DOMESTIC ENERGY POVERTY AND WILLINGNESS TO PAY FOR ALTERNATIVE ENERGY: THE CASE OF PAKISTAN

by

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Submitted to the Institute of Social Sciences
in partial fulfillment of the requirements for the
degree of Master of Arts

Sabancı University
July 2018

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Approval date: July 20, 2018

ABSTRACT

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Economics, M.A. Thesis, July 2018

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Reliable and affordable energy service is an essential input factor for the human development and the improvement of the living standard of households. However, Pakistan has been in the grip of severe energy deficiency and under electrification. This study investigates the determinants of the household's willingness to pay (WTP) for an alternate energy source in Pakistan. Moreover, we explore the factors that affect the adoption of solar home system as an alternative energy source. Using World Bank data collected from 8500 households we applied ordered logit and binary probit approaches to examine these research questions. The results indicate that socio-economic and solar awareness characteristics significantly affect the household WTP for the alternative energy source. Moreover, we document affordability and costs saving attributes are of potential alternative source are important in determining the WTP. Further, the empirical analysis estimated the importance of affordability of electric source and improved availability of the energy for the adoption of solar home system as an energy alternative. These results imply that governments in developing countries need to design policies for the affordable solar home system. Besides our results highlight the importance of ongoing research for better solar energy batteries that could provide longer availability of the energy.

Key words: Energy poverty, Alternative energy, Willingness to pay, Solar home system

ÖZET

ALTERNATİF ENERJİ İÇİN ÖDEMEK İÇİN YURT İÇİ ENERJİ YOKSULLUK VE MÜCADELE: PAKİSTAN ÖRNEĞİ

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Ekonomi, Yüksek Lisans Tezi, Temmuz 2018

Tez Danışmanı: Dr. Öğr. Üyesi Erdal Aydın

Güvenilir ve uygun fiyatlı enerji hizmeti, insan gelişimi ve hane halkının yaşam standardının iyileştirilmesi için önemli bir girdi faktörüdür. Bununla birlikte, Pakistan şiddetli enerji eksikliği ve elektrik enerjisini endüstri, ulaşım ve gündelik yaşama uygulama, elektrik enerjisini her alanda kullanılır duruma getirmede ciddi sıkıntılar çekmektedir. Bu çalışma, hanehalkının Pakistan'da alternatif bir enerji kaynağı için ödeme istekliliğinin (WTP) belirleyicilerini ve ayrıca, güneş enerjisi sisteminin alternatif bir enerji kaynağı olarak benimsenmesini etkileyen faktörleri araştırmaktadır. 8500 haneden toplanan Dünya Bankası verilerini sıralı logit ve ikili probit yaklaşımlarına uygulayarak araştırma soruları incelenmiştir.Sonuçlar gösteriyor ki, hane halkının alternatif enerji kaynağı için ödemeye istekliliğini (WTP) etkileyen önemli iki faktör sosyo ekonomik ve solar farkındalık karakteristikleridir Çalışmamızın sonuçlarına göre ayrıca alım gücü ve daha düşük enerji maliyetleriWTP'nin belirlenmesinde önemli diğer faktörlerdir. Dahası, ampirik analiz, elektrik kaynağının karşılanabilirliğinin ve enerji alternatifi olarak güneş ev sisteminin benimsenmesi için enerjinin daha iyi kullanılabilirliğinin önemini ortaya koymuştur. Bu sonuçlar, gelişmekte olan ülkelerdeki hükümetlerin uygun fiyatlı güneş ev sistemi için politika tasarlamaları gerektiğini göstermektedir. Bu sonuçların yanı sıra, araştırmamız enerjinin daha uzun süre kullanılabilir olmasını sağlayabilecek güneş enerjisi pillerinin önemini vurgulamaktadır.

Anahtar Kelimeler: Enerji yoksulluğu, Alternatif enerji, Ödeme istekliliği, Güneş ev sistemi

ACKNOWLEDGEMENT

I am deeply grateful to my thesis advisor Dr. Erdal Aydın for his guidance throughout the thesis.

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CHAPTER 1
INTRODUCTION

Pakistan is an energy deficit country. There is a huge demand and supply gap for the energy in the country, which is brewing since 2007 until reaching the current levels. The statistics of 2015 showed that the demand for electricity is 22,158 MW but the installed capacity is 18,000 MW which gives rise to a 5000-7000 MW shortfall per day. Such a huge gap has led to load-shedding of 12-16 hours per day across the country (Government of Pakistan, 2016). This gap led to a deprivation of energy for more than 212 million people across the country. There is no reliable access to the electricity, for both grid-connected and non-connected households. It is because either the grid-connected households experience daily blackout of 12-16 hours or residences are not connected to the grid system at all (International Finance Corporation, 2017).

Most of the countries throughout the world rely on fossil fuel to meet energy requirement. In 2014 non-renewable fossil fuels such as coal, oil, and gas have a share of 87%, while 9% and 4 % is by renewable energy and nuclear power respectively (Sheikh, 2010). Like most other countries in the world, Pakistan mainly depends on fossils fuel to meet its energy requirement. Electricity generation sources like oil, coal, gas, nuclear hydro and wind contribute to 37%, 0.1%, 26%, 5%, 31% and 0.8% respectively of primary energy supplies (International Energy Agency, 2015).

Pakistan has limited and underdeveloped fossil fuel resources and there is a need to import to fill the resources gap (Sheikh, 2010). In recent years, there is a continuous increase in the adoption of the renewable energy technologies, such as solar and wind. Renewable energy could provide a solution to the electricity shortage problem. The renewable energies such as solar, wind, and biomass have a great potential to fulfill the rapid supply demand gap of the electricity in Pakistan. The potential for renewable energy is 2,900,000MW for solar, 346,000 MW for wind, 3,000MW for biogas, 2,000MW for small hydropower and 1,000MW for waste-to-energy (Wakeel *et al.*, 2016). However, the current adoption of the renewable energy alternatives is far below these numbers. Two possible explanations for slow growth are the lack of awareness and

knowledge of alternative energy technology among potential customers. Studies indicate that, in general, many rural households across the world are not aware of solar technology (Friebe *et al.*, 2013; Samad *et al.*, 2013; Urpelainen and Yoon, 2015). However, solar power is promising among the renewable energy sources. The use of solar energy in Pakistan will not only help to reduce the electricity generation burden, it will also reduce the budget deficit of the country. There is an urgent need not only to generate more energy but also to shift the power generation from the expensive method of using furnace oil to alternative cheap energy sources.

