Socio-Economic Acceptance for Stand-Alone Solar PV Systems: Survey Evidence from Southern Punjab, Pakistan

Muhammad Kamran*, Muhammad Mudassar**‡, Shah Rukh Ahmed**, Hafiz Shahid Mehmood**, Farooq Mustafa Joyia**, Muzamil Hussain***, Hassaan Ahmad**, Saqib Saeed****

*Department of Electrical Engineering and Technology, Riphah International University, Faisalabad, Pakistan

**Department of Technology, The University of Lahore, Lahore, Pakistan

***Department of Mechanical Engineering, NFC- Institute of Engineering and Technology, Multan, Pakistan

****Center for Energy Research and Development, UET, Lahore, Pakistan

(kamran_ramzan@outlook.com, mudasser_90@hotmail.com, engr.shahrukh@yahoo.com)

‡ Corresponding Author; Muhammad Mudassar, Tel: +92 333 467 4112, mudasser_90@hotmail.com

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Abstract- Despite being affluent in solar energy, Pakistan has not yet exerted serious efforts in disseminating socioeconomic awareness and development in solar energy throughout the country. This study aims to explore the current level of solar energy utilization and the existing public interest in the growth of solar energy in southern Punjab, Pakistan. Moreover, this work finds the problems in solar energy adoption and the public expectations from the government and other entities involved in the development of solar energy. The survey results that 82% of respondents are keenly interested in solar energy adoption. Nevertheless, most of the respondents recount the difficulties like expensive solar panels, competitive matured technologies, lack of information and the public mistrust of the solar providers that could hinder them from solar acceptance. In addition, 78% of respondents highlight the importance of research funding and 73% favor the installation of new solar power plants. Regarding the government contribution, 85% reported the government institutes to be the most important in establishing solar energy in Pakistan. Furthermore, this paper gives some survey-based policy recommendations favoring solar energy development. Therefore, this work presents some useful knowledge for solar energy policy makers, solar developers, and solar investors.

Keywords: Solar energy utilization; Energy policy; Socio-economic acceptance; Pakistan.

1. Introduction

Pakistan is a developing Asian country quenching its energy thirsts by using conventional fossil fuel-based energy resources. Rapid growth in industrialization and population has increased energy requirements. These fossil fuels are not locally available in abundance to fulfill the requirements and are imported. The extinction of fossil fuels has raised the energy and electricity prices causing a severe effect on the availability of electricity. The energy crisis has introduced a blackout of 8-10 and 14-18 hours in urban and rural areas respectively [1,2]. The shortfall of electricity of 5000 MW has been consistently there for the last five years [3].

About 70% of the population resides in rural areas. Only 55% Pakistanis are so far electrified [4] while the remaining 45% are yet to be electrified either by the national electricity grid or by the distributed renewable energy resources. These off-grid areas meet their energy needs using wood and animal dung. This deforestation has not only spoiled the

atmosphere badly but also damaged the natural beauty of the northern hilly areas of Pakistan. The government of Khyber Pakhtun Khwa has successfully completed the billion tree project to regain the natural beauty and minimize the environmental effects. Solar PV technologies are best suited for remote off-grid areas with small and medium power requisite applications. Baluchistan, the largest area-wise province, has only 21% per km^2 population density. Rural areas contain 77% of the population living in houses consisting of only one room [5]; the maximum electricity requirements for such houses is 50-100 watts per house. Only 10% of villages are yet electrified. The electrification of the remaining 90% off-grid villages for such low power requirements will incur an uneconomic investment on the installation of transmission and distribution grid. The stand-alone solar power system is the only feasible solution for these far-off widely spread areas [6].

