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Analysis of Solar PV Technology Adoption in Off-Grid Communities of Khyber Pakhtunkhwa

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***Abstract*—** There has been a growing concern in the energy avenues owing to the fast depletion of the conventional energy resources. Pakistan imports 1000 MW of solar PV panels annually, mostly for large scale solar applications. Close to one-fifth of the population being off grid makes Pakistan a perfect contender for distribution solar PV. Considering this interest, this paper endeavor focus on the factors causing the lag in solar PV adoption at community and household level. Solar PV adoption has a direct linkage with the socioeconomic standing of the subjects. The families who adopted solar PV technology reported an improved education, health, work, information access, social and world perception, and communication with outside world. These factors cumulatively affect the quality of life in the rural communities. The high capital costs associated with the adoption of solar PV technology is a major inhibitor of large-scale dissemination of the technology. The environmental gains occurring from the solar PV technology pertaining to the reduced fuel usage have been common. Skill level of the technicians in the rural circles was found lacking which cascades down to the negative perception creation from sub-optimum performance of the solar PV panels installed. However, the awareness regarding safe usage would be highly beneficial for eliminating any negative perception about the technology. The study analyzed 90 households from three different villages of District Dera Ismail Khan in Khyber Pakhtunkhwa through primary data collected by surveys.

***Keywords*—** Solar PV, Social impact, adoption, rural development, Environment.

I. INTRODUCTION

The fast-paced depletion of the global fossil fuels supplies compounded by the limited nature of the reserves will inevitably lead to the exhaustion of these resources in the third quarter of the proceeding century. The morbid state of the world environments prohibits the use of the fossil fuels anyways. On the flip side the world energy demands are incessantly on an upward path underscoring the search for alternative supply of energy to fuel the needs of growing economies. This best modus operando in such a conundrum could be to augment the current energy mixes of the countries around the world with renewable options, beefing them up overtime to eventually completely replace the fossil fuels. The track was set with Kyoto protocol with countries taking the impending environmental doom seriously for the first time and seriously committing to redesign their energy supplies in accordance with the requirement of the below 2 degrees plan [1]. The Paris climate Agreement stipulated an even more ambitious plan of environmental conservation in face of the increasing challenges. Over the intervening period between the Kyoto Protocol and PCA the global energy dynamics have changed drastically a noticeable facet of which is that now the concept of western developed economies as the major polluters of the world has been largely debunked with the Asian and African countries on track to surpass the energy consumption of these countries for the first time in 2020 [2] A poignant aspect of this monumental growth in the use of energy is that the countries regarded as the least polluters are impacted the most by the adverse effects of the global warming. This is partly due to their location on the sunbelt along the equator and partly because of their struggling economies and significantly more poverty levels ill equipping them with the means to cope with the manifestation of global warming. The progressing renewable energy technologies at turn of the increased problems in environmental conservation can be seen as an epitome of human resilience and adaptation in the face of adversities. Renewable energy installations have far outpaced the conventional energy extraction technologies over the past decade. According to the Renewable Energy Report for the year 2017 renewable energy has been a major contributor in the new installations by some distance with capacity additions of 167 GW, almost 3 times higher than the 57 GW for coal and 5 times higher than 29 GW from gas. Additionally, the forecast is even more encouraging; by 2022 the most conservative forecasts puts the overall renewable

energy capacity around the world at 920 GW as can be seen from the figure 1.[3].

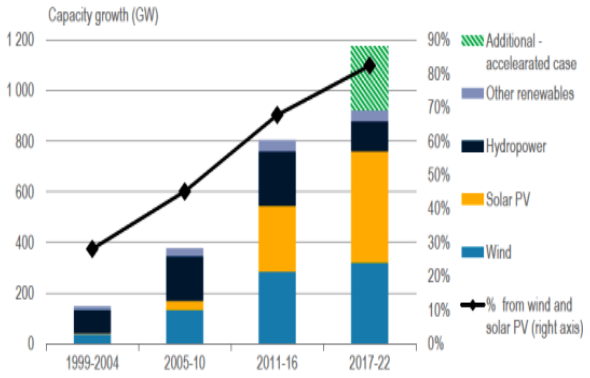


Figure 1 Renewable energy projections 2017-22 [3]

EASE OF USE

To tackle these challenges of insatiable energy demand around the world, set to grow by 25% by 2040, more than 2 trillion dollar investment is required per year. In the modern lack of proportionate investment from the private sector the governments around the world have to take up the mantle and spearhead the investments in the energy arena. The projections show that with the current level of private-public investments ratio in the enrgy sector the government around the world have to contribute around 70% of the investments in the sector to match up with the growing demand [4].

Pakistan still lacks electricity access for a considerable proportion of its population. The energy woes of the past decade and a half are well known. The energy shortage at its peak reached 8000MW and 5000 MW in the summers and winters respectively. This meant some areas of the country experienced 14-18 hrs long blackouts from the electricity grid as shown in the figure 3.

