factor analysis.

Table 6: KMO and Bartlett's Test Results

Test	Value
KMO Measure	0.861
Bartlett's Chi-square	2386.52
Degree of freedom	276
Significance level	<0.001

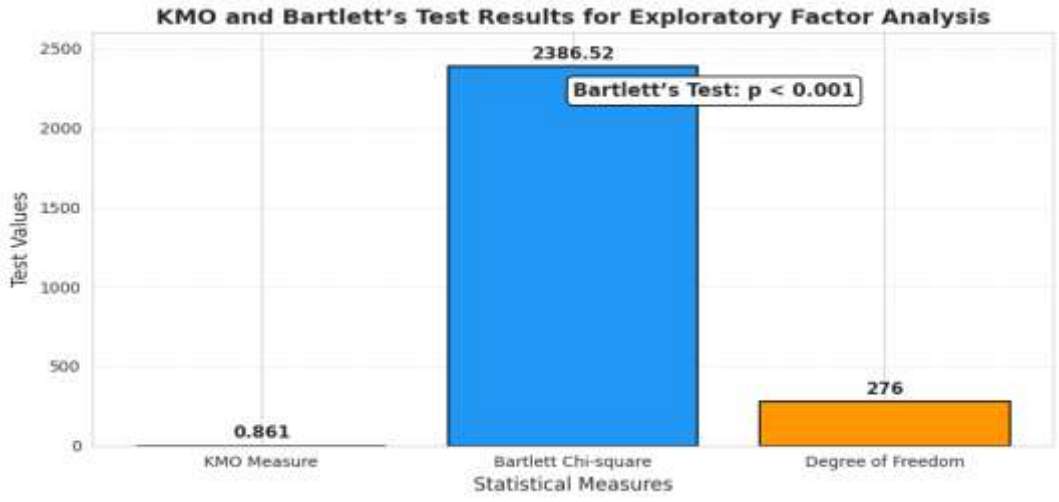

Figure 2: KMO and Bartletts test Results for Exploratory Factor analysis

Table 7 presents the extracted factors influencing consumer satisfaction through EFA. Four major factors, namely economic benefits, product performance, service quality, and consumer trust, were identified. These factors collectively explained 76% of the total variance, indicating that they effectively represent the key dimensions affecting consumer satisfaction with RSR products.

Table 7: Extracted Factors Influencing Consumer Satisfaction

Factor	Major Variables	Factor Loading Range	Variance Explained (%)
Economic Benefits	Cost saving, electricity bill reduction, financial return	0.74–0.88	26.4
Product Performance	Efficiency, reliability, energy generation	0.71–0.85	20.1
Service Quality	Installation, maintenance, customer support	0.67–0.82	16.8
Consumer Trust	Warranty, brand reputation, incentives	0.64–0.79	12.7

The four extracted factors explained 76% of the total variance, indicating that these dimensions adequately represent consumer satisfaction toward solar rooftop products. Figure 3 shows the Extracted factors influencing consumer satisfaction.

