

Prospect of Sustainable Rural Development through Solar Electrification in Bangladesh

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Abstract: Despite rapid economic growth in Bangladesh, overall prevalence of electrification for households is 60% for the nation but much lower for rural areas at only 42.5%. In this context, this study aims to examine the potential of renewable energy technologies like Solar Home System to meet the unprecedented energy demand and thereby contribute in uplifting the rural living standard. By extracting the research concentrations and findings of pertinent studies, this paper attempts to identify the gap in present literature on the significance of solar energy usage to promote sustainable rural development. The study proceeds further by synchronizing qualitative and quantitative information collected from key informant interviews, peer reviewed journals and reports issued by regulatory organizations. Based on the theoretical arguments presented in this qualitative research, the study signifies the resulting socio-economic benefits and environmental impacts of disseminating SHS in rural communities. The paper concludes with an emphasis on multilateral collaboration among various stakeholders to enhance the rural development initiatives. Thus, it adds value to the existing literature on assessing the impact of rural electrification in a developing country like Bangladesh that sets an impressive example in resilience and innovation in the face of possible climate change adversity.

Keywords - Rural Development, Sustainability, Solar Electrification, Solar Home System

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I. INTRODUCTION

At present, 1.317 billion people i.e. 20.5% of the world's population do not have access to electricity and most of these people live in the rural areas of Asia and Africa [1]. To upgrade the socio-economic condition and alleviate poverty, electricity sector has been prioritized by all the Governments as a major agenda for sustainable development to alleviate global poverty and inequality. Hence access to electricity has attained considerable global attention especially among the developing nations like Bangladesh, where majority of the population, around 77%, live in rural areas with the prevalence of low electrification rate of 56.8% [2]. Despite the rapid economic growth in Bangladesh (more than 6 percent growth in GDP), per capita availability of electricity of 293 kwh, which is one of the lowest amongst the developing countries [3].

To meet the electricity requirements across the globe, renewable energy sources such as solar energy technology have received major importance due to their social acceptance as well as an ability to provide sustainable energy generation [4]. As electrification in rural Bangladesh has lagged behind than in urban areas, renewable energy such as Solar Home System (SHS) stands out to be one of the prospective sources to meet the unprecedented energy demand due to the geographic location of the country [5]. Bangladesh is a subtropical country with an average daily solar radiation of 4–6.5 kW h m⁻², with highest amount in April and lowest amount in December [6][7]. It is found that 94% of the land area in Bangladesh has such radiation which is sufficient for appropriate utilization based on available technology [8].

As electrification using grid electricity in rural areas has lagged behind than in urban areas, renewable energy technology, particularly electricity generation from off-grid Solar Home Systems (SHS) stands out to be one of the prospective sources to meet the unprecedented energy demand [9]. Solar Home Systems are small photovoltaic systems that transform solar energy into electricity, which does not require any kind of conventional fuels. The major components of SHS are solar panels, batteries, charge controllers, and some electric appliances (e.g., lamps, small fans, or televisions) which can be operated with minimum training [10].

SHS programs have been implemented in the country by the state-owned Infrastructure Development Company Limited (IDCOL) established in 1997 by the Government of Bangladesh. IDCOL operates the SHS program with 56 Partner Organizations (PO), mostly NGOs like Grameen Shakti, Rural Services Foundation, BRAC Foundation, Bengal Solar etc. [11]. The POs utilize their expertise in micro-finance to have greater reach in the rural community for making renewable energy applications affordable to the users. In the renewable

energy industry, Grameen Shakti (GS), the largest partner organization of IDCOL with an installation of 1.6 million SHS across the country, has played a significant role in the growth of RE usage in rural Bangladesh. The credit program of GS in renewable energy has reached many rural households [12]. Till December 2016, More than 4 million SHSs have already been installed in the off-grid rural areas of Bangladesh, thus providing 18 million beneficiaries with solar electricity which is around 12% of the total population of Bangladesh [11]. In the light of this discussion, this study is aimed to integrate the economic, social and environmental benefits of SHS interventions in addressing the sustainable rural development of the country. The study also identifies the challenges prevailing in this sector that limit the mass adaptation of renewable energy usage.