Various authors conducted a study on the electrification of these off-grid areas either using renewable energy resources like solar, wind, biomass, biogas, geothermal and micro-hydro or the hybrid energy systems. Sukhera outlined the solar conversion technologies suitable for the local conditions of the Cholistan desert [7]. Hasnain and Gibbs studied the importance of renewable energy resources for the development of the remote villages in Pakistan [8]. Jabeen et al. conducted a socioeconomic analysis of the utilization of solar technology in Abbottabad, Pakistan [5]. They conducted a survey and found that in blackouts of electricity, 61.25% of respondents prefer UPS (Uninterruptible Power Supply) and 38.75% use petrol engines. The initial and maintenance cost of both of these standby systems are much higher. They concluded that 65% of respondents were willing to pay for alternate solar energy systems. Abdullah et al. explored the northern areas of Pakistan to know the willingness of the people toward solar home systems and the challenges they face in the adoption of solar home systems [9]. The survey found the higher cost of the solar panels, lack of technical information and the trust of the solar panel dealers as the major obstacles in using solar home systems. However, 81% of respondents showed interest in solar home systems. 77% of respondents showed a higher interest in solar home systems if the solar panels were 50% subsidized by the government. Fara et al. studied and designed a standalone solar PV system for mountain regions of Romania having no connection to the grid [10]. They affirmed that the extension of the grid to these hilly areas would be an uneconomic activity and acknowledged the feasibility of solar PV system for these off-grid mountainous regions.

Khan and Latif stated the following more prevalent obstacles in the utilization of the solar PV technology in Pakistan [11].

- the high preliminary cost of a PV system
- inadequate renewable energy policy
- unawareness in the local communities
- inadequate availability of technical know-how.

The stand-alone solar energy system comprises of a PV module as an energy conversion technology, a charge controller and battery storage for the consistent supply of the electricity [12]. When compared to the conventional energy system, solar PV is often considered more expensive which is because of the misconception of the cost analysis. In the analysis, the cost of the PV module is compared to the electricity available at the load from the grid. Khan and Latif compared the construction cost/MW from Ghazi Brotha Dam (hydropower plant) and solar thermal power plant. Cost of hydro-electricity was 118 million/MW and 70 million/MW from the solar power plant whereas the O&M (Operation and Maintenance) cost of both the systems was almost the same [11].

The paper is organized as follow: Section 2 reviews the development of solar photovoltaic in the country. Section 3 briefs the methodology adopted to analyze the public behavior towards the solar PV. Section 4 presents the results and discussion. Section 5 recommends the survey based solar energy policy and section 6 concludes the study.

2. Review of the Solar PV Energy Situation in Pakistan

Pakistan enclosed an area of 796,096 km^2 in its borders situated between latitudes 24° and 27°N and longitudes 61° and 76°E [3]. Located in the Sun Belt, Pakistan receives 5-7 kWh/m^2/day average global solar insolation in its major sunny areas. The sun shines for more than 300 days/year with 8-10 hours a day amounting to 1500-3000 hours per year [13] generating 1.9-2.3 MWh/m/year [3] which is sufficient to electrify 40,000 villages in the country [14]. The solar energy available in Pakistan is promising for both solar PV and solar thermal. 95% of its area remains exposed to solar insolation throughout the year [3]. The World Bank's Energy Sector Management Assistance Program (ESMAP) is funding the ground-based solar and wind data assessment project in Pakistan. Under this project, AEDB (Alternative Energy Development Board) has installed nine weather measuring stations at different following universities throughout the country [3].

- Quaid e Azam Solar Park, Bahawalpur
- National University of Science and Technology (NUST), Islamabad
- UET Lahore, Kala Shah Kaku, Lahore
- Muhammad Nawaz Sharif UET, Multan
- University of Engineering and Technology (UET), Peshawar
- NED University, Karachi
- Mehran University, Jamshoro
- Balochistan University of Information Technology (BUITEMS), Quetta
- Balochistan University of Engineering and Technology (BUET), Khuzdar

The project started measuring data in October 2014. World Bank intended to measure and collect the Global Horizontal Irradiance (GHI) and Direct Normal Irradiance

(DNI). World Bank will use this data to develop solar atlas and maps for Pakistan that would be useful for solar PV installations and measuring the potential of concentrated solar power plants. This highly accurate data will be available for solar commercial developers and the Government of Pakistan with a better understanding of the solar resources in the country [3]. In its first phase, a satellite data set for almost 13 years (2000-2012) has been evaluated to develop an unauthenticated introductory solar atlas of multi-year means of GHI and DNI as shown in Fig. 1. and Fig. 2.