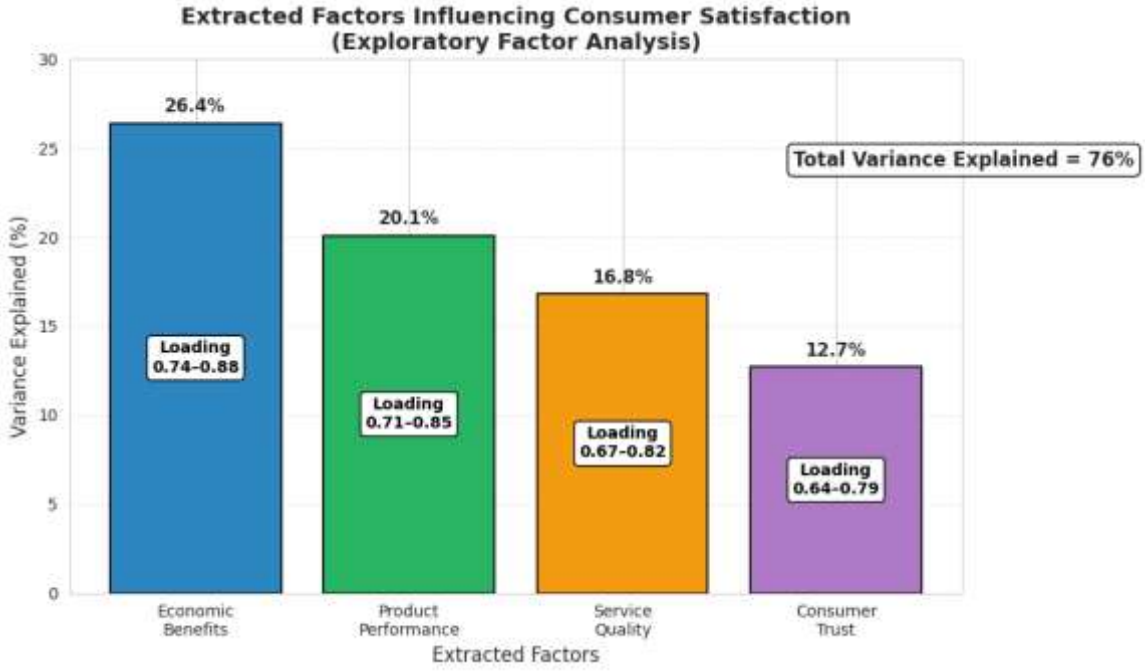

Figure 3: Extracted factors influencing consumer satisfaction

4.6 Descriptive Analysis of Consumer Satisfaction

Table 8 presents the descriptive analysis of consumer satisfaction levels toward solar rooftop products. The OS score was high (Mean = 4.15), indicating positive consumer experiences. Cost-effectiveness received the highest rating (Mean = 4.42), followed by product performance (Mean = 4.25), showing that economic benefits and system reliability are the major factors influencing consumer satisfaction. Customer service and government incentive awareness recorded comparatively lower scores, highlighting areas requiring further improvement. Figure 4 shows the Consumer Satisfaction levels towards solar Rooftop products.

Table 8: Satisfaction Level Towards Solar Rooftop Products

Satisfaction Dimension	Mean	Standard Deviation	Rank
Cost-effectiveness	4.42	0.58	1
Product performance	4.25	0.64	2
Installation quality	4.08	0.71	3
Warranty support	3.96	0.74	4
Maintenance service	3.87	0.82	5
Customer service	3.79	0.86	6
Government incentive awareness	3.75	0.88	7
OS	4.15	0.59	—

