Off-Grid Solar Electrification Sustainability Assessment A Case Study of Swat

Naila Saleh[*] and Iftikhar Ahmed[**]

Abstract

Access to energy is crucial not only for the well-being of people but also for the socioeconomic development of a region. Today, 46.3 million people in Pakistan lack access to the grid whereas those connected have unreliable and interrupted access to energy supply. However, in the wake of prolonged power outages in rural areas accompanied by coincidental spread of awareness on solar photovoltaic (PV) technology, an interesting shift in terms of energy transition is underway. This study focuses on these undocumented changes taking place in the district of Swat. As success and optimality of any system can be best gauged through user's perception, the study attempts at assessing both the sustainability of the installed off-grid solar systems as well as barriers in their diffusion at a larger scale. Where on one hand the findings reveal strong social acceptance for the solar PV technology among users, on the other hand the study observes limited dependence on the technology where reliance on the conventional energy is still very prevalent for heavy load appliances during running electricity hours. Amongst the non-PV users, a strong desire for instalment of PV technology exists. Nevertheless, lack of government support and economic barriers remain major impediments in its adoption. The findings hence underscore significance of supportive policies for augmenting the momentum toward a sustainable energy transition.

Keywords: Renewable Energy, Solar Energy, Sustainability, Energy Transition, Swat.

Introduction

The report of the World Commission on Environment and Development (WCED) titled *Our Common Future*, also known as Brundtland Report (1987) famously defined 'sustainability' as 'development that meets the needs of the present without compromising the needs of future generations.'[1] Since then the concept has evolved with increased international recognition centring upon management of exhaustible

---

[*] Researcher, Institute of Policy Studies (IPS), Islamabad, Pakistan.
[**] PhD, Assistant Professor, School of Public Policy, Pakistan Institute of Development Economics (PIDE), Islamabad, Pakistan.

[1] World Commission on Environment and Development, *Our Common Future*, report (Oxford: Oxford University Press, 1987), https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/152/WCED_v17_doc149.pdf?sequence=1.

resources, ecological balance and intergenerational equitable distribution. Today, both the dwindling fossil fuels and threats posed by the carbon dominated energy sector have prompted structural changes in the global energy supplies. Power procurement from solar PV—one of the most abundant and widely distributed resource—is seen as the optimally sustainable technology for meeting energy needs. Today, many countries across the globe have put it at the frontline of their transition agendas.[2]

Pakistan has been facing severe power shortfalls since 2006 where the energy demand exceeded the existing power generation and supply. Owing to the daily blackouts experienced, over 144 million people across the country lack reliable access to the grid.[3] Another 46.3 million people still have no connection to the grid—majority residing in rural areas.[4] With rising population and increased industrialization and urbanization, demand for energy is projected to further rise in the coming decades.

Against the existing power mix which is heavily skewed towards fossil-based power generation sources, solar energy has abundant potential and scope in Pakistan. Geographically positioned in a topmost solar insulation region, the country has ideal solar potential which accounts for more than 100,000 MW.[5] The sunshine hours range from 8-10 hours in majority areas and solar radiation intensity exceeds 1500 W/m^2/day. With the ideal solar potential and prevailing energy access gap, solar PV systems could prove a promising technology particularly for areas characterised by low population density, geographic remoteness or positioning in difficult terrain which makes grid extension economically exorbitant.[6] Even in grid-based areas with unreliable and

[2] Toby Couture, *Renewables in Cities*: *2019 Global Status Report-Preliminary Findings* (Paris: REN21 Secretariat, 2019), https://www.ren21.net/wp-content/uploads/2019/05/190626_REC-2019-GSR_Preliminary_Findings_web.pdf.
[3] World Bank, *Pakistan Off-Grid Lighting Consumer Perception: Study Overview,* report 112020 (Washington, D.C.: World Bank Group, 2017), http://documents.worldbank.org/curated/en/865301486382674587/Pakistan-off-grid-lighting-consumer-perceptions-study-overview.
[4] *Electricity Access Database 2019*, s.v. "electricity," accessed November 29, 2019, https://www.iea.org/sdg/electricity/.
[5] Muhammad Shahid Khalil, Nasim A. Khan and Irfan Afzal Mirza, "Renewable Energy in Pakistan: Status and Trends" (paper, Ministry of Energy, Power Division, Government of Pakistan, 2014), http://www.mowp.gov.pk/mowp/userfiles1/file/uploads/publications/repk.pdf.
[6] Nicola Ursina Blum, "Fostering Rural Electrification: The Case of Renewable Energy-Based Village Grids in South East Asia" (PhD diss., Department of Management, Technology, and Economics, ETH Zürich, Zürich, 2013), https://doi.org/10.3929/ethz-a-009974640.

