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Residential Solar Energy Adoption: An Empirical Study on Consumer Awareness, Perception, and Influencing Factors

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Abstract

Technological advancement though has undeniably propelled global economic development; however, it has contributed to environmental degradation, particularly by escalating carbon emissions, depletion of the ozone layer and bringing a climatic change. In response to these challenges, rooftop solar panels have emerged as a viable and increasingly adopted source of sustainable residential energy. This study investigates consumer awareness and examines the key determinants influencing the adoption of residential rooftop solar panels in Ludhiana, Punjab. Primary data were collected from 200 respondents via structured questionnaires administered through Google Forms. The dataset was analyzed using SPSS, employing percentage analysis, frequency distribution, Chi-square test, and independent samples t-test to derive meaningful insights.The analysis revealed a moderate level of overall consumer awareness, with significant occupational variations. Business respondents exhibited complete awareness (100%) and a higher inclination toward adoption (98%) compared to professionals. Business owners also demonstrated greater familiarity with government subsidy schemes and exhibited a broader acceptance of the preferred price range for solar panel systems. Among the 25 perception-related items evaluated, 15 showed statistically significant differences. Business respondents were more inclined to agree with aspects such as the renewable nature of solar energy, impact of electricity outages, brand reputation, aesthetic appeal, social influence, durability, seasonal applicability, and ecological benefits. In contrast, professional respondents expressed stronger agreement with statements related to environmental friendliness and price affordability.

The findings of this study offer a nuanced understanding of consumer perceptions and behavior regarding rooftop solar adoption. These insights can serve as a strategic foundation for policymakers, energy providers, and sustainability advocates aiming to design targeted awareness campaigns and incentive structures to enhance adoption rates within distinct occupational segments.

Keywords: Rooftop Solar Panels, Consumer Awareness, Perception, Adoption Drivers, Renewable Energy, Punjab

Introduction

Due to the accelerated technological development globally, new products and inventions have become more efficient but have also had negative impacts on the environment through greenhouse gas emissions, pollution, and depletions of natural resources. Due to these adverse effects, globally, there has

been a push towards eco-friendly and sustainable approaches, with the use of renewable energy becoming an important player. In contrast to traditional energy forms based on fossil fuels and emit toxic gases, renewable energy utilizes natural resources such as sunlight, wind, water, and biomass and provides virtually zero carbon emission. This transformation is vital due to overdependency on fossil fuel, causing global warming, heat rise, and health issues. More than 130 nations currently encourage renewable energy through enabling policies.

Among the sources of renewable energy, solar energy is a useful option. Solar panels use sun rays to produce electricity without causing environmental pollution. Residential rooftop solar panels, fixed on houses, allow families to produce their own electricity, cut down on power bills, and even earn revenue by selling excess energy to the grid. Underpinned by government incentives and policies, India, the US, and China are promoting the take-up. Aside from protecting the environment, rooftop solar systems provide a break away from grid power and increase property value, thus being an eco-friendly and cost-effective choice for contemporary households.

Review of literature

Different researches in different parts of the world identify the diverse factors driving the adoption of residential rooftop solar panels.Cragoa and Rong (2025) uncover that people with greater risk tolerance and patience prefer ownership, whereas risk-averse people prefer rental options. Reidl and Wüstenhagen (2025) observe Swiss renters prefer apartments with rooftop solar, particularly when combined with EV charging. Tham et al. (2025) and Kaewngam et al. (2025) emphasize that government incentives, environmental awareness, and trustful information channels enhance adoption in Vietnam and Thailand, respectively. Alpandi et al. (2025) emphasize ease of use and government support in Malaysia, although high costs continue to be a hindrance. US studies (Naim & Sarker, 2024; Johnson & Reimer, 2024; Palanca-Tan, 2024) indicate that net savings, incentives adapted to the situation, and raising awareness can bridge the interest-adoption gap. Indonesian (Aditya et al., 2024) and New York (Badole et al., 2024) studies suggest community participation and financial incentives as a means to increase willingness to pay. San-Martín and Elizalde (2024) connect adoption to education and peer, whereas Lemay et al. (2023) highlight insolation and political orientation. Chinese (Asif et al., 2023) and Indian studies (Prajapati, 2022; Raghavendra, 2022) highlight environmental consciousness and government initiatives, but also refer to issues such as funding and poor awareness. In Saudi Arabia (Ashour et al., 2021), where there are favorable attitudes, low government electricity prices discourage adoption. Consumers worldwide prioritize practical benefits like cost savings (Gręboszc-Krawczyk et al., 2021), lightweight design (Abreu et al., 2019), and aesthetic appeal (Bao et al., 2017; Gardzelewski& Denzer, 2017). Despite forces such as cost of payback (Hayat et al., 2017), social impact (Aggarwal et al., 2019), and customized promotion (Wolske & Todd, 2018) leading to adoption, drawbacks such as a high initial expenditure (Mamkhezri et al., 2018), problems with shading (Ninsawat& Hossain, 2016), and inefficient policies (Devi & Narayan, 2018; Rachit & Vinod, 2016) continue. Research from Mumbai (Singh & Banerjee, 2015) and Canada (Islam & Meade, 2013) highlights the promise of solar power generation and the key role of awareness, incentives, and education in achieving large-scale adoption worldwide.