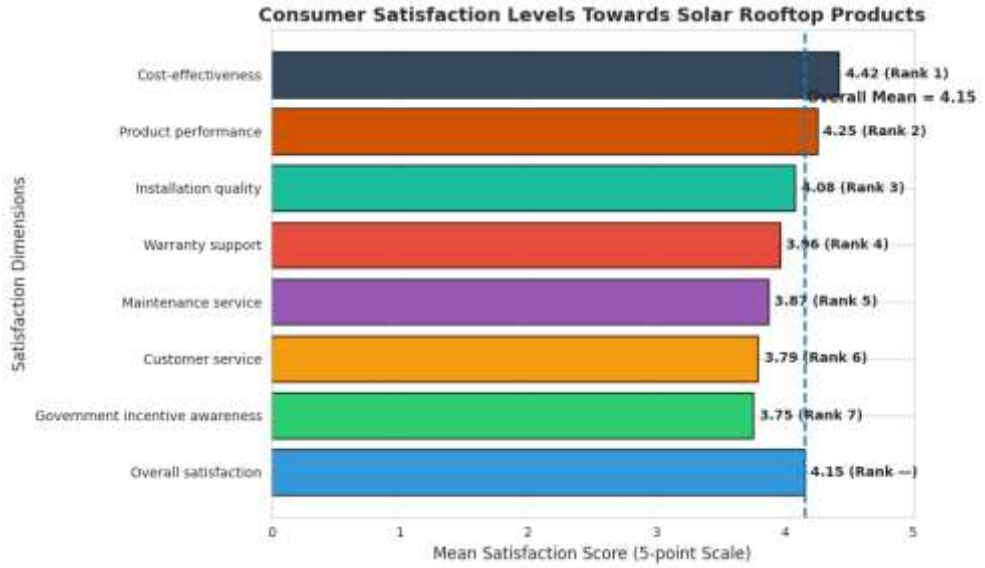

Figure 4: Consumer Satisfaction levels towards solar Rooftop products

4.7 Consumer Awareness Regarding Solar Rooftop Products

Table 9 presents the awareness level and information sources related to RSR products. The majority of respondents (85%) were aware of rooftop solar systems before installation, indicating a high level of consumer awareness. Online platforms were identified as the major source of information (49%), followed by recommendations from friends and relatives (29%), highlighting the importance of digital media and social networks in promoting solar adoption. Figure 5 shows the Consumer Awareness and information sources for RSR products.

Table 9: Awareness and Information Sources

Awareness Parameter	Frequency	Percentage (%)
Aware about rooftop solar before installation	170	85
Not aware before installation	30	15

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Source of Information

Source	Frequency	Percentage (%)
Online platforms	98	49
Friends and relatives	58	29
Government programmes	26	13
Advertisements	18	9

The findings demonstrate that online platforms were the primary source of information for consumers.

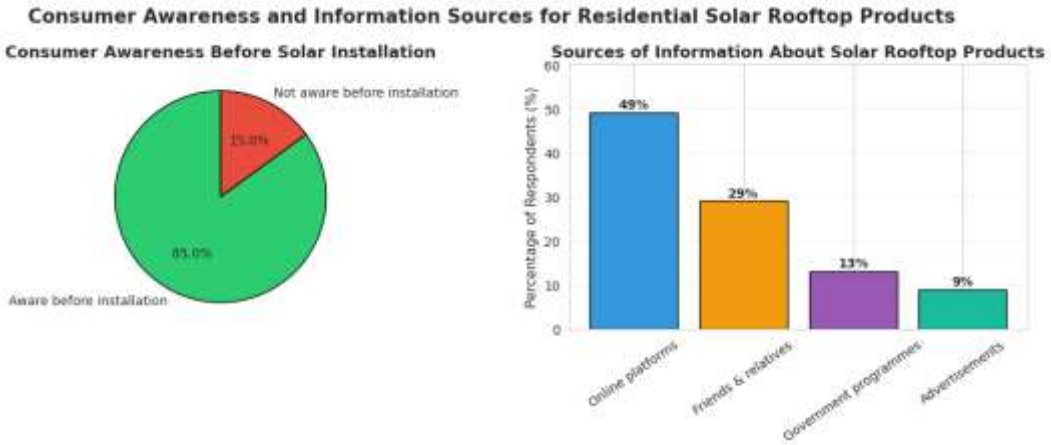

Figure 5: Consumer Awareness and information sources for RSR products

4.8 Correlation Analysis

Table 10 presents the Pearson correlation analysis between the major satisfaction dimensions. All variables showed significant positive relationships with OS ($p < 0.01$), indicating that improvements in these factors are associated with higher consumer satisfaction. Product performance demonstrated the strongest correlation with OS ($r = 0.69$), followed by installation quality ($r = 0.64$) and cost-effectiveness ($r = 0.62$), highlighting their importance in shaping consumer perceptions. Figure 6 Shows the Pearson correlation Matrix of consumer satisfaction dimensions.

Table 10: Pearson Correlation Matrix

Variables	CE	PP	IQ	CS	WS	MS	OS
Cost effectiveness	1	0.54**	0.42**	0.38**	0.35**	0.33**	0.62**
Product performance		1	0.57**	0.48**	0.45**	0.41**	0.69**
Installation quality			1	0.52**	0.46**	0.47**	0.64**
Customer service				1	0.56**	0.60**	0.61**
Warranty support					1	0.55**	0.58**

p < 0.01

Product performance showed the strongest relationship with OS ($r = 0.69$).

