Renewable and Sustainable Energy Reviews 78 (2017) 754–763

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Factors responsible for solar PV adoption at household level: A case of Lahore, Pakistan

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ARTICLE INFO

Keywords:
Solar photovoltaic (PV)
Household adoption decisions
Determinants
Innovation diffusion model
Pakistan

ABSTRACT

The crisis in electricity generation sector of Pakistan is causing load shedding. All sectors including household-domestic, commercial and industrial activities get severely affected by such power outages which could be minimized by adopting modern technologies such as solar PV. The use of solar PV system in many countries has become a promising solution to meet energy needs but in Pakistan its usage at household level still remains largely untapped despite huge potential. This study identifies the determinants that influence the household's decisions regarding solar PV adoption in Lahore, Pakistan. For this, initially, a generic list of significant determinants was extracted from literature. Later, detailed interviews (based on persuasion attributes of Roger's theory of Innovation Diffusion) of both adopters and non-adopters of solar PV system were conducted at household level to rank the determinants on the basis of their significance in solar PV adoption decision. The household's adoption of solar PV system faced many barriers regardless of the fact that it exceeds in advantages as compared to other conventional sources of electricity. The cost of solar PV system appeared to be the most significant barrier in the diffusion of solar PV system. Additionally, the absence of adequate financial support by government for the installation of small solar PV systems at household level further intensified the adoption decisions. Other important barriers included difficulty of using all appliances at the same time and shortage of reliable vendors as well the technicians. While, environment friendly feature of solar PV system along with its availability in local market appeared as significant driver of diffusion at household level.

1. Introduction

Like many other developing countries, Pakistan is also an energy deficient country. Demand for electricity remains unmet with existing supply. In year 2015, electricity shortfall reached 5500 MW with 15,500 MW supply out of 23000 MW installed capacity [1]. One reason of supply shortage is heavy reliance on thermal based power plants [2] which are costly to run all the time to meet the electricity demand. Dependence on thermal power added with a number of subsidies has plagued the power sector with inter-corporate circular debt which restricts it from functioning at full capacity [3]. This has put the social and economic life under intense pressure. This strain can be reduced by enhancing the access of subsidized sectors (e.g. household) to other than grid based and conventional energy resources.

Solar photovoltaic (PV) at household level has gained momentum as an alternate source of clean energy in many countries [4]. The PV module made up of silicon converts sunlight directly into DC electricity which is converted into ordinary power by inverter for its usage to operate appliances. For instance *Energiewende* program in Germany has widely transformed the traditional energy profile of the country.[1] Germany, as a result, is leading with its share of 32% of total world solar PV generation, followed by Italy and USA with 16% and 7.2% respectively [5]. Furthermore, the share of solar PV generated electricity is 7.9% in Italy, 7.1% in Germany, 3.4% in Spain and less than 1% in USA [6]. Similar to developed countries, many developing countries in Asia, Africa and South America are emphasizing the inclusion of solar power in their energy mix to lessen the burden on non-renewable and expensive sources of energy [7]. Despite huge potential, utilization of solar energy still remains in lacklustre in Pakistan that has not contributed markedly to energy mix of the country [8]. It is evident from a study [9] that the total electricity demand of Pakistan can be met by just installing solar PV of 20% efficiency on one percent of Baluchistan land. The annual average mean daily solar irradiation in Lahore ranges from 5.1 kWh/m^2 to 5.4 kWh/

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[1] http://energytransition.de/

http://dx.doi.org/10.1016/j.rser.2017.04.020
Received 1 August 2016; Received in revised form 5 December 2016; Accepted 17 April 2017

m^2 which is also promising for solar energy utilization [10].

Similar to other countries, adoption of solar PV at household can also relieve Pakistan from chronic electricity shortage. Household is important for solar PV adoption because it is a major electricity consumption sector in Pakistan and also a major receiver of subsidies [11]. Adoption at household level can provide off-grid and environment friendly solutions to electricity shortage. However, adoption of solar PV still faces hurdles in Pakistan that needs to be explored. There are few studies in the context of Pakistan which explored hurdles to the adoption of renewables in different parts of the country [8,12,13]. However, those studies mostly focussed on different aspects of renewables' diffusion and did not comprise a specialised investigation of the diffusion of solar PV technology particularly at household level under some authentic analytical framework. In this study, we tried to investigate the issue of diffusion of solar PV at household level by utilizing Rogers' Theory of Innovation Diffusion-a more systematic analytical framework [14].

2. A brief review of factors responsible for innovation diffusion

A decision regarding the adoption of solar PV at a household level, is based on many factors including endogenous (e.g. technology awareness and intention of conserving energy) and exogenous factors such as cost, characteristics of PV system, market system, etc. A study found that electricity generation at household level through solar PV is socially an acceptable technology due to its environmental value but its adoption success is mainly based on its economic feasibility [15]. It is revealed from a cost-benefit study on different micro-generation options in UK which concluded that electricity production by micro-generation was unsuccessful even in the presence of incentive system due to long payback periods [16]. It was further identified that current market structure in which the energy prices are not accounted for the externalities of climate change and limited availability of fossil fuels is a barrier to the adoption of renewables [12].