Research Methodology

Objectives of the study:

- To assess the awareness level of rooftop solar panels among residents of Ludhiana.
- To determine the factors influencing residents' decision to adopt rooftop solar panels.

Research Design:

Exploratory research was used in this study to investigate the research questions and provide insights based on existing information. This approach was suitable due to limited availability of past data, with only a few studies available for references.

Sample Size:

The sample size was 200 respondents. These respondents, consisting of 100 professionals and 100 businessmen, was selected to explore the study.

Sampling technique

A convenience sampling, which is a non-probability technique, was used for collection of data.

Collection of data

As it was primary research, therefore questionnaire technique has been employed as primary means of data collection. Questionnaire was clearly defined, inclusive of multiple choice, dichotomous question and five points Likert scale-based statements. These statements were labelled as Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree based upon agreement or disagreement.
The Numeric score associated with these options were:

Options	Scores
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

The basic idea behind the statement used in 5 points Likert scale was taken from the previous year research papers as mentioned in the literature review.

Tools of Data Analysis:

Various tools were used to carry out the data analysis which are explained below:

Chi-Square Test

When two categorical variables exist within a single population then chi square test for independence is applied to determine whether there is significant association between two variables or not. This test includes four steps:

- The first step is defining the hypothesis. Hypotheses are categorized into two parts: null hypothesis, which states that there is no connection between the variables and alternative hypothesis, which sugg

est connection between variables.

- The second step involves the formulation of an analysis plan, which helps describe how sample data can be used to accept or reject the null hypothesis. The plan also specifies the significance level, which was taken as 5% for this research.
- The third step includes analysing the sample data using expected frequencies, degree of freedom, calculated value and critical value for the test statistic.
- Last step involves critically examined the critical value, calculated value and asymptotic value known as p value. If p value is less than 0.05 then we reject null hypotheses otherwise accept null hypotheses.

Independent Sample t-test

An independent sample t-test is used to calculate the mean of two groups which are not depend on each other than compare them to analysed if there is any significant difference or not.

In order to carry out research analysis two types of hypotheses were defined: Null hypothesis and Alternative hypothesis as:

H_0: There is no significant difference in perception regarding residential rooftop solar panels between professionals and businessmen.

H_a: There is a significant difference in perception regarding residential rooftop solar panels between professionals and businessmen.

The statistical package use for data analysis is SPSS.

Limitations of study

- The study was limited to only Ludhiana city, so the result may not be generalizable to customer perception for other areas.
- The research focused on only 200 respondents, which could not give complete picture of whole market.
- Convenience sampling which is a non-probability method was used which influenced the result and reduce the applicability of findings to broader population.
- Collection and analysis were done in short period of time which might have impacted the profundity of the research.

RESULTS

Demographic analysis of respondents on the basis of age group reveals that 26% respondents fall within 18-25 age group, 20% respondents come under 26-30 age group, 23% respondents are part of 31-35 age group, 20% respondents belong to 36-40 age group and 11% respondents belong to more than 40 age group as shown in Table 1.

Gender-wise the analysis reveals that 61% of respondents are male and 39% are female as shown in Table 1.

The study includes an equal distribution of respondents by occupation, with 50% being professionals and 50 % being businessman as detailed in Table 1.

Table 1: Demographic profile of respondents

Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-25	52	26.0	26.0	26.0
	26-30	40	20.0	20.0	46.0
	31-35	46	23.0	23.0	69.0
	36-40	40	20.0	20.0	89.0
	more than 40	22	11.0	11.0	100.0
	Total	200	100.0	100.0	
Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	122	61.0	61.0	61.0
	Female	78	39.0	39.0	100.0
	Total	200	100.0	100.0	
Occupation					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Professional	100	50.0	50.0	50.0
	Businessman	100	50.0	50.0	100.0
	Total	200	100.0	100.0	

- **Awareness level of respondents**

In order to analyze the awareness of respondents towards residential rooftop solar panels, respondents were evaluated through questions related to their general awareness, sources of information, level of knowledge, awareness of companies, and knowledge about government subsidies and schemes. The data is shown in Table 2.