This study analyzes the determinants that affect households' willingness to pay (WTP) an additional amount for the alternate energy source and aims to investigate the factors that drive the households' choice of solar home system as an alternative energy source. In this study, the alternative energy source refers to the energy source that is expected to fill the gap between the energy demand and supply for the households. This study chooses to investigate the consumers' WTP for the alternate energy source to provide an idea regarding the financial burden consumers' can bear on their own and help the private sector to make the investment decision in the market. Answers to these questions are important to the policymakers and given the level of energy poverty and the economic condition of the country, more capable energy policy could be shaped. The empirical analysis is based on the estimation of the ordered logit model for the WTP analysis for the alternative energy and binary probit model to determine the factor affecting the installation of the solar home system.

The results indicate that affordability of electric source and costs saving attributes are important in determining the WTP for the alternative energy. The affordability of electric source and improved availability features of a potential alternative are significant for the adoption decision of solar home system. Hence the adoption of energy alternative in a developing country like Pakistan is mainly driven by the household daily need for energy, unlikely developed countries where household resort the alternative energy source for the adoption of an innovation or a remedy to the greenhouse gas emission (Borchers, 2007, Scarpa, 2009). Our empirical analysis also shed light on the importance of peers' effect in the adoption of the solar home system. It reflects the importance of social norms in the adoption decision. Our results imply that the government needs to design policies for the affordable solar home system and research for the better solar energy batteries for the longer availability of energy. The

financial incentives could be given in the form of subsidy or attractive payment installments.

In Pakistan, unfortunately, in the past limited work has been done on the conceptual and methodological scope of the energy poverty Almost all the existing literature comprises a limited amount of survey data. The academic work which already exists tends to be focused on descriptive analysis based on small survey data, limited to the particular areas. It leads to the policies on the subject being formulated in the absence of systematic and detailed scholarly research with the econometric model. This study is designed as an exploratory investigation because limited knowledge is available regarding the WTP additional amount for the alternative energy and adoption of solar home system in Pakistan. Our study aims to contribute positively to literature by providing an empirical analysis representing the economic perspective of energy alternative sources. The survey data used in this study is the most comprehensive and detailed to this date that focuses on energy poverty, the alternative to the energy source and willingness to pay attributes of the households. The study is also significant as it contributes to the growing body of research on the alleviation of energy poverty through solar energy technology.

1.1 Solar Home System: Opportunities and Challenges in Pakistan

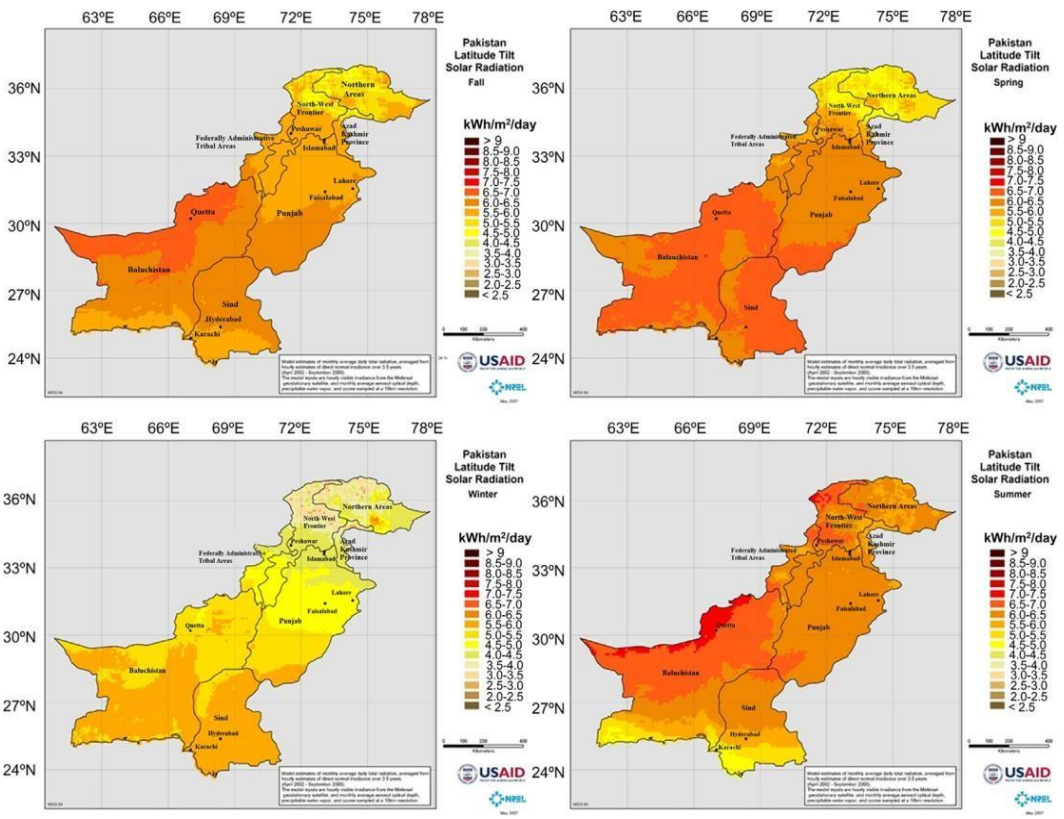
Pakistan is bearing a huge fiscal burden as a result of the dependence on furnace oil for electricity generation. In the fiscal year, 2016-17, power sector consumed 33% of the total petroleum oil lubricants. Particularly keeping it in view the policymakers have suggested shifting the energy policy paradigm (Sher *et al.*, 2014). One particular solution is the encouragement of renewable energy sector in the country. Under this policy solar energy is a major potential energy source available as a solution in the country.

Pakistan is located at an area that has sufficient solar radiation. This high level radiation is available abundantly throughout the country. There are areas in Pakistan that are afar off the populated regions. It is hard for the government to provide grid connection to the residents of such areas. The residents in these areas could acquire their energy needs through solar power. Pakistan receives an average irradiation of 5–7 kWh/m^2 a day in 95% of its land (Sher *et al.*, 2014). Out of the five provinces in most of

the area receives above 5 kWh/m^2 per day. This makes it possible for the far away residences, which are not connected to the grid, to install a solar energy system. The map in Figure 1 has provided the available four seasons of solar irradiation in Pakistan (National Renewable Energy Laboratory (NREL), 2014). It is clear from the map that the country receives global insulation over more than 95% of its area (Alternative Energy Development Board, 2018).