The paper proceeds in seven stages; first it presents the introductory discussion and dissemination of SHS. Part two specifies the research methodology followed by part three with a brief literature review on the SHS interventions. The conceptual framework representing the scope of the research and subsequent inferences on RE interventions to promote social, economic and environmental developments in Rural Bangladesh have been discussed in the fourth and fifth part of the study. The sixth part highlights the challenges and possible strategic options. Finally, the study concludes with an emphasis on relevant policy formulations and further research in promoting sustainable rural development through solar electrification.

II. RESEARCH METHODOLOGY

To explore the intricacies of solar electricity interventions for rural development, the qualitative study is characterized as exploratory in nature by employing both qualitative and quantitative data collected from primary and secondary sources. The primary data source comprises of key informant interviews, site visits and field observations conducted from April 2017 to June 2018 in the villages of Singair, located at District of Manikganj, in the division of Dhaka.

Key Informant Interview (KII) includes obtaining information from:

- i. Renewable Energy Program Managers of Grameen Shakti, the largest partner organization of IDCOL
- ii. Renewable Energy Consultants from public and private sectors in Bangladesh
- iii. Bangladesh Solar and Renewable Energy Association
- iv. Climate Change Experts from Bangladesh Centre for Advanced Studies
- v. Advisor for Sustainable Energy for Development (SED) Programme, GIZ
- vi. Director, Operations, Technologies for the Unreached, collaborated by Grameen Communications, Bangladesh and Kyushu University, Japan.

The interview session was organized with the practitioners, policy makers and researchers who are in a position to know the user community as a whole, as well as they have expertise in the subject area relevant to this research. This method of data collection has been applied to avail the opportunity for establishing rapport/trust and get an insiders' view regarding the dissemination of SHS in rural Bangladesh [13].

The secondary data collection include reports issued by Government and Non-government organizations, websites of regulatory institutions and POS, extensive and systematic literature search in peer reviewed international journals conducted at Google Scholar, Research Gate, IEEE, JSTOR and Science Direct platforms to gather essential insights for the study. The pertinent studies have been analyzed on the basis of research concentration and subsequent findings. Both qualitative and quantitative evidences, scrutinized from these literatures, have been appraised to examine the socio-economic benefits and environmental impacts of SHS along with prevailing challenges for the sustainability of the program.

III. LITERATURE REVIEW

This part of the study discusses the growing body of literature on solar energy interventions, particularly on SHS dissemination in developing nations like Bangladesh. SHS is a form of renewable energy, that is generally is collected from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy usually supplies energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services [14]. Globally, there are an estimated 7.7 million jobs linked with the renewable energy industries, with solar photovoltaics being the largest renewable employer [15].

A rich literature is evident through research studies on the potential, progress status monitoring and impact assessments of SHS dissemination in South Asia, Africa & Latin American countries, particularly in developing nations like Bangladesh. Research papers in renewable studies have analyzed the relationship between access to electricity on enhancing the living standard and economic productivity of the SHS users [1][16][17][18][19][20]. These literatures acknowledge that SHS installation in the underprivileged communities usually gives favorable outcomes for upgrading the living standard of rural households.

However, some research studies also identified certain constraints regarding difficulty in matching the output of SHS with customers' electricity requirements [20][33][17]. The amount of sunshine combined with the relatively small size of SHS at the household level poses a limitation on the electricity generating capacity.

Consequently, as the production of electricity is typically in the range 30–130 Watt peak, SHS would normally allow households to use only low-powered electrical appliances such as electric lamps, radios and televisions (TV), and mobile phone rechargers.

To draw global attention on mitigating the adverse effects of climate change, the environmental benefits of the growing usage of solar energy has also been addressed by many researchers. Adoption of SHS results in the decline of carbon dioxide emissions from kerosene usage and other fossil fuels replacement [5][17][20][21].