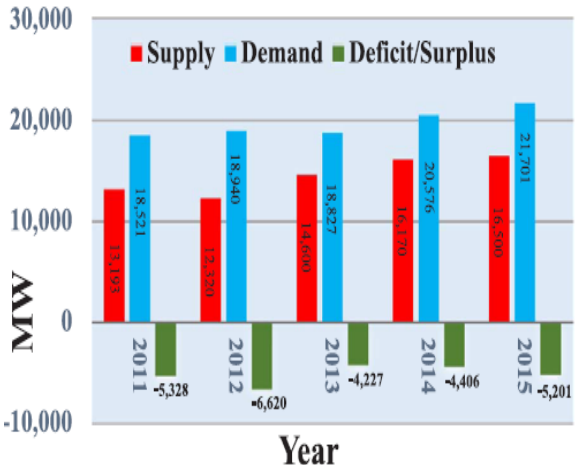


Figure 2 Electricity shortage in Pakistan [4]

Consequently, the energy challenges of the country have compounded over the past decade putting a strain on the economy. The sector wise consumption patterns also add insult to the injury further exacerbating the miserable situation. The consumption in the household or domestic sector has been steadily increasing at the expense of industrial consumption to reach 45% in 2017 against the more sustainable pattern of less than 30 % in the developed economies [5].

The current and proposed (2025) Energy mix of Pakistan as shown in the figure 3 below suggest the next 5 years require ever more addition of renewable resources. Fortunately, the renewable resources of the country are abundant. There are ample opportunities in solar, wind, biomass, and hydro power extraction in Pakistan [6].

There is, however, a lag in renewable off grid acceptance in the country as compared with the countries in the region. This thesis will go in to the heart of this matter.

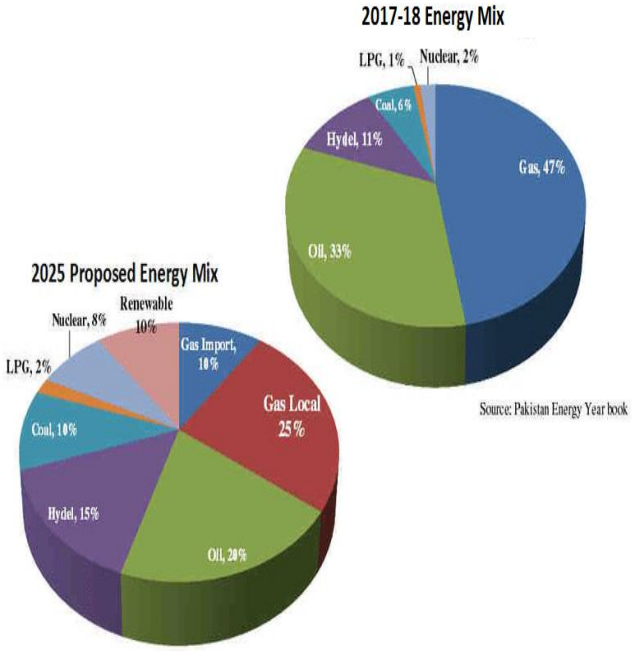


Figure 3 Pakistan Current and Projected Energy Mix [6]

The utilization of energy in a country fuels the prosperity and development. This unequivocal fact is supported by the figure1-3 below which plots the energy consumptions in the countries around the world with their Human Development Index (HDI). A visible pattern could be discerned from the figure supported by research in the human development and energy. The greater the energy consumption in a country, the greater its HDI, as a rule of thumb. Take Canada and US for instance, which fall under the highest HDI countries. These countries consume some of the highest energy per capita in the world. Now contrast that with the countries in the developing world such as Pakistan and India where the energy consumption per capita is among the lowest- 550 kWh per year per person for Pakistan. Consequently, Pakistan is at rank 150 out of the 189 listed countries with an HDI of 0.56 [7]. The concept of social value of energy is important as it underscores the means of achieving greater and greater progress from the

energy system. The energy system design should not be carried out in context of the energy access only, rather a part of a grand scheme of achieving durable progress and positive changes in the society [8]. This approach is in line with the Sustainable Development Goals (SDGs) envisaged by United Nations (UN).

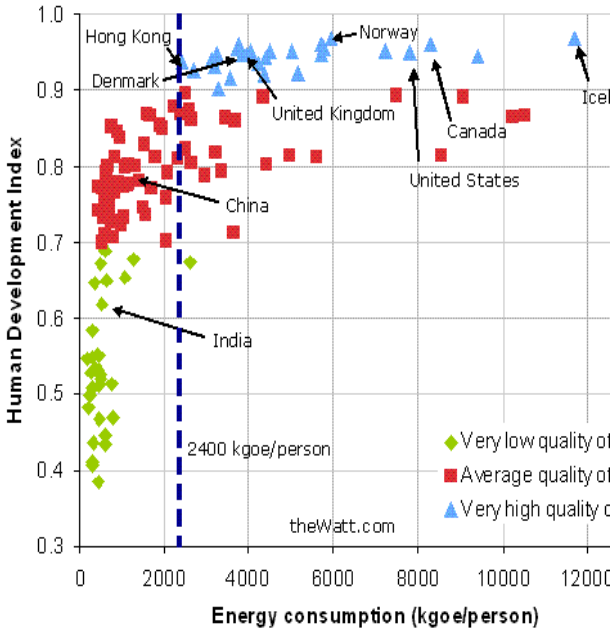


Figure 4 HDI-Energy correlation [7]

This concept is the main focus of this thesis where I have endeavored to find the impact of the solar projects installed in Khyber Pakhtunkhwa on the community. Accordingly, the thesis also gives a measure of the factors that act as a deciding factor in the minds of the adopters of the technology in the off grid community.