Various renewable energy institutions are actively involved in disseminating renewable energy in Pakistan. The proper development of renewable energy projects started late in Pakistan. However, on a small-scale initiative, National Institute of Silicon Technology (NIST) was organized in 1981 for research, development, and commercialization of the solar photovoltaic in the country. Later on, in 1985, Pakistan Council of Appropriate Technology (PCAT) was established to disseminate energy conversion technologies like mini-hydro, small wind systems, solar cookers, and biogas plants. On May 8, 2001, National Institute of Silicon Technology (NIST) and Pakistan Council of Appropriate Technology (PCAT) were fused into a more vivacious single entity, Pakistan Council of Renewable Energy Technology (PCRET) [9]. PCRET is the principal institution for organizing research and development and persuasive activities in different renewable energy technologies in the country. PCRET started research on small-scale solar PV, solar dryers, solar water heater, solar cookers, solar mobile chargers, and solar biomass plants to check their validity and performance in the local market and environment situations. PCRET installed 300 photovoltaic systems with 100 kW cumulative capacity for small houses, mosques, schools and park and streetlights. PCRET developed solar dryers suitable for the local environment and installed 21 solar dryers for 5230 kg fruit capacity and planned to install 4 community-sized solar dryers all over the country [3]. AEDB was established in 2003 as a sole representative of the federal government that encourages, facilitates and promotes renewable energy projects. AEDB facilitates and governs private investors and foreign-funded renewable energy projects as one window facilitator. AEDB is responsible for executing all renewable energy policies and projects. 28 solar PV projects of cumulative capacity 957 MW are at different project development stages under the policy and procedural framework of AEDB [3]. The government of Punjab established Center for Energy Research and Development (CERAD) in University of Engineering and Technology Lahore to spread efficient, innovative and cost-effective energy solutions in Punjab province. CERAD has carried out deep research on efficient solar-powered home appliances and developed efficient solar powered deep freezer, solar-powered sewing machine, and solar-powered energy-efficient washing machine. Along with that CERAD has given its services in solarization of schools, offices, Quaid e Azam library, Islamia University Bahawalpur, Rescue 1122 buildings, Management and Professional Development Department (MPDD), Planning and Development Department, and Punjab IT labs in the Punjab province [3].

Japan International Cooperation Agency (JICA) under the Cool Earth Partnership aided an on-grid solar power project of cumulative capacity of 356.16 kW titled “Introduction of Clean Energy by Solar Electricity Generation System”. The solar power plants were installed on Planning Commission building and Pakistan Engineering Council, Islamabad. The solar energy system of 178.08 kW each was inaugurated in 2012. Both projects incorporate the net metering facility to sell surplus electricity to the grid [3]. National Assembly of Pakistan has become the first in the world using 100% solar energy. The speaker of the National Assembly announced on Feb. 12, 2016, that the 1 MW solar plant with net metering facility generated 80 MWh. 62 MWh were expended by the parliament house and remaining 18 MWh were dispatched to the grid [3].

