

Willingness to Pay for Solar Home Systems in Faisalabad: An Application of Multitier Framework for Choice Experiment

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Abstract

Pakistan's high dependency on imported energy and environmental degradation has prompted a shift towards renewable energy sources, notably solar home systems. The study aims to assess the acceptance and willingness to pay for solar home systems in Faisalabad as well as to identify the determinants of solar energy adoption. A conditional logistic model are employed to determine the willingness to pay for a solar home system. The results indicate the total cost, cost of the battery, manufacturing company origin, manufacturing country significantly impact the acceptance of solar home systems (SHSs). A simple logit model is applied to check the

determinants of solar home systems. Results showed that house size, exposure to SHSs, awareness about SHSs, and trust plays a significant role in the willingness to adopt SHSs. Conversely, gender, electricity bill, and environmental ethic negatively affect the willingness to adopt. This study offers valuable suggestions for policies promoting the acceptance of solar home systems. The findings underscore the significance of addressing cost, family status, and awareness as primary barriers to the adoption of solar home system.

Keywords: Willingness to Pay, Choice Experiments, Multi-tier Framework, Acceptance of Solar Home Systems.

1. Introduction:

Along with global development, the energy demand has increased. In developing countries, energy demand has grown faster than energy supply due to the demands of growing economies and industries and population growth (Ministry of Planning, Development & Special Initiatives, 2021). Energy is essential for social development and economic prosperity, and meeting the world's energy needs is a significant challenge (Hasanuzzaman et al., 2017; Rahman & Ahmad, 2013). The highest absolute decrease in energy consumption after the Second World War and the greatest worldwide occurred in 2020 when it decreased by 4% globally (International Energy Agency [IEA], 2021a). The electricity proportion in the world's total energy consumption has consistently increased in the last few years. Also, in Pakistan, electricity demand is increasing, while the availability of energy sources, including water, fossil fuels, and natural gas liquefied (LNG), is decreasing. Thus, power outage occurs throughout Pakistan, particularly in rural areas.

Coal, liquefied natural gas, and petroleum products are some of Pakistan's mixed energy sources to produce power. However, the fact is that these sources are less than the demand. Thus, the government of Pakistan imports it from other nations. Pakistan imported oil 17.03 billion, 24.36% gas 373MMBtu LNG in FY2021, due to which the prices of mixed energies sources increased, which increased the electricity expenditures as well (Ministry of Finance, Government of Pakistan, 2022). Pakistan faces many severe problems due to high electricity expenditures and a power crisis. As a result, the economy of Pakistan is also suffering from a crisis, due to which the value of the rupee is decreasing. Rising energy prices negatively impacted the small manufacturing markets in Pakistan. Unplanned daily power outages negatively impact people's

quality of life. Conventional energy sources damage the environment and cause resource depletion, hindering sustainable economic growth (Zhang & Liang, 2021). Pakistan's energy production relies on fossil fuels, which hurts the environment (Irfan et al., 2019). Coal and other fossil fuels are significant sources of pollution as burning coal and fossil fuels produces CO₂ and other greenhouse gases (GHGs).

We must move towards renewable energy sources to prevent climate change and lower emissions from petroleum goods. Reducing GHG and improving our environment is crucial as solar home systems are one of the most effective applications for supplying rapid and reliable power (Antonanzas-Torres et al., 2021). There are several types of renewable energy, including geothermal, biomass, and wind. However, in this study, we only focus on one of the major types of renewable energy, which is solar energy, because the demand for Solar home systems will increase more globally. Solar PV is estimated to account for 145 TWh, or more than 18%, of the total electricity generation, approaching 1000 TWh. As transportation activity gradually increases, the biofuel market is expected to grow again and approach 2019 production levels. (International Energy Agency [IEA], 2021b). Increases in solar PV and hydropower installations more than decreases in annual wind capacity (International Energy Agency, 2022). The solar energy market in Pakistan is expected to grow at a CAGR of over 2.5% between 2022 and 2027.

Due to Pakistan's sunny climate, it is the best place for solar energy development and can produce electricity using the solar system. However, it still generates electricity using fossil fuels, which can cause climate change and destructive gases such as CO₂, which produces GHGs, and other gases such as sulfur dioxide and nitrogen oxides. South Asian countries generate most of their electricity from fossil fuels, about 64%, while renewable sources make up 4% of the total (The Nation, 2022). The power crisis in Pakistan causes load shedding, which affects domestic, commercial, and industrial activities. Advanced technologies like solar PV can reduce power outages, but their potential still needs to be explored in Pakistan (Qureshi et al., 2017). To overcome its energy problems, the government of Pakistan should consider alternative sources of electricity, including solar, hydroelectric, and wind energy.

Promoting consumer adoption of solar systems can help achieve these goals, which call for adding 9,700 MW of renewable energy technologies by 2030 (The Nation, 2022).