poor electricity availability, small-scale renewable-based technologies or backups can become an affordable substitution for electrification.[7]

District Swat[8] is one such region which witnessed large-scale community driven solar energy transition in recent years. Demonstration effect and social spillovers were among the two key determinants of this new technology dissemination in the region. The PV installations by the United Nations Development Program (UNDP) under its funded 'Peace and Development Program'—initiated in an endeavor to aid the war torn region of Swat in the aftermath of 2008 Swat operation—introduced the technology to the locals.[9] These installations were mostly made in public places such as mosques, schools, and educational institutes. Further in the year 2014, the Khyber Pakhtunkhwa government under its plan 'Green Growth Initiative' connected around 450 government schools to solar panels.[10] Collectively these initiatives distilled large-scale awareness about this technology in the region. Ultimately the prevalent hours of prolonged load shedding combined with the awareness on the utility instilled a momentum unto 'PV systems' engaging large number of people, who began installing solar panels at their own expense. The PV systems analyzed in this study were not connected to the grid. Instead, they required batteries which ensured power output even in the absence of sunlight. The hybrid systems—energy from the conventional grid combined with the solar PV backup—provided adequate flexibility to the consumers in terms of using the backup power during load shedding hours alongside using it as an energy saving option during running sunlight hour i.e., daytime.

This study provides an insight on the ongoing transformation in the energy sector driven by the locals' lack of access to grid in Swat. Further for long-term viability of such instalments, its sustainability needs to be discerned from the start. Thus, the study surveys the economic efficacy of the PV, examining both the sustainability of the installed solar systems as well as barriers in its diffusion at a larger scale.

---

[7] Jean-Baptiste Lesourd, "Solar Photovoltaic Systems: The Economics of a Renewable Energy Resource," *Environmental Modelling & Software* 16, no. 2 (2001): 147-156, https://doi.org/10.1016/S1364-8152(00)00078-5.
[8] Swat is positioned in Khyber Pakhtunkwa—the northwestern province of Pakistan.
[9] Intikhab Amir, "Solar Technology Brightens Swatis' Lives," *Dawn*, January 6, 2012, https://www.dawn.com/news/686014/solar-technology-brightens-swatis-lives.
[10] Asad Zia, "Solar Panels Installed in 405 Schools across K-P," *Express Tribune*, April 15, 2016, https://tribune.com.pk/story/1084629/adding-facilities-solar-panels-installed-in-405-schools-across-k-p/.

Sustainability Assessment of Solar PV Systems

The research uses case study method for surveying people's experiences vis-à-vis sustainability of solar PV systems and barriers in the way of its diffusion. Purposive sampling has been used at two stages: First, for the selection of the wards wherein three wards of Tehsil Babuzai in District Swat were selected, namely Odigram, Rahim Abad, and Tendo Dag; and second, for selection of respondents within the selected wards.

A meaningful sample size is essential for statistically valid findings of any survey. This research faced this limitation owing to unavailability of database/information on households relying on PV systems in the region. For the survey, a total of 120 respondents were selected, sporadically distributed in the study area. Out of them 'sixty' households were the beneficiaries of solar PV technology, whereas for gauging the barriers unto PV installment the remaining 'sixty' were those who were not using the technology. From each household, one person was surveyed for providing data.

Sustainability assessment generally involves broad assessment of tools covering the economic, social and environmental aspects of a project. Various approaches are currently used for assessing the sustainability of new technologies and decentralized energy systems.[11] This research looks at three dimensions of sustainability, namely financial, technical, and socioeconomic.[12] A structured questionnaire was designed hence seeking information on demography of respondents, socioeconomic makeup, statistics on the stated three dimensions and barriers in the way of adoption of the technology (see Table.1).). Finally, data for the study was collected in 2017, so the analysis is reflective of the stated time period.

