Rural Electrification with Renewable Energy Based Village Grids in Bangladesh

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Abstract: Providing the rural poor with access to modern energy services is a major challenge in Bangladesh striving for economic growth, social development and environmental integrity. Socially, rural residences suffer from higher poverty levels accompanied by greater inequality, faster growing populations, more unsolved health issues and lower educational levels than urban residences. Economically, they struggle with a largely untrained workforce and a lack of public and private financial resources. Environmentally, developing countries have to juggle new industrial development with environmental precaution. A major environmental threat is climate change. Cities are often disproportionately affected by it, which poses challenges in terms of adaptation and mitigation. In an attempt to address these challenges in a concerted international effort, the United Nations defined the Millennium Development Goals (MDGs) in 2001. Currently the follow-up goals, the so called Sustainable Development Goals (SDGs), are under discussion. An important lever to address the MDGs and SDGs is the provision of (renewable energy-based) electricity to a wider population. As of today, more than 1 billion people worldwide still lack access to electricity. Access to electricity is a prerequisite for industrial progress and an increased standard of living for these people. Additionally, Compared to the alternative rural electrification approaches (e.g., solar lanterns, stand-alone systems, diesel-based village grids and grid extension), renewable energy based village grids (RVGs) are - in light of the MDGs and SGDs - the most appropriate solution to provide rural poor with access to electricity. RVGs are decentralized electricity systems which power a rural village with electricity produced by renewable energy technologies.

Key word: Rural electrification, village-grid, renewable energy.

Introduction

Power is the life blood of a developing economy. BANGLADESH is currently in a country of burgeoning economic development. But the power scenario in Bangladesh still has a long way to go. The government policies are well in place to take care of the power requirements of the country at a macro level. However, the issue of Energy Access at the grass root level still remains a cause of major concern. We believe that a lot of work can be done in this regard and hence we decided to formulate the 'Initiative on Sustainable Energy Access' (ISEA) and take up the preparation of this paper. Energy Access is about making accessible to the common man electricity, heat, or other forms of energy. Often referring to the situation of people in the developing world, lack of energy access also implies any quality of life issues relating to this lack of access. The rural parts of the country still remain largely devoid of an efficient power infrastructure. Research and policy implementation at this level can strengthen the power position of the country at the ground level. Rural area of Bangladeshi is the backbone of Bangladesh's economy. Nearly 70% of Bangladesh's population lives in villages and agricultural is the main support for their livelihood. It is, therefore, ironical that Bangladesh's rural population shares a much larger burden of poverty as well as energy poverty. For realization of Bangladesh's ambitious dream, ensuring inclusive growth would be essential. Alleviation of rural energy poverty in Bangladesh has to be an important component of such inclusive growth agenda. With vast diversity of our rural population in physical, social, cultural, educational, and economic background, the solution would need to be developed on case by case matching with the peculiarities of a particular region. Eradicating energy poverty requires that adequate infrastructure is put in place so that power can reach the corners of the country. Moreover, this power must be clean enough to be environmentally acceptable, affordable by the people and also feasible to implement. Most of these criteria are satisfied by Renewable Energy. Also, renewable energy can be implemented in a distributed format which makes it more suitable for providing power to areas with difficult geographical accessibility. This topic looks at the providing energy access to the rural part of the country through renewable energy. This report can be a comprehensive effort, at macro level, to make an assessment of the current scenario of energy access to the rural population, what should be our objectives and targets to remove the rural energy poverty and how we can meet the challenges encountered and accomplish this stupendous but important task. This report identifies the vital role offer, especially the renewable energy. Also looks at new technologies and emerging solutions. We would consider this research a success if the inputs from this topic can be useful in getting further insights into the power problems of the country.

Geography and Climate

The People's Republic of Bangladesh is located in South-east Asia between latitudes 20°34' and 26°38' N and longitudes 88°01' and 92°41' E. The country is bordered by India on the east, west, and north and by the Bay of Bengal on the south. There is also a small strip of frontier with Myanmar. The land is a deltaic plain with a network of numerous rivers and canals. The total area of the country is 147,570 km^2, in which about 17% is forested. There are a few hilly areas in the southeast and the northeast of the country. Bangladesh enjoys generally a sub-tropical monsoon climate while there are six seasons in a year, with

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three being more prominent, namely winter, summer and monsoon season. Winter begins in November and ends in February. In winter, there is not much fluctuation in temperature, which ranges from minimum of 7°-13°C to a maximum of 24°C-31°C. The maximum temperature recorded in the summer months is 37°C although in some places this occasionally rises up to 41°C (105°F or more). Monsoon season starts in July and lasts up to October. This period accounts for 80% of the total rainfall. The average annual rainfall varies from 1429 to 4338 mm.