As discussed, Pakistan faces high electric expenses as the unit price of electricity produced by

fossil fuel is higher because these are imported resources. However, according to PSA (Pakistan Solar Association), Solar energy costs 6 PKR per unit, whereas battery energy costs 9.5 PKR per unit. In short, solar is cheaper than fossil fuel electricity. Many people initially adopted solar energy to prevent load shedding, but it has now evolved into a cost-effective option that reduces electricity bills while protecting the environment (Pakistan Today, 2020). Adopting solar panels at the household level lowers CO₂ emissions (Akbar et al., 2021). Pakistani consumers face an energy crisis, with a gap between supply and demand. Solar PV technology can address this gap relatively cheaply and environmentally friendly, but its adoption could be faster compared to other developing countries (Ali et al., 2020). Adoption and willingness to pay for solar home systems are impacted by many factors like income, cost, and awareness of solar home systems (Abdullah et al., 2017; Jan et al., 2020). Individually, the willingness to pay for the solar home system differs as most residents indicate a strong or moderate adoption intention even when their cost is high. Cost concerns, however, are associated with low willingness to pay (Chen et al., 2020).

This research adds a novel contribution to the collection of literature. Due to Pakistan's energy crisis and high electricity costs, the public is turning to renewable energy sources like solar household systems. However, their adoption has several obstacles, including their high initial cost, lack of knowledge, and other factors. It shows the public preferences for solar home systems' quality and conformity to product standards. This study also shed light on the willingness of people at the individual and collective levels to pay for solar household systems. For adequate economic and social growth, households must have access to renewable energy sources, such as solar home systems. However, many people choose to avoid switching due to high initial costs, installation difficulties, battery replacement problems, and a dearth of nearby markets.

This study's main objective is to determine how much people are willing to pay for solar systems. Electricity is short in Pakistan's cities, particularly during the summer. As in Faisalabad, some areas face almost 8 to 10 hours of electricity shortages. There is an increase in billing day by day. So many people are moving towards renewable energy. For this purpose, we used the choice experiment to know the quantitative value of the willingness to pay for a solar home system. To make the choice card, I used MTF and its attribute. The MTF has six tiers or levels (0-5) and seven attributes. The study's second goal is to investigate the variables influencing the

acceptability of solar systems. Here we use different determinants for the first demographic determinants, in which we have used different variables like name, gender, income, family income, age etc. Other factors are the solar energy market and knowledge or awareness about solar energy—technology (capacity and other factors), cost, etc.

A third factor is people's trust in others, government, and business support. Lastly, we want to investigate the impact of WTP on individual characteristics. Socioeconomic variables, awareness, source of awareness, and trust do not all impact the willingness to pay an individual character. For all this purpose, we used off-grid solar panels, and we used both adoptive and non-adoptive respondents for our analysis. The rest of the study consists of four parts. Section 2 is about the literature on previous studies. Section 3 is devoted to explaining the methodology adopted in this study. Section 4 is about results and discussion. The final section presents the conclusion of the study and policy recommendations.

2. Literature review

This section provides a brief overview of the research conducted to analyze the adoption of solar home systems and their willingness to pay for solar home systems.

The demand for energy increases than its supply so many people are moving towards the renewable energy system. Because traditional energy sources are in short supply and there are worries about climate change, renewable energy is given particular focus in Korea. (Lee et al., 2018). Households place a high value on renewable energy use, but more is needed to cover the already high costs of microgeneration energy systems (Scarpa & Willis, 2010). Like many countries, Pakistan also moves toward renewable energy, especially solar home systems. As Irfan et al., (2021) conducted research to identify the utilization of renewable energy, they found a positive relationship between driving factors (Perceptions of awareness, self-efficacy, and neighbor involvement) and customer desire for renewable energy, while renewable energy price has hurt consumers' intention. Renewable energy has positive and negative impacts on the environment, as the environmental impact of electric power stations based on renewable energy sources was investigated by (Rahman et al., 2022). They found that RES has a negative impact on the environment, including wind, bioenergy, thermal energy, hydroelectric, tidal currents, tidal waves, solar energy, and ocean thermal energy. On the other hand, Akella et al., (2009)

explored the social, economic, and environmental impact of renewable energy systems, and they found that the use of renewable energy systems helps reduce emissions in rural areas and effectively manage social, economic, and environmental issues. Another study (Abdullah et al., 2017) researched Pakistan's acceptance of solar household systems and readiness to pay for them. They found that 81% of people were interested in them, but the public was misinformed about power production and bills. A lack of funds and independent research is the primary obstacle to SHS installations. Although there is still a slow acceptance rate, renewable energy sources could provide Pakistan with all of its energy requirements (Ali et al., 2020).