Table 2

		Are you aware of residential rooftop solar panels?		
		No	Yes	Total
Occupation	Professional	7	93	100
	Businessman	0	100	100
Total		7	193	200
Pearson Chi-Square value=7.254, p value=0.007, df=1				

		What was your source of information regarding rooftop solar panels?				
		Online Source	Friends and Family	Solar company Representatives	Government agencies and awareness programs	Total
Occupation	Professional	44	31	6	19	100
	Businessman	36	34	9	21	100
Total		80	65	15	40	200

Pearson Chi-Square value=1.638, p value= .651, df=3							
		What is your level of knowledge about rooftop solar panels?					
		Very High	High	Moderate	Low	None	Total
Occupation	Professional	5	18	61	13	3	100
	Businessman	13	45	30	12	0	100
Total		18	63	91	25	3	200

Pearson Chi-Square value= 28.727, p value < .001, df=4										
		According to you, which of the following companies provide rooftop solar panels?								
		Waaree Energies	UTL Solar	NTPC Solar	Tata Power Solar	Adani Solar	Bharat Heavy Electricals Limited (BHEL)	Vikram Solar	Luminous Power Technologies	Total
Occupation	Professional	18	10	5	23	15	3	8	18	100
	Businessman	19	6	3	20	24	0	6	22	100
Total		37	16	8	43	39	3	14	40	200

Pearson Chi-Square value=7.499, p value =.379, df=7				
		Are you aware of any government subsidies or incentives for installing rooftop solar panels?		
		No	Yes	Total
Occupation	Professional	32	68	100
	Businessman	9	91	100
Total		41	159	200

Pearson Chi-Square value=16.229, p value <.001, df=1						
		Which of the following government subsidies are available for residential rooftop solar panels?				
		Grid Connected Rooftop Solar Programme	PM KUSUM Scheme	PM Surya Ghar: Muft Bijli Yojana	STP Scheme	Total
Occupation	Professional	23	11	46	20	100
	Businessman	43	11	27	19	100
Total		66	22	73	39	200
Pearson Chi-Square value=11.031, p value=.012, df=3						

The analysis indicated significant difference between businessmen and professionals in terms of knowledge and awareness of rooftop solar panels in residential areas. All the businessmen knew about

rooftop solar panels, whereas 7% of professionals did not know, indicating a strong association (p = 0.007). Both groups primarily obtained information from online resources and friends or relatives, without any significant difference (p = 0.651). Yet, businessmen showed greater knowledge (p < 0.001), as a larger number of them indicated their knowledge as 'high' or 'very high' than professionals, who were primarily in the 'moderate' range. Awareness of solar panel companies revealed no significant variation (p = 0.379), with Tata Power Solar and Adani Solar being the most known among both groups. A large difference was seen in the awareness of government subsidies (p < 0.001) as 91% of the businessmen were aware versus 68% of professionals. In addition, businessmen indicated higher awareness regarding the PM Surya Ghar: Muft Bijli Yojana, whereas professionals reported the Grid Connected Rooftop Solar Programme more often (p = 0.012).