The progress scenario and sustainability of SHS programs have been critically reviewed by several researchers as a vital dimension of research in renewable energy. Most of these studies have been conducted in Sub-Saharan Africa and developing Asian countries [4][22][23][24][25][26]. The authors in these studies have analyzed the rural electrification programs through solar energy interventions which is the foremost decentralized technology used to improve access to electricity in rural communities. These studies also identified the challenges to the sustainability of solar energy based rural electrification which include lack of awareness, limited trained manpower, high upfront costs of the systems and lack of source of funds. These findings were based on the studies in Bangladesh, Indonesia, Thailand, India, Sri Lanka, the Philippines, Ethiopia and Nigeria.

The arguments presented above suggest that further research should attempt to analyze how to synthesize policy tools with the aim of mitigating the challenges and capitalizing on the development opportunities derived from SHS to meet the energy needs in rural households. From the reviewed literature, it has been noted that there is a lack of attention in assessing and integrating the potential of off-grid solar energy in sustainable rural development. This research is intended to fill this gap of present literature on sustainability of solar energy dissemination programs by addressing the remarkable growth of SHSs in a developing country like Bangladesh. By accomplishing the research objective, the present study attempts to unbundle these issues and offer beneficial insights for policy makers and industry stakeholders in formulating pertinent strategies for sustainability and expansion of renewable energy ventures.

IV. CONCEPTUAL FRAMEWORK OF THE STUDY

Sustainable Development (SD) can be defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [27][28]. Provision of social services along with a growing economy and clean environment has recently been recognized as the pre-requisite for sustainable development [35]. Hence, the concept of sustainable development necessarily includes economic, social and environmental issues. Improved energy supply is essential for socio-economic development and poverty alleviation. Access to energy has a great impact on the life situation of rural population by influencing their economic productivity, health, education, and gender-related issues [29]. Thus energy, particularly in the form of electricity, is the building block of modern civilization and prerequisite for sustainable development [30]. To meet the electricity requirements across the globe, renewable energy sources such as solar energy technology have received major importance due to their social acceptance as well as an ability to provide sustainable energy generation [4]. The prevalent energy crisis demands Government of Bangladesh to develop of a stable and sustainable power supply that will increase electricity access, enhance energy security, improve economic productivity and mitigate climate change [31]. In this respect, implementing solar electrification programs plays a vital role in achieving the goals of sustainable development, as illustrated in Fig. 1.