Many factors have affected the acceptability of renewable energy resources, especially for solar home systems for example Bhowmik et al., (2018) explored the social acceptance of the determinants of green energy in a specific region, which found that 74 percent of respondents were aware of green energy and included land requirements, a fraction of dirty fuels, commercial energy consumption, income. Inequality, local resource scarcity, foreign direct investment, and technology transfer are the most influencing parameters. Jan et al., (2020) conducted a study to identify the main factors influencing the societal acceptance of solar photovoltaic systems in Pakistan. They found that income, the monthly cost of electricity, education, and information about solar energy are the main factors that determine whether solar energy is acceptable. Another study Qureshi et al., (2017) explained that the expense of a solar PV system was the biggest obstacle, followed by the government's lack of sufficient financial support, the difficulty of using all utilities at once, the lack of trustworthy sellers, and the supply of goods in the local market. A neighborhood threshold of between 12.5% and 15% is needed for optimal solar home systems installations, with potential expansion increasing with increasing effect radius (Opiyo, 2019). Government incentives are the main factor influencing solar energy acceptance in Malaysia, with 70% of respondents believing that government is the major factor (Solangi et al., 2015).

3. Methodology

This section contains the techniques and tools used for analysis and data collection. In this section, three models are investigated. Model 1 is about the exploration of determinants that have an impact on the adoption of solar home systems. For this model, the null hypothesis is $H_0 =$ The socioeconomic variables, awareness, source of awareness, and trust all have no impact on

the willingness to adopt. Model 2 describes the acceptance and willingness to pay for solar home systems in Faisalabad. To test the null hypothesis H_0 = There is an insignificant impact of all attributes on a person's acceptance and willingness to pay, different attributes are utilized. Model 3 analyses the willingness to pay for solar home systems at the individual level and test the null hypothesis H_0 = The socioeconomic variables, awareness, source of awareness, and trust all have no impact on the willingness to pay at individual character.

3.1.Survey design and data collection

To investigate the willingness to pay for solar home systems in Faisalabad, it was necessary to conduct a survey in Faisalabad so a questionnaire was designed for this purpose. The questionnaire consists of three sections; the first part is about socioeconomic and demographic information. In the second section, we asked about the awareness of solar home systems and trust in their surroundings Last portion is related to the choice experiment as the study is about conducting the discrete choice experiment to calculate the willingness to pay for solar home systems. For this purpose, a suitable framework was needed to select our attributes and level, therefore, a multi-tier framework developed by the Energy Sector Management Assistance Program (ESMAP) is used in this study. As shown in table1, the MTF has seven attributes to measure electricity access: capacity (power capacity or rating in W kWh), availability (day or night), reliability, quality, affordability, formality or legality, health and safety, and 7 tiers (from 0 to 5). In Tier 0, the consumer is willing to adopt the least amount of solar home system which is 3KW at least minimum price range and affordability like 458000 PKR. In Tier 1, the user is adopting a 4 KW solar system at a minimum price of 60,000 PKR, which gives about 3–4 hours of backup through battery usage. In Tier 4, the consumer is willing to adopt a 6 KW solar home system at a range price of 850000 PKR, with the backup of this solar home system being about 3-4 hours. In Tier 5, consumers are willing to pay more than a 6 kW solar home system, which is more affected by overall home usage. Solar home systems with less than 3 KW of capacity are not eligible to produce enough electricity to power all necessary appliances.

Table 1: MTF attributes & Tier

Attributes of MTF		Tiers/Level					
Attributes		Tiers 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Affordability	Cost	20000-30000	45800 PKR	60600 PKR	69800 PKR	85000 PKR	85000 PKR
Capacity/availability	Power production by SHS	420 watt or <3KW	3KW	4KW	5KW	6KW	>6KW
Battery-capacity/availability	Day or night availability	0 hours	0-3 hours	3-4 hours	3-4 hours	3-4 hours	4-5 hours
Reliability		Yes	Yes	Yes	Yes	Yes	Yes
Quality of SHSs and battery	Yearly	SHS5Year	SHS6 year	SHS9 year	SHS10 year	SHS10 year	SHS10 year
		a	6	7-	8-	H	10
		r	yea	9	10	S	year
	Battery	Batt	r	year	year	1	s
	ery	Bat	s	s	s	0	Batt
	<1 year	ter	Batt	Batt	Batt	year	ery

			y 1	ery	ery	s	5
			yea	2	<3y	Batt	year
			r	year	ear	ery	s
				s	s	3ye	
						ars	
Legality	Reduct	0-50%	50%	55%	50-	60-	70-
	ion in				60%	65%	75%
	Bill						
Health & safety	Eco	YES	YES	YES	YES	YES	YES
	frien						
	dly						

4 choice cards of 7 different alternatives $4 \times 7 = 28$ choices are given to respondents as shown in (Table 2). Different capacity is used like for card 1 the solar home systems of capacity 3KW is used that have 2-4 years' payback guarantee. For card 2 the capacity of the solar home system is 4KW which gives 2-4 years payback guarantee. In both solar home systems, the number of batteries used is 2 and the number of panels that will be used in a 3 KW solar system is seven panels of 420 watts each on the other hand 8 panels totaling 480 watts will be utilized in a 4 KW solar system.

