Energy for Sustainable Development 38 (2017) 10–20

Contents lists available at ScienceDirect

Energy for Sustainable Development

Performance and impact evaluation of solar home lighting systems on the rural livelihood in Assam, India

Mayur Barman [a,b], Sadhan Mahapatra [a,*], Debajit Palit [c], Mrinal K Chaudhury [d]

[a] Department of Energy, Tezpur University, Tezpur 784028, Assam, India
[b] Department of Electrical Engineering, National Institute of Technology, Silchar 788010, Assam, India
[c] The Energy and Resources Institute, Darbari Seth Block, Lodhi Road, New Delhi 110 003, India
[d] Assam Energy Development Agency, Bigyan Bhawan, Guwahati 781005, Assam, India

ARTICLE INFO

Article history:
Received 21 October 2016
Revised 28 January 2017
Accepted 27 February 2017
Available online xxxx

Keywords:
Solar home lighting system
Performance evaluation
Livelihood
Rural electrification

ABSTRACT

This study was carried out in four districts of Assam to assess the technical functionality of the solar home lighting systems (SHLS), service delivery model, institutional mechanism, maintenance and monitoring, user's awareness and its impacts on rural livelihood. The study found that only 28.9% of the systems are functional, 62.3% are found working with minor faults and 8.8% are either non-functional or having major faults. The average working durations per day for winter, summer and monsoon seasons are 2.2 h, 3.5 h and 2.3 h respectively. The study observes noticeable benefits due to adoption of SHLS such as reduction in kerosene consumption, increase in children's study hours, extended working hours of small businesses and income generation through mobile phone charging. One of the key reasons for unsatisfactory technical performance of SHLS is because of poor service delivery model and inefficiency in existing institutional structure such as passive village energy committee and non-availability of service centres or local technicians for post-installation maintenance. The study observes that user perceptions on the system are positive. However, cost considerations seem to be the main obstacle for system adoption. This study concludes that availability of local technicians, effective village energy committees, demand driven system design and appropriate social awareness towards livelihood improvement options will improve the sustainability and economic viability of the SHLS.

Introduction

In India even as village after village is electrified under different schemes of the Central or State Government, still 18,500 villages had no access to electricity (As on March 2015). Central Electricity Authority indicates that the central grid has reached 97% of the villages but yet, policies and institutions that contributed to this achievement still could not bring electricity to approximately 300 million people in India. There is also a huge urban–rural disparity. While the rural household electrification rate is only 67% (CEA, 2015), the urban electrification rate is 94% (Census of India, 2011). The rural households which are yet to have electricity access usually fall into three categories (i) households in remote inaccessible villages where extending the grid is technically not feasible or economically daunting, (ii) households in unconnected hamlets of grid connected villages and (iii) un-electrified households in grid connected villages (Palit, 2015). In the last case, the issue appears to be less of opportunity to get connected to the grid, but more of inability of the households to take electricity connection due to their financial constraints or the perception that electricity services (quantity and quality) will be inadequate (Palit and Chaurey, 2011). In addition, high poverty level, lack of effective developmental programmes and policies, resource constraints and weak institutional arrangements have also contributed to the low energy access level in rural India (Balachandra, 2011; Palit and Chaurey, 2011). The consequence is that the kerosene continues to be the major source of lighting for the un-electrified households as well as households with intermittent access to electricity in rural areas of India. Kerosene based lamps are inefficient so replacing them with energy efficient lamps not only reduces the health issues associated with it but also reduces the primary energy consumption (Mahapatra et al., 2009; Urpelainen and Yoon, 2015).

While the centralized grid-based electrification has been the most common approach in India, decentralized renewable energy options, especially solar photovoltaic (PV) based systems, have also been adopted and being increasingly considered as a cost-effective mode for providing electricity access (Palit and Bandyopadhyay, 2015). There were more than one million households in India in 2011 using solar PV power as their primary source of lighting (Census of India, 2011). With an average household size of five, this means five million people in India rely on solar power for their lighting needs (Census of India, 2011; Urpelainen and Yoon, 2015). Of the various distributed

* Corresponding author.
E-mail address: sadhan.mahapatra@gmail.com (S. Mahapatra).

http://dx.doi.org/10.1016/j.esd.2017.02.004
0973-0826/

generation systems implemented in off-grid areas, solar home lighting systems (SHLS), centralized charging of solar lanterns as well as solar mini-grids (both AC and DC), has proven to have a positive impact on the lives of the rural population. Various studies have highlighted the contribution of solar PV to improve the socio-economic enhancement of the rural areas, access to clean energy and contribute to mitigation of CO_2 emission from kerosene base systems for lighting (Chakrabarti and Chakrabarti, 2002; Nouni et al., 2006; Mahapatra et al., 2009; Urpelainen, 2016). Studies have also revealed how PV systems have contributed towards enhancing the livelihood activities of rural households (Borah et al., 2014; Palit, 2013; Harish et al., 2013; Mondal, 2010; Halder and Parvez, 2015; Wijayatunga and Attalage, 2005). The SHLS have been promoted as one of the better options for off-grid electricity supply among all the solar programs in the developing countries (Holtorf et al., 2015).