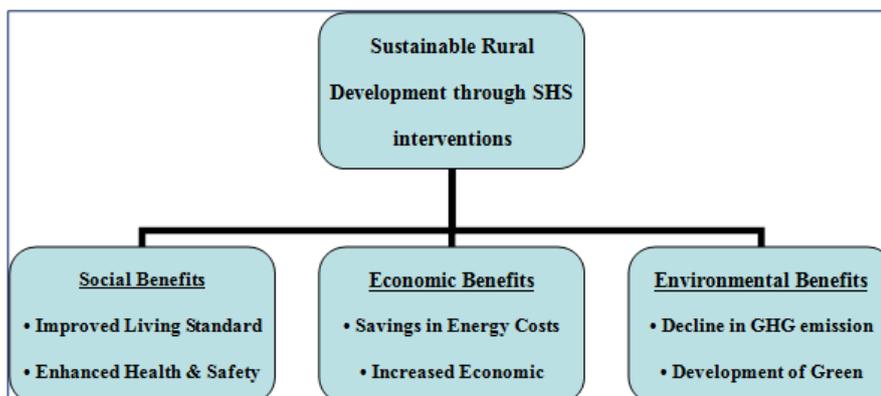


Fig. 1 sustainable development through solar electrification

V. ANALYZING RURAL DEVELOPMENT INTERVENTIONS

In Bangladesh, about 80% of the population lives in rural areas. Data from the Household Income and Expenditure Survey revealed that 44% of the rural population was classified as poor and a vast majority of them remain without connection to the national electricity grid [2]. The substantial number of rural citizens without access to electricity is one of the primary challenges in the Bangladesh energy sector. From the perspective of resource endowments and user acceptance, solar photovoltaic energy is the most viable electrification option in the country relative to the other renewable energy sources [7]. SHS represents an import-independent source of energy with improved durability, minimal environmental hazards and reduced maintenance cost [29]. Therefore, it is apparent that SHS has the best potential as an alternative source of electrification in rural Bangladesh [4]. Hence, the growth of solar energy industry has significant long-term benefits as it improves country's energy security and contributes in sustainable development as analyzed below:

5.1 Economic Contributions

- Savings in energy costs: SHSs have the potential for reducing expenses incurred for lighting facilities, resulting in savings in energy costs and thus ease the strained households' budget.
- Economic productivity: In the off-grid rural areas, better lighting conditions from SHSs support rural businesses increase their productivity and income through extended working hours after dark [38].
- Access to information: Enabling the usage of electronic home appliances like mobile phones, televisions and radios increases access to information about market opportunities and prices and assists in emergency situations.
- Employment generation: The domestic production of SHS components like solar lamps and charge controllers creates job opportunity for technicians and local youth in solar industries. According to IDCOL, with more than 4 million SHS installed in the off-grid rural areas in Bangladesh, as highlighted in Fig. 2, the renewable energy program has provided livelihood to 70,000 people by creating jobs in a green industry [11].

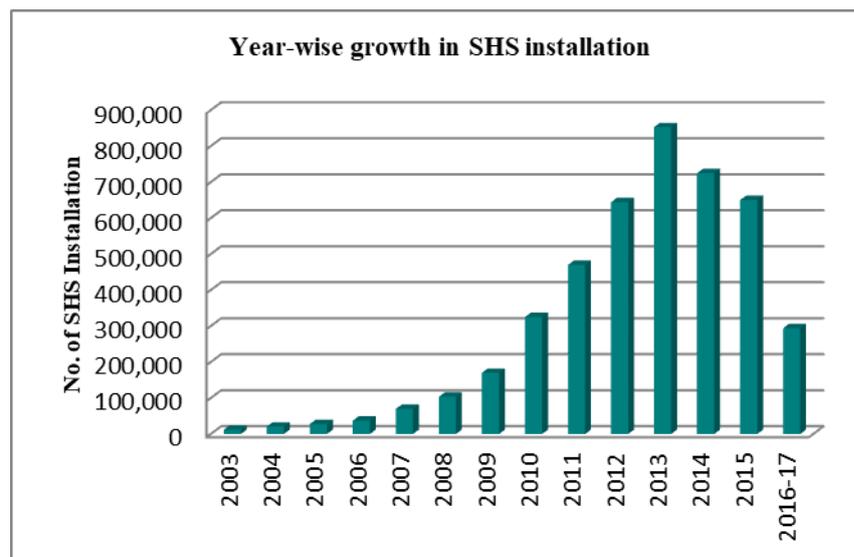


Fig. 2. Year wise Growth in installation of Solar Home System by IDCOL

5.2 Social Contributions

- Improved health & safety conditions: Since SHS is an environmentally sound technology, the increasing adaptation of SHSs in the rural communities reduces harmful in-house air pollution resulting from kerosene vapors, thus contributes in improving health and safety conditions among the most vulnerable groups within the nation.
- Improved educational opportunities: Access to solar electricity benefits the students with extended study hours at night and promotes the educational performance in developing countries. Based on Bangladesh, a World Bank case study also revealed the positive correlation between rural electrification and educational enrollment ratios [32].
- Gender aspects: Grameen Shakti, leading PO of IDCOL has established village based technology centers to train and empower rural labor force, especially young women to become Renewable Energy Technicians and Entrepreneurs. Inclusion of women to disseminate solar electricity has enhanced their social-economic value in the communities and upholds women empowerment [12][33].