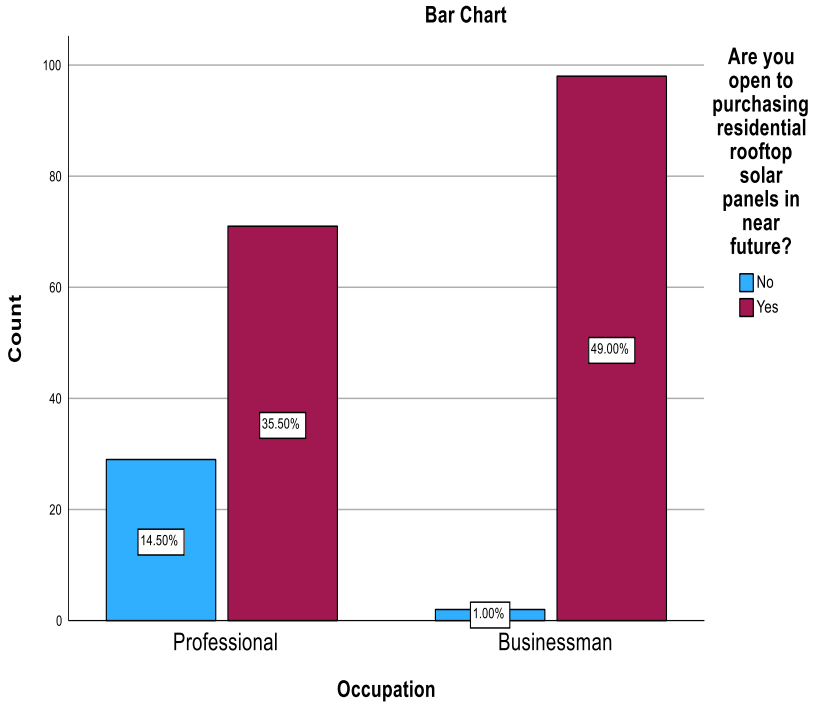

Fig 1

- **Openness towards purchasing residential rooftop solar panels in near future.**

A significant difference (p < .001) was found between professionals and businessmen regarding their openness to purchasing residential rooftop solar panels, with 98% of businessmen showing willingness compared to 71% of professionals. The data is shown in Table 3 and corresponding chart is depicted in figure 1.

Table 3

		Are you open to purchasing residential rooftop solar panels in near future?		
		No	Yes	Total
Occupation	Professional	29	71	100
	Businessman	2	98	100
Total		31	169	200
Pearson Chi-Square value=27.830, p value<.001, df=1				

- **Preferences for type of solar panel system.**

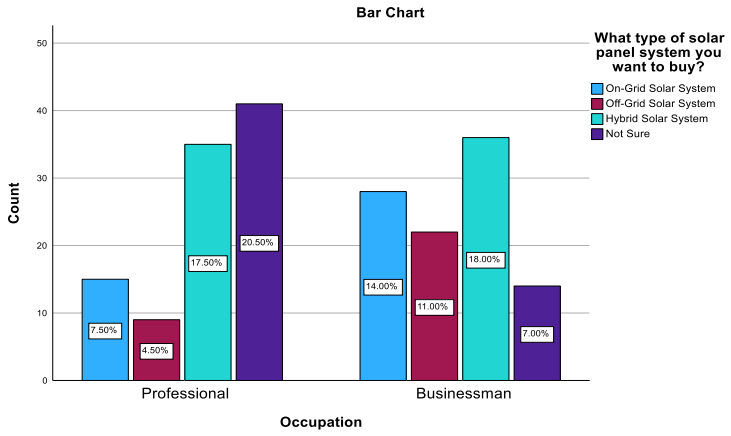

Fig 2

A significant difference ($p < .001$) was observed in the preference for solar panel systems, as most professionals were unsure (41%), while businessmen largely preferredhybrid systems (36%) and on-grid (28%). The data is shown in Table 4 and corresponding chart is depicted in figure2.

Table 4

Count						
		What type of solar panel system you want to buy?				
		On-Grid Solar System	Off-Grid Solar System	Hybrid Solar System	Not Sure	Total
Occupation	Professional	15	9	35	41	100
	Businessman	28	22	36	14	100
Total		43	31	71	55	200
Pearson Chi-Square value=22.650, p value<.001, df=3						

Fig 2

- **Preferred price range for purchasing rooftop solar panels.**

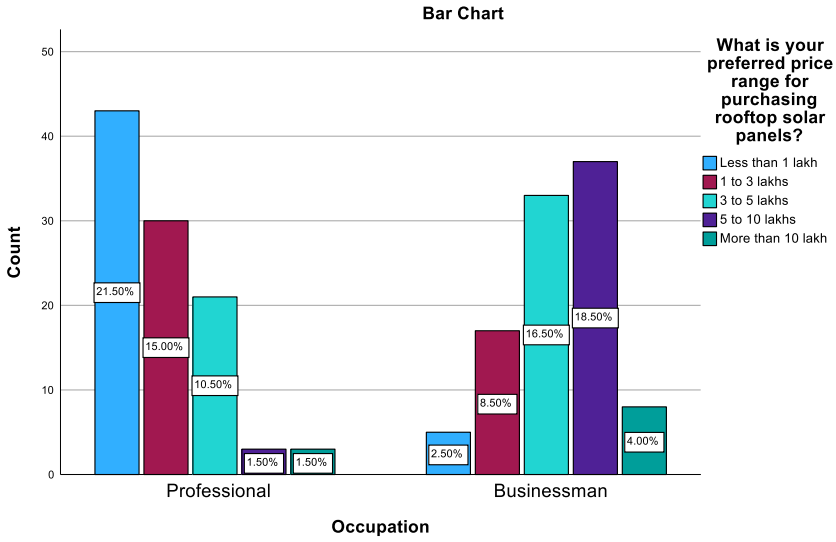

Fig 3

A significant difference ($p < .001$) was found in the preferred price range, as most professionals favoured options below 1 lakh, while businessmen preferred higher ranges between 3 to 10 lakhs. The data is shown in Table 5 and corresponding chart is depicted in figure3.