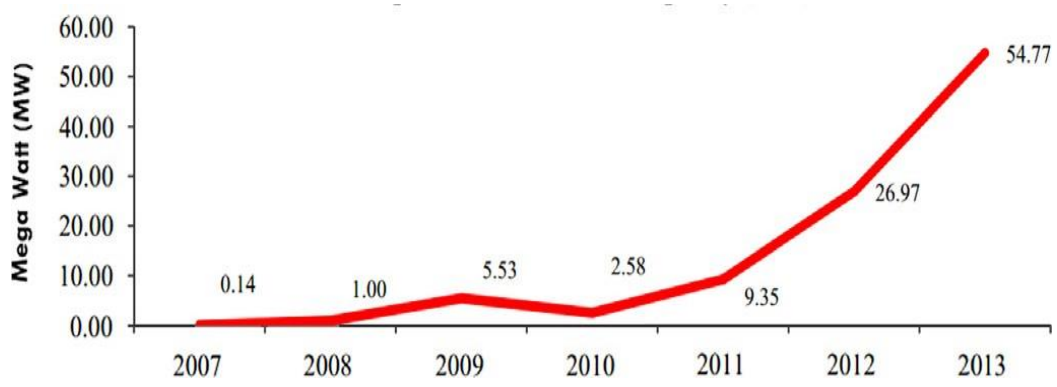
The data used in this study has gathered information about two main categories of solar appliances: Solar Lanterns and Solar Home System. Solar lanterns are characterized by a LED lamp, solar panels, battery, and charge controller. On the other hand, Urpelainen and Yoon (2015) have characterized solar home system as "a solar panel and the ancillary equipment typically batteries, charge controllers, wiring, and electric appliances needed to generate electricity for household uses". The solar home system charges a battery during the day, and households typically use the electricity at night. These solar systems are available in different energy power; their size possibly varies from 10 to 500 W, depending on the household's energy need, and willingness and ability to pay.

Figure 1: Irradiation map Pakistan (National Renewable Energy Laboratory (NREL), 2014)



In Pakistan the use of solar products by the households is mostly energy need driven. There are several such products available in the market to be used as an energy alternative. Most of the reliable solar products are newly available in the country. In a field survey by the IFC, households were asked in the questionnaire the date of purchase of their solar product. It was estimated that almost 90 % of the households made their purchase within the last 12 months (International Finance Corporation, 2017). Recently, there is an increase in the use of the solar energy products in the country. This increase is more obvious from the solar energy product import data from the last years. Subsequently, in the last few years, solar energy emerged as a part of the other energy generation sources in Pakistan. Figure 2 shows its share in the electricity production increases from 2008 to 2013.

Figure 2: Year wise import of the solar panel capacity (MW)



Source: (Ministry of Finance, 2014)

CHAPTER 2
DATA DESCRIPTION

This study employed a large household-level micro data from World Bank (WB). In the WB Country Partnership Strategy (CPS), the energy sector is declared as one of four precedence strategy pillars for the WB's engagement in Pakistan (Wakeel *et al.*, 2016). The data was collected through questionnaire from households. This World Bank survey was conducted in 2016, covering a sample of 8,500 households. The information collected in the survey identified the household profile, their energy attributes, information and communication product usage, solar awareness and household financial details. In this way, the collected questionnaire focused information in the four thematic areas: measure the attributes of energy services, energy consumption patterns, the economic feasibility of energy and psychographic driver's behaviors related to energy use.

The data used in this study provides insight into the factors that affect the willingness to pay an additional amount for the alternative energy sources. Moreover, this study also analyzes the factor that affects the deployment of the solar home system as an alternative energy source in their residence. The alternative energy refers to an energy source used to solve the household's energy access problem. It is an energy solution used in case of absence of resident's current primary source of energy and expected to fill the gap of the energy needs of the households. In this survey, the electrified and unelectrified households both are inquired about the WTP for the alternative energy source. Both the grid connected and non-connected household suffers from the energy access problem. Household even who have grid connection often have limited hours of access because of the poor quality of supply.

In this survey, randomly stratified sampling methodology was adopted in such a way that it recruits the sample with a highly represented rural area. Hence it led to the data highly representing energy-deprived areas. Under this methodology, those areas of the country are highly represented in the data that are expected to suffer more from unmet energy demand. This sampling method was followed to clearly understand the 'energy poor' segment of the country. This will allow getting a better picture of the energy poverty and WTP for the alternative energy source in the country and to understand the barriers that could appear while developing the alternative energy sector

in Pakistan.

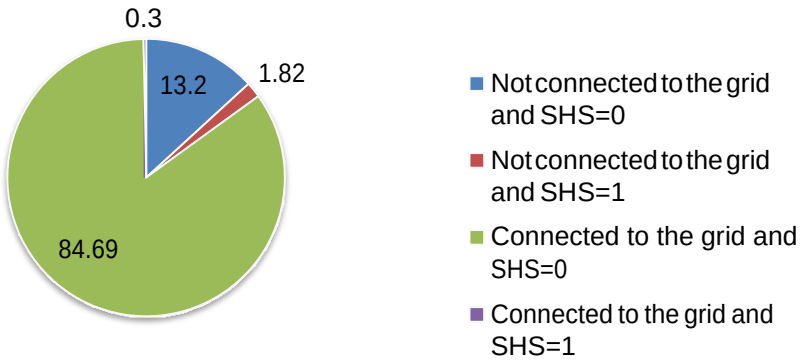
In the analysis, the households living in rental houses, which comprises around 5.5% of the sample, are excluded from the data, as it is the house owner who would make the decision whether to adopt the alternative energy source or not. Hence, we have taken only owner-occupied homes into account. Furthermore, the outlier observations are eliminated by discarding observation below 1st and above 99th quintiles of the income distribution. The final sample consists of 7,745 households. The descriptive statistics for these households are presented in Table 1, which summarizes the full sample, the house with and without solar home system separately. It shows household characteristics including the gender of the head of household, household size, number of rooms, household composition, education status and occupation of the head of the household. This descriptive analysis shows that most of the residences which have the solar home system have a male as the head of the household, are single parents' households and smaller size families. The table further revealed that the influence of the number of the room in the residence is less clear and a large number of unskilled workers adopt solar home system.

Table 1: Socio-demographic characteristics of households

Variable	Full sample %	No SHS %	SHS %
Gender			
Male	63.46	62.75	96.34
Household size			
1-3	10.54	10.14	28.66
4-5	39.32	39.39	35.98
7 or more	50.15	50.47	35.37
Room does the house have			
Hall type	16.64	16.67	15.24
2 rooms	34.67	34.44	45.12
3 rooms	24.34	24.31	25.61
4 or more rooms	24.35	24.57	14.02
Household composition			
Single	12.68	12.27	31.71
Education of Head of household			
Illiterate	34.82	34.80	35.98
Less than 10 years of schooling	28.96	28.85	34.15
Matric or intermediate	26.61	26.63	25.61
University Graduate	9.61	9.72	4.27
Occupation of head of household			
Unskilled worker/ Petty Trader	36.73	36.38	53.05
Skilled Worker/ Non-Executive Staff/ Supervisory Level	42.43	42.61	34.15
Small Businessmen/ Lower/Middle: executive, officer	14.54	14.67	8.54
Self-employed/ Medium Businessmen	5.09	5.12	3.66
Senior Executive/Officer/ Large Businessmen	1.21	1.23	0.61
Number of observations	7,745	7,581	164

Another important feature of the households given in the data was the main source of the electricity in the residence i.e. grid and non-grid connection. The statistics indicate that alternative energy sources are used by both the grid and off-grid users. Hence, we subdivide grid connected and non-connected households to solar home system owners and non-owners. The on-grid user uses energy alternatives because of the everyday frequent energy breakout and off-grid energy users use alternative energy sources to fulfill the basic energy needs. Figure 3 shows 15 % of the households are not connected with the grid. Among them, 12% of households own solar home system. Among grid-connected households, a small percentage of only 0.4% of the households adopted the solar home system. These statistics indicate that major solar home system adopters are grid non-connected households.