---

[11] Ninad Mutatkar, "Sustainability Assessment of Decentralised Solar Projects: Introducing a Multi-Criteria Approach" (Masters diss., School of Industrial Engineering and Management, KTH, Stockholm, 2017), http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1117450&dswid=4196.

[12] Elisabeth Ilskog and Björn Kjellström, "And Then They Lived Sustainably Ever After?—Assessment of Rural Electrification Cases by Means of Indicators," *Energy Policy* 36, no. 7 (2008): 2674-2684, https://doi.org/10.1016/j.enpol.2008.03.022.

Table 1: Dimensions for Analysis of Off-Grid Solar Electrification	
Dimension	**Indicator**
Financial Viability	Installation cost Maintenance cost Other associated expenditure
Technical Analysis	○ Supply efficiency (Whether basic energy needs are fulfilled through Solar energy generation) ○ Availability of PV panels in local market ○ Availability of spare parts and technical assistance in local market ○ Problems related to Solar energy
Socioeconomic Impact	• **Education** ○ Improved performance of children at school ○ Longer study time • **General Welfare** ○ Overall consumer satisfaction in terms of better lighting, access to TV, fans, water pumps, solar heaters • **Economic** ○ Job creation ○ Increased agricultural productivity ○ Impact on household income ○ Cost-effectiveness of the technology • **Environmental** ○ Improved health ○ Reduced pollution
Barriers	○ Technical barriers ○ Economic barriers ○ Lack of government support ○ Any other barriers

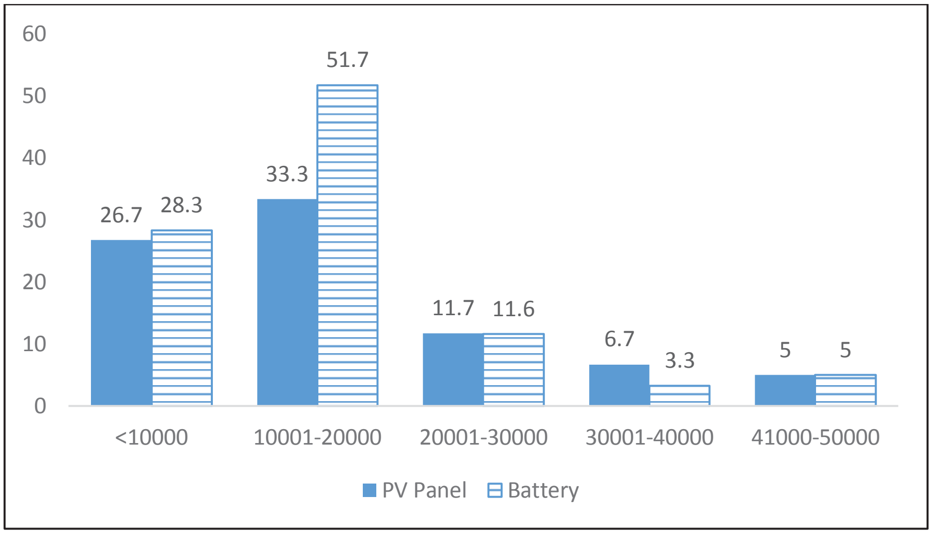
Source: Authors' own.

Financial Viability of the PV Technology

Solar PV systems are associated with high capital payments (including capital cost of panels and batteries). Their dissemination and survival in the long run remains contingent upon the financial viability. Whereas in the wake of complete absence of any supportive remuneration schemes, the stated feasibility becomes further challenging. Examining financial capacity and affordability of the technology hence was a primary research question that this study sought to examine.

In the post 2008 Swat operation, a range of welfare and development organizations were engaged in the rehabilitation of the war-scarred region. Multiple NGOs also assisted households financially for PV instalments. In this study however only 16% of the respondents indicated some kind of assistance from NGOs with regard to capital cost of the technology, whereas the remaining PV users installed these capacities at personal expense. Fig.1 shows the installation cost of both PV panels and batteries.

Figure 1: Installation Cost of PV Panel and Battery PKR (%)



Source: Authors' own.

Regarding the cost of PV panels and battery, majority of the respondents fell in the bracket of less than PKR 20,000. In addition, respondents also indicated the wiring and labor cost wherein the average cost was estimated at PKR 2500.