Another aspect is consumers' willingness to pay for better life [17]. This study revealed that consumers are usually willing to pay more for better quality of life, and solar PV system is appearing as one of the reliable and clean sources of electricity for households. Therefore, in general, some of the households are willing to pay more for better and reliable services. Further, a study on the socio-economic contexts of solar PV usage in Pakistan concluded that solar technology can enhance the consumer quality of life in the urban areas of Pakistan [18]. Moreover, solar technology utilization is the best available technology on the basis of comparative cost analysis and user friendliness. The research also acknowledged the huge potential (65%) of solar technology in mitigating the country's energy crisis. A number of studies [19,20] revealed that higher income and higher education level have correlation with the adoption decision of solar PV as an alternative source of energy. It was also found that higher income have direct relation as it may overcome the cost barrier but the correlation between education and adoption decision is less clear.

Unavailability of grid connection in developing countries provides an opportunity to solar PV diffusion among potential users more rapidly [21]. The unreliable electricity supply from grid in Pakistan and frequent load shedding is being experienced by household including commercial and industry in various parts of the country, thus putting pressure on urban households to switch to another reliable electricity source like solar PV. This situation is eventually driving the solar PV diffusion in the local context. A recent study [17] on the decision making factors for the adoption of solar PV system among households of Netherlands revealed four factors (components). These factors included perceived relative advantage of technology, complexity of the innovation, social influence and knowledge about grants and costs. It concluded that cost of PV system was the main element behind the adoption decision for both adopters and non-adopters of PV system.

A number of studies found that consumers give more importance to cost aspect than environmental concerns [22,23] for selecting solar PV system. These studies revealed that solar PV technology is not compatible with personnel priorities of household users because most of them are interested in technology just to reduce the cost and save money rather than environmental consciousness. For meeting the challenge of high up-front cost of solar PV system and promotion of renewable energy projects in Pakistan, State Bank of Pakistan is providing loans to potential adopters of solar PV system. However, the loan provision under Financing Scheme for Renewable Energy is valid only for electricity producers between 4 kW and 50 MW [24]. Since adoption of solar PV is also geared up by environmental concerns, however accumulative impact of solar PV utilization over environment is minor due to limited usage of solar PV [25]. However, a study conducted in the Pakistan context identified that a 5 kW standalone solar PV system can minimize the net annual Greenhouse Gases (GHG) by 2.9 t to 3 t of CO_2 [10].

Lack of technology awareness among the users was also identified as a key barrier in developing countries [21]. [26] also supported this fact that lack of awareness resulted in the dissemination of misinformation among the potential adopters about the technology benefits. She also mentioned that high cost phobia among potential adopters of solar PV usually paralyzed the diffusion process at initial stages of adoption decision. [4] identified that the fear of adoption of new technology is one of the major barriers among the people of Pakistan.

A study conducted in Pakistan identified (a) high initial cost of PV system (b) unawareness of local community (c) inadequate availability of technical expertise (d) inadequate renewable energy policy as the main barriers in widespread solar PV utilization [27]. Another study [28] identified and categorized (i) policy barriers (ii) institutional barriers (iii) financial barriers (iv)market related barriers (v) technological barriers and (vi) social barriers as the renewable technology adoption barriers in the context of Pakistan. Whereas [29], identified inadequate policies, component failure, lack of solar compliant buildings and problem of research and development as diffusion barriers in African context. However, the common diffusion barrier found in the literature is high capital cost of solar PV system for households in most developing countries. In Pakistan, average cost of a 1 kW good quality solar PV system (panel, inverter, controller and energy meter) without battery backup is around 280,000 to 330,000 PKR. Whereas, the cost of 2 kW and 3 kW capacity solar PV system ranges from 530,000 to 800,000 PKR. However, the battery backup of 3 h increases the cost at the rate of nearly 70,000 PKR per kW for the above mentioned solar PV systems [30].

Similarly, a study about the barriers in renewable energy penetration came up with a large number of barriers of seven different categories based on their type [31]. These categories included i) market failure/imperfection ii) market distortions iii) economic & financial iv) institutional v) technical vi) social, cultural and behavioural and vii) other barriers. In Indian context, economic and financial barriers were found as the most influencing for diffusion of solar PV at household level [32].

3. Rogers' model of innovation diffusion–an analytical framework

According to Roger's (2003) theoretical model, the potential adopter passes through a number of steps before accepting or rejecting an innovation. Since, the potential adopter has a lot of uncertainties about new product or service, therefore this model helps them to make a final decision [14]. The Roger's diffusion of innovation in a society is a process by which new technology adoption is communicated over time by utilizing various channels. This diffusion process has been modelled and theorized over time. It assumes that potential adopters get interested in new innovation only when they start collecting knowledge of innovation. That knowledge guides the individuals to persuade them