Figure 3: Connection to the grid and solar home system adoption



Another important feature to be considered is the economic conditions of the grid-connected and non-connected households. In Figure 4 the average annual income, annual electricity expenditure and WTP for the energy alternative are considered for grid-connected and non-connected households. It is visible that all three monetary figures i.e. average annual income, electricity expenditure and average WTP for the energy alternative are lesser in case of grid non-connected households as compared to the grid-connected households. The average annual income of the grid non-connected is 1693.24$. It is 822.60$ lowered as compared to the average income of the grid-connected households. It is pertinent to mention that grid non-connected residents are on average spending 7.25% of their average income to access the electricity and they are on average willing to pay an additional payment of 33% of their electricity expenditure to adopt an alternative energy source to get better electricity service. Here alternative energy refers to the energy source that solves the energy access problem of the households. In the case of grid-connected households on average electricity expenditure

is the 10.52% of their average income and they are on average willing to pay 24% of their electricity expenditure as an additional amount for an alternative energy source. The households in the data are using a significant amount of their income on the electricity expenditure. Income and electricity expenditure might influence the investment decision in the alternative energy sources.

Figure 4: Income, electricity bills and WTP for alternative energy

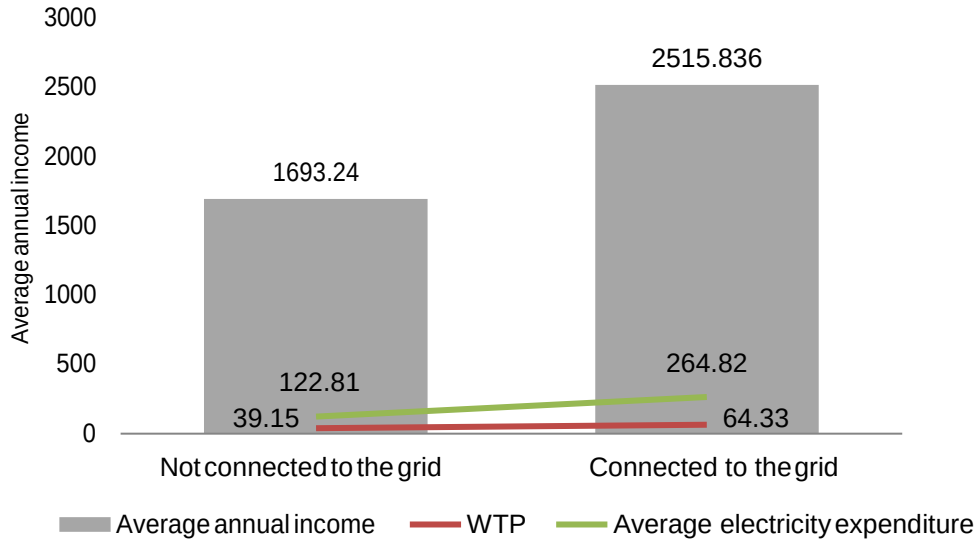


Figure 5 provides information on the household electrical appliances. More than 73% of the household stated that they used low energy light bulbs. The cooling appliance like fan is also used by the majority of the households, at more than 81%, while electrical kitchen appliances are not in as much frequent use. They were used by only a small minority of households, by 5% only. These statistics indicate that electricity used by the households is mainly for cooling and lighting purposes.

As lighting is one of the major energy service used in the residence, hence Figure 6 provides the statistics on households' satisfaction level from the current source of energy for lighting. The respondents were asked to indicate how satisfied they are from the current source of energy for lighting. A considerably high percentage of the respondents are dissatisfied from lighting energy source. It is visible that more than 68% of the households are between extremely and slightly dissatisfied with the energy source for lighting. Only a small fraction of the residents are extremely satisfied.

Figure 5: Main appliances used in the households

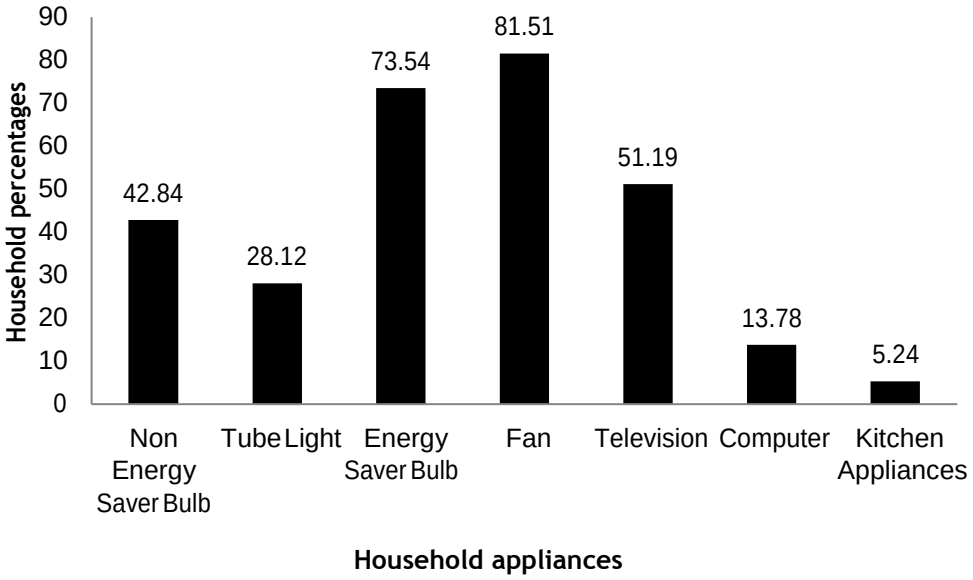
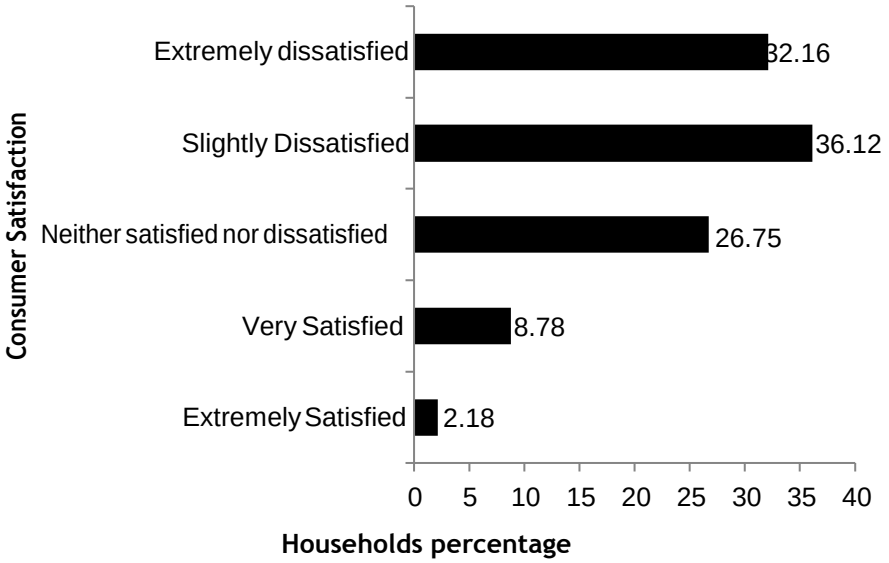