The social value or the impact of the project on the community here is adjudicated on several factors pertaining to the population. Chief among them are impact on the education levels, the health, and the economic conditions of the adopters. These factors are also observed in the non-adopters of the solar PV technology for electricity provision and contrasted with that of the adopters.

Albeit there are studies conducted in this domain for the factors impacting the adoption of the technology in other developing countries in Africa, however, in the peculiar socioeconomic conditions of Pakistan such studies are nonexistent. This study aims to identify the areas where the solar PV technology has positively impacted the lives of the community. This will provide a baseline for the socioeconomic design of such projects in future.

For the purpose of this assessment a number of households in the Dera Ismail Khan District of KP have been surveyed. The surveyed households have been divided in two groups: the houses which have installed the solar PV technology for electricity; and the households where there is no electricity provision. The impact of the technology adoption is assessed by utilizing the DFID (1999) framework specifically designed for the assessment of sustainable livelihoods [9].

The data was analyzed using the SPSS software. Raw interview results in quantitative form are presented in certain cases for some hypothesis while t-test, and chi-square test are used in other instances.

Based on the findings of the research recommendations have been presented which would streamline and strengthen the feasibility of solarization projects in future.

The overall power produced from solar PV modules stands at 570 TWh for the year 2018. With this trend of increase, the share of the solar PV in global energy arena reached 2% for the first time: fourth largest renewable energy technology behind hydro, wind and bio energy. 2018 marked the year when the global solar PV additions outranked all the other single resource capacity additions making almost half of all the renewable energy added during the year with 97 GW. After doubling in the total capacity in the preceding year the growth stagnated around the same mark in 2018 largely due to policy transformations in the major adopting countries like China, US and India. The encouraging trend of 10% year over year decline in PV price continued as well [10]. The main theme throughout the renewable revolution of the past decade has been the constant innovation of technology, governed by the solar prices competitiveness as predicted by Swanson's law as shown in the figure 5.

The major challenge hampering the acceptability of solar PV on large scale is the variability of power output leading to grid instability and the accruing skepticism among the grid operators. With greater penetrations the innovation in smart grid technology, and the distributed generation expansion these challenges could be somewhat mitigated.

Innovations in the grid technology have meant there is now a wide variety of system design available for even more integration of solar PV technology. Grid designs such as off-grid, mini-grid, micro-grid, and on-grid installation have increased the avenues for the growth of the technology.

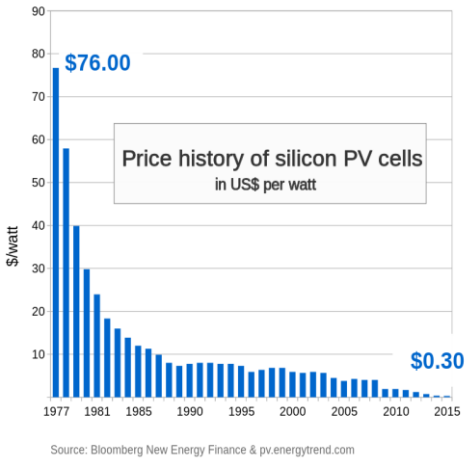


Figure 5 Solar PV prices following Swanson's law [11]

The World Bank's electrification scheme of multi-tier framework has further paved the way for enhanced solar PV adoptions due to the modular nature of the technology. The technology can be used to electrify a single household or even a city; all that is needed is to stack up the number of individual panels. The multi-tier framework enables countries to target specific communities for specific tier of electrification based on the cost benefit analysis of the social and economic benefits accruing thereof. The multi-tier framework as detailed in the table 1 consists of 6 levels or tiers of electrification based on the number of hours or the kWh of electricity provided to the household.

TABLE 1 MULTI TIER ELECTRIFICATION FRAMEWORK [12]

Tier	0	1	2	3	4	5	
Attributes of Access							
Peak available capacity (*W*)	N/A	>1 W	>20 W	>200 W	>2000 W	>2000 W	
Duration of supply (hours)	N/A	>4 hrs	>4 hrs	>8 hrs	>16 hrs	>22 hrs	
Evening supply (hours)	N/A	>2 hrs	>2 hrs	>2 hrs	4 hrs	4 hrs	
Possible Electricity Supply Technologies							
Dry cell			√				
Solar lantern			√	√			
Rechargeable batteries			√	√	√		
Home system			√	√	√	√	√ √
***Mini-grid*/grid**			√	√	√	√	√ √

Within the silicon family of solar panels, the Aluminum back screen printed solar cells referred to as Al BSP for short occupies three fourth of the market while the rest is occupied by the multi crystalline and other thin film technologies. The recent gains in the Passivated Emitter Rear Cell technology, PERC for short, are quite remarkable, and promises a bright future for the technology. The distribution of the market share of the various solar PV technologies is given in the figure 6.