FIG.1. Map of Bangladesh

Rural electrification

Rural electrification is the provision of long term, reliable, and satisfactory electricity service to households in remote, rural communities via grid or decentralized/centralized, renewable/nonrenewable energy resources supply. Many consider electrification as a fundamental strategy for poverty alleviation in terms of financial, energy, and sustainable developments to meet the Millennium Development Goals. Rural electrification started more than a century ago in many developed countries. They have completed their missions a few decades after launching their electrification programs. Some developing countries, such as Bangladesh, started approximately 40 years ago, yet more than 60% of its population does not have access to electricity. Bangladesh may not be able to complete its mission because the economic aspect of a country is the key barrier in promoting increased access to electricity in rural areas. However, rural electrification is not only a technical issue but also a multidimensional phenomenon that is affected by several factors, such as politics, economic development, and culture. Moreover, the outstanding problems of the power ministry are hardly uncommon in almost all are developing countries. Even developed countries are experiencing these problems.

General challenges faced by rural communities

Rural electrification is defined here as the process by which access to electricity is provided to households or villages located in the isolated or remote areas of a country. Remote or rural regions lacking electricity supply are often characterized by well identified challenges. They may lie at a reasonable distance from national or regional electricity grids (remote villages in the Amazon), may be difficult to access (far from urban centers with a difficult terrain such as large rivers or jungles), or may suffer harsh climatic conditions that render electrification through grid extension a perilous task. Rural communities are also often highly dispersed with a low population density and characterized by a low level of education, low load density generally concentrated at evening peak hours, and low revenues. Adding to these challenges, the rural poor without access to electricity either spend relatively large amounts of their scarce financial resources on energy, or a disproportionate amount of time collecting firewood.
In light of these challenges, electricity provision to the world's rural poor calls for a committed and long-term action plan. The benefits that electricity access brings to households and communities are justified not only on social and economic grounds but also on grounds of equity objectives.

Rural electrification approaches

Even if economically viable, socially beneficial and environmentally unproblematic, the provision of (renewable energy-based) electricity to the rural poor remains a challenge in developing countries. The lack of diffusion of RETs, especially in rural areas, is due to financial, political, and technological challenges which have yet to be met. In terms of finances, national and international policy makers aim to invest public money efficiently and to tap additional financial sources from the private sector. Both are challenging tasks for governments with scarce budgets and a list of competing issues, such as health improvements or education (Perkins et al. 2013,p. 105). In terms of political challenges, policy makers have to evaluate what type of investment, in which projects, most effectively and efficiently promotes access to electricity through RET. The answers are influenced by factors such as the country's electricity needs today and in the future, the current and future desired design of the electricity sector, the costs of the different approaches and their environmental impact. From a technological point of view, there are competing rural electrification approaches (see Table 1) which have, so far, partially diffused within and between developing countries. The extent of diffusion differs between approaches and depends, among others, on the countries' public support in terms of subsidies, taxes and the like for RET, and the competing non-renewable solutions. The involvement of the private sector also varies between countries as well as between electrification approaches
In the following, I provide an overview of rural electrification approaches, with a focus on their environmental and socio-economic implications. RET are in general considered to be environmentally friendly, as fossil fuel-based solutions contribute to climate change, among other negative impacts. In socio-economic terms, electricity has the biggest effect if it is used for productive activities (e.g. the processing of rice or coffee, agricultural purposes) and social infrastructure (e.g. health clinics, schools and information and communication technologies (ICT)and not solely for consumption in the household (e.g. for light, cooking and entertainment). When used productively, electricity increases people's chances to perform income-generating activities, which improves their economic situation and, in the long run, their living conditions.
Table 1 – Rural electrification approaches and their environmental and socio-economic dimensions in terms of

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energy source (renewable energy in grey) and potential for use of electricity