Installation cost however corresponds to the type of PV system being installed. There are different types of solar systems. Solar Pico system is the smallest power system with a capacity of up to 11 watt[13]—used for low-load electric appliances such as lighting or phone charging. Solar Home System (SHS) is usually designed to directly run relatively larger loads including appliances such as TVs or fridges.[14] They can be in a range of 12–300 watts. In this study, whereas 11.7 % were using Solar Pico systems i.e. capacities below 10 watts, 76.7 % of the respondents

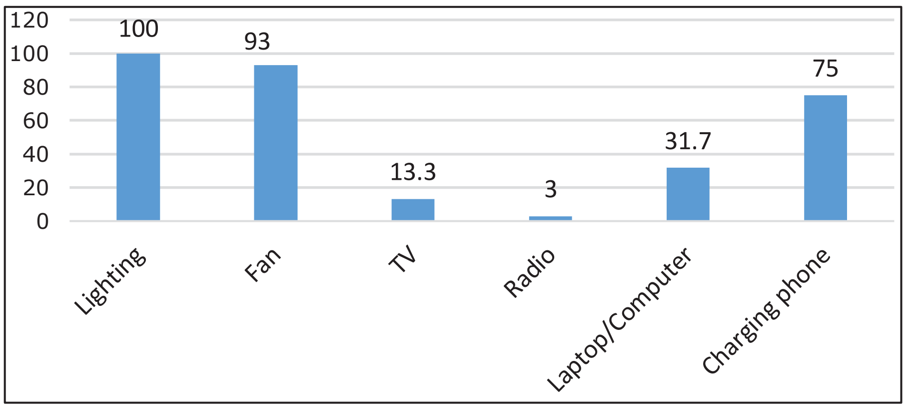
---

[13]Toby Couture, Setu Pelz, Catherina Cader and Philipp Blechinger. "Off-Grid Prosumers: Electrifying the Next Billion with PAYGO Solar," in *Consumer, Prosumer, Prosumager* (Cambridge: Academic Press, 2019), 311–29, https://doi.org/10.1016/b978-0-12-816835-6.00014-0.

[14] Ibid.

relied on systems with capacity ranging between 11-130 watts. Another, 11.6% of the respondents had systems exceeding 130 watts of capacity. The villages surveyed for this study already had connection to the conventional grid. The responses revealed that only partial loads were shifted unto the installed solar systems and people still relied on the conventional power for heavy load appliances. The information on the consumption pattern revealing the purpose of reliance on solar energy is depicted in Figure 2.

Figure 2: Purpose of using Solar Electricity (%)



Source: Authors' own.

In addition to the installment cost, repairing of batteries is another major charge linked with direct current (DC) PV solar systems.[15] The average life of a battery corresponds to its quality— is approximately up to 5 years. Further determinants such as know-how on its effective operation can increase its life and vice versa. 53.3% respondents indicated that they have made expenditures on either replacing or repairing their batteries, since installation of their solar infrastructure. The rest, 46.7% indicated that they have not yet replaced or repaired their batteries. Table below looks into the approximate cost incurred by the respondents last time for repairing/replacing their batteries.[16]

---

[15] There can be other minor maintenance costs such as purchasing or replacing of DC bulbs or fans, which this study has not taken into account.
[16] The table gives a rough idea on the amount of repairing/replacement cost of batteries—a regular maintenance cost incurred by the PV system users.

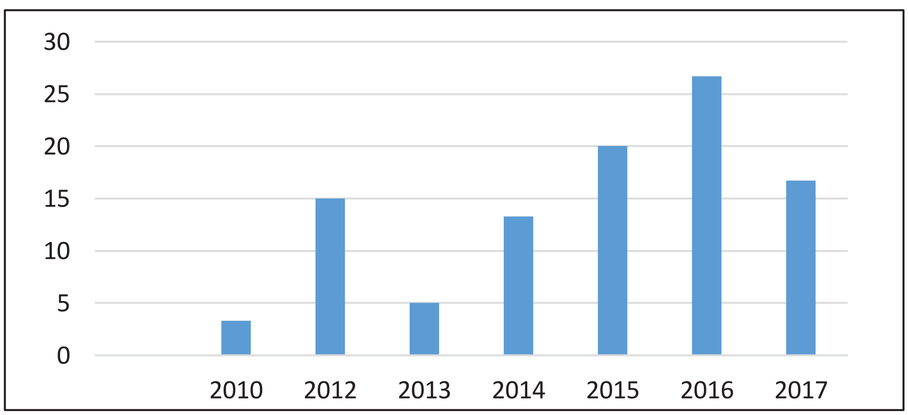
Table 2: Replacement or Repairing Cost

Approximate Replacement/Repairing Cost	
Pak. Rupee	**Frequency**
Less than 5,000	06
5,001-10,000	07
10,001-15,000	16
15,001-20,000	00
20,001-25,000	03
Total	32

Source: Authors' own.