With the plans for enhancing the levels of solar PV in the off grid communities, comes the question of the social acceptance of the technology in general and in context of the overall cost per kWh. This is directly linked with the cost benefit analysis that the technology presents. The decision of technology adoption invariably stems from the net benefit in the lives of the adopters. Albeit not at the same levels as big power plants but still the decision of a household to put solar panels on their roof, in an economically challenged environment, ought to have feasibility or cost benefit analysis. Research shows a disparity in the acceptance of renewable energy projects by the consumers primarily due to the fact that renewable energy has big support only if it is not in the backyard of the user [14]

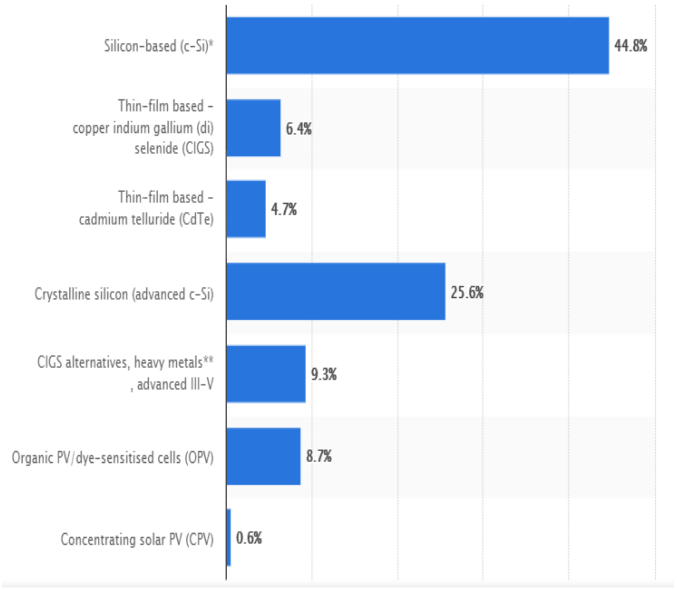


Figure 6 Market share of various solar PV technologies [13]

Albeit the population of India is close to 5 times that of Pakistan, still there is a huge disparity, almost a factor of 10 times, when it comes to solar PV installation in the countries. The main driver of this schism in the solar PV installation in both the countries is primarily the policy level. Indian government devised an ambitious and aggressive plan to push through the renewable revolution in the country through technology imports, soft financing, and other measures. However there are others factors as well. The household level solar PV installation is primarily dependent on the buying power of the residents. In this area India far exceeds Pakistan on average. To put it in simple words an average Indian household has more financial power to install a solar PV system on their rooftop and reap the rewards than an average Pakistani family.

With the levels of pollution and the environmental disasters affronting the country on a regular level, Pakistan needs to enhance its renewable energy portfolio on a fast tracked basis. Solar energy in particular has the greatest potential in this regard. From Karachi to Peshawar the country's plains and mountains are blessed with some of the best solar resource in the world. It has been empirically demonstrated through research that the worst crisis of energy in the past 15 years was the result of over dependence on the imported fuels for meeting energy demands. The natural path forward is to shift the energy dependence to indigenous resources which are aplenty and low cost. This will lead to the elimination of energy poverty in addition to enhancing the country's energy security. The gains in solar energy technologies around the world have meant that governments could make more ambitious plans for renewable energy integration in their energy mixes. However in Pakistan the strides are small and not many. The country has a few large

solar PV projects completed and in pipeline, however the stress is still on the imported coal and that definitely will prove a stress on the economy and environment in the future. The under construction solar PV projects given in the table 3 below tells the whole story, where the projects are too little and too sparse to keep up with the ever-growing energy demands.

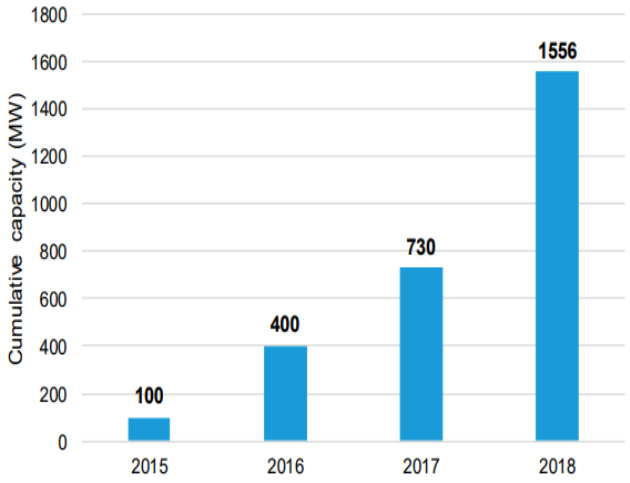


Figure 7 Solar PV growth in Pakistan [15]

TABLE 2. UNDER CONSTRUCTION SOLAR PV PROJECTS IN PAKISTAN[15]

Sr.No	Developer	Project Capacity (MW)	Location
1	Asia Petroleum	30	Chakwal, Punjab
2	First Solar Ltd.	2	Sindh Province
3	Act Solar Ltd.	50	Noori Abad, Sindh
4	Jafri Associates	50	Noori Abad, Sindh
5	Blue Solar Ltd.	50	Punjab Province
6	Adamjee Power	10	Thatta, Sindh
7	ET Solar Ltd.	25	Attock, Punjab
8	ET Solar Ltd.	50	Sialkot, Punjab
9	Crystal Energy	2	Thatta, Sindh
10	Forshine	50	Thatta, Sindh

The NEPRA's net metering policy is supposed to incentivize taking initiative by the households to produce their own energy and also sell the extra units to the national grid in time of lower used. This policy albeit great for the grid connected areas is going to bear little to no effect on the off grid communities. A study conducted in Pakistan dived deep in to the dynamics of the country's solar PV markets and uncovered a list of barriers and challenges faced.