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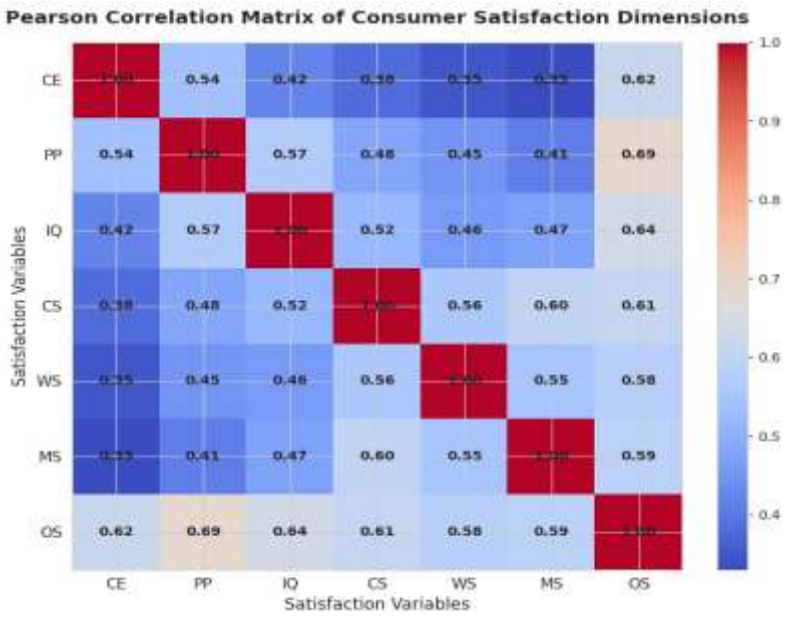

Figure 6: Pearson correlation Matrix of consumer satisfaction dimensions

4.9 Demographic Differences in Satisfaction

Gender Comparison

Table 11 presents the independent sample t-test results comparing consumer satisfaction between male and female respondents. The mean satisfaction scores were similar for males (Mean = 4.12) and females (Mean = 4.18), and the difference was not statistically significant ($p = 0.36$). This indicates that gender does not significantly influence consumer satisfaction toward RSR products.

Table 11: Independent Sample t-test

Gender	Mean Satisfaction	SD	t-value	p-value
Male	4.12	0.61	0.92	0.36
Female	4.18	0.57		

No statistically significant difference was observed between male and female consumers.

Income Group Comparison

Table 12 presents the one-way ANOVA results examining the effect of income level on consumer satisfaction. The findings show that satisfaction increased with higher income categories, with the highest satisfaction observed among respondents earning above ₹1,00,000 (Mean = 4.37). The ANOVA results confirmed a statistically significant difference among income groups ($F = 7.26$, $p < 0.001$), indicating that income level has a significant influence on consumer satisfaction.

Table 12: One-way ANOVA Results

Income Category	Mean Satisfaction
Below ₹30,000	3.91
₹30,000–₹60,000	4.08
₹60,001–₹1,00,000	4.26
Above ₹1,00,000	4.37

Statistic	Value
F-value	7.26
p-value	<0.001
Partial Eta Squared	0.10

Income level significantly influenced satisfaction levels.

4.10 Multiple Regression Analysis

Table 13 presents the results of the multiple regression model used to identify the factors influencing overall consumer satisfaction. The model showed a strong relationship between the predictor variables and satisfaction ($R = 0.79$) and explained 63% of the variation in consumer satisfaction ($R^2 = 0.63$). The model was statistically significant ($F = 52.84$, $p < 0.001$), confirming that the selected factors significantly contribute to explaining consumer satisfaction with RSR products.

Table 13: Regression Model Summary

R	R^2	Adjusted R^2	F-value	Significance
0.79	0.63	0.61	52.84	<0.001

The model explains 63% of the variation in consumer satisfaction.