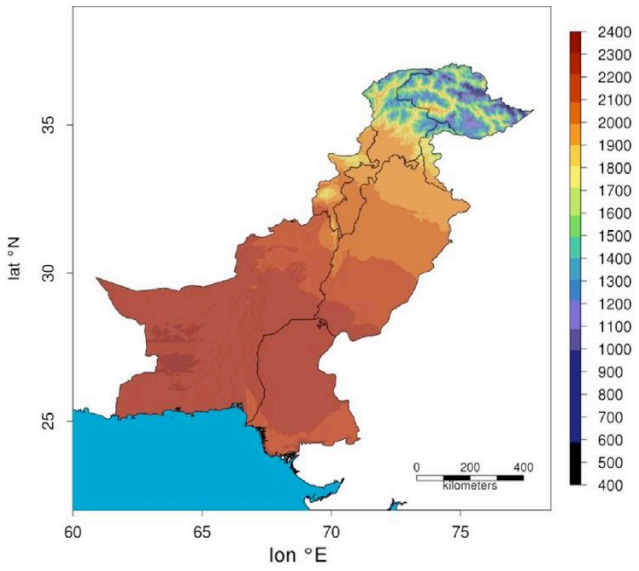

Figure 1. Multi-year mean (2000–2012) of annual Global Horizontal Irradiance (GHI in kWh/m²) for Pakistan, based on satellite data

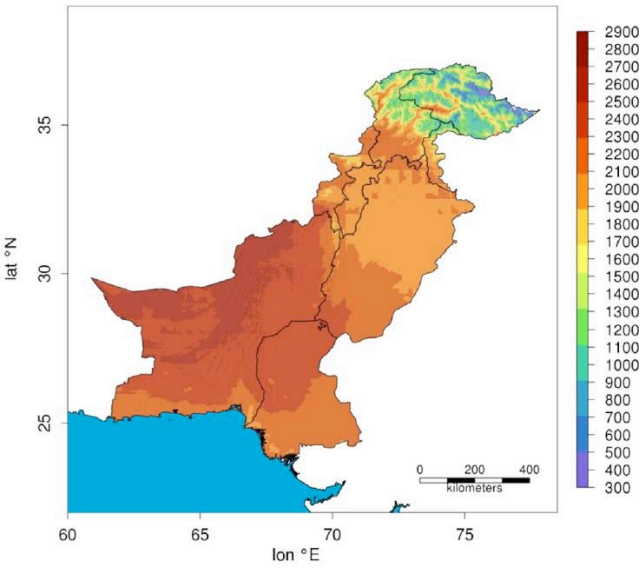

Figure 2. Multi-year mean (2000–2012) of annual Direct Normal Irradiance (DNI in kWh/m²) for Pakistan, based on satellite data

3. Methodology

This study is wished-for as a fact-finding exploration because inadequate knowledge is available regarding the social acceptance of solar energy in Pakistan. The methodology has been adopted from [15] who surveyed in Kuala Lumpur, Malaysia. The survey was conducted in southern Punjab with major cities Bhakkar, Layyah, D.G.Khan and Rajan Pur and their outskirts villages. The survey was conducted and organized in April and May 2018 by the following three methods.

3.1. Questionnaires

The questionnaires were prepared in quite simple and national language 'Urdu' for the ease understanding of the respondents irrespective of their education level. The respondents were shopkeepers, homeowners, students and farmers, the inhabitants of the above stated rural areas. The technical terms like grid parity and investment tax credit were also explained in the questionnaire. Southern Punjab is a developing area with no major universities, colleges, and technical institutions. The questionnaires were also distributed to the respondents who were already using solar energy in their homes or shops. The survey of the local inhabitants was used as primary data for the analysis.

3.2. Unstructured interviews

To have the better understanding of the trend in solar market and the utilization potential in the villages of southern Punjab, unstructured interviews were conducted with the residents of the southern Punjab having a know-how of the technicalities and advantages/disadvantages of the solar energy especially shopkeepers who were dealing in solar modules, components, storage batteries and their maintenance. Interviews were also conducted with the people developing locally made solar-powered fans, solar-powered air coolers, and solar operated LED lights.

3.3. Observations

Data composed through structured questionnaires and unstructured interviews were validated on the basis of personal interpretations.

