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Mini-grid based electrification in Bangladesh: Technical configuration and business analysis

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ABSTRACT

This paper presents a local level study of a village off-grid system in Bangladesh. It applies an integrated methodology that identifies the demand in the off-grid village context using alternative scenarios. The techno-economic analysis of the optimal off-grid system architecture is then presented using HOMER software. Three energy resources are considered, namely solar energy, wind and diesel fuel. The optimal configuration suggested for the scenarios consists of diesel generators for the basic level of demand and PV-diesel hybrid for higher demand and reliable supply scenarios. The cost of electricity per kWh remains high for the basic level of supply and decreases as the system size increases. However, the capital and asset replacement costs increased considerably for bigger systems. The business case is then analysed for each scenario and it was found that it is practically impossible to reach grid price parity even with full capital cost subsidy, indicating significant amount of operating cost subsidy requirement that makes the larger systems financially unsustainable. Moreover, the small mini-grid system for the basic level of supply emerges as a cheaper option than providing the consumers with solar home systems. But the monthly electricity bill will become unaffordable for most consumers when demand restrictions are removed. Accordingly, the paper suggests a mini-grid based electricity supply to provide the basic level of provision alongside productive energy use during off-peak hours as the starting point. If the business develops and the demand improves, the system can be expanded subsequently using appropriate technology combinations.

1. Introduction

Being at the forefront of Solar Home System (SHS) dissemination in the world, Bangladesh holds a special place in any discussion on off-grid electrification. In this densely populated, low-income country of 152 million people (in 2012), the overall rate of electrification is reported at 56% in 2011, thereby forcing about 40% of the population to rely on kerosene for lighting purposes [1]. However, there exists a significant variation between the rural and urban areas. 80% of the population resides in rural areas but only about 49% of the rural population is electrified whereas about 89% of the urban population is said to be electrified [1]. Although SHS has been successfully introduced in the country, particularly by Grameen Shakti, it has reached only 4% of the rural households and 0.5% of the urban households so far [1]. The Government aims to provide electricity to all by 2021 and although the strategy appears to consider both off-grid and grid extension options, the task looks increasingly challenging.

Although a lot of academic and other studies have analysed the case of Bangladesh, the literature focuses on two dimensions: the success of Bangladesh in introducing rural electrification through the rural electrification co-operatives (Palli Bidyut Samitis or PBS) (see Ref. [2] for example) and the success of Grameen Shakti in introducing SHS (see Refs. [3,9] and [11] for example). However, neither PBS nor SHS has succeeded in ensuring universal electrification of the country and in the case of SHS the use of electricity for productive purposes has remained insignificant. Moreover, a field-based appraisal of SHS in Bangladesh [9] reported various shortcomings including use of poor quality components, poor installation and an inadequate quality control mechanism. A few other studies (e.g. Refs. [4–6] and [10]), among others) have considered the case of hybrid off-grid systems for rural electricity supply but their analysis remains limited to just techno-economic analysis using a simulation tool, namely HOMER. Most of these studies are hypothetical in nature, rely on representative households consuming identical levels of energy for a given period of time, use generic technology/financial information and thus provide an

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overall understanding of the hybrid option. Although these provide useful information, such techno-economic analysis does not really indicate whether the service can be provided as a viable business, whether costs can be recovered through affordable tariffs and whether the investment can be mobilized and if so, under what conditions.

The purpose of this paper is to argue for a transition to mini-grid based off-grid power supply in Bangladesh through a comprehensive analysis of the business case. The main aim is to understand the needs of the rural communities and identify the appropriate solutions based on local resource availability so that an affordable solution can be proposed that is financially viable and socially desirable. This work thus goes beyond the standard application of a simulation tool and adds value by bridging the above knowledge gap.

The paper is organized as follows: Section 2 presents the methodology used in this work; Section 3 presents the case study background information, Section 4 presents the techno-economic analysis of alternative scenarios using HOMER, and Section 5 presents the business case analysis. Finally some concluding remarks are provided in the concluding section.

2. Methodology

Unlike most studies that focus on techno-economic feasibility of a given solution or alternative solutions (e.g. see Refs. [13–16]), this study presents a multi-dimensional analysis covering the techno-economic, business and governance dimensions. Although techno-economic analysis still remains relevant, the work does not stop there. The outcome is further processed to consider the appropriate business delivery option and the conditions required to achieve such a delivery model. Moreover, given the diversity of local conditions that exist in reality, instead of using a stereotypical representative village or locality with fixed characteristics, this paper relies on scenarios of cases that capture different socio-economic conditions, stakeholder preferences, potential opportunities and alternative options. Thus this analysis aims to add value by expanding the knowledge frontier through a holistic analysis of off-grid systems.