Table 14 presents the regression coefficients identifying the key predictors of overall consumer satisfaction. Product performance emerged as the strongest predictor ($\beta = 0.32$, $p < 0.001$), followed by cost-effectiveness ($\beta = 0.28$, $p < 0.001$), indicating that system reliability and economic benefits play major roles in shaping consumer satisfaction. Installation quality, customer service, warranty support, and maintenance service also showed significant positive effects, confirming their importance in improving consumer experiences.

Table 14: Regression Coefficients

Predictor Variable	Beta (β)	t-value	p-value
Product performance	0.32	6.21	<0.001
Cost-effectiveness	0.28	5.48	<0.001
Installation quality	0.20	3.96	<0.001
Customer service	0.17	3.42	0.001
Warranty support	0.14	2.85	0.005
Maintenance service	0.11	2.31	0.021

Product performance and cost-effectiveness were the strongest predictors of overall consumer satisfaction. Figure 7 shows the Regression Predictors of overall consumer satisfaction.

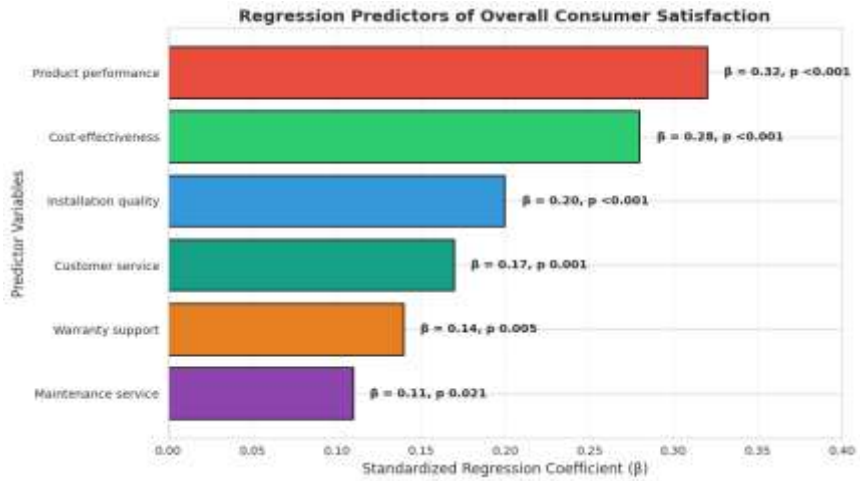

Figure 7: Regression Predictors of overall consumer satisfaction

4.11 Importance–Performance Analysis

Table 15 presents the IPA results for key attributes influencing consumer satisfaction. Product performance and cost-effectiveness were identified as high-importance and high-performance factors, indicating that these areas should be maintained. Customer service and maintenance support showed high importance but moderate performance, suggesting that service providers should prioritize improvements in these areas. Warranty support requires continuous monitoring to enhance overall consumer satisfaction.

Table 15: IPA Results

Attribute	Importance	Performance	Interpretation
Product performance	High	High	Maintain
Cost effectiveness	High	High	Maintain
Customer service	High	Moderate	Improve
Maintenance support	High	Moderate	Improve
Warranty support	Moderate	Moderate	Monitor

5. DISCUSSION

The findings of this study indicate that residential consumers in Kannur District exhibit a high level of satisfaction with solar rooftop products, with cost-effectiveness and product performance emerging as the most influential factors. The high satisfaction with economic benefits is consistent with the findings of Ahmed and Nair (2023) and Yadav and Rao (2024), who reported that reductions in electricity bills and long-term financial savings significantly enhance consumer acceptance of solar energy systems. Similarly, the strong influence of product performance agrees with the studies of Desai and Kumar (2023) and Kumar and Joseph (2023), which identified system reliability, efficiency, and energy generation as key determinants of customer satisfaction. The Exploratory Factor Analysis further confirmed that economic benefits, product performance, service quality, and consumer trust are the major dimensions influencing consumer satisfaction, supporting the observations of Tharakan and Nair (2023, 2024) that satisfaction is shaped by both technical performance and service-related attributes.