5.3 Environmental Contributions

- Reduction in Greenhouse Gas emission: For emerging economies, like Bangladesh, SHSs provide cost effective opportunities to adopt low carbon development electrification program without compromising the efforts in continuous developments of living standards [39]. This is evident in the fact that, with the usage of 4.4 million SHSs, the program replaces 242,000 tons of kerosene having an estimated value of USD 300 million per year which is one of the primary sources of greenhouse gas emissions in developing nations [11]. Since about 11% of people in off-grid areas have accepted SHSs, there is a significant potential for even greater diminutions of harmful greenhouse gases.

VI. CHALLENGES & REQUIRED POLICY IMPLICATIONS

From the above mentioned discussions on assessing the prospect of solar electrification, the proposed study identifies the consequent socio-economic and environmental opportunities to promote sustainable rural development by the adoption of Renewable Energy Technology like SHS. However, at present, renewable energy remains a small portion, 2.89% of current electricity generation portfolio in Bangladesh [20][35]. In this regard, the study will make an attempt to unfold the barriers preventing the mass scale-up of renewable energy in rural Bangladesh and calls for attention on multi-lateral collaborations among the stakeholders in the sector. Through the Key Informant Interview (KII) with the partner organization officials and renewable energy consultants, some crucial constraints have been identified which needs to be brought under the attention of the policy makers. Despite the significant potential in the commercialization of solar energy, there are a number of challenges in the large scale adaptability of the renewable energy program [33][36][40]. This section of the paper presents a discussion on these critical aspects limiting the potential of rapid growth in SHS:

6.1 Higher installation cost:

With the prevalence of rural poverty in Bangladesh, disseminating SHS needs to address the lower purchasing power of rural customers [10][19][34]. One of the major challenges that need urgent attention in this sector is to reduce the high upfront cost of a solar system. Research reveals that, reduction in price by 10% would encourage 61% of non-SHS households to consider adopting SHS [33]. Financial mechanisms should be devised for easy access to loans for installations of SHS in the rural areas.

6.2 Lack of awareness about solar energy technology

Renewable energy still constitutes of a small share of Bangladesh's energy generation portfolio. At present, the installed RE generation capacity is 2.89% [35][41]. The lack of awareness and acceptance of solar technology necessitates demonstration of it to rural population. An intensive effort on the part of the government and the disseminating organizations is essential to make the benefits of the solar technology known to people through the media and via practical demonstrations [10][36][37].

6.3 Lack of availability of better quality system components

Research studies revealed that low availability of better quality SHS parts like batteries and charge controllers affects customer's attitude and longevity of the system [17][20][33]. Hence, sustainability of the SHS Program also requires the availability of the solar accessories in the remote rural locations so that the users can buy them easily when required.

6.4 Low after-sales service support and need for technician training

Customer satisfaction and impact assessment researches revealed that in some cases, SHS users experience the lack of regular and satisfactory maintenance service from the POs [17][18][20]. In this regard, training local technicians will yield better results. Moreover trained service personnel can educate the users on the proper usage and maintenance of SHS, which may avoid technician calls and increase system reliability.

6.5 Supervision of POs' performance & regulatory affairs

Research studies asserted that lack of integrated efforts from the stakeholders is evident to promote the commercialization of renewable energy [7][29][30]. There are problems of management of a decentralized technical system on a one to one basis between service provider on the ground (POs) and the client (household or enterprise). Also, IDCOL should strengthen its quality control and inspections of POs to ensure the quality and benefits of SHS installations.

6.6 Financial policy limitations

The country's solar energy initiatives have been subjected to face a setback as the government has proposed import duty on solar panels in the budget for fiscal 2017-18. Imports of solar panel, the main component of a solar power system, will be subject to 10 percent customs duty, value added tax (VAT) and other taxes, totaling an additional cost of 37.5 percent in the next fiscal year, whereas the sector has been enjoying zero duty [42]. Bangladesh has largest solar home systems in the world mainly because of zero duty on import of solar panels since 2009. The move of import duty may result in escalating costs and affect solar energy ventures, which have already been planned and are being set up.