4. Results and Discussion

The development in the solar energy field has been surveyed by using above-mentioned methodology. This section presents the general demography of the respondents, public interest, and attitude toward solar energy utilization, obstacles that hinder them from the use of solar energy and the public expectations to develop the solar energy. The questionnaires were distributed among 500 persons and we received 300 responses. The survey was conducted regardless of society, income level, gender, qualification, and job type. The results were analyzed in Minitab 17.

4.1. Respondents' general demography

The general demography of the participants is as follow. Among 300 respondents, male and female covered 77 % and 33% of the participants respectively. 12% were below 18 with mostly high school students having knowledge of renewable energy. Rural respondents were 67% while the urban was 33%. Urban respondents were only the main city residents. The majority of the respondents were shopkeepers and mostly had rooftop solar energy systems for the shop electricity requirements. By qualification, most of the respondents were shopkeepers and farmers having little/no education. The detailed demography of the respondents is shown in Table 1.

Table 1. Demography of the respondents (n=300)

Respondent's characteristics	Frequency	Percentage
Gender		
Male	200	66.7
Female	100	33.3
Age		
Below 18	0	0
18-30	37	12.3
31-40	147	49.0
41-50	53	17.7
51-60	67	22.3
Residential Area		
Rural	200	66.7
Urban	100	33.3
Occupation		
Shopkeeper	93	31.0
Farmer	83	27.7
Student	75	25.0
Government Servant	27	9.0
House Wife	22	7.3
Qualification		
Primary	100	33.3
High school	93	31.0
College	51	47.0
Graduate	27	9.0
Post Graduate	7	2.3
Diploma	22	7.3

4.2. Existing public attitude toward solar energy utilization

The survey was conducted to explore the current utilization level and the interest level of the public toward solar energy. Public interest level toward solar energy utilization is shown in Table 2. About 82% of respondents showed prodigious interest in the utilization of solar energy. Among those interested respondents, 47% of respondents were those already using solar energy either for the partial load fulfillment or the full load. Only 5% of respondents

showed reluctance toward solar energy. 13% of respondents were hesitant to answer. The unstructured interviews with these uninterested and uncertain respondents revealed that either they were using alternative energy sources (UPS and generators) or unaware of the green energy and climate change. The overall public response toward the utilization of solar energy was satisfactorily high.

Renewable energy policy 2006 and its revised editions exempted the renewable energy equipment and machinery from the duty taxes, withholding tax, and sales tax for the development of renewable energy in Pakistan. In view of the aforesaid incentives in renewable energy policy, the survey was conducted to determine the public inclination toward buying and using solar PV energy systems in their residences and shops. Regarding this, three questions were put forward in the survey.

- First, they were asked to purchase the solar modules if the government provided a 50% subsidy on the total cost of the solar modules.
- Second, they were asked to purchase the solar-generated electricity if it was available at grid parity rates, i.e. the rate of electricity from fossil fuel is equal to the rate of electricity from solar panels [16].
- Third, they were asked to install solar panels at their residential or commercial buildings if government bestowed Investment Tax Credit (ITC), i.e. some percent of the investment in the solar system that is paid to you by the government to pay your tax liabilities.

Table 2. Public interest level in solar energy systems

Public interest level in solar energy system	Frequency	Percentage
Agree	246	82.0
Disagree	15	5.0
No opinion	39	13.0
Total	300	100.0

The results are summarized in Table 3 that depicts 71% of the respondents were inclined to buy 50% subsidized solar panels. Only 8% declined to buy solar panels whereas 21% were dubious. Personal observation of the surveyed data revealed that 8% were those with low monthly income and were unable to bear the initial capital cost. The results of the second question were highly in favor of solar energy if the electricity from solar systems is available at grid parity. 88% of respondents replied "Yes", 8% said "No" whereas only 4% were unsure. The third question showed that 82% of respondents were interested to get an ITC by installing solar energy systems. 12% said "no" and the rest 6% were unsure. For the sustainable development of solar energy systems in the country, the government will have to introduce various incentives and subsidies on solar energy systems.