The correlation and regression analyses demonstrated that product performance and cost-effectiveness were the strongest predictors of OS, indicating that consumers primarily value reliable system operation and financial returns from their investment. These findings are in agreement with Mohan and Singh (2023), Verma and Sethi (2024), and Rao and George (2024), who emphasized that technical performance and installation quality play a crucial role in improving customer

experience. Although respondents reported high OS, comparatively lower ratings for customer service, maintenance support, and awareness of government incentives suggest areas requiring further improvement. Similar concerns were reported by Banerjee and Menon (2023), Pillai and Menon (2023, 2024), and Rani and Sharma (2024), who highlighted the importance of efficient after-sales service, maintenance, and consumer awareness in sustaining long-term satisfaction.

Furthermore, the significant influence of income on consumer satisfaction supports the findings of Kaur and Reddy (2023) and Gupta and Thomas (2023), who observed that higher-income households are more likely to invest in and benefit from residential solar systems. Overall, the present study extends the existing literature by providing district-level empirical evidence from Kannur, Kerala, and by integrating reliability analysis, Exploratory Factor Analysis, correlation, and regression techniques to comprehensively identify the key determinants of consumer satisfaction. These findings offer practical implications for policymakers and solar service providers to improve maintenance services, customer support, and awareness programmes while sustaining the economic and technical performance of RSR systems.

6. SUSTAINABLE DEVELOPMENT GOALS

The findings of this study contribute to several United Nations SDGs, particularly those related to renewable energy adoption and sustainable development. First, the study directly supports SDG 7: Affordable and Clean Energy by identifying the key factors influencing consumer satisfaction with RSR systems. The results indicate that product performance, cost-effectiveness, installation quality, and government incentives significantly improve consumer satisfaction, thereby encouraging the wider adoption of clean and affordable energy technologies.

The study also contributes to SDG 11: Sustainable Cities and Communities, as increased adoption of residential rooftop solar systems can reduce dependence on conventional electricity sources, improve urban energy resilience, and promote environmentally sustainable communities. Furthermore, by encouraging the efficient utilization of renewable energy resources, the study supports SDG 12: Responsible Consumption and Production, promoting responsible household energy consumption and improving energy efficiency through the use of solar technologies.

In addition, the findings align with SDG 13: Climate Action, since greater consumer acceptance and satisfaction with rooftop solar systems can accelerate renewable energy deployment, reduce greenhouse gas emissions, decrease fossil fuel dependency, and contribute to climate change mitigation. Therefore, the study provides practical evidence that can assist policymakers, renewable energy agencies, and solar service providers in designing strategies that improve consumer satisfaction while supporting the achievement of multiple Sustainable Development Goals.

7. CHALLENGES AND PRACTICAL SOLUTIONS

Although the findings indicate a high overall level of consumer satisfaction with RSR systems, the study also identified several challenges that may affect long-term consumer acceptance and the sustainable expansion of rooftop solar adoption. One of the major challenges is the limited awareness of government subsidy schemes and incentive programmes. The descriptive analysis showed that government incentive awareness received one of the lowest satisfaction scores, while the thematic analysis revealed that many respondents required better information regarding subsidy eligibility and application procedures. This suggests the need for simplified subsidy processes and stronger awareness campaigns through government agencies, electricity distribution companies, digital platforms, and community outreach programmes.

Another significant challenge is the quality of after-sales service and maintenance support. Although product performance and cost-effectiveness received high satisfaction ratings, customer service and maintenance service recorded comparatively lower scores. Respondents frequently reported delays in maintenance services and difficulties in obtaining timely technical assistance after installation. To address this issue, solar service providers should establish efficient maintenance networks, introduce digital service request and complaint management systems, increase the availability of trained technicians, and ensure prompt after-sales support to improve consumer confidence.

The study also highlights inadequate post-installation technical guidance as an important concern. Several consumers expressed the need for additional assistance in system operation, routine maintenance, and troubleshooting. Providing user-friendly operation manuals, conducting periodic training programmes, organizing awareness workshops, and offering dedicated technical helplines can improve users' understanding of system performance and enhance long-term satisfaction.