The electricity sector of the country suffers from acute problems in terms of insufficient power generation and a lack of distribution infrastructure [5]. In this context, the high upfront cost of expanding the national electricity grid to the remote rural areas of the country is a critical constraint in rural electrification [33].

To improve the situation, effective utilization of renewable energy technology has been prioritized as a policy of the Government of Bangladesh which aims to meet 10 percent of the total power demand by 2020 from renewable energy sources through a private-public partnership [31].

To address the significance of research, a holistic framework has been proposed emphasizing multidisciplinary and multi-stakeholder participation as illustrated in Fig. 3. This necessitates a strategic collaboration among the regulatory bodies, donor agencies, POs and component suppliers to address the sustainability of SHS program. Following the concept of ‘action research’ that calls for problem solving research and closer interactions between academic researchers and industry players [43][44], the framework in Fig. 3 proposes the development of local and international collaborative partnerships which, importantly, include direct links to the RE industry. To address the significance of further research in this regard, a holistic approach is required emphasizing multidisciplinary and multi-stakeholder participation to accelerate the emerging solar electrification ventures in order to foster sustainable rural development.

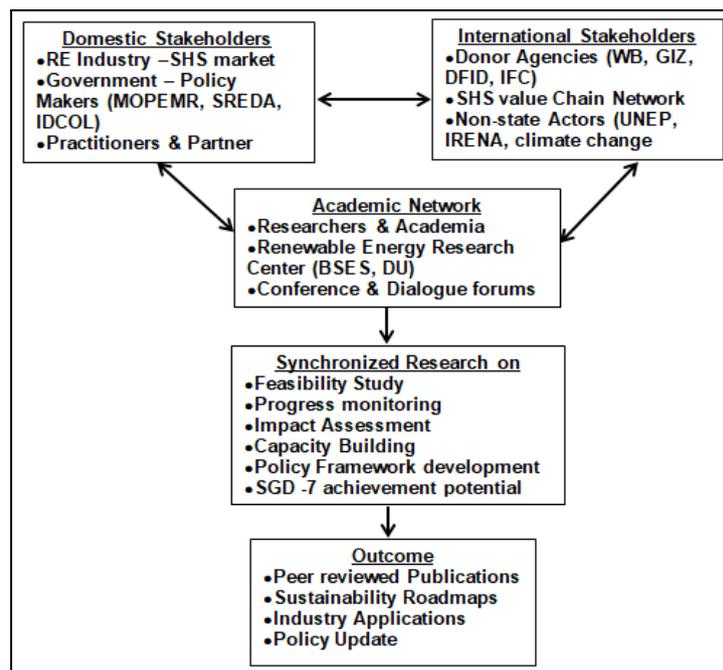


Fig. 3. Proposed framework for holistic sustainability research on solar electrification

VII. CONCLUSION

In Bangladesh, more than two-third of the population lives in rural areas and a vast majority of them have no access to conventional grid electricity. The resulting electricity shortages are expected to impede sustainable economic growth and are considered urgent issues in Bangladesh’s energy sector. Hence, rural electrification is an essential concern for making the development process inclusive and sustainable. That is why it is high time to recognize the important role that solar energy can play in addressing the development goals of the country. Since the instigation of solar power technologies, there has been a notable growth in the adaptation of the SHS for green energy. Based on the inferences on off-grid solar electricity presented in this study, the increased adoption of renewable energy ensures a stable power supply in rural areas that will improve energy access, conditions of living standard, economic growth and climate change mitigation by reducing carbon footprint. This study has additionally emphasized some of the major constrains that must be taken care of to capitalize on the potentials of SHS. In the present-day scenario, when moderating climate change and socio-economic concerns have been receiving attention among the researchers and policy makers around the world; solar power highlights itself as a promising solution for sustainable development. This study concludes with an emphasis on the policy formulation by multilateral cooperation and calls for further research to regulate and streamline the technical, managerial and financial aspects of the program.

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