Electrification approach	(Non)- renewable energy source	Potential for use of electricity	
Solar lanterns	Solar PV	Household purposes	Light and mobile phone charging
Household-based system	Solar PV (mostly) Wind Pico hydro	Household purposes	Light and mobile phone charging Cooking, cooling and entertainment for a single household
Village grids	Diesel Solar PV Wind Micro hydro Biomass Hybrids (combinations of the above often in combination with batteries or diesel)	Household purposes	Light and mobile phone charging Cooking, cooling and entertainment
		Productive use	Machinery (e.g. coffee or rice proceeding machines, carpenter tools)
		Social infrastructure	Health clinic School ICT
Grid extension	Mixed, depending on national electricity mix	Same as village grids, however depending on the grid's reliability	

In order to improve the socio-economic situation of the rural poor rural residences at low (or no) environmental cost, RVGs are the best fit (compare Table 1). Compared to solar lanterns and household-based system, RVGs offer more electricity and therefore allow for productive use and social infrastructure in addition to household purposes.

Electricity Load Profiles

In the first step we estimate the village electricity demand by defining the size of a generic Bangladeshi village, two electrification strategies, and the corresponding village load profiles. Our generic village consists of 2250 people in 450 households, with 5 people per household on average. While previous rural electrification studies have typically only considered household electricity demand to reflect the variability of villages across Bangladesh and incorporate potential demand growth for rural electricity. We define two types of electrification scenarios as classified in Table 1 considering three categories of end-user consumers: household, productive use and social infrastructure.

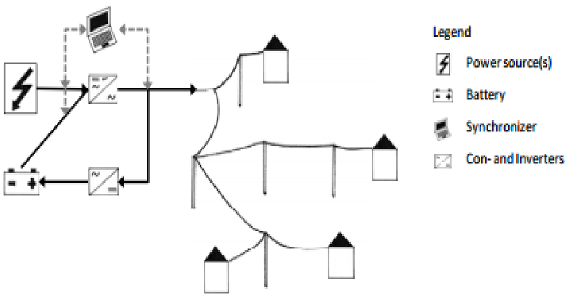
Table2 -Two types of rural village electrification scenarios are considered in this study to reflect the variability of villages across Bangladesh.

	Scenario A Basic Electrification	Scenario B Advanced Electrification
Overview of village	Remote rural village, with agriculture as the main economic activity.	Rural village with established or growing economic activities, beyond agriculture.
Power availability and end-consumer sectors	Electricity is available 18:00 – 06:00 for: • Household sector (night)	Electricity is available 24 hours for: • Household sector (day and night) • Productive use (majority during daytime) • Social infrastructure (majority during daytime)

Based on the proposed electrification scenarios for the generic village, in the next step we determine the load profile for both scenarios. As meters are often not employed in small off-grid electricity networks there is a lack of empirical data on electricity consumption from Bangladeshi villages. Therefore, the load profile is estimated by determining the demand for electricity for each end-user category at hourly intervals during a typical day. The demand for electricity is estimated by identifying the electricity appliances required by consumers in each end-user category and the times of usage all assumptions to the demand model side are outlined in, based on previous studies and our own Bangladeshi field investigations and interviews.

Village grids (based on renewable energy)

The village grid concept and technology evolved inthe 1980s in developing countries when public energy authorities realized that a centralized electrification approach, which until then was the dominant strategy (in both industrialized and developing countries), is often not the most economic option for remote areas in developing countries (Peskett, 2011). In this thesis, a village grid is defined as an isolated (i.e. off-grid), small (sizes vary between 5kW and 500kW) grid which powers a rural village (ESMAP, 2007; Bardouille et al., 2012). A village grid's purpose is to connect one or more power sources to the households and other consumers (such as workshops or medical centers) of a village and balance the load with the supply. The core components of a village grid are synchronizers, transformer(s), potentially a battery back-up to address intermittency of the sources, switchgears and the respective software to balance the load with the supply from the power plant(s), and the wiring (see Figure 2). In the case of a power source which produces direct current (DC), additional inverters are needed to feed the alternating current (AC) village network. Power sources can be both non- and renewable energies (see Table 1). The choice depends on the availability of (natural) resources and influences the system's design since renewable energy sources such as solar PV or wind are intermittent and require storage and balancing components. The load is determined by the electricity demand of the village, which depends on the number of households, their electric appliances (such as lamps, rice cookers, TVs and radios), the requisites of the social infrastructure (e.g. schools and medical centers) and businesses (e.g. small grocery shops, coffee processing plants and rice mills), and their respective consumption patterns (Saengprajak, 2006; Terrado et al., 2008; Raharjo, 2009). While village grids typically serve one common purpose, no single standard design exists because each village grid has to be adjusted to the context where it is implemented. The final design thus heavily depends on factors such as the amount and variability of supply and demand, and the availability and cost of materials and power sources (Inversin,2000).