In the light of their experience of these costs, the respondents were asked to indicate the affordability of installation as well as maintenance cost of their respective PV setups. A little less than half (46.7%) indicated the installation cost affordable, whereas every two out of three (66.7%) indicated the maintenance cost as affordable. Thus, installation cost was indicated to be a major financial challenge by majority of the respondents in the survey.

Figure 3: Year of Solar Panel Installation (in percentage)



Source: Authors' own.

Overall, an ascending trend was observed in terms of installation of the PV system overtime i.e. from 2013- 2016 (see Figure 3.)

Technical Dimension

Availability of any technology in the local markets is central to its successful diffusion among communities. With regards to it, very interesting developments were found in this survey in terms of development of proper market in the region for the trade of PV technology including availability of its spare parts and technical expertise. Almost all respondents stated access to solar panels, its spare parts and repairing services within their respective local markets.

Further, the survey probed satisfaction level of PV users with reference to the performance of the technology. Respondents were asked to express their contentment level keeping in perspective the purpose for which it was installed. Seventy percent of the respondents expressed their contentment with the technology; 21.7% said that they were partially satisfied with supply outputs of their PV systems and another 8.3% indicated their discontentment with its performance.

Responding to a multiple choice question on inefficiencies surrounding the technology, every two of the three (66.7 %) respondents said that their systems were limited to running few appliances, 25% indicated weather-related operation limitations, 8.3% highlighted constraints with regards to reserve capacity and wearing out of the battery, 13.3% stated that it worked best only during peak sunshine hours and 8.3% highlighted the declining efficiency of the panels with passage of time. As observed, the inability of the PV system to run heavy load and multiple appliances simultaneously were cited among major constraints by majority. Nonetheless, it is important to note here that the solar panels installed by majority of users had a capacity of below 100 watts, i.e., not adequately sized for heavy load/ simultaneous running of multiple appliances.

Socioeconomic Impact

The socioeconomic approach to sustainability transitions centered on community acceptance has been recently growing in both extent and influence.[17] For gaining insight on social impacts and support processes of transition to solar energy, respondents were asked to reveal any observed impacts post installment of the PV panels. For a better understanding, some questions were also put to non-PV users for objectively gauging deviations in output of the two groups.

[17] Jed J. Cohen, Johannes Reichl, and Michael Schmidthaler, "Re-Focussing Research Efforts on the Public Acceptance of Energy Infrastructure: A Critical Review," *Energy* 76, no. 1 (2014): 4-9, https://doi.org/10.1016/j.energy.2013.12.056.

Power cuts or load shedding disrupt daily life for households. It prevents people from enjoying basic routine facilities such as running lights, electric fans (especially during summers in Pakistan when temperatures reach as high as 130°F) or pumping clean water in the scorching summer. The blackouts to varying degrees (depending on its frequency and intensity) conflict with the study hours of students, sleeping hours of households, and contraction of businesses and working hours. Access to electricity hence is deemed critical for better living standards in terms of smooth studying hours, better academic pursuits, and improved earnings and health conditions.[18] In this survey, 71.7% of the respondents stated smooth and improved study hours of their school going children, 53.3% stated improved academic performance whereas 86.7% of the respondents indicated substantial improvement in sleep hours due to solar electrification.

Table 3: Impact of Solar Electrification on Social Life

Impact of Solar Energy on Study Hours	
Study hours	**PV Users**
Improved	71.7%
Neutral	25%
Impact of Solar Energy on Educational Performance	
Improved	53.3%
Neutral	46.7%
Impact on Sleeping Hours	
Improved	86.7%
Neutral	13.3%

Source: Authors' own.