Card 3 includes 5KW solar home system that gives us a 4-6 year payback guarantee. 9 panels totaling 530 watts will be utilized in a 5 KW solar system. For card 4 6KW solar home systems are used which give 4-6 years' payback guarantee. 12 panels totaling 545 watts will be utilized in a 6 KW solar system. In both of these solar home systems, 4 batteries are used. In 7 alternatives, different pair of choices are given as in alternative 1 is about none option, in 2 we use Longi (made by China) SHSs with tubular battery, in alter 3 we use the same solar home systems like Longi with Lithium battery, in alternative 4 and 5 we use same solar systems like Jinko (made by china) with tubular and lithium battery and in last two alternatives (6 and 7) we use Canadian SHSs (made by Canada) with tubular and lithium battery.

Table 2: An example of choice cards

Attributes	Alter 1	Alter 2	Alter 3	Alter 4	Alter 5	Alter 6	Alter 7
Total installation cost	NON E	458000 PKR	475000 PKR	508000 PKR	525000 PKR	558000 PKR	575000 PKR
cost of panels with inverter	NON E	358000 PKR	358000 PKR	408000 PKR	408000 PKR	458000 PKR	458000 PKR
Cost per Watt	NON E	153 PKR	158 PKR	169 PKR	175 PKR	186 PKR	192 PKR
Company Names	NON E	Longi	Longi	Jinko	Jinko	Canadia n	Canadia n
Country Names	NON E	China	China	China	China	Canada	Canada
Cost of Battery	NON E	100000 PKR	117,000 PKR	100000 PKR	117,000 PKR	100000 PKR	117,000 PKR
Battery capacity	NON E	230 Ah	100Ah	230 Ah	100Ah	230 Ah	200Ah
Battery Back up	NON E	5 hours	4 hours	5 hours	4 hours	5 hours	4 hours
Battery Type	NON E	Tubular	Lithium	Tubular	Lithium	Tubular	Lithium

Choice	A	B	C	D	E	F	G
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4. Econometric Models

4.1. Model 1

Adoption theory is used to find out the determinants that impact the adoption of solar home systems. According to the theory, when people are introduced to new technology, various variables influence their choices about how and when to use it. Technology adoption is a challenging process that is inherently social and developmental. People develop unique, adaptive perceptions of technology, influencing their adoption decisions. It is essential to consider cognitive, emotional, and environmental factors while promoting technology adoption (Straub, 2009). The binary logit model estimates the factor influencing the adoption of solar home systems as the dependent variable is categorical or in the form of yes or no. Logistic regression is one of the variations of standard linear regression. The dependent variable Y is used when it has a clear character. In binary logistic regression, the Y variable is of the "yes/no" type. This allows evaluation of how effectively the set of variables predicts your particular dependent variable (Fritz & Berger, 2015).

Following is the binary logit model

$$\begin{aligned}
 WTA = & \beta_0 + \beta_1 age + \beta_2 Edu + \beta_3 inc + \beta_4 P. Outage + \beta_5 trust + \beta_6 Env + \beta_7 E. E \\
 & + d_8 gen + d_9 H. size + d_{10} Exp + d_{11} F. s + d_{12} aware + d_{13} H. status + \varepsilon
 \end{aligned}$$

Where WTA is Willingness to adopt solar home system (1=Yes, 0=No), β_0 denotes the Intercept of the equation, β_s represents the coefficient value of all variables in the equation, age is Age of respondent, edu explains about the education of respondent, inc tells about Income (in 1000) E.E is Electricity Expenses (1000), Env denotes Environmental ethics, trust is the product of trust on government and trusts on surroundings P.Outage is power outage, gen denotes gender(year), H.size is House size (Dummy), Exp explain about expositors of SHSs (Dummy), F.s is Family size (Dummy), aware is about Awareness of SHSs (Dummy), H.status is House status (Dummy), ε is Standard Deviation.

Table 3 Variable Descriptions for Willingness to adopt of SHSs

Variables	Variables Name	Descriptions of variables
Dependent variables	WTA	Dummy (yes/ No)
Independent variables	Age	Years
	Gender	Dummy (male=1, female=0)
	Educational	Years of schooling average
	Income	income in 1000
	Family status	Dummy (Nuclear=0, joint=1)
	House status	Dummy (own=1, rented=0) In
	Housing size,	Marla's
	Electricity bill,	Average bill per year
	Exposers of	Dummy (yes/ no)
	SHSs, SHSs	Dummy (yes/ no)
	awareness	Categorical
	Trust	Categorical
	Environmental	Hours of power outage
	ethics	
	Power	
	outage	

4.2. Model 2

The choice experiment collects the data based on random utility as CE is generally used to calculate the economic values of environmental well-being that are central to policy research (Holmes et al., 2017). In low and middle-income economies DCEs are used to evaluate alternative scenarios, products, or services in order of preference Mangham et al., (2009). In this study, the CE data are collected by a survey as the respondents are given different choices to choose one that will maximize their utility. Every person has their utility for the attributes of the product. Let's suppose U is the utility of a person i and for the attributes of j so the utility is U_{ij} is written as