The major hurdles as per the study as quoted by the respondents are listed in the table 3.

TABLE 3. BARRIERS TO SOLAR PV ADOPTION AS PER LITERATRUE [16]

Barriers	Items	Percentage
Economical barriers	Solar Energy projects are capital intensive	28.9
	Buying solar energy system need high installation costs	28.4
	Government Subsidies are limited	22.6
	Limited bank loans for solar energy projects	20
Policy barriers	Government policies are confusing	38.9
	Solar Energy projects have limited feed-in tariff	35.8
	Low priority for renewable energy technologies	25.3
Technological barriers	Local technology is unreliable	26.6
	The production of solar cells is limited in the country	23.9
	There is large dependency on foreign technology for core parts and equipment	24.5
	There is a lack of local personnel to operate large solar farms	25
Information and human resource barriers	The information regarding modern solar technology, markets and suppliers is limited	37.4
	Human resource potential is limited for the installation and maintenance of solar energy projects	31.8
	Collection of solar energy data is unreliable and inefficient	30.8
Social barriers	There is unawareness of solar energy in rural areas	27.4
	Social acceptance and participation of solar energy products is limited	25.3
	This is inconvenient to install solar water heaters on high roofs	24.2
	Local users lack practical knowledge to fix solar energy systems, if suddenly some problem occurs	23.2

Moreover, the current level of renewable energy share in the country's energy mix is not sustainable in the long run. The renewable energy technologies are the main weapon of the future where a country with least dependency on foreign resources will have the most advantages in terms of easy growth and prosperity in addition to the added benefit of mitigating climate warming [17]. The increase of 9% per annum in the national energy demand will inevitably push the market towards cheaper and evergreen technologies. With the demand slated to increase eight fold till 2030 and by twenty-fold by 2050, a clear and sustainable vision is required to cope with this astronomical rise [18] Pakistan's geographical location falls on most of the sunbelt which receives large influx of solar radiation all year around to make the solar PV technology utilization worthwhile for the consumers. As discussed earlier the public sector investment has been the major driver of solar PV technology around the world [19]. The estimates regarding the aptness of the solar PV technology for mitigating or completely eliminating Pakistan's energy scarcity are already present and have been largely deemed as the savior of the country's electricity woes [20].

Some researchers consider solar thermal as the best way forward while for others simple PV will be enough to tackle the demand in future [21].

II. METHODOLOGY

A. *Study Location*

The study focused on the Dera Ismail Khan district of Khyber Pakhtunkhwa. The district as shown in the figure lies in the southern part of the province on the western front of

Indus River. D.I Khan lies 300 km south-west of the capital city of Islamabad. With a population of 1.6 Million in 2017 the district is at 37th position in the most populated districts of the country. D.I. Khan enjoys extreme weathers in summer and winter seasons separated eras of moderate weather in autumn and spring. The yearly average solar irradiance in the district of above 1000 W/m^2 in the peak time makes it a perfect candidate for the solar PV experiment. The residents are mostly lowly educated with most of the population lying in the lower middle and poor class.

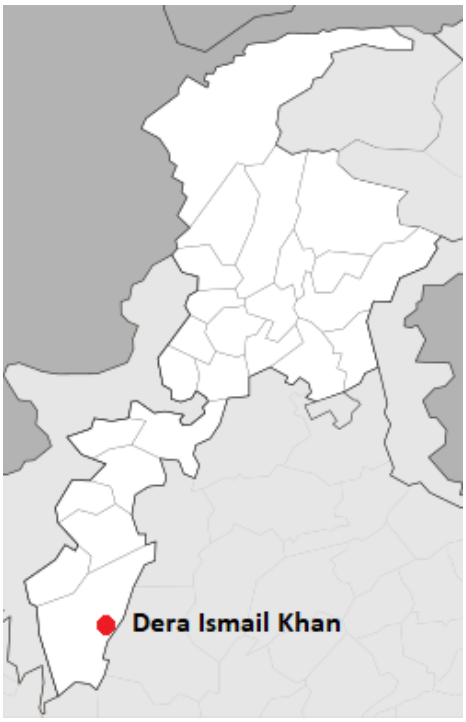


Figure 8 Dera Ismail Khan

The district is spread over 9334 km^2, mostly plain area and produces agricultural products such as wheat, sugar cane, and maize. Literacy rate is 47% among the male population, while the female population is 21 % literate.