The respondents were asked about their current alternative electricity sources to assess the current level of solar energy utilization. Interestingly, 29% of the public already uses solar electricity to keep ON partial loads or some percent of the demand factor. Furthermore, 35% are using UPS and 10% diesel generator whereas 26% public is using no alternative energy source as shown in Table 4. The survey reveals that there is potential for solar energy utilization if it is properly developed and made available cheaper than UPS and diesel generators that incur heavy operation and maintenance cost. Table 5 shows the percent reduction of the utility electricity bills for those using solar energy. Among 29% of solar energy consumers, 40% of consumers got 41-55% reduction whereas 33% reduced their electricity bills by 26-40%.

Table 3. Public interest in purchasing subsidized solar modules and incentive-based electricity at grid parity rates

Public interest İn solar energy	Yes		No		Unsure	
	Freq.	%	Freq.	%	Freq.	%
If Govt. gives 50% subsidy on solar modules	213	71	24	8	63	21
If solar energy is available at grid parity	263	88	23	8	14	4
If Govt. gives investment tax credit	245	82	37	12	18	6

Table 4. Alternative energy resources

Alternative energy resource	Frequency	Percentage
UPS	105	35
Diesel generator	30	10
Solar system	87	29
No alternative	78	26
Total	300	100

Table 5. Percentage reduction in utility electricity bills

Percent Reduction	Frequency	Percentage
0-25	23	27
26-40	29	33
41-55	35	40
Total	87	100

4.3. Respondents' response to difficulties in solar energy utilization

This section puts the light on the difficulties and reasons for these hitches that hurdle the impending consumers from the installation and utilization of the solar energy system. The survey identified various potential obstacles on the way to the development of solar energy. We asked the respondents about the hindrances such as initial capital cost, availability of correct information, best possible price, trusty solar panel provider and the technical impediments. They were asked to choose from four options regarding the importance level of the above-stated hindrances. Results are graphed in Fig. 3. The survey revealed the capital cost as the major obstruction in the installation and utilization of the solar energy system. Almost 67% of respondents regarded this feature as the most important obstacle. Moreover, 59% of respondents declared the low cost of competitive fossil-

fueled electricity to be the most important aspect that hinders the purchase and install a solar system. Regarding the correct information of the solar technology and solar appliances, 51% showed hesitancy in buying and installing solar system until they get the correct information like efficiency, lifetime, and other technical aspects of the solar panels. Likewise, 57% of participants were reluctant to be interested in solar systems until they get the best possible price quotation. Distrust solar panel provider was another major aspect keeping the respondents hesitant in buying and installing solar systems. 48% took this feature as the most important one. In addition to the above-stated obstacles, unstructured interviews with the highly qualified respondents revealed that the lack of information on climate change, the absence of experience and inaccessibility of technical assistance, and unavailability of DC home appliances are other obstructions in the way of solar energy utilization. By addressing these issues carefully, solar energy can be brought into utilization competing for conventional fossil fuels.

4.4. Respondents' expectations for growth of solar energy utilization

In order to develop solar energy in the country, the government's renewable energy policy should be in harmony with public expectations. This part of the study determines the public expectations and attitude for solar energy to develop a policy encouraging solar energy utilization in Pakistan. Furthermore, this study inspects and analyzes the organizational role in the public perspective that could lead to the development of solar energy in the country.