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

U_{ij} is the utility that the respondent obtained from alternative j , and V_{ij} is the non-stochastic variable that attributes of the choice cards can measure and ε_{ij} is a stochastic variable.

$$V_{ij} = ASC_i + \alpha_1 T.C_{ij} + \alpha_2 C.P_{ij} + \alpha_3 C.B_{ij} + \alpha_4 C.W_{ij} + \alpha_5 M.C_{ij} + \alpha_6 B.G_{ij} + \alpha_7 B.Used_{ij} \\ + \alpha_8 P.used_{ij} + \alpha_9 B.B_{ij} + \alpha_{10} P.G_{ij} + \alpha_{11} M.com1_{ij} + \alpha_{12} M.com2_{ij}$$

So that the utility function of the model is written as with the error term

$$Utility = ASC_i + \alpha_1 T.C_{ij} + \alpha_2 C.P_{ij} + \alpha_3 C.B_{ij} + \alpha_4 C.W_{ij} + \alpha_5 M.C_{ij} + \alpha_6 B.G_{ij} \\ + \alpha_7 B.Used_{ij} + \alpha_8 P.used_{ij} + \alpha_9 B.B_{ij} + \alpha_{10} P.G_{ij} + \alpha_{11} M.com1_{ij} \\ + \alpha_{12} M.com2_{ij} + \varepsilon_{ij}$$

Where ASC_i is an alternative specific constant α s is a coefficient parameter while $T.C_{ij}$, $C.P_{ij}$,

$C.B_{ij}$, $C.W_{ij}$, $M.C_{ij}$, $B.G_{ij}$, $B.Used_{ij}$, $P.used_{ij}$, $B.B_{ij}$, $P.G_{ij}$, $M.com1_{ij}$, $m.com2_{ij}$, is the Total cost of SHSs in 1000, the cost of the panel in 1000 is the cost of the battery (1000), is cost per watt in 1000, manufacture country, battery guarantee, the battery used, the panel used, battery backup, a guarantee of the panel, manufacture company 1 manufactured company two and ε_{ij} is an error term.

Where α_{ij} is the parameter of respondent i preferences for attribute j , and P_i is the price parameter.

Table 4: Variable description for Willingness to pay for SHSs

Variables	Variables Name	Descriptions of Variables
Dependent variables	Choice	Dummy (yes/ No)
Independent variables	Total cost	PK
	Cost of panels	R
	Cost of	PK
	battery Cost	R
	per watt Panel	PK
	used	R
	Guarantee of panels	PK
	Battery used	R
	Guarantee of battery	Number of panel used

battery backup	Payback guarantee in
Manufacture	years Number of battery
country	Payback guarantee in
Manufactured	years Hours
company	Country name which produced SHSs
Manufactured	Longi
company Card_id	Jinko

4.3. Model 3

To investigate the impact of WTP on individual characteristics, we use a simple OLS model, and to convert it on different levels like lower-class, middle-class, and upper-class respondents, quantile regression is used where WTP is used as the dependent variable and other variables like age, gender, education, average income, family status, house size, electricity bill, exposers of SHS, awareness of SHS, trust, environmental ethics, and power outage as independent variables.

OLS model for willingness to pay for solar home systems:

$$WTP = \beta_0 + \beta_1 age + \beta_2 Edu + \beta_3 inc + \beta_4 P. Outage + \beta_5 trust + \beta_6 Env + \beta_7 E. E + \beta_8 gen + \beta_9 H. size + \beta_{10} Exp + \beta_{11} F. s + \beta_{12} aware + \varepsilon$$

Where WTA is Willingness to adopt solar home system (1=Yes, 0=No), β_0 denotes the Intercept of the equation, β_s represents the Coefficient value of all variables in equation, age, edu, inc, E.E, Env, trust, P.Outage, gen, H.size, Exp, F.s, aware, denotes the age, education, income(1000), electricity expenses, environmental ethics, trust, power outage, gender, house size, exposers of SHSs, family size and awareness about SHSs while ε denotes Standard Deviation.

Table 5: Variable description for willingness to pay at individual characteristics

Variables	Variables Name	Descriptions of variables
Dependent variables	WTP	PKR
Independent variables	Age	years
	Gender	Dummy (male=1, female=0)
	Education	Years of schooling
	Income	Average income in 1000
	Family status	Dummy (Nuclear=0, joint=1) in Marla's
	Housing size,	Average bill per year
	Exposers of SHSs, SHSs awareness Trust	
	Environmental ethics Power outage	
	Electricity bill,	

5. Results and discussion

This part of the study explains all findings & recommendations related to the study's main objectives.

5.1.Descriptive analysis

We have some demographic variables like age, education, gender, household income, annual electrical expenditure, family size, house size, family type, house type, occupations, residential area, source of adoption, and awareness.