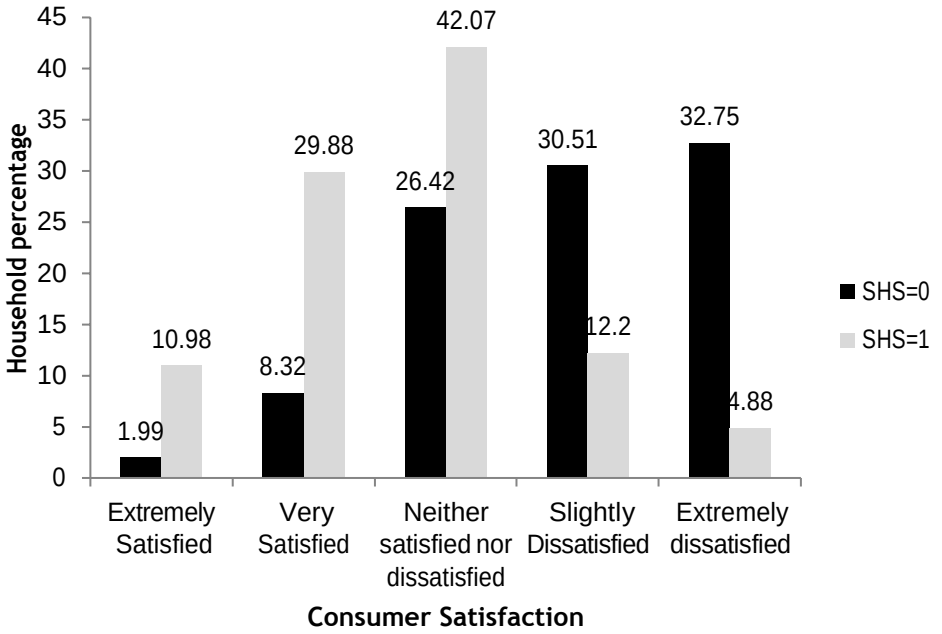
Figure 6: Satisfaction from the current source of energy for lighting



Once the households are divided according to the level of satisfaction from the current energy source, in Figure 7 we further subdivide household percentage according to the solar home system users and nonusers. The solar home system satisfies the basic energy needs like lighting. It is observed that a higher percentage of solar home system users had expressed the level of extremely satisfied and very satisfied as compared to the percentage of slightly dissatisfied and extremely dissatisfied. Almost 40.76% of

the solar home system user households are extremely satisfied or very satisfied, as compared to the 10.31% of solar nonusers.

Figure 7: Solar home system adoption and satisfaction from the current source of energy for lighting



To measure which features are important for the households when they think about a potential alternative for energy, three most important features of new potential lighting solutions were asked from the respondents. Figure 8 indicates that around 82% of the respondents are interested in the improved availability of energy, whereas 74% are interested in the affordable energy source and about 64% expressed cost saving as an important feature for the potential energy alternative. The statistics in Figure 8 support that the respondents believe that an improved availability which leads to an access to the electricity without any breakouts is the most important feature for a potential solution.

The solar home system can be considered as one of the major potential alternative energy sources. Table 2 summarizes data regarding solar power awareness of the households. It includes respondent knowledge about solar, trust in the solar home system, peers effect, having solar home system or solar lanterns. In the survey, about 53% of the respondents have knowledge of solar power and more than 63% trust the solar powered products. Social norms are important in the adoption of any innovation.

In the sample 34.38% of the respondents are aware of the peers using solar home system. In the data, 12.07% of the households own solar energy products at the residence.

Figure 8: Most important features of new lighting solution for households

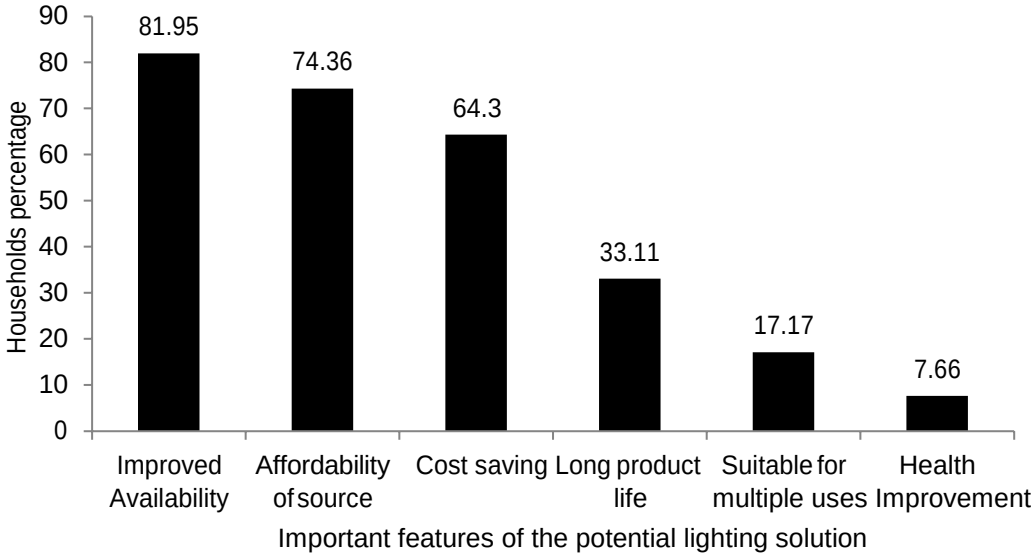


Table 2: Solar energy attributes of the households

Question	Response	%
Do you know what solar power is?	Yes	53.08
Do you think solar powered products can be trusted?	Yes	63.62
Do any of your neighbors, friends or relatives have solar power?	Yes	34.38
Does the household use solar lanterns or solar home systems for lighting?	Yes	12.07

CHAPTER 3

RESEARCH METHODOLOGY

In order to analyze the factors affecting willingness to pay for alternative energy source and adoption of solar home system, we apply two approaches respectively: an ordered logit model is used when the dependent variable is the resident's willingness to pay for the alternative energy sources while a binary probit model is used when the dependent variable is the adoption of solar home system. The starting point is following model with latent variable,

$$y_i * = x_i \beta + \mu_i \quad (1)$$

where β is a vector of coefficients and x is a vector of explanatory variables. It includes the household characteristics, energy attributes and solar awareness variables. Whereas y_i* is unobserved what we observe is the categories or response.