Renewable energy based village grids

We consider micro hydro and solar PV/battery based solutions on Village grid.

Micro hydro

In areas with sufficient natural resources (flow rate, water availability and head), micro hydro is a proven reliable and low-maintenance technological option to address rural electrification access. Through our interviews with industry practitioners, we discover that micro hydro popularity in Bangladesh is also underpinned by the strong local technical knowledge base, mature domestic micro hydro industry and manufacturing capability. However, currently only 19% capacity of Bangladesh estimated 230 MW micro hydro potential have been tapped .Similarly to the estimation method for diesel, the micro hydro power plant capacity in this study is sized such that it matches the peak load of the village, including distribution losses.

Solar PV/battery

Solar PV systems, which directly convert solar energy into electricity, offer a number of additional benefits; including high modularity, zero noise, and particularly the availability of high solar resources in almost all Bangladesh. Previous studies have concluded that standalone solar PV off-grid networks are still less competitive when compared to other more mature renewable energy technologies, driven by high investment costs. The main challenge concerning the use of an intermittent power generation source such as solar PV/battery is that all electricity can only be produced during day time, leaving night time or cloudy day consumption reliant on battery storage. However, this peak production pattern does not match the demand curve, where peak demand occurs at night time, where the solar PV panels do not produce electricity (compare van der Veen) . For an isolated network, this significantly raises the need for battery storage to meet electricity demand during non-daylight hours. We assume a solar PV system configuration which consists of crystalline silicon (cSi) based solar PV power plant connected to advanced lead-acid battery storage. The electricity produced by solar PV panels is used directly to satisfy demanded levels of electricity at that point in time. Excess electricity production during daylight-hours will be stored, and discharged at night or during cloudy days to meet the requested demand.

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Solar PV/battery with 90% and 80% reduced supply contingencies

To reduce the levelised cost of electricity (LCOE) of the higher renewable energy based village grid solution, the solar PV/battery. We consider an alternative solution with reduced supply contingencies. We argue that since the SAIDI (System Average Duration Interruption Index) of PLN is 6.9614 and based on practitioners' advice from our own field interviews, an isolated village grid with sub-100% availability can be acceptable, provided that it is explicitly covered in a community agreement approved by the villagers. We therefore consider two levels of reduced supply contingency approach to the solar PV configuration. First, under a 90% reduced supply contingency the power generation system configuration is able to supply sufficient electricity to fully meet the demanded levels as reflected by the load profiles. In the remaining 36 days (10% of the days in the year), a shortage of electricity supply may be expected. Second, under the 80% configuration, there are 72 days (20% of the days in the year) where electricity supply shortage may be expected.

Conclusion

Rural areas suffer from energy poverty and lack of human and economic development. Renewable energy based village grid is the most promising option for feasible, sustainable decentralized rural electrification generation systems, particularly in rural areas with massive renewable energy resources. This option should be considered because of the high cost of grid electricity and transportation cost of fossil fuel to remote areas (along with increased fuel market prices), as well as the environmental concern about the exhaust of burning fossil fuel. Provision of affordable electricity to remote households is an essential aspect of human and economic development in rural areas worldwide and an obligation of governments toward their citizens. For many developing countries, this obligation is a huge challenge because of their weak economy, which is a key barrier to rural electrification. Thus, developed countries should not be perplexed in assisting less developed countries in their renewable resource-based because low-income households in these countries need merely a few watts for their daily energy demand. According to the availability of electricity generation resources in rural areas and to the selection criteria of feasibility and sustainability, micro hydro is the top choice of rural households, followed by PV and diesel-fueled generators. Although micro is the most cost-effective option, PV is the most dominant renewable energy technology for rural electrification because of the availability of solar energy resource all over the world.

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