B. Methods and Approach

1) Data collection

Both primary and secondary data was utilized for this research study. The primary data was collected by conducting household survey within DI Khan. Secondary data for the research was provided by Pakhtunkhwa Energy Development Organization (PEDO). Local elected council members provided support throughout the household survey. The survey was conducted through easy to understand questionnaire formed with the aim of finding out the below information about the respondents. Special consideration was given to the ratio of the adopter and non-adopter households by keeping the survey radius closer to not disturb the socioeconomic and cultural conditions of the respondents. The information collected included:

1. Social and economic situation of the respondents
2. Age of the surveyed person
3. Reasons of solar PV adoption
4. Reason of non-adoption of solar PV (from non-adopters)
5. What is the educational and literacy level of the respondent?
6. What is the satisfaction levels of the households who have adopted the technology?
7. What are the means through which the awareness about the existence of this technology came about?
8. The costs incurred on the installation of the solar PV system
9. The maintenance and technical aspects of the solar PV system
10. The impact of the solar PV system on the livelihoods of the respondents through further questions.

2) Sampling procedures

According to the international standards prevalent all over the world the sampling was kept such that the bias of various aspects such as education, income, and previously held perceptions would not impact the end results obtained through the survey. For this purpose, Purposive Stratified Sampling Protocol (PSSP) was utilized to get the most optimum mix of respondents from both types of households. As per the PSSP results 100 households were surveyed in the fixed radius keeping the ratio of 70 to 30 among the adopters and non-adopters. As per the result of Statistical Package for Social Science (SPSS) tool the results of the survey can be reiterated for the whole of DI Khan district with a confidence level of 95% without losing the accuracy of the assertions.

3) Data Analysis

Pursuant to the completion of the data collection process through the surveys in the selected union council of DI Khan and after availing the secondary data from the relevant authorities the data was streamlined in MS Excel, SPSS software, and further statistical analysis was performed to gather further insights from the raw data.

The tests conducted on the pre-processed data included t-tests, chi-square test, and p-value determination for various analyses. A brief description of these various tests and analyses is as given below.

a) *Chi Squared Test*

Represented by the symbol $\chi 2$, this covers any test for which the sampling spread is chi squared for the cases when null hypothesis is taken true. In simple terms the test determines significant disparities between the expected and observed frequencies for single or multiple categories of data.

b) *P-value determination*

The p-value analysis uncovers the probability of the occurrence of the test results in broad sector when the null hypothesis yields zero.

c) *t-test*

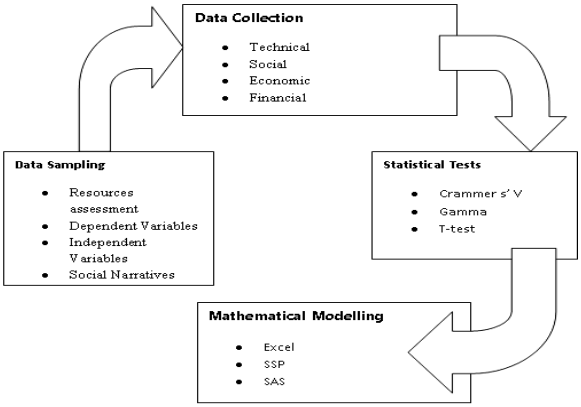
Includes all such statistical hypothesis tests where the values follow a t- distribution when null hypothesis is considered zero.

4) Other analysis

In continuation to the above analyses simple pre-and post-installation statistical analysis from retrospective recalling of the conditions was conducted on the respondents' data. The additional analyses included:

- Comparison of lighting fuel pre-and post-installation which practically can, for practical purposes, be the difference of fuel usage among the adopters and non-adopters of the solar PV technology.
- Ranking of the motivations for solar PV adoption as well of the inhibitors for the non-adopters.
- Ease of work following the system installation
- Is there any change in the educational standard among the adopters and non-adopters of the solar PV
- If there is any change in the health of the adopters and non-adopters of the PV technology.

A schematic of the research methodology from the data sampling techniques to the end impact assessment of the technology through SPSS, SAS software is given in the schematic below.



III. RESULTS AND DISCUSSIOS

This chapter delineates the results of the surveys carried out in the DI Khan district of KP. These survey results are further analyzed through SPSS software to get an insight in to the various correlations and statistical significance of various parameters selected in the survey. The analyses, mostly in the form of tables give the complete background of the various tests carried out in the research. The survey results were also analyzed to determine whether certain parameters like education, income levels, location of the residents, and technical knowhow of the responders and other factors. The presence and extent of the significance of these parameters give an insight of the accuracy of the various correlations and causations drawn throughout the research.

Additionally the analyses also include the various factors driving the solar PV adoption decision of the respondents, or lack thereof. Also listed are the results of the surveys uncovering the various awareness channels which persuade the respondents to adopt PV technology for household electrification.

A. Income of the household

For assessing the factors influencing the permeation of the solar PV technology in the rural society in KP first the income of the household was recorded. Based on the statistical analysis of the income data of the respondents the significance of the parameter was determined through Chi square test and p value tests. The chi square value of 0.811 together with the p- value of 0.667 as shown in the table 4 suggests the income of the households in this domain is not significant.

This seemed counter intuitive because the high upfront capital costs of a solar PV system should mean that the income levels of the adopters should reflect a disparity based on the income levels. However, a deeper look in to the funding for the system unveils a possible explanation for this effect. Most of the systems installed in the households of the adopters were funded through welfare organization funding. for instance, 40 out of the 100 solar PV systems installed were through a European Union project while other 20 were installed during a KP government funded project.