3.1. Ordered logit model specification for willingness to pay

Firstly, the ordered logit model is used to analyze the factors affecting the willingness to pay (WTP) for the alternative energy to access the alternative energy source. This alternative energy source provides the energy requirement in case of the absence of primary energy source. WTP is provided in the data as a categorical variable. It is expressed in the form of the amount resident is willing to pay weekly for the alternative energy source. The potential responses are ordered from 1 to 6. A WTP is expressed as six if the respondent is willing to pay an additional amount greater than 4$. A rating of five is for payment between 3-3.99 $, four for 2-2.99$, three for 01-1.99$, two for 1-0.99$, and one for the payment of nothing.

The ordered logit model analyzes ordered response. The model is constructed around a latent regression of the following form

$$y^* = x^T \beta + \varepsilon \quad (2)$$

where x is the vector of independent variables affecting the WTP, β is a vector of coefficients, Ɛ is the error term and y* is the unobserved dependent variable. Instead of y* following categories are observed,

$$y = \begin{cases} 1 \text{ if } y_i * \leq 0 \\ 2 \text{ if } 0 < y_i * \leq .99 \\ 3 \text{ if } 1 \leq y_i * \leq 1.99 \\ 4 \text{ if } 2 \leq y_i * \leq 2.99 \\ 5 \text{ if } 3 \leq y_i * \leq 3.99 \\ 6 \text{ if } y_i * \geq 4 \end{cases}$$

3.2. Probit model specification for adoption of solar home system

The binary probit regression is used to model the factors affecting the adoption of the solar home system. In this case the solar home system is a dummy variable which includes a binary (0/1) decision to own a solar home system or not. There is a vector of regressors X which are assumed to influence the outcome Y. The vector X includes the household characteristics, energy attributes and solar awareness variables. We specifically, assume that the model takes the form

$$\Pr(Y=1] \mid X) = \phi(X'\beta) \qquad (3)$$

where Pr denotes probability and ϕ is cumulative distribution function (CDF) of the standard normal distribution. The parameter β is estimated by maximum likelihood. For writing the probit model specification as a latent variable model, it is supposed that there exists a random variable

$$Y^* = X'\beta + \varepsilon \qquad (4)$$

where $\varepsilon \sim N(0, 1)$ and then Y can be viewed as an indicator for whether this latent variable is positive:

$$Y = 1_{\{y^*>0\}} = \begin{cases} 1 \text{ if } Y * > 0 \text{ i.e } -\varepsilon < X'\beta, \\ 0 \text{ otherwise} \end{cases}$$

Hence for this study, the empirical results to examine the factors affecting the solar home system adoption decision are based on the estimation of the following expanded Probit specification. Probit model is specified as

$$SHS_i^* = \beta_o + \beta_1 X_{i1} + \beta X_{i2} \ldots\ldots\ldots + \beta X_{ij} + \mu_i \quad (5)$$

$$\text{Where } SHS_i = \begin{cases} 1 \text{ if household own solar home system} \\ 0 \text{ otherwise} \end{cases}$$

$$\Pr [SHS_i = 1] = \Pr [SHS_i^{*}>0] = \Pr [\mu_i> - \beta_o - \beta_1 X_{i1} - \beta X_{i2} \ldots\ldots\ldots\ldots - \beta X_{ij}] = \phi (\beta_o + \beta_1 X_{i1} + \beta X_{i2} \ldots\ldots\ldots\ldots.. + \beta X_{ij})$$

where X is the vector of the independent variables reflecting household characteristics, solar awareness, and energy attributes and ε is an error term. The basic probit command depicts coefficient estimates and also standard errors, which are index coefficients. They only provide the direction of the effect and the partial effect on the probit index/score. These underlying indexes do not correspond to the average partial effect. Thus the marginal effects are measured.

CHAPTER 4
RESULTS AND DİSCUSSİON

This section presents the empirical results on the factors affecting WTP for the alternative energy source and the adoption of the solar home system. In the analysis, the household characteristics, solar awareness and energy attributes are taken into account. The results of the ordered logit model and binary probit model are presented in the Table (3). In the case of WTP for the alternative source of energy, the ordered logit model coefficients revealed that all the household socio-economic variables and solar awareness coefficients are significant except for the source of the income. The study estimated the existence of gender difference in WTP for the energy alternative. In our study females are willing to pay more for the energy alternative when compared with males. These findings are in accordance to a previous study by Bigerna and Polinori 2015, in which males expressed willingness to pay less for the alternative energy. While some other studies in the literature (Urpelainen and Yoon, 2015; Mozumder *et al.*, 2011) estimated no significant difference among gender in the WTP. Theoretically, it is considered that women spend more time in the home on average. Hence, they are more willing to pay the additional amount for better energy services. On the other hand, on average women have less impact on the financial decision at the household level.

Household characteristics coefficients further indicate that positive attitude towards WTP increases with an increase in the income, better occupation and education; and decreases with the increase in the family size. The relevance of these characteristics for the WTP for the alternative energy has been recognized in the literature (Urpelainen and Yoon, 2015; Mozumder *et al.*, 2011; Sardianou and Genoudi, 2013; Bigerna and Polinori, 2015). Moreover, the solar awareness attributes play an important role in determining the WTP. The results revealed that knowledge, trust and peer effect of the solar home system has a significant effect on the WTP for the alternate energy source.

In a previous study Abdullah *et al.* (2017) indicate that households have the best affordable price yardstick to purchase and install the energy alternative. In our study, consumers ranked important features of the potential alternative energy source. Among these features the affordability of alternative energy source and cost saving features of alternative source are likely to affect the WTP for the energy alternative. The respondents who ranked both of these features among the important features are willing

to pay more for the alternative energy. The possible reason could be that the motivation for paying for an alternative energy in a country like Pakistan is the fulfillment of the need rather than the adoption of innovation or climate protection. Households adopt the alternative energy sources due to under electrification and they have to consider the cost due to the financial constraints. In a previous study Graber *et al.* (2018) documented that the consumers' preference for electricity is based most significantly on power, reliability, and price of the alternative source. In addition, the appliances used at the household level are also significant in determining the WTP for the alternative energy. The results imply that the effect of household television and computer ownership coefficient on WTP is positive and significant. Moreover, the household interest in the energy alternatives is a strong predictor of higher willingness to pay.