The analysis starts with a detailed needs assessment which involves local information gathering to understand the socio-economic characteristics of the local population, their existing and potential livelihood, commercial and productive activities (agriculture and small-scale industries) as well as community-related needs. Instead of developing a single point energy demand estimate, alternative scenarios are developed considering different levels of energy service development (e.g. basic lighting needs, lighting and some livelihood/productive needs, service for a limited period of time, and reliable round-the-clock service, among others). It is also possible to consider multi-village systems for economies of scale.

The techno-economic analysis of appropriate electricity supply system for each scenario is then carried out using HOMER software package developed by NREL. Each case study considers alternative resource options taking local resource availability into consideration as well as alternative scenarios for electricity needs developed in the previous step. This also leads to a further level of iteration that provides a rich set of system configurations and their life-cycle costs corresponding to alternative development paths. Information has also been used to reflect the local cost of energy system components wherever possible.

Whereas other studies end here, this study takes a step further to analyse the results obtained from the techno-economic analysis to consider the practical electricity supply business issues such as viability, funding, tariff and cost recovery, as well as issues related to business environment such as regulatory governance. The flowchart of the framework is presented in Fig. 1. This work thus enhances the framework suggested in Ref. [12] and complements it.

In the following section, the above framework is implemented using a case study.

3. Case study of a village electricity system in Bangladesh

3.1. Village background

This paper considers a non-electrified village in Netrokona district of Dhaka division. Netrokona has the lowest level of electrification in the Dhaka division and is comparable to other poorly electrified districts of the country. Although Netrolona Palli Bidyut Samiti (PBS or village co-operative) exists and has electrified the urban areas, the villages remain non-electrified. The district is in the north of the country and its remoteness has resulted in poor level of electrification in many semi-urban and rural areas.

The chosen village, Mahishpur, comes under Atpara sub-district and is situated at 90°50′E and 24°48′N. Atpara is a remote sub-district, many parts of which are not well connected by road. The village under consideration holds 108 households with a total population of 546 people as per 2011 Census (of which 295 are male and 251 female). The average household size is 5.1 persons but the household size follows a bell-shaped curve with a minimum of 2 persons and a maximum of 8+ persons. The village is not electrified and does not have piped water supply. All households live in houses owned by them but more than 97% of the houses are “kutcha”. 47% of the population is less than 14 years old while about 5% is above 60 years of age. Of the working-age population, women largely take care of household activities and men work in agriculture for living. The village is connected through rural roads from Atpara and Baniajan, which are bigger villages nearby but part of it gets disconnected during the rainy season.

Being non-electrified, the local population relies on kerosene and candles for lighting purposes and fuel-wood, agricultural residues (e.g. jute sticks) and cow-dung cakes for cooking energy. The energy resources for cooking are collected or procured locally.

3.2. Needs assessment and scenarios

As an agricultural village, the local population is highly dependent on agricultural activities for living. The soil is fertile and generally multiple crops are produced. The main crops are paddy, wheat, jute, mustard seed and potato. The village also supplies various fruits, namely mango, jackfruit, banana, and papaya. The area receives more than 2400 ml of rainfall during the year but the monsoon brings most of the rain, thereby causing floods in the area on a regular basis. The area, being part of the freshwater wetland ecosystem, boasts of a number of large water bodies (ponds, lakes, etc.) and fishing is also an important activity. However, due to lack of electricity no processing of food or fish takes place locally and most of the produce is sold in raw form in the nearby markets. However, natural drying of food crops, fruit and cash crops like jute takes place in the village.

To analyse the possibility of electrification through off-grid systems, the scenario approach is used to develop alternative electrification options and pathways. Given the non-electrified nature of the village, the demand is unknown but through alternative scenarios, a range of demand possibilities is considered as follows:

a) Basic: Basic Service (residential demand) – In this scenario, it is assumed that the poor households only use electricity for lighting purposes, while the middle income and rich households use it for fans, TV and battery charging. There is no demand for productive use and the service is available for a limited period of time in the evening hours.