Degraded air quality and its damaging impact on health is one of the major global concerns arising out of fossil-dominated power generation system. Comparably, solar energy is categorized among the cleanest sources of energy having negligible environmental implications. As PV replaces some of the alternate fuels such as thermal based

[18] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali and Douglas F. Barnes, "Who Benefits most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, http://dx.doi.org/10.5547/01956574.35.2.4.

generators or kerosene, it diminishes pollution in the surrounding.[19] This survey, also sought answers on any noticeable impact of solar electrification on either health conditions or ambient quality of air.

The non-PV users in the study were still relying on alternative electric appliances (generators, lanterns or candles), the effects of which could be hazardous for health. Comparing the two groups, the ratio of asthma among non-PV users was almost three times higher than PV users. Again, the incidence of bronchitis was found in 5% of PV users compared to the 2.1% in the other group. No incidence of eye infection was observed in the case of PV users compared to its 3.3% ratio among non PV-users. Above analysis reveals a slightly lower incidence of diseases in PV users except for the case of bronchitis. Based on the analysis, no clear conclusions could be drawn on positive environmental impact of solar electrification. Also, the inconsistent environmental impacts could be explicated through both limited reliance and relatively small number of clean electric capacity adoption wherein majority of end-users fall beyond its scope.

As energy and economic growth are strongly correlated, this study probed any visible economic impact of solar electrification in terms of jobs output, working hours, smooth running of tube wells, shrinkage utility bills and the like. Table 4 shows, majority of the PV users indicated no effect of solar energy on both business and agricultural activities i.e. with an exception of 15% and 11.7% respectively; rest of the PV users expressed unnoticeable impacts on agricultural productivity. Also, though the region under study was largely dependent on agriculture, the benefits of solar electrification, if any, remained restricted to those segments who were simultaneously relying on agricultural sector and PV pumps. Further, around 42% cited an increase in household income post solar electrification.

---

[19] Vilja Varho, "Environmental Impact of Photovoltaic Electrification in Rural Areas," *Energy & Environment* 13, no. 1 (2002): 81-104, https://doi.org/10.1260/0958305021501092.

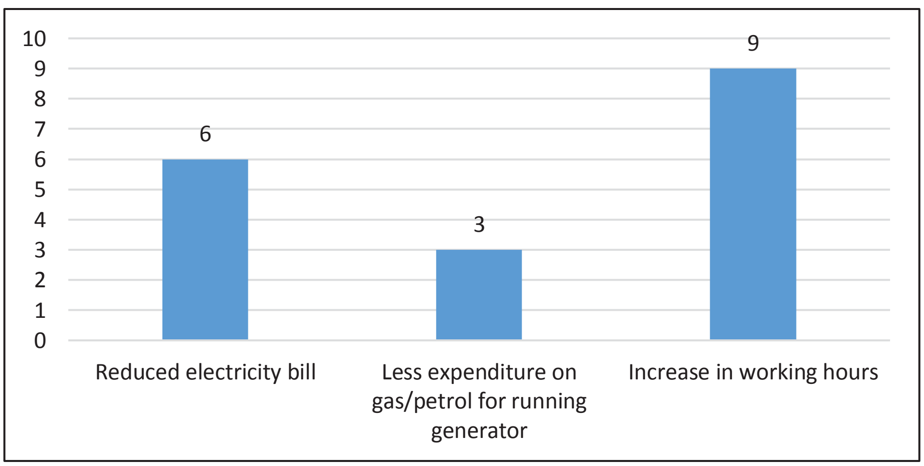
Table 4: Economic Impact of Solar Electrification

Impact on Agricultural Productivity	
	PV Users
Neutral	85%
Increased	15%
Impact on Business Activity	
Neutral	88.3%
Increased	11.7%
Impact on Household Income	
Neutral	58.3%
Increased	41.7%

Source: Authors' own.

Increase in working hours and reduced electricity bills were cited as key factors leading to a rise in income. Fig.4 reveals the responses to a multiple choice question on reasons behind improved household income.