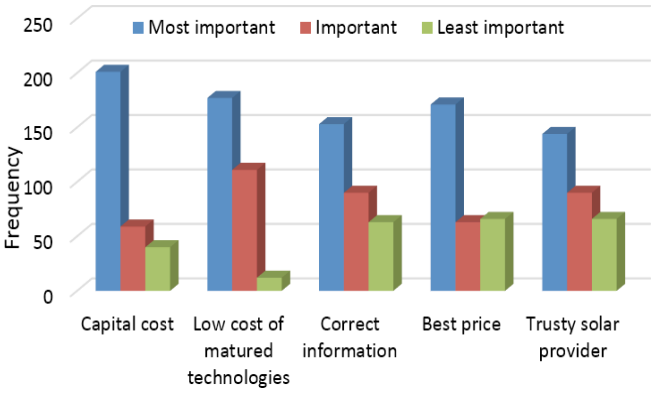

Figure 3. Public reaction to difficulties in using solar energy

Public opinion on the development of solar energy is shown in Fig. 4. Almost 89% of the public believes that government incentives are the major role player in promoting solar energy development. Unstructured interviews revealed that almost 30% of the respondents were aware of the Feed-in tariff (FiT), Investment Tax Credit (ITC), and Renewable Portfolio Standards (RPS). In addition, 75% of the public supported the application of bill for GHG (Green House Gas) emissions, whereas 69% claimed the reliable contractor a key feature to increase the solar installations. 69% believed that the government should establish some solar system as a model for the people to clear most of their ambiguities about solar energy. People were asked about the implementation of new solar energy policies and projects, the response is shown in Fig. 5.

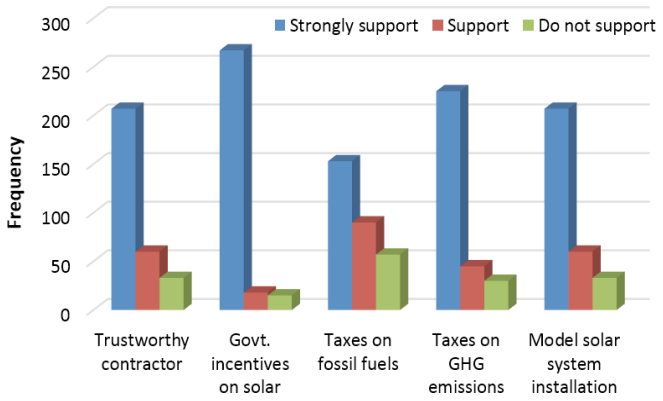

Figure 4. Public response to increasing solar consumption

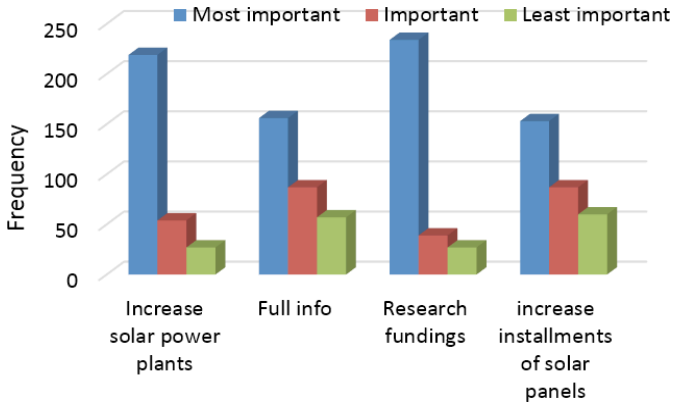

Figure 5. Public response to implementation of new solar projects

About 78% of the respondents supported the increase in research funding for solar energy. Moreover, 73% responded to install more solar energy system throughout the country; 52% claimed the access to full information regarding the meteorological data, solar technology, and the solar appliances; and 51% chose to install more solar panels. This study fully claims that the government should play a sole role in increasing solar energy utilization by offering lucrative incentives and subsidies for a solar PV system, imposing heavy taxes on fossil fuels, ensuring the complete access to the solar related information, and allocating more funds for solar-related energy projects. Finally, to comprehend the public expectations on the development of solar energy, they were analyzed regarding the institutional role in Pakistan. Fig. 6 shows the results of the survey for the role of organizations with 85%, 79% and 75% respondents giving top priority to the government organizations, research, and academic institutes respectively in the development of solar energy. Moreover, 62% of respondents believed that awareness campaigns through social, print and electronic media would have a better impact on the development of solar energy.