In the further analysis, a binary probit regression is taken into account to check the factors affecting the adoption of the solar home system as an option for the alternative energy source[1]. In this case, the household characteristics results reveal that the coefficient of the household size is negative and significant. It suggests that large size households are less likely to adopt the solar home system. In a previous study Gitone, 2014 estimated that family size has a negative and significant impact on the adoption of the solar home system. Likewise, the residential size is also an important factor to determine the solar home system adoption. The houses with the larger number of rooms are more likely to adopt the solar home system. In addition, households having agriculture or livestock as an income source is more likely to adopt the solar home system.

Moreover, from the solar awareness attributes the peer effect increases the probability of adopting the solar home system. While the knowledge and trust of solar power products do not have an explanatory reason for the adoption of the solar home system. In addition, the households who own energy saver device are more likely to install the solar home system. Another important result is that the probability of solar home system adoption decreases with the increase in the electricity access hours. So, access to the electricity primary source reduces the demand for the solar home system as an alternative source. Furthermore, the households with access to grid electricity are less likely to adopt the solar home system. This may induce the notion that solar home

[1] The results for the marginal affect for the factor affecting the adoption of solar home system are provided in the Table A1 in the appendix.

system is a potential substitute where the grid is not available. These results are not in line with the literature; Smith and Urpelainen, 2014, report that in 2007, households with grid electricity are more likely to own solar panels than their unelectrified counterparts. Conversely, our study indicates a negative and significant impact of the grid-connection on the adoption of the solar home system.

Finally, from the resident's ranked important feature of the potential alternative energy the affordability of energy source and improved availability of potential alternative are measured as important features for the adoption decision of solar home system. Their positive and significant coefficients show that an affordable energy source and improved availability are more attractive attributes for the consumers who adopted the solar home system. Hence the adoption of energy alternative in a developing country like Pakistan is mainly driven by the household daily need of energy under financial constraints, unlike developed countries where households resort to alternative energy source due to their interest in the adoption of an innovation or a remedy to greenhouse gas emissions.

Our estimation of factors affecting the WTP for the alternative energy source and solar home system adoption may differ based on the grid connection status. Hence, we estimated our model again by using data of a small sample only from non-grid connected households. The results are provided in Table 4. The explanatory factors are the same as in Table 3. As the table shows all the main results remain unchanged in case of adoption of solar home system. The only important difference in the outcomes is the knowledge of solar power is no more insignificant. Hence in case of non-grid connected households the knowledge and awareness are important factor for the adoption of solar home system.

Table 3: Ordered logit results for WTP and binary probit results for solar home system.

	Ordered logit model		Binary probit model	
VARIABLES	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**
Household Characteristics				
S1) Gender (Female = 1)	1.508***	(0.0742)	-0.175	(0.259)
S2) Household size (1-3)				
4-6	-0.130*	(0.0781)	-0.612***	(0.135)
7 or more	-0.240***	(0.0790)	-0.789***	(0.142)
S4) Number of Rooms (Hall type)				
2 Rooms	0.658***	(0.0701)	0.406***	(0.144)
3 Rooms	1.065***	(0.0779)	0.439***	(0.168)
4 or more Rooms	1.276***	(0.0878)	0.355*	(0.199)
S6) Household composition (Couple)				
Single parents	-0.154**	(0.0686)	0.217*	(0.131)
S7) Education of Head (Illiterate)				
Less than metric	0.429***	(0.0599)	0.220*	(0.121)
Intermediate	0.428***	(0.0658)	0.207	(0.141)
Graduate	0.345***	(0.0939)	-0.324	(0.267)
S8) Occupation of Head (unskilled worker)				
Skilled worker/ supervisory level	0.507***	(0.0566)	0.420***	(0.119)
Small business/middle officers	0.551***	(0.0782)	0.674***	(0.203)
Medium business/ self employed	0.583***	(0.111)	0.320	(0.256)
Large business/ senior officers	1.284***	(0.213)	0.465	(0.677)
HH2) Income	0.108***	(0.0179)	-0.177***	(0.0546)
E2) Source of Income: Agriculture and livestock (Yes = 1)	-0.00468	(0.0674)	0.509***	(0.159)
Solar awareness				
SA1) Know About Solar (Yes = 1)	0.206***	(0.0606)	0.0615	(0.128)
SA3) Trust on solar home system (Yes = 1)	-0.455***	(0.0633)	0.121	(0.166)
SA5) Peers effect (Yes = 1)	0.347***	(0.0556)	0.771***	(0.120)
Energy Situation				
ES2) Household connected to grid (Yes = 1)	-0.150	(0.128)	-0.901***	(0.196)
ES7) Grid is too far from household (Yes = 1)	-0.304**	(0.132)	0.392**	(0.153)
ES9) Has energy saver in the house (Yes = 1)	-0.0502	(0.0586)	0.721***	(0.122)
ES9) Has computer in the house (Yes = 1)	0.189***	(0.0708)	0.0551	(0.225)
ES9) Has television in the house (Yes = 1)	0.615***	(0.0558)	-0.679***	(0.179)
ES12) Access to the electricity in the month of low electricity supply	0.00611	(0.00733)	-0.192***	(0.0459)
ES18) Interest in the alternative (Yes = 1)	0.382***	(0.0598)	0.298	(0.205)
ES19) Important features for potential lighting solution				
ES19) Health improvement (Yes = 1)	0.240***	(0.0856)	0.207	(0.227)
ES19) Availability (Yes = 1)	0.0511	(0.0585)	0.355**	(0.160)
ES19) Affordability (Yes = 1)	0.253***	(0.0524)	0.254*	(0.140)
ES19) Cost Saving (Yes = 1)	0.228***	(0.0473)	0.0599	(0.115)
E3) Type of energy source for lighting in the household				
E3) Local Mini Grid (Yes = 1)	0.203**	(0.0980)		
E3) Generator (Yes = 1)	0.0371	(0.0942)		
E3) Solar (Yes = 1)	0.467***	(0.0828)		
E3) Rechargeable Batteries (Yes = 1)	0.136***	(0.0526)		
/cut1	-0.107	(0.173)		
/cut2	3.177***	(0.178)		
/cut3	5.066***	(0.184)		
/cut4	6.383***	(0.189)		
/cut5	7.468***	(0.197)		
Constant			-3.057***	(0.349)
Observations	7,745		7,745	

Table 4: In case of grid non-connected Ordered logit results for WTP and binary probit results for solar home system