Figure 4: Reasons Cited for Increased Household Income (Responses)

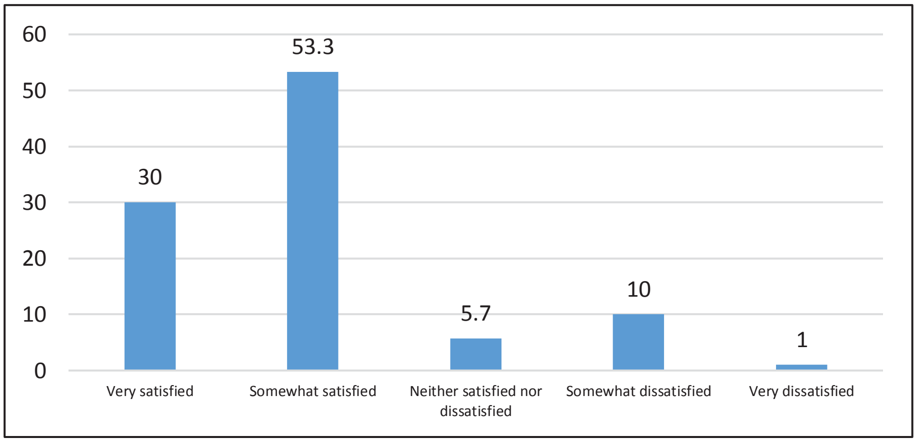


Source: Authors' own.

Consumer's Satisfaction with Solar Energy

On overall satisfaction with respective PV systems, greater level of satisfaction was indicated by majority of PV users. Further, an overwhelming 71.7% also expressed their willingness to continue relying on the PV technology. At the same time, on the desirability to expand their existing systems, only 21.7% responded positively.

Figure 5: Satisfaction Level of Households with Solar Electrification



Source: Authors' own.

Barriers in Solar Technology Diffusion

Investigating barriers in the adoption of PV technology was another key question examined by this study. As per literature, the most important barriers slowing down the transition toward renewable energy sources include awareness gap, high down payment, lack of trust in technology, missing micro-financial schemes and supportive policies for PV system installations.[20] All these slowing factors can be broadly categorized under

[20] Fred Beck and Eric Martinot, s.v. "Renewable Energy Policies and Barriers," *Encyclopedia of Energy* (Cambridge: Academic Press, 2004); Dan Arvizu, Palani Balaya, Luisa F. Cabeza, K.G. Terry Hollands, Arnulf Jäger-Waldau, Michio Kondo, Charles Konseibo, Valentin Meleshko, Wesley Stein, Yutaka Tamaura, Honghua Xu and Roberto Zilles, "Direct Solar Energy," in *Renewable Energy Sources and Climate Change Mitigation*, Special Report of the Intergovernmental Panel on Climate Change, eds. Ottmar Edenhofer, Ramón Pichs Madruga, Youba Sokona, Kristin Seyboth, Patrick Eickemeier, Patrick Matschoss, Gerrit Hansen, Susanne Kadner, Steffen Schlömer, Timm Zwickel, Christoph von Stechow (Cambridge: Cambridge University Press, 2012), https://www.ipcc.ch/site/assets/uploads/2018/03/SRREN_Full_Report-1.pdf; and Staffan Jacobsson and Anna Bergek, "Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology," *Industrial and Corporate Change* 13, no. 5 (2004): 815-849, https://doi.org/10.1093/icc/dth032.

economic, technological, and institutional barriers where economic pertains to the installment and maintenance cost of the technology, technological barriers signify low reliability of the technology including its efficiency and susceptibility to break down and institutional barriers surround difficulties faced in market for promotion of the technology. In this study, lack of supportive policies by the government to promote and sustain PV technology also constitutes institutional barriers.

In this survey 87% of the non-PV users had awareness on the solar PV technology. Responding to a multiple choice question on barriers, 80% of respondents cited economic barriers as a major impediment which hampered installment of PV system. Further, 31.7% indicated lack of trust on the technology. Again, a huge majority i.e. 81.7% cited lack of supportive policies as a hindering factor.

Conclusion

The contemporary energy transition discourse is often dominated by the techno-economic paradigm of integration. This research takes a refreshing departure from the approach by exploring users' perceptions underlying success and optimality of the undergoing transition in the district of Swat wherein the energy deprivation stirred a social change. At the time of the survey, the average load shedding hours in the study region ranged between 13-15 hours. Against the extensive blackouts, households were pushed toward adoption of alternative appliances for bridging the energy access gap. These undergoing changes have not only received limited attention but also are largely undocumented.

The study explored several key issues. A major observation was extensive reliance on the grid for larger consumption, where merely partial loads were shifted unto PV systems. Not only PV systems of very small capacities were installed but also all users were relying on DC systems. The consumption pattern revealed that the PV systems were used chiefly for running low-load appliances. Further, as the financial viability is a significant indicator for long-term sustainability of a technology, the survey found that capital payment of PV installation was cited as a major challenge by most users. Again as these systems were not connected to the grid, it added additional cost of installment/repairing of the batteries to the system increasing the financial burden for users.