Age is an important variable influencing the willingness to adopt solar home systems. The expected impact of age is positive on the WTA of SHSs, which means that aged people are more willing to adopt the solar home system, as 63% of respondents are middle age. Out of this, 40% are adopters. This is related to (Jan et al., 2020)

Household income is also another essential variable. As the respondent's income increases, the WTA for SHSs will also increase. In this study, we use both incomes, like the sum of the monthly income of the respondent and his/her family income or income for all resources. The results of the descriptive analysis show that 29% of respondents earn about 10000-40000 PKR in a month. Only 12% of people are willing to adopt the solar home system out of 29% because of their less income mean, while 51% of people earn between 40000-120000 PKR. Out of this, 34% are willing to adopt solar home systems.

The Electrical expenditure is a more critical variable as it is expected that if the respondent faces more electrical expenditure, then the willingness to adopt solar home systems will increase. The results show that about 56% of respondents pay an annual 30000PKR electricity bill, out of this, 34% of people are WTA the solar home systems.

Education is a more critical variable to influence the WTA for SHSs. As 39% of respondents are more educated, like inter to master level. 25% are adopters out of this 39 % respondents. The family type also impacts the adoption of SHSs, as 68% are nuclear and 32% are joint. Another variable is house status, as 87% own houses and 13% of respondents are rented.

Regarding the residential area, 85% of respondents live in urban areas while 15% live in rural areas. Some respondents are employed, about 60%, and some are self-employed (40%). If we look at house sizing, 7% have small houses, while 39% of respondents have large houses. Family size is another critical variable in the WTA for SHSs as 50% of respondents have small family sizes while 45% have medium family sizes only 5% have large family sizes.

Table 6: Descriptive Analysis

Variables	Frequency	Percentage	Standard Deviation	Mean
Age				
18-30	30	19.00		
31-40	62	31.00		
41-50	64	32.00	0.0705105	1.475

51-Above	35	17.00		
Education				
1-10	57	28.00		
11-15	78	39.00	0.0552927	1.04
16-Above	65	32.00		
Gender				
Male	121	60.00		
Female	79	40.00		
Income				
1000-40000	59	29.00		
40001-80000	52	26.00		
80001-120000	50	25.00	0.0778471	1.345
	39	19.00		
Annual Electric Expenditure				
1000-10000	28	14.00		
10001-30000	112	56.00		
30001-50000	42	21.00	0.0570418	1.25
50001-Above	18	9.00		
Family Size				
minimum-5	101	50.00		
6-10	88	44.00	0.0423849	0.55
11-Above	11	6.00		
House Sizing				
1-2	13	7.00		
2-4	67	33.00	0.0609792	1.745
4-6	78	39.00		
6-Above	42	21.00		

Variable	Frequency	Percentage
Occupation		
Employed	119	60.00
self-Employed	81	40.00
Residential area		
Urban	170	85.00
Rural	30	15.00
Family Type		
Nuclear	135	68.00
Joint	65	32.00
House Status		
Own	174	87.00
Rented	26	13.00
WTP		
Adopter	127	64.00
		4.00
		0.00
		0.00
		0.00
Non-adopter	73	36.00
		6.00
		0.00
		0.00
Total	200	100.00
		0.00
		0.00
		0.00

5.2. Regression Analysis for WTA of SHSs

Logistic regression analysis was used to estimate willingness to pay for the solar home system and factors influencing the adoption of solar home systems in Faisalabad. Logistic regression

analysis is preferred if the dependent variable takes a categorical/ordinal form.

The adoption of solar home systems (either adopted or not) has been taken as the dependent variable. Age is significantly associated with the likelihood of adopting solar home systems at a 10% level of significance. As people of middle age are more likely to adopt SHS than the younger age group. This finding is supported by the results of (Jan et al., 2020). Income has a positive and significant impact on the adoption of solar home systems at a 5% significance level, suggesting that an increase in income increases the likelihood of adopting solar home systems. Most low-income respondents expressed their willingness to install solar systems in their homes if the cost of solar panels is lowered. The results align with the findings of (Jan et al., 2020; De Groote et al., 2016). House size has a positive and significant impact on the WTA for solar home systems at a 10 % level, which means that respondents with larger house sizes would be more willing to adopt solar home systems.

People who experience solar home systems in their family, friend circle, or their area are significantly more willing to adopt solar home systems. Awareness about the SHS coefficient also positively and significantly impacts solar home systems adoption at a 1% level of significance. People with more knowledge about SHS are more likely to adopt solar technology. Awareness means knowing about solar home systems, their cost, and their capacities. This supports the findings of Abdullah et al., (2017) and Jan et al., (2020), which state that the lack of information is the foremost hurdle to adopting solar home systems at the 5% significance level. The coefficient of the variable trust (combined effect of trust on government and commercial entities) positively and significantly impacts the adoption of solar home systems. If trust in government and commercial entities increases, the likelihood of adopting solar home systems will increase.