	Ordered logit model Dep. Var: WTP		Binary probit model Dep. Var: Solar home system	
VARIABLES	**Coeff**	**Std. Err**	**Coeff**	**Std. Err**
Household Characteristics				
S1) Gender (Female = 1)	0.555**	(0.264)	0.000671	(0.322)
S2) Household size (1-3)				
4-6	0.662***	(0.201)	-0.770***	(0.179)
7 or more	-0.0680	(0.211)	-1.044***	(0.186)
S4) Number of Rooms (Hall type)				
2 Rooms	0.562***	(0.172)	0.352*	(0.181)
3 Rooms	0.780***	(0.198)	0.539**	(0.212)
4 or more Rooms	1.015***	(0.251)	0.506**	(0.249)
S6) Household composition (Couple)				
Single parents	0.526***	(0.180)	0.402**	(0.159)
S7) Education of Head (Illiterate)				
Less than metric	-0.106	(0.151)	0.0827	(0.151)
Intermediate	-0.0702	(0.200)	-0.0164	(0.191)
Graduate	0.648**	(0.320)	-0.240	(0.320)
S8) Occupation of Head (unskilled worker)				
Skilled worker/ supervisory level	0.556***	(0.157)	0.518***	(0.153)
Small business/middle officers	0.560**	(0.284)	0.778***	(0.279)
Medium business/ self employed	-0.0268	(0.356)	0.0148	(0.361)
Large business/ senior officers	1.261	(0.957)	0.895	(0.790)
HH2) Income	0.127**	(0.0618)	-0.273***	(0.0770)
E2) Source of Income: Agriculture and livestock (Yes = 1)	-0.0308	(0.206)	0.586**	(0.233)
Solar awareness				
SA1) Know About Solar(Yes = 1)	0.0631	(0.173)	0.277*	(0.169)
SA3)Trust on Solar home system (Yes = 1)	-0.150	(0.199)	0.233	(0.213)
SA5)Peers effect (Yes = 1)	-0.166	(0.170)	0.805***	(0.148)
Energy Situation	-		-	
ES2) Household connected to grid (Yes = 1)				
ES7) Grid is too far from household (Yes = 1)	-0.655***	(0.148)	0.362**	(0.161)
ES9) Has energy saver in the house (Yes = 1)	-0.0839	(0.176)	0.811***	(0.147)
ES9) Has computer in the house (Yes = 1)	-0.157	(0.260)	-0.381	(0.327)
ES9) Has television in the house (Yes = 1)	0.571**	(0.238)	-0.633**	(0.269)
ES12) Access to the electricity in the month of low electricity supply	omitted		Omitted	
ES18) Interest in the alternative (Yes = 1)	-0.00686	(0.184)	0.142	(0.247)
ES19) Important features for potential lighting solution				
ES19) Health improvement (Yes = 1)	-0.997***	(0.342)	-0.448	(0.474)
ES19) Availability (Yes = 1)	0.379**	(0.175)	0.575***	(0.215)
ES19) Affordability (Yes = 1)	0.703***	(0.189)	0.378*	(0.203)
ES19) Cost Saving (Yes = 1)	0.394***	(0.152)	0.118	(0.162)
E3) Type of energy source for lighting in the household				
E3) Local Mini Grid(Yes = 1)	0.231	(0.166)		
E3) Generator(Yes = 1)	0.143	(0.314)		
E3) Solar(Yes = 1)	1.366***	(0.218)		
E3) Rechargeable Batteries (Yes = 1)	0.411**	(0.168)		
/cut1	0.109	(0.382)		
/cut2	3.672***	(0.403)		
/cut3	5.650***	(0.428)		
/cut4	6.563***	(0.454)		
/cut5	7.003***	(0.476)		
Constant			-3.449***	(0.439)
Observations	1,163		1,163	

CHAPTER 5

CONCLUSION

Pakistan is facing a severe energy shortage. Solar energy is deemed as an appropriate source of energy as a solution to the energy access problem. As geographically Pakistan lies in sunny belt and has abundant amount of the sunshine throughout the year. This study has presented an ordered logit model to investigate the factors that affect the willingness to pay the extra amount for the alternate energy source as a solution to the energy access problem. Moreover, a binary probit model explores the factor responsible for the adoption of solar home system as an energy alternative source.

The results indicate the importance of the household and solar awareness attributes in determining the WTP for the energy alternative. The study also highlights the important features of the potential energy alternative for the households, which affect the adoption of solar home system. These are the uninterrupted availability of energy and affordable alternative; both features allow better access to the energy for households.

Our results imply that the government needs to enhance the research for the better solar energy batteries for the longer availability of the energy service. There is also a need to design the policies for an affordable solar home system. In this regard, the financial incentives could be given in the form of subsidy, loan or attractive installment payments. Our empirical analysis also sheds light on the importance of peers' effect in the adoption of the solar home system. It reflects the importance of social norms in the adoption decision.

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APPENDIX

A1: Average marginal effects

Household Characteristics	**dy/dx**	**Std. Err.**	**P>|z|**
S1) Gender (Female = 1)	-.005	.007	0.498
S2) Household size (1-3)			
4-6	-.024	.006	0.000
7 or more	-.028	.006	0.000
S4) Number of Rooms (Hall type)			
2 Rooms	.010	.003	0.002
3 Rooms	.011	.004	0.009
4 or more Rooms	.009	.005	0.090
S6) Household composition (Couple)			
Single parents	.006	.004	0.098
S7) Education of Head (Illiterate)			
Less than metric	.006	.004	0.073
Intermediate	.006	.004	0.156
Graduate	-.007	.005	0.163
S8) Occupation of Head (unskilled worker)			
Skilled worker/ supervisory level	.011	.003	0.001
Small business/middle officers	.022	.008	0.008
Medium business/ self employed	.008	.008	0.278
Large business/ senior officers	.013	.024	0.585
HH2) Income	-.005	.001	0.001
E2) Source of Income: Agriculture and livestock (Yes = 1)	.014	.005	0.001
Solar awareness			
SA1) Know About Solar (Yes = 1)	.002	.004	0.631
SA3) Trust on Solar home system (Yes = 1)	.003	.005	0.467
SA5) Peers effect (Yes = 1)	.022	.003	0.000
Energy Situation			
ES2) Household connected to grid (Yes = 1)	-.025	.006	0.000
ES7) Grid is too far from household (Yes = 1)	.011	.004	0.010
ES9) Has energy saver in the house (Yes = 1)	.020	.003	0.000
ES9) Has computer in the house (Yes = 1)	.002	.006	0.807
ES9) Has television in the house (Yes = 1)	-.019	.005	0.000
ES12) Access to the electricity in the month of low electricity supply	-.005	.001	0.000
ES18) Interest in the alternative (Yes = 1)	.009	.006	0.146
ES19) Important features for potential lighting solution			
ES19) Health improvement (Yes = 1)	.006	.006	0.362
ES19) Availability (Yes = 1)	.010	.005	0.027
ES19) Affordability (Yes = 1)	.007	.004	0.070
ES19) Cost Saving (Yes = 1)	.002	.003	0.601