An interesting finding of this study was proper development of solar PV markets in the local region. These developments assisted easy access for buying the solar infrastructure and accessing technicians for its installation and repair. On efficiency of the technology, majority of the respondents indicated the technology to be reliable, yet few limitations of the technology included weather related constraints, short-life of battery and the limited reserve capacity. Regardless of these problems, majority expressed strong social acceptance for the technology. On socioeconomic aspects, significant improvements were observed in terms of improved long study hours, educational performance and sleeping hours. At the same time, except for slight indication on improvement in household income of PV users, no significant environmental or economic impacts were found.

On barriers impeding diffusion of PV technology at larger scale, absence of supportive policies and high capital cost of the technology were cited as primary obstacles. In addition, a clear desirability for adoption of the technology was indicated where majority of the respondents expressed their intent to switch to solar electrification if provided a 50% subsidy on it. However, it is important to note here that obvious deviations in financial status of PV and Non-PV users were observed where 30% of the latter had an income level less than PKR 10,000—at the time of the study. Similarly, a slight divergence in the economic status of both the groups existed in terms of asset ownership where the non-PV users were comparatively less resourceful.

Today, where considerable interest exists in energy transition, higher penetration of solar energy in Pakistan could prove an optimal transition tool. The power crisis in Pakistan has already led to a momentum of alternate energy transition. It is estimated that around $ 2.3 billion per annum is spent by Pakistani households on alternative lighting products alone.[21] Further in reciprocation of the demand for the PV technology, proper markets and relevant expertise have now been developed in the region. However, high upfront payment alongside absence of incentives in terms of fiscal and financial supportive policies is impeding its dissemination. In this backdrop, few initiatives which could potentially scale-up the transition include:

- Solar PV infrastructures are associated with high upfront installation cost. Investment in the technology can become more attractive for people if somehow they are aided with the initial investments. In this regard, micro financial schemes aiding easy access to loans and credit from banks can stimulate investment in solar energy systems. The current "Scheme for Financing Power Plants using RE" in Pakistan does not apply to PV setups with a capacity below 4kW.[22] For truly harnessing solar potential on rooftops, a strong need exists

[21] World Bank, *Pakistan Off-Grid Lighting Consumer Perception: Study Overview*.
[22] "SBP Financing Scheme for Renewable Energy," Circular no. 10 (Karachi: State Bank of Pakistan, 2019), http://www.sbp.org.pk/smefd/circulars/2019/C10-Annex-I.pdf.

for all solar consumers financing. Unless that happens, the technology will fail to disseminate with only a fortunate few to benefit.

- Subsidies on PV panels to the less resourceful civilians can offset the high initial infrastructure cost hence aiding inclusive transition. Direct engagement of local bodies for this task should be considered as it will help streamline existing power distribution infrastructure to the less resourceful.

- Currently, people have adopted the technology merely for fulfilling their immediate energy needs (or at least in the case of this study). Expansion of these technologies and their dissemination at larger scale will remain dependent on the profitability of investment in PV systems. Implementation of net-metering regulations in regions with access to grid and alternate supportive measures in non-electrified villages hence is vital. A strong need exists for making investment in renewables profitable.

- In stand-alone PV systems (designed to operate independent of the electric utility), batteries used as storage devices comprise a routine maintenance cost, which makes operational finance further challenging. This necessitates some kind of allocation of energy funds to local bodies for partial financing of maintenance funds which could relieve the poor/deserving consumers from this additional financial burden.

- As the study was conducted in 2017—which implies that people at the time of the study had an opportunity to avail net-metering facility or mainstream the off-grid installed setups to the grid through the facility. However, an important finding of the study was large-scale unawareness about government schemes pertaining to solar PV installments such as net-metering or existing financial schemes—in the study region. Any supportive policies related to renewable energy promotion hence need to be properly advertised for maximum awareness among potential users.

The power shortfalls in the country and strong community acceptance for PV technology have created a firm ground for solar transition in Pakistan. By and large, the diffusion of solar PV system remains contingent upon the role of policy makers and regulators in creating a supportive and enabling environment for prompting its uptake.