Although cost-effectiveness emerged as the highest-rated satisfaction dimension, the high initial investment required for rooftop solar installation may still discourage potential consumers, particularly those from lower-income households. Expanding financial assistance programmes, offering low-interest loans, introducing flexible financing mechanisms, and streamlining subsidy disbursement procedures can reduce financial barriers and encourage wider adoption of residential solar systems.

Finally, continuous consumer awareness remains essential for sustaining satisfaction and increasing adoption. The study found that online platforms and social networks were the primary sources of information for most respondents, indicating that digital awareness campaigns can play an important role in promoting rooftop solar technologies. Collaborative initiatives involving government departments, renewable energy agencies, local authorities, and solar companies should be strengthened to improve public awareness regarding the environmental, economic, and social benefits of residential solar rooftop systems.

Overall, addressing these technical, financial, service-related, and awareness-related challenges through coordinated practical solutions will enhance consumer satisfaction, strengthen public confidence in residential solar rooftop technologies, and support the long-term growth of renewable energy adoption in Kerala and similar regions.

8. POLICY AND REGULATORY IMPLICATIONS

The findings of this study emphasize the need for stronger policy and regulatory measures to improve consumer satisfaction and promote the wider adoption of RSR systems. Government agencies should strengthen subsidy schemes under the MNRE by simplifying application procedures and increasing public awareness. Effective implementation of net metering policies and continued support through KSEB rooftop solar initiatives can enhance the financial benefits of rooftop solar systems and encourage greater household participation.

In addition, regulatory authorities should establish standardized installation guidelines, quality certification for solar equipment and service providers, and clear consumer protection measures to ensure reliable system performance. Strengthening warranty regulations, improving after-sales service standards, and regularly monitoring service quality will increase consumer confidence and long-term satisfaction. These policy and regulatory improvements will support sustainable renewable energy adoption while enhancing the overall consumer experience with residential solar rooftop systems.

9. BROADER APPLICABILITY OF THE FINDINGS

Although this study was conducted in Kannur District, Kerala, the factors influencing consumer satisfaction identified in this research—cost-effectiveness, product performance, installation quality, customer service, warranty support, maintenance service, and awareness of government incentives—are fundamental dimensions that have been widely reported in residential solar rooftop adoption studies. These factors are not unique to the study area but are relevant to residential solar markets where consumers evaluate system performance, economic benefits, and service quality. Therefore, the analytical framework and key findings can serve as a useful reference for researchers, policymakers, and industry practitioners in other regions with comparable socio-economic conditions and renewable energy policies. Nevertheless, differences in government regulations, climatic conditions, electricity tariffs, subsidy schemes, and consumer behavior may influence satisfaction levels across locations. Accordingly, future studies should validate the proposed framework using larger multi-region and cross-country datasets to improve the generalizability of the findings.

10. CONCLUSION

This study evaluated consumer satisfaction with RSR products among households in Kannur District, Kerala, by examining the influence of cost-effectiveness, product performance, installation quality, customer service, warranty support, maintenance service, and awareness of government incentives. The findings revealed a high level of overall consumer satisfaction, with product performance and cost-effectiveness emerging as the strongest predictors of satisfaction. Installation quality, warranty support, customer service, and maintenance service also made significant positive contributions, while customer service, maintenance support, and awareness of government incentives were identified as priority areas for improvement. Although the empirical analysis is limited to Kannur District, the determinants of consumer satisfaction identified in this study represent widely recognized dimensions of residential solar rooftop adoption and provide a transferable framework for evaluating consumer satisfaction in similar regions. The findings offer practical guidance for policymakers, solar manufacturers, installation agencies, and service providers seeking to improve service quality, strengthen

post-installation support, and enhance consumer awareness to accelerate renewable energy adoption. Future research should extend this framework to multiple regions and different countries to validate its broader applicability under diverse policy, economic, and environmental conditions.

AUTHOR CONTRIBUTIONS

K. K. Muneer: Methodology, Laboratory Analysis, Data Curation, Formal Analysis, Supervision, Writing—Review & Editing.

Dr. Chi. Nanjappa: Conceptualization, Investigation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Ethical approval was not required for this study.

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