Table 5

		What is your preferred price range for purchasing rooftop solar panels?					
		Less than 1 lakh	1 to 3 lakhs	3 to 5 lakhs	5 to 10 lakhs	More than 10 lakh	Total
Occupation	Professional	43	30	21	3	3	100
	Businessman	5	17	33	37	8	100
Total		48	47	54	40	11	200
Pearson Chi-Square value=67.518, p value<.001, df=4							

- **Perception of respondents towards residential rooftop solar panels.**

Five points Likert scale has been utilized to determine the perception of the respondents towards residential rooftop solar panels. Participants were asked to rate the following statements by checking any one of the choices ranging from Strongly Agree (SA), Agree(A), Neutral (N), Disagree (D), Strongly Disagree (SD).Relevant statements were coded and analysed likewise.

Out of 25 statements the 15 statements (R3, R4, R8, R9, R12, R13. R15, R17, R19, R20. R21, R22, R23, R24, R25) showed significant differences in the mean score values with businessman strongly agreeing to all the statements except R4 and R9. In order to find out if these 15 statements show significant differences independent sample T test was conducted and Likewise Levene's test of equality of variance was observed these statements showed significant 2-tailed significance value of 0.038, <0.001, 0.009, 0.021, <0.001, <0.001, 0.038, 0.001, 0.011, 0.047, <0.001, 0.012, 0.010, 0.011, 0.035 as shown in Table 7. These values confirming that occupation wise, Professionals and businessman do differ in their responses.

Table 6

Independent Samples Test						
		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Significance Two-Sided p
R3	Equal variances assumed	.003	.958	-2.091	198	.038
R4	Equal variances assumed	21.154	<.001	4.207	198	<.001
R8	Equal variances assumed	.836	.362	-2.653	198	.009
R9	Equal variances assumed	7.720	.006	2.324	198	.021
R12	Equal variances assumed	.142	.707	-3.496	198	<.001
R13	Equal variances assumed	.716	.399	-4.377	198	<.001
R15	Equal variances assumed	1.785	.183	-2.090	198	.038
R17	Equal variances assumed	.700	.404	-3.307	198	.001
R19	Equal variances assumed	.214	.644	-2.563	198	.011

R20	Equal variances assumed	.282	.596	-1.995	198	.047
R21	Equal variances assumed	.050	.823	-3.558	198	<.001
R22	Equal variances assumed	2.170	.142	-2.543	198	.012
R23	Equal variances assumed	.042	.838	-2.605	198	.010
R24	Equal variances assumed	2.691	.103	-2.557	198	.011
R25	Equal variances assumed	.578	.448	-2.122	198	.035

Findings

The findings revealed significant differences in the awareness and preferences of residential rooftop solar panels based on occupation. 100% of businessmen and 93% of professionals were aware of the panels, with a significant difference ($p = 0.007$), indicating that businessmen were more aware. Both groups primarily sourced information online (44% of professionals and 36% of businessmen), but no significant difference was found between them. Knowledge levels also showed a significant difference ($p < 0.001$), with businessmen having a higher level of knowledge. There was no significant difference in the companies considered as providers, with Tata Power Solar and Luminous Power Technologies being most preferred. A significant difference in openness to purchasing was observed, with 98% of businessmen willing to buy compared to 71% of professionals ($p < 0.001$). Both groups preferred hybrid solar systems, though professionals were more uncertain about their choice (41% vs. 14%). A significant difference was observed regarding price preference, businessmen (78%) favoured higher price ranges above 3 lakhs, while professionals (73%) preferred lower ranges ($p < 0.001$). Awareness of government subsidies was also significantly higher among businessmen (91%) compared to professionals (68%) ($p < 0.001$). In terms of specific subsidy knowledge, businessmen favoured the Grid-Connected Rooftop Solar Programme (43%), while professionals leaned towards the PM Surya Ghar: Muft Bijli Yojna (46%) ($p = 0.012$). Finally, independent sample t-tests revealed significant differences in perceptionson 15 out of 25 statements, with businessmen strongly agreeing on factors such as brand reputation, power outages, panel appearance, and environmental concerns, while professionals showed more agreement on affordability and environmental responsibility.

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