TABLE 4. HOUSEHOLD INCOME LEVEL: SIGNIFICANCE IN ADOPTIONO OR NOT?

Household income (000)	Adopters Stats		Non-Adopters Stats		Total Dist.		Chi square $\chi 2$	P value	df
	N	%	N	%	N	%	0.811 (ns)	0.667	2
10-20	60	61.9	42	66.7	102	63.8			
20-50	33	34	19	32.5	52	32.5			
Above 50	4	4.1	2	3.8	6	3.8			

TABLE 5. IMPACT ASSESSMENT THROUGH VARIOUS FACTORS

Variable	Adopters stats			Non-Adopters stats		
	Mean	Std. Dev.	Std. Mean Error	Mean	Std. Dev.	Std. Mean Error
Family size	5.30	1.98	0.14	4.98	1.75	0.16
Age of Household Head (Yrs)	53.4	10.7	0.79	47.1	11.5	1.04
Children below 5 years	1.60 4.49	1.37 1.89	0.20 0.13	1.43 4.30	0.68 1.66	0.11 0.15
Number of People Living in the Household	4.49	1.89	0.13	4.30	1.66	0.15

The average family income of all the 162 families was around 15.5 thousand PKR. The various parameters of the surveyed households as given in the table 5 gives an indication

of the standard deviation and the means of family size farm size, age of the household head, the number of children aged less than 5 years among other parameters.

B. Impact of house size on adoption of biogas technology

In this analysis the survey questions were designed to gauge the impact of economic consideration for the solar PV technology through three different hypothetical options. The respondents were given three different payment options for the installation of the solar PV system. Since most of the already installed solar PV systems were via grants from funding agencies, it was prudent to gauge the payment preferences for solar PV as it is an important parameter world over. The three options given to the respondents were: the whole payment upfront with a fixed government subsidy of 25% on the system termed as option A in the table 6, soft loans from banks with fixed payback installment equivalent to the average monthly bills paid to the utility termed option B, and grid extension to the area which would mean them charging the households as per the domestic tariff set up by NEPRA termed option C, and the option of grants providing minimum level i.e. 100 W systems providing the essentials such as lighting and a fan termed option D.

TABLE 6. IMPACT OF PAYMENT METHOD ON ADOPTION OF BIOGAS TECHNOLOGY

Farm parameters	Adopters Details		Non-Adopters Details		Total distribution		Chi Square	P value
	N	%	N	%	N	%		
Farm Size in Acre								
B	56	68.3	43	78.2	99	68.3	2.08 (s)	0.038
A	12	14	7	12.7	19	14		
C	9	11	2	4.5	11	11		
D	5	6.7	3	4.5	8	6.7		
Construction material in the households								
Mud and stone	19	0	35	62.2	22	1	63.36	<=0.001
Wood	0	19.6	3	2.7	58	35.1		
Cement, bricks	78	80.4	20	35.1	98	63.9		
Roof Type in the households								
Cement	59	47	59	93	105	80.8	18.87 (s)	P<=.001
Steel Sheets	5	7	5	7	32	19.2		

As per the Chi squared test result of 2.08 for the payment option it is found that the mode of payment is a significant parameter for solar PV adoption in DI Khan. Furthermore the majority of the respondents' i.e.99 preferred the option of loans at easy installments equivalent to the monthly average household bill in DI Khan. Second most attractive option was the subsidized system procurement with 50 respondents opting for this option.

Additionally, it was found out that the roof type is also a significant determinant of the solar PV technology adoption in KP along with the construction material of the houses.

C. Gender, education, and age demographics of the respondents

The survey results were analyzed through the SPSS software to assess the impact that the age, education, and gender of the respondent had on the adoption or lack thereof of the solar PV technology. The head of the household usually being the respondent in the case of the survey makes it relatively simple. Considering the cultural background of the DI Khan area it is only obvious that the respondents and head of the household's lion's share of the cases were males. Gender of the household head does not seem to be a determinant in the adoption of the solar PV technology. The age of the respondents came out to be a significant factor in the installation or decision of installation of solar PV system with chi squared and P value respectively of 18.41 and 0.001 as seen in table 7.

Interestingly enough the education of the respondent and in most of the cases the household head did not show statistical significance in the decision to adopt the technology. In isolation it may seem an aberration but when taken in the context of the age analysis, where age of the household head was a determinant in the decision, and in the coming analysis of the driving forces behind decision to adopt it is clear that the education of the solar household head is not as important as the age and the communication and knowhow of the outside world.

TABLE 7. REASONS BEHIND SOLAR PV TECHNOLOGY ADOPTION

Determinants	Adopting household		Non adopting households		Grand total		Chi Squared value	P-value
	Number	Percent	Number	Percent	Number	Percent		
Age of the respondents								
21-40	12	13.3	20	32	32	20.8	18.41 (s)	≤0.001
41-60	57	63	35	57.4	92	60.7		
61-80	21	23.8	6	10.7	27	18.5		
Gender of the survey respondents								
Male respondents	78	87.7	53	83.5	132	85.9	1.11 (ns)	0.292
Female	11	12.3	11	16.5	22	14.1		
Education levels of the survey respondents								
Primary (grade 5)	24	29.1	17	33	41	30.6	2.12 (ns)	0.331
Secondary (Grade 10)	33	40	24	44.3	57	41.7		
Tertiary (Above grade 10)	26	30.9	12	22.6	38	27.7		

This part of the survey focused on unearthing the reasons behind solar PV technology adoption in the selected area of DI Khan. This analysis and survey results suggest the most compelling reason for solar adoption was the economy of the whole system to provide cheap electricity at no running costs. In case of the households who adopted the solar PV through grants this question was rephrased to provide for their special case. The non-adopters were asked what would be the most compelling reasons for the solar PV technology and were asked to rank at least 4 options as shown in the table 8.