Our null hypothesis is rejected for age, income, exposure of SHSs, house size, awareness about SHSs, and trust, which means that these variables significantly impact willingness to adopt solar home systems in Faisalabad.

Table 7: Regression for Willingness to Adopt SHSs

Variables	Coefficient	Standard Error	z Value	p>(z)
Age	0.0311	0.0176	1.76	0.078
Gender	-0.156	0.3595	-0.43	0.664
Education	0.0261	0.0667	0.39	0.695
Average income (1000)	0.0383	0.0169	2.27	0.023
Electrical expenditure	-0.0058	0.0111	-0.53	0.597
SHS exposure	0.6239	0.3466	1.80	0.072
Family status	0.449	0.369	1.22	0.223
House size	0.1622	0.085	1.90	0.057
House status	-0.118	0.497	-0.24	0.812
Awareness about SHSs	0.3483	0.128	2.71	0.007
Duration power outage	0.091	0.069	1.31	0.191
Trust	0.354	0.170	2.08	0.037
Environmental ethics	-0.202	0.1431	-1.41	0.158
constant	-2.984	1.429	-2.09	0.037
Number of Observation	200			
LR chi ² (10)	38.04			
Prob >Chi ²	0.0003			
Log Likelihood	-112.228			
Pseudo R ²	0.1449			

5.3. Product attribute of Conditional Logit for SHSs acceptance and Willingness to pay for SHSs

We use a discrete choice experiment model to estimate the acceptance and willingness to pay for the solar home system. As the dependent variable is in dichotomy or binary form, we use logistic regression for our model. However, the fact is that we give the respondent some choices for our choice experiment. We made choice cards and asked them to choose one option if they would pay. To make choice cards, we use some attributes of solar home systems. So that the model is

not only binary logit but also a conditional logit model. The conditional logit model describes the relationship between the product's attributes and its choice by giving different situations or conditions. The cost of the panel, output per day, cost per watt, country name, cost of a battery, battery capacity, the battery used, battery type, battery backup, and reduction in the bill are the attributes that impact the choice of solar home systems.

The results show (Table 8) that total cost, cost of the panel, cost of the battery, cost per watt, number of panels used, manufactured company1, manufactured country, and battery used significantly impact the acceptance of solar home systems. The coefficient of the attribute of the total cost has a negative and significant impact on the respondent's choice at a 5% significance level. This means that if the total cost increases by 1000 PKR, the willingness to pay for solar home systems will decrease. The coefficient of the attribute of cost of the panel has a negative and significant impact on a respondent's choice at a 10% significance level, suggesting that more costly panels are less likely to be chosen by the consumers. The coefficient of the attribute of the

Willingness is the maximum amount a person is ready to pay for the product. We want to check the willingness to pay for solar home systems in Faisalabad and conduct a choice experiment for this analysis. We can easily calculate the WTP of the solar home systems using the coefficient value of attributes of choice cards. The results show (Table 8) the mean value of WTP is positive for cost per watt, cost of battery, panel used, battery used, manufactured country, and manufactured company2, which shows that the respondent is more willing to pay for all these attributes or willing to pay for these attributes. As the mean value of WTP is negative for the cost of the panel, battery backup, guarantee of panels, guarantee of battery, and manufactured company1, this shows that the respondent is less willing to pay for all these attributes or not willing to pay for these attributes.

Table 8: Product attribute of Conditional Logit for Acceptance of SHSs and willingness to pay for SHSs

Attribute Description	Coefficient	Standard Error	z Value	p>(z)	Mean WTP
Total cost (1000)	-0.0674	0.303	-2.22	0.02	--

Cost of panel(1000)	-2.3565	1.216	-1.94	0.05	-34.971
				3	
Cost of battery (1000)	0.0948	0.0378	2.51	0.01	1.406
				2	
Cost per watt	57.753	28.95	2.00	0.04	857.044
				6	
Panel used	122.84	63.101	1.95	0.05	1822.89
				2	
Battery used	45.235	24.63	1.84	0.06	671.27
				6	
Guarantee of panel	-0.137	0.183	-0.75	0.45	-2.036
				3	
Guarantee of battery	-0.289	0.589	-0.49	0.62	-4.288
				3	
Battery backup	-0.342	0.616	-0.56	0.57	-5.075
				9	
Manufacture country	146.26	80.03	1.83	0.06	2170.51
				8	
Manufacture company	-94.85	45.56	-2.08	0.03	-1407.56
1				7	
Manufactured	24.80	19.171	1.29	0.19	368.041
				6	

Company 2

Number of observations	5593
LR chi ² (10)	1996.45
Prob >Chi ²	0.0000
Log Likelihood	-557.61632
Pseudo R ²	0.6416

Willingness to Pay for Solar Home Systems of Individual Characteristics The coefficient of exposers of solar home systems has a positive and significant impact on the willingness to pay

for the solar home systems at the 5% level, which means that the person who experienced solar home systems in their family, friend circle, or their area has significantly more willing to adopt solar home systems. While in the middle class, it has a positive significance of 1%, and in the high class, it also has a positive significance of 10%. Awareness about the SHS coefficient also positively and significantly affects solar home systems WTP at a 10% significance level.