Therefore, the survey results determine the government efforts, the participation of research organizations and academia, awareness strategies and commercial participation are the most promising key feature to promote solar energy utilization in Pakistan.

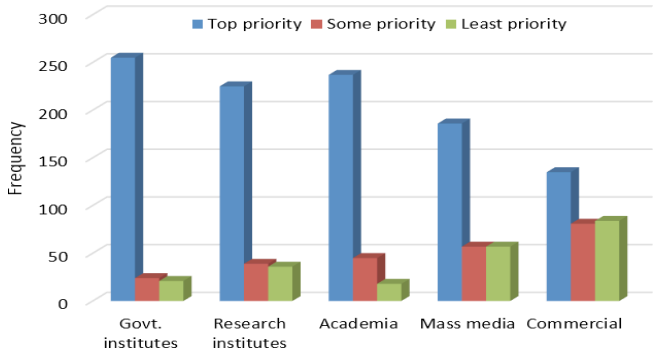

Figure 6. Public response to an organizational role in solar energy development

5. Recommendations

Policy recommendations as deducted from the survey are as follow:

1. Government renewable energy organizations like AEDB and PCRET has installed modeled based renewable energy projects (the wind, biomass, and biogas etc.) in rural areas of Pakistan. The government should install solar energy systems in public places of villages like schools, mosques, parks, and clinics to fascinate the public interest toward solar energy.

2. It is observed that the government provides FiT incentives to the commercial level solar power plants only. Standalone solar energy systems do not avail such incentives. The government should introduce incentive based renewable energy policies to persuade the public on investing in solar energy utilization in their homes, shops, and facilities.

3. The government must overcome the impediments that public face while thinking about solar energy system installation. Meteorological data regarding solar irradiance, atmospheric temperature, and humidity level for the location where the installation is intended must be available to the public.

4. The government should invest in induction public awareness campaigns about green energy, climate change, efficient DC appliances, and energy storage systems through seminars, television, and newspapers. The government also needs to launch certified vocational training programs regarding solar cell technologies and solar installation to promote solar energy utilization in Pakistan.

5. Improvement of R&D facilities for the research institutes and the research-oriented postgraduate programs in universities are important aspects to be addressed to promote solar energy utilization in Pakistan.

6. Conclusion

Socioeconomic assessment of technology is an essential footstep to form a policy equally accepted by the consumers for the development of that technology. Current energy scenario of Pakistan is not well enough for social development. Alternative renewable energy technology utilization must be introduced among the consumers to diversify the national energy mix. This study aims to evaluate the existing level of acceptance of the solar energy utilization and to assess the provisional public attitude to adopt it in future in southern areas of Punjab, Pakistan. Moreover, this study highlights the public opinion on impediments in the utilization of solar energy, public expectations on the growth of solar energy and the institutional role to promote solar technology in Pakistan.

Key findings and conclusion are as follow:

1. Majority of the respondents (almost 82%) are keenly interested in utilizing solar energy in southern Punjab, Pakistan.

2. About 71% respondents have the proclivity to buy solar modules if subsidized by 50% by the government, whereas 88% respondents are ready to buy solar electricity at grid parity rates and 82% are willing to install solar energy systems if they get a tax credit by the government.

3. Majority of the respondents claims the initial capital cost (almost 67%), a big hurdle in solar energy utilization whereas others state the low prices of the competitive fossil fuels and the lack of information are big obstacles in using solar energy.

4. Regarding the development of the solar energy, most of the public considers the government a big role player in increasing the solar panels installation, ensuring the availability of low-cost solar panels and providing the full and correct information to the consumers.

5. The majority of the public (almost 85%) states that the government organizations should come forward in boosting the solar energy utilization at competitive rates. Moreover, research institutes, academia, and mass media have also been reported important in this regard.

Acknowledgments

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