Urpelainen (2016) critically examined the perceptions of solar power in marginalized communities in Uttar Pradesh, India. This study found that users are not satisfied with the kerosene based lighting and solar entrepreneurs needs to deliver quality service and products. Harish et al. (2013) observe based on an empirical study in Karnataka that even the grid-connected households do not hesitate to adopt SHLS without any subsidy as the users found grid is not a reliable source for lighting due to its frequent brown-outs and black-outs. Urmee and Harries (2011) investigated the determinants towards the success of SHLS in Bangladesh. This study found that the primary reasons for the program's success is due to strong focus on meeting household needs and ability to make the systems as affordable as possible to the users. This study also observed that SHLS has resulted in improvements in the quality of life, create opportunities for new income generation activities like mobile phone charging shops, operating social TV halls, ability to work at night and enjoy the superior quality light. An interesting observation is that SHLS is not only used for lighting in the households but also found uses in the small shops as it relates with extra income generation activities which indicate better economic viability of the systems (Mondal, 2010; Halder and Parvez, 2015). Komatsu et al. (2011) found that the household income, ownership of rechargeable batteries, kerosene consumption, and the number of mobile phones are the key determinants of the adoption of the SHLSs. The capacity of the SHLSs chosen by households is related to the amount of kerosene consumption, number of children and demand for electricity for lighting in the household in addition to extra household income generation. This study concluded that kerosene consumption is the significant factor on both the adoption of SHLSs and the selection of the system size.

Solar lighting programs have been implemented by adopting various delivery models, such as leasing of energy products, consumer financing model and direct subsidy (Palit, 2013). Institutional arrangement is also one of the important aspects in these kinds of programs. Wong (2012) analysed the obstacles towards the effective solar lighting interventions in South Asia. This study identified the major obstacles like financial exclusion, weak governance, passive NGO and customer participation that constrained poor people to implement the solar lighting systems. This study suggested that poverty sensitive cost management; better governance and robust technical support are the key solutions to make the solar lighting projects more effective, inclusive and pro-poor. Brooks and Urmee (2014) observed that lack of adequate technical training and appropriate social understanding resulted in the failure of most of the solar project in Philippines. The poor installation and maintenance, lack of understanding by the system owner, non-availability of local technician are the primary reasons of non-functioning of the systems. Adequate user and local technician training are an important attributes towards successfully implementation of solar power systems. Nathan (2014) observes that the primary reasons for the failure of solar PV systems is due to the location in rural and remote areas, where households cannot afford to pay much and also lack of supply chain and skilled manpower for maintaining the systems. Thus, availability of skilled local technician, user's awareness and proper collaboration among the concern stakeholders are to be the key determinant for successful implementation of any solar projects (Karakaya and Sriwannawit, 2015; Holtorf et al., 2015).

In India, SHLS implementation has been supported under the Ministry of New and Renewable Energy (MNRE) subsidy programme since the early 1990's to provide access to clean energy specially meeting the lighting loads of rural households which are not connected to the central grid. A typical SHLS, supported under the government programme consisted of a 37Wp module, a 12 V 40AH tubular plate battery, luminary of two 9 W CFL, a charge controller and module mounting structure. A large number of SHLS have been installed by various agencies in rural households of Assam. Hence, it is important to understand the impacts, success, limitations or failures of these installed systems based on a comprehensive field survey analysis. While there are some literature on ex-post evaluation of systems in India in general and Assam in particular (Palit and Hazarika, 2002; Buragohain, 2012; Borah et al., 2014 and others), there is absence of recent scholarly work on ex-post evaluation of decentralized solar PV system for the state of Assam and North-eastern region of India. This paper thus attempted to undertake the evaluation and presents the analysis of the technical performance and functionality of the installed systems based on field study conducted in Assam, as the state has installed 40,035 SHLS under the remote village electrification programme[1] of the Government of India (AEDA, 2015). This constitutes one of the largest dissemination of decentralized solar PV systems in India. So to look forward the future scope of PV projects in this region, the general and scholar's curiosity here is to know about the present performance of these already installed SHLSs. This study thus critically examined the performance of the installed SHLSs in terms of service delivery model used in implementation of the systems, financial scheme and institutional structures, user's technological know-how capability about the systems, benefits and improvements in the livelihood of these households and suggests recommendations for strengthening the implementation and functioning of the SHLS.

Study area

The study area is the state of Assam, India is located at the longitude of 89.42° E to 96.0° E and the latitude of 24.8° N to 28.2° N. Assam has a peak shortage of power supply of 189 MW as on March 2016 (APDCL, 2016). The per capita electricity consumption in Assam is as low as 314 kWh, whereas national average is 1010 kWh (CEA, 2015). The number of un-electrified villages in Assam is 803, out of the total 25,372 villages (as on March, 2015). This also includes the number of villages, which are not complying with the definition of village electrification and number of villages where no electrification infrastructure is available (CEA, 2015). While, little more than 93% villages in the state are officially electrified, however, only 34.22% of the rural households have access to electricity[2] (as on May 31, 2016). The situation is little better in the urban areas. Of the total number of 6,367,295 households in Assam, 37% depends on electricity for lighting and 62% depends on kerosene for lighting (Census of India, 2011). The villages which were not covered under the erstwhile grid electrification programmes such as Rajiv Gandhi Grameen Vidyuktikaran Yojana (RGGVY) were covered under the Remote Village Electrification programme (RVEP). Mostly PV based lighting systems were installed in these villages to meet the basic

[1] The Remote Village Electrification Programme (RVEP) was initiated in 2001 for provision of basic lighting facilities in un-electrified census villages whether or not these villages were likely to receive grid connectivity. As part of the programme, central financial assistance of up to 90% of the project cost is provided as a grant with specific benchmarks as applicable in respect of the technologies adopted for electrification, with the balance of project costs being met by the beneficiaries and/or the state governments (Palit et al., 2014).

[2] http://www.garv.gov.in/assets/uploads/reports/statesnaps/Assam.pdf, Accessed on 15th October, 2016.