At the 10% level, the coefficient of the variable environmental ethic negatively and significantly affects the WTP for solar home systems. While in the middle class, it will also be harmful and significant at a 1% level.

On the other hand, in the high class, it is negative and significant at a 5% level. The coefficient of family status positively and significantly affects solar home systems' willingness to pay at a 5% level. This means that the joint family is more willing to pay for solar home systems as joined families can more efficiently use solar home systems. In the middle and high classes, the coefficient of family status is positive and significant at 5%. The low-class respondent is more concerned with income as the coefficient on income is positive and significant at a 10% level, which means that if the income is increased, then the willingness to pay for solar home systems will also increase.

Table 9: Willingness to pay for SHSs at individual characteristics

Variable Description	Coefficient	Standard Error	Quantile		
			25%	50%	75%
Age	-1842.60	4133.457	2616.91	2060.745	-1266.436
Gender	54387.83	82721.66	27440.2	-31449.18	-70921.07
Education	-2997.351	16147.07	9971.85	10933.82	-3361.519
			3		
Average income (1000)	2599.02	2435.071	5280.33	2956.053	2576.22
			9*		
Electrical expenditure	2453.524	2558.843	1634.79	-1923.344	1864.845
			4		
SHS exposure	178996.1**	83027.13	56110.2	231822.9*	112827.5*

			6	**	
Family status	174316.6**	85231.88	34393.1	159971.8*	144063.7*
			1	*	*
House size	18193.95	17201.09	24552.4	11795.31	10935.73
			6		
Awareness	49192.97*	28735.12	28999.1	40783.88	29742.99
abo			1		
ut SHSs					
Durationpower	2933.464	15482.22	20929.1	13061.55	15749.09
			1		

6. Conclusion and Policy Recommendations

Solar energy is a form of renewable energy by which we can produce electricity for our home and commercial needs. As the demand for energy increases and we do not have fossil fuel resources to produce electricity in Pakistan, Pakistan highly depends on imported energy (fossil fuel, natural liquefied gases, and coal), significantly increasing the cost of electricity generation. Another disadvantage of electricity produced from fossil fuels is environmental degradation due to pollution emissions like CO₂ and GHGs emissions. Many people are moving towards renewable energy to reduce environmental degradation and electricity consumption expenditures.

The main purpose of this study is to check the acceptance and willingness to pay for solar home systems in Faisalabad and the determinants related to product attributes and individual characteristics that impact the adoption of solar technology and willingness to pay. A field survey was conducted by choice experiment. Conditional and binary logit was used to find the determinants related to product attributes and individual characteristics, respectively of SHS adoption. The MTF is used to make choice cards by using their attributes (cost of panels, output per day, cost per watt, manufactured country, cost of battery, battery capacity, battery used, battery backup, bill reduction) and levels (tier1, tier2, tier3, tier4). The main factors related to product attributes that make consumer preferences are cost, manufacturing country, and manufacturing company.

The main determinants of individual characteristics are the respondent's age, income, house size,

trust in government and commercial entities, awareness, and whether the respondent experienced solar technology in their surroundings.

Quantile regression and Ordinary Least Squares techniques explored the determinants of willingness to pay for solar home systems. Income is a crucial determinant for households with low WTP. Other key determinants were age, awareness, and family type, whether joint or nuclear.

7. Policy Recommendations

According to study findings, individuals are less willing to pay for solar home systems because of the SHSs' overall cost. It follows that the primary obstacle to the adoption of solar home systems is their high cost. As a result, the measure must remove tariffs or provide green financing that covers its installation cost. The family status also has a vital role in adopting solar home systems. Joint families are more willing to adopt solar systems because large households can more efficiently utilize solar technology than small households. According to the study, people prefer high-quality products for their uses, so if solar home systems are imported from a more developed nation like Canada, people will be more ready to pay for them. As a result, the purchase of solar house systems from superior nations like Canada is necessary. Most respondents stated that they are more concerned with merchandise quality than price. Considering the study's findings, people must pay more for battery technology, including capacity, backup, and battery types. Government should upgrade this technology. Also, the government should incentivize the production of SHSs in Pakistan, which may reduce the Cost of SHSs. Since the adoption of solar home systems is influenced by public awareness of the technology. As a result, 32% of respondents need to become more familiar with the technology. Therefore, social media channels, including TV, seminars, magazines, and workshops, should promote public awareness about SHS technology and its benefits. The findings show that the person who experienced solar home systems in their family, friend circle, or area is significantly more willing to adopt solar home systems. Additionally, they will undoubtedly update the systems, so the government should promote SHS adoption and help people take advantage of its benefits.

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