TABLE 8. MOTIVATING REASONS FOR FARMERS TO INSTALL BIOGAS TECHNOLOGY

Motivation	Responses		
	N	%	Rank
Economy of electricity	73	73	3
Environmental benefits	63	62.5	4
Smoke eradication	61	61	5
Health	36	36	6
Competition with their neighbors or relatives	27	27.5	7
Grant for installation or ready-made solution	26	15.5	8
Social reasons	17	16.5	9
Reliability of electricity provision	9	9.5	11
Children motivated	7	7.5	12
Solar distributors advertised	4	3.5	13
High cost of utility provided electricity	2	1.5	14
Other reasons for installation	3	1.5	15

D. Source of information about the solar PV technology: the awareness channels

This field of the survey tested the major drivers of the solar PV technology penetration in KP's rural communities. Most of the solar PV installed being thought funding welfare organizations makes this point a little out of place but to tackle this the adopters and the non-adopters were asked where they have heard about the technology the most frequently. This yields the results given in the table 9.

TABLE 9. MAJOR INFORMATIONAL SOURCES FOR SOLAR PV TECHNOLOGY

Source of information	Adopters		Non Adopters		
	N	%	N	%	rank
People to people interaction	79	75	43	54	1
Awareness drives by government	18	18	14	17.4	2
Television, or other conventional communication channels	14	14	13	16.8	3
Promotional drives by sellers	9	9	7	9.7	4
schools	4	3.5	-	-	5
Newspaper ads	0	0	1	0.6	6

The most frequently quoted motivator for adopting solar PV technology as per the respondents of the survey was the people to people interaction. Seventy-seven percent of the respondents quoted that they were motivated or pushed over the edge in their decision to adopt the solar PV technology by a relative or friend or an acquaintance.

E. Reasons of lack of biogas technology adoption

After finding out the most compelling arguments for solar PV installation decision, the survey focused on the main hurdles or barriers in way of the technology in rural KP. The respondents overwhelmingly suggested that the high upfront cost of the system was a major deterrent in the solar PV system adoption, further increased by the need of battery storage. As shown in the table 10, the second most important inhibitor of the technology is the lack of knowhow of the system.

This is followed by the lack of technical experts in the area who could maintain any problems. Bad news travels fast. In the past some households who have adopted the system faced maintenance issues in the initial few months of the system installation which has tarnished the reputation of the technology as a reliable source of electricity provision. A government or NGO run awareness campaign would go a long way in the mainstreaming of the solar PV technology in this area.

TABLE 10. MAJOR BARRIERS FOR SOLAR PV ADOPTION

Reason for not owning Biogas	N	%	Rank
High cost of installation and procurement	96	44.7	1
Don't know much about the system	39	18.3	2
Complexity of the system	29	13.6	3
Lack of operational capacity	12	5.6	5
Lack of maintenance or installation personnel	9	4.2	6
Safety reasons, No experience with electricity	2	0.9	7

These analyses provide a very detailed analysis of the social aspect of solar PV technology in the DI Khan district of KP. The lessons learnt can provide insights for creating a solar PV revolution in the whole province. The recommendations based on the analyses presented above are detailed in the following chapter of this document.

CONCLUSIONS

The energy provided by the solar PV projects inevitably becomes the life of the adopting households and an essential component of their everyday life. Albeit installed with the primary intention of lighting or cooling, the technology brings a lot more to the table. A whole new life is introduced to the rural world which would be unthinkable absent the electricity provided by solar PV systems.

Having said that, the rate of solar PV adoption has been found to be extremely disappointing which can be judged by the fact that the 100 solar PV adopting household were located in three union councils. This research, through the various analyses unearthing the factors responsible for greater integration of the solar PV technology provided a means of

addressing the morbid state of standalone PV market in Pakistan.

Through the analysis aimed at finding the correlation between various parameters it came to light that the major obstacles in the way of enhanced solar PV adoption are the high upfront costs of the system. Also interesting was the realization that the education level of the households in general and of the head of the family in particular was not a significant factor in the decision to adopt. On the other hand, the age of the household head was a factor of significance in the adoption of solar PV.

Accordingly, the survey also focused on the channels which could be utilized in future to further the solarization efforts in the province. The main source of information about the solar PV technology in an off grid community invariably has to be the word of mouth- the testimonials from relatives and friends. The survey also uncovered the hampering agents in solar PV mainstreaming, indicating the high upfront cost to be the main culprit here.

The social benefits from the installation of the solar PV technology were testified to by the adopting families. The use of solar PV electricity for lighting replaced the kerosene based lamps which reduced the health issues. The students had extra time to